Assessment Of Flood Risk Of Cross River State Using Geographic Information System (Gis).

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KEY WORDS: Flood Risk, Geographic Information System (GIS), Remote-Sensing, Environment.

ABSTRACT

Floods are the major disaster affecting many countries in the world from year to year causing great human and economic loss. The impact of floods has increased due to a number of factors which includes rising sea level and increased developmental activity on the floodplains). Considering the enormity of this problem, the United Nations Environmental Program (UNEP) in 1991 pointed out that many countries considered uncontrolled storm water to be their greatest problems as far as the preservation or urban infrastructure is concerned. In cities such as Bangkok, Culcutta, Dares Salam, Jakarta, Guayanguil, Manila, Lagos, many neighborhoods are flooded at least once a year, and inhabitants have to cope with the water in their dwellings. The trend of urban expansion has continued just as industrial activities has opened up new fields without critically considering the consequences of this unbridled development on the environment. Farming and other agricultural activities are increasingly being carried out on the flood plains. This leads to the loosening and disintegration of the resilient nature of the soil structure and texture in this area. Going by the above, it is therefore necessary and expedient for a study such as this to be carried out if the state is to avoid the associated problems of floods faced by many countries in the world.

The potential of Geographic information System (GIS) in flood studies cannot be over emphasized. It allows for a proper integration of all physical, socio-economic and demographic data, as data management and map representation capabilities of GIS help in exploring the environment and its integration with Remote Sensing, enhances the ability for forecasting/predicting of new scenarios and preparation of flood hazard maps. This work is aimed at assessing the flood risk vulnerability of Cross-River State of Nigeria using geospatial technologies.

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1.0 INTRODUCTION

Floods are the major disaster affecting many countries in the world from year to year causing great human and economic loss (Thilagavathi, et al. 2011).The impact of floods has increased due to a number of factors which includes rising sea level and increased developmental activity on the floodplains. In most cities of the world, the problems of floods are rapidly growing (Balogun and Okoduwa, 2010). Considering the enormity of this problem, the United Nations Environmental Program (UNEP) in 1991 pointed out that many countries considered uncontrolled storm water to be their greatest problems as far as the preservation or urban infrastructure is concerned. In cities such as Bangkok, Culcutta, Dares Salam, Jakarta, Guayanguil, Manila, Lagos, many neighborhoods are flooded at least once a year, and inhabitants have to cope with the water in their dwellings (UNDP, 1991; Usoro, 2004). The potential of Geographic information System (GIS) in flood studies cannot be over emphasized. It allows for a proper integration of all physical, socio-economic and demographic data, as data management and map representation capabilities of GIS help in exploring new portions, hence, its integration with remote sensing, enhances the ability for forecasting/predicting of new scenarios and preparation of flood hazard maps (Thilagavathi, *et al. 2011*). Besides its constraints like technological Knowledge requirements, hardware and software requirements, GIS can be very useful in flood hazard study and mitigation. Geographic information System (GIS) has been applied extensively to flood studies. GIS is a technological system that reflects all kinds of spatial data of the real world. It can input, output, store, search, display, analyze and be applied under certain support of software and hardware (Mayer *et al.* 1998, ***Usoro***, *2004).* Gurin *et al. (2004),* carried out a community-based flood risk assessment of San Sebastian, Guatamcla, using three epochs of aerial photographs acquired in 1964, 1991 and 2000, questionnaire and integrated GIS techniques for the study. Based on field survey, two maps were developed; one for the water height and another for damages. A GIS point interpolation method (ordinary kringing) was performed from plots containing water height data. A report on the building and their contents was compiled during the survey. This qualitative report was further converted into numerical values for every specific level of damage. Level topography, blockage of the drainage channels, sedimentation and most importantly heavy rains caused by hurricanes were identified as factors that induced flood in the study area. Duan *et al.* (2003) used Remote Sensing and GIS to map flood Hazard in Chiang Mai Province, Northern Thailand. Hazard mapping was prepared using the population data, the land use data, and the flood depth in the GIS environment. Land use and flood depth were classified and internal weight was given to each class, and the final hazard map was calculated using Analytical

Hierarchical Process (AHP) technique'. Monsoon climate and flood plain landscape were identified as factors that induced flood in the province.

Hagget (1975) and Offiong *et al.* (2008) have asserted that flooding has become a frequent hazard which is related to heavy precipitation, which can collapse the natural or man-made dams and the release of impounded waters. Okeke (2003) observed that a major environmental problem in the Niger Delta is flooding which comes from rainfall and runoff from rivers and urban chains and tidal movement and winds.

1.1 Statement of Problem

Heavy rainfall lasting for a considerable longer duration often builds up excess water beyond which percolation can accommodate. This leads to a rise in the water level resulting in surface flow down the slope into nearby depressions. There is also a rise in the water-table due to prolonged infiltration arising long duration of rainfall. It is observed that there is lack of good drainage networks and the few existing ones are poorly maintained. Blockage of natural channels, refuge dumping in existing drains and non-observance of building code characterized the drainage system in the study area.
The rate of urbanization in the study area is amazing. There is rapid deforestation of hitherto natural forest which served as natural reservoirs for flood water. Again, this natural vegetation which as natural embankment against flood water are been depleted. The resulting environment reduces the infiltration rate of the soil, increasing surface runoff and the potential flood occurrence. The trend of urban expansion has continued just as industrial activities has opened up new fields without critically considering the consequences of this unbridled development on the environment. Farming and other agricultural activities are increasingly being carried out on the flood plains. This leads to the loosening and disintegration of the resilient nature of the soil structure and texture in this area. Going by the above, it is therefore necessary and expedient for a study such as this to be carried out if the state is to avoid the associated problems of floods faced by many countries in the world.

This research seeks to answer the following questions:

I. How can we analyze and model flood hazard based on certain physical, environmental and climatic Parameters favorable to flooding in Cross River State?
II. How can we analyzed and modeled flood vulnerability taking into account the socio- economic factors linked with peoples' vulnerability to flooding in the study?
III. How best can flood risk map be produced using GIS/RS technologies for used in flood control programs in Cross River state?

1.2 Aim and Objectives of the research

The aim of this research is to apply Geographic Information System (GIS) and Remote Sensing (RS) in flood hazard studies in Cross River State of Nigeria. The following objectives were considered in the realization of the research aim:

I. Analyzed and model flood hazard based on certain physical, environmental and climatic parameters that give rise to flood menace in Cross River State.
II. Analyzed and modeled flood vulnerability vis-a-vis socio-economic factors linked with peoples' vulnerability to flooding in Cross River State.
III. Use Geographic Information System (GIS) and Remote Sensing (RS) technologies to produce flood risk map for used in flood control program in the state.

1.3 Scope and Significance of the study

This research work is limited to the study of flood hazard using GIS in Cross River State. The findings of this work will be useful to policy makers in sustainable settlement planning and flood management and mitigation.

1.4 The Study Area

Cross River State is located within the tropical rainforest belt of Nigeria. It lies between latitude 4^o 28' and 6^o 55’ North of the Equator and longitude 7^o 50’ and 9^o 28' East of the Greenwich meridian. It shares common boundaries with the republic of Cameroon in the East, Benue state in the north, Ebonyi and Abia state in the west, Akwa Ibom state in the southwest and the Atlantic Ocean in the south. It has a total landmass of about 23,000km (CRS SEEDS, 2004).

Arising from its location, the state enjoys a tropical climate with the Obudu plateau at an altitude of 1,595.79m above sea level enjoying a temperate change. The state records heavy rainfall during the wet season (CRS, SEEDS, 2004). At least five distinct ecological zones are represented in the state ranging from mangrove and swamp forest towards the coast, tropical rain forest further inland,, and savannah woodlands in the northern parts of the state. The highlands of the Obudu plateau offer montane type of vegetation. Up the Obudu plateau, the climate is essentially temperate. This coupled with the favourable climate of tropical, humid, dry and wet season give rise to rich agricultural lands thus encouraging both perennial and annual crop cultivation (CRS SEEDS, 2004). The state with its underlying crystalline basement rocks is rich in oil in its coastal regions and other identified mineral resources such as limestone, quartz, natural gas, clay, salt, tin, granite, basalt, etc. some of which are yet to be exploited. Cross River State has a total population of 3.0 million based on an average growth rate of 3.0% (Ottong, *et al. 2010).40%* of the estimated population constitutes an active population that is 'engage in various economic activities ranging from subsistence agriculture to urban commerce and transport business. It is often referred to as a miniature Nigeria because of its diversity in ethnic composition as well as its natural heritage. These have the potential of greatly enhancing the tourism industry in the state and country at large. The people are noted for the warm and hospitality which arguably is rated unequalled in Nigeria. In spite of the numerous dialectical groups that exist in the state, there are three dominant languages groups. These are Efik, Bekwarra, and Ejagham. Nevertheless, all the language groups have a common linguistic root that is traceable to one ancestry (CRS SEEDS, 2004).

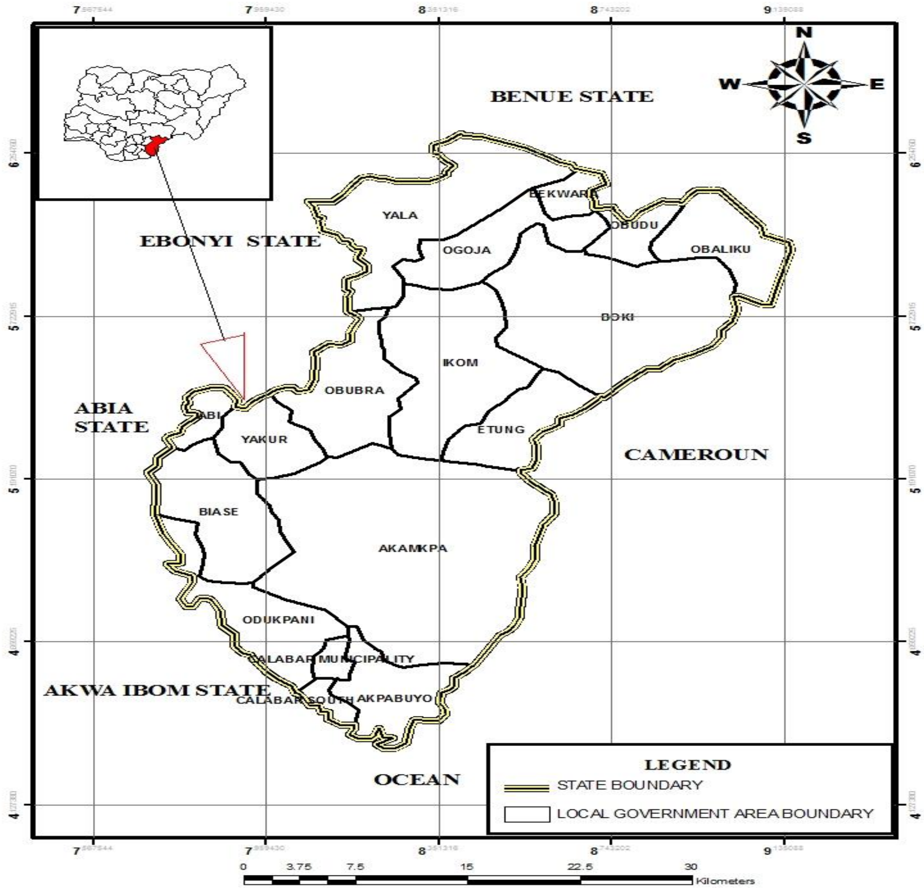

Figure: Map showing Cross River State and neighboring states Source: Author 2017

1.5 Vulnerability to Flood Hazard:

Van Westen *et al. (2002*) studied building vulnerability to multi-hazards (earthquake, landslide and flood) by using a GIS approach. The study focused almost solely on direct tangible losses in its vulnerability assessment of the buildings and their contents. The basic method used was the application of damage-state curves, also known as loss functions or vulnerability curves (Smith, 1994). The cadastral database of the city was used in combination with the various hazard maps for different return periods, to generate vulnerability maps for the city. In an estimate of damage to building contents, two factors were evaluated;

contents requirement value and percentage of damage. Replacement values were obtained by sampling building contents for different socio-economic classes. Four socio-economic levels were recognized in the urban area low, middle-low, middle and middle-high. The procedure evidenced how damage is influenced by socio- economic class as building more assets inside will show greater expected damage (Guarin *et al.* 2001). The most affected stakeholders are usually the vulnerable poor who do not have access to areas that are physically planned with drainage structures and other infrastructural facilities (Ogba *et al.*2009).

1.6 Flood Risk Mapping:

Sunyal and Lu (2005) designed flood hazard mapping which has vital components for appropriate land use planning in flood prone areas. It creates easily - read, rapidly accessible charts and maps which facilitate the administrators and planners to identify areas of risk and priorities their mitigation/response efforts.

Venkata and Salt (2005), tried to identify areas of risk and prioritize their mitigation/response effort in the flood-Hazard areas in the Kosi River Basin, North Bihar, India in a GIS environment. Data sets used in this study were; topographic maps, district level maps and census data, DEM and digital remote sensing imagery. The primary decision factors considered in the study area were geomorphic features, elevation, vegetation, land cover, distance to active channels and population density.

Balogun and Okoduwa (2000) applied GIS to an assessment of flood risk in Benin, Nigeria. This was achieved by creating a digital database of selected variables such as relief, Land use, Land cover and soil strength. An overlay operation was carried out using the ArcMap 9.0 software. It was observed that areas with low soil strength, high intensity of land use and low relief are prone to low flood risk. Again, area with medium soil strength, medium intensity of land use and medium relief are exposed to moderate vulnerability to flood risk.

1.7 CONCEPTUAL FRAMEWORK

The conceptual foundation of this study includes:

I. Concept of Hazard and Participatory GIS
II. Concept of Multi-Criteria Analysis
III. Concept of GIS implementation and planning operations.

i. Concept of Hazard and Participatory GIS:

Hazard refers to the probability of occurrence of potentially damaging phenomenon. Hazard are the threats that have the potential to harm people (and the things the value) and places (cutter, *et al.* 2008). Blaikie *et al*. (2004) argued that people most often live in physical areas of hazard that commensurate with their economic stability. In other words, societal work opportunities may be present only in areas of high hazard and risk. The variety of land and space for work and habitation provide varying degrees of opportunities and risk to hazard. They argued that factors such as race, class, gender, and ethnicity all affect social susceptibility to hazard. Hazard vulnerability is determined by social influence and power and not the force of nature. Indeed, map based GIS recognize the interactions of various exposures, sensitivities and adaptive capacities function across scales (Anyanwu, 2015). Hence, GIS and remote sensing (RS) technology creates needs and opportunities for adaptation than can help shape exposure, sensitivities to flood hazard and adaptive capacities to a local safe community environment in the study area. Therefore, stakeholders' cost effective coordination and efficient adaptation planning, however requires GIS/RS technology (Anyanwu, 2015).Figure 2 presented a general summary of participatory GIS-based sustainable flood risk assessment/management and implementation.

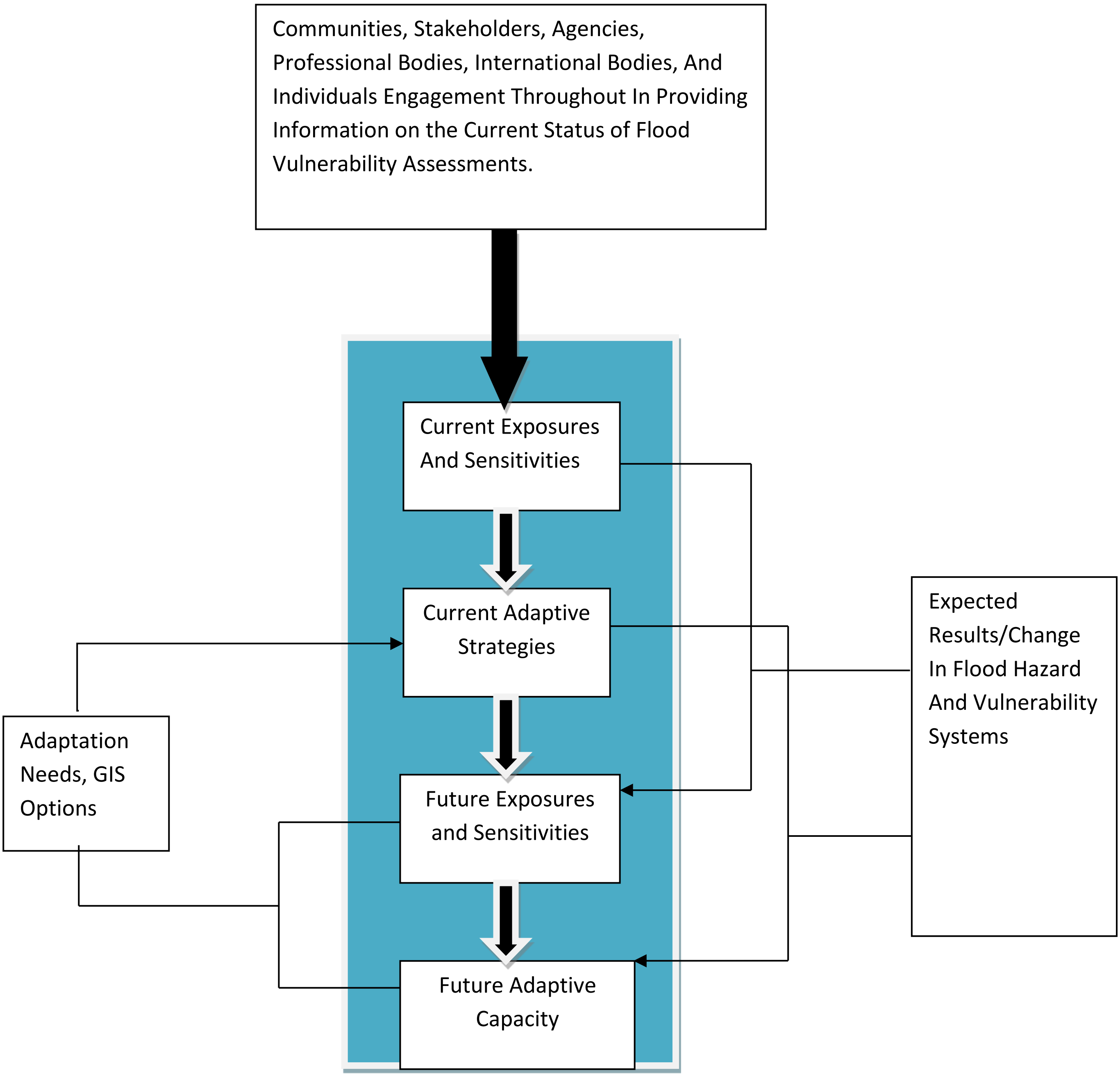

Figure 2: presented a Modified illustration of Participatory GIS Based Sustainable Flood Vulnerability Assessment/Management. Adapted after Anyanwu, 2015.

ii. Concept of Multi - Criteria Analysis

The term Multi Criteria Analysis (MCA) refers to a group of formal approaches to the analysis of decision process and problems, which aim at determining preferences among overall different alternatives. Each alternative under estimation is evaluated on the basis of its performance with respect to a body of decision criteria (Bolton & Stewart, 2002). GIS-based MCDA can be thought of as a process that combines and transforms spatial and aspatial data (input) into a resultant decision (output). The MCDM procedures (or decision rules) define a relationship between the input maps and the output map. The procedures involve the utilization of geographical data, the decision maker's preferences and the manipulation of the data and preferences according to specified decision rules. Accordingly, two considerations are of critical importance for spatial MCDA: (i) the GIS capabilities of data acquisition, storage, retrieval, manipulation and analysis, and (ii) the MCDM capabilities for combining the geographical data and the decision maker's preferences into uni-dimensional values of alternative decisions (Malczewki, 2004). The criteria to be used for evaluation can cover economic as well as social and ecological aspects so that multi criteria decision analysis offers the possibility to integrate into the decision process both easy to be quantified economic and non- economic aspects which can't be quantified or are difficult to be quantified based on economic efficiency to be quantified.

iii. Concept of GIS Implementation and Planning Operations

Geographic information systems (GIS) have gained wide spread attention and use in recent times. It provides many benefits to the government, organization, groups and individuals who use it. However, the effectiveness and efficiency of GIS technology depends on how it is implemented. Therefore implementation is the process of moving an idea from concept to reality and GIS has these capabilities as shown in Figure 3.

I. To improve data access
II. To eliminate or reduce redundancy or duplication of effort
III. To enhance coordination and cooperation.
IV. To realize cost savings.

Thus in order to assess flood risk in the study area, implementation process should involve
the followings:

I. Planning that defined the scope of GIS and developing a general plan to provide a firm foundation for GIS implementation and operation delivering of flood risk assessment.
II. Requirements-Analysis and Design is very important in flood risk assessment. This is because it provides detailed information necessary for Design and GIS implementation.
iii. Acquisition and development of system components to create a unique system operation is required. Also required maintenance by putting the system into operation and maintaining data and the system.

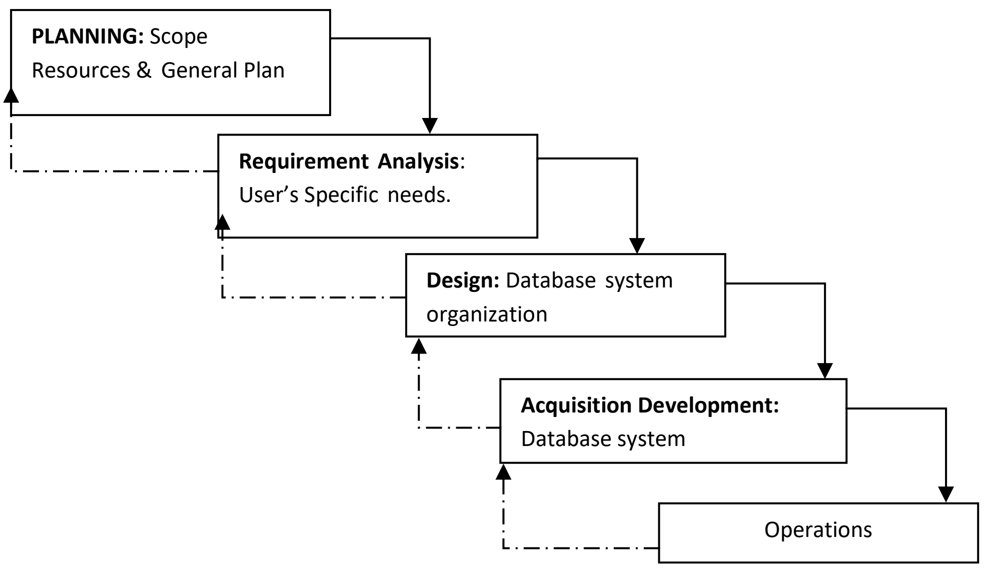

Figure 3: GIS implementation process for assessment of flood risk. Adapted after Somers, R.M.

Based on the research questions and objectives of the study, the review of related literature and conceptual framework, this section has demonstrated the essential framework needed to derive the research methodology in section three.

2.0 METHODOLOGY

The detailed record of research methods and procedures used in the study are presented in this section. These include the types of data used, their sources, methods of collecting, analysis, and the interface on GIS platform for flood risk assessment. The research design demonstrates the effectiveness and efficient work plan in realizing the aim and objectives of the study as shown on the schematic diagram in figure 4.

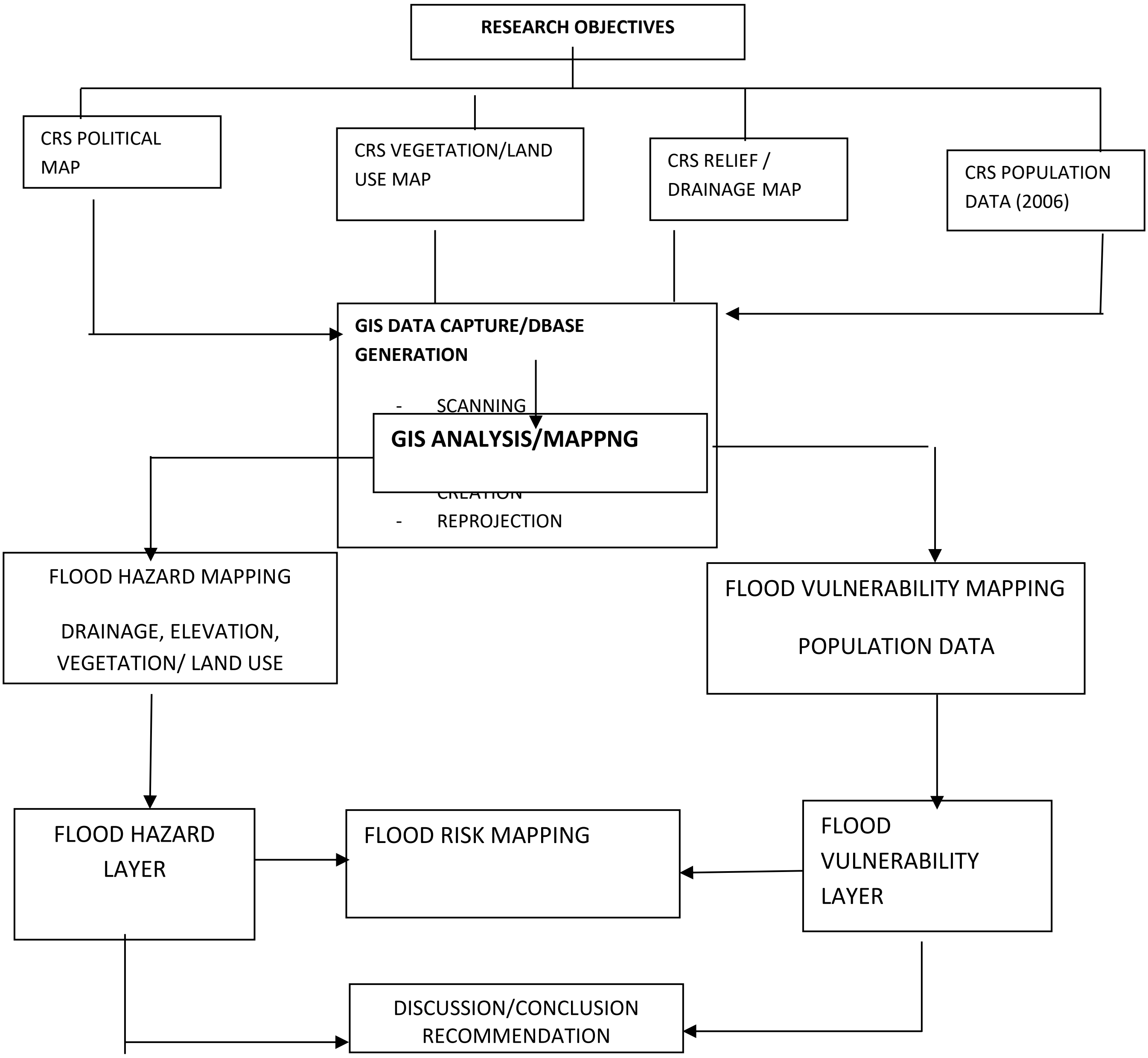

FIGURE 4: The Research Schematic diagram for Assessment of Flood Risk in Cross River State.

2.1 DATA TYPES, SOURCES AND METHODS OF COLLECTION

Geo-referenced digital data sets used for this research were generated from existing analogue base maps and thematic data. These are summarized in Table 3.1 and they provide their sources from where the various datasets for the study were obtained.

Table 3.1 Data types and Sources

S/N	Data type	Identification	Scale & Date	Format	Source
1	State & L.G.A. Boundaries	Administrative Map Of Cross River State	1:50,000 (1992)	Analogue	Ministry of Lands And Town Planning Authority
2	Land use And Vegetation Map	Cross River State Land use & Vegetation Map	1:50,000(1982)	Analogue	Cross River Basin Development Authority
3	Population Data	Cross River State 2006 Population Census	2005 To 2017 Projection	Tabular	National Population Commission 2006
4	Relief And Drainage Data	Relief And Drainage Map Of Cross River State	2009	Analogue	Encarta Map In Microsoft Document.

2.2 GIS POLICY IMPLEMENTATION AND ASSESSMENT FOR FLOOD RISK

A phased approach to implementation allows the necessary time to gather first- hand information about the assessment of flood Risk characteristics of (Cross River State) of the study area, personnel and cultural norms so that the delivered solution be tailored appropriately. Therefore, for phases of implementation were considered as shown in table.

Table 3.2 Flood Risk Assessment Implementation

S/N	PHASE	IMPLEMENTATION	COST
1	Initiation	The goal of this phase is to successfully mobilize the organization, remedy any current at-risk activities and set the stage for the level. Here, flood Risk Assessment methodology is introduced and software training is conducted	
2	Installation	This utilizes information gathered from pilot Assessments in the Initial phase to roll-out structured project planning and control possession. Establishing the office of the organization with necessary infrastructure.	
3	Enterprise-level installation	This involves Flood Risk Assessment Status, Project Scheduling based on available resources and entire tools implementation	
4	Maintenance	This involves providing the enterprise-level information and analysis required by management in Assessing Flood Risk. It is a transitory phase with well trained staff.	

GIS implementation such as Assessment of Flood Risk in the study area build relationships, identify needs and understand Expectations, provide options to address the risk, hazard and vulnerability to Flood.

2.4 DECRIPTION OF DATASETS

1. **Administrative Boundaries/Units:**
   The administrative map of Cross River State (1992) on a scale of 1:50,000 were used to determine the political boundaries of the 17 LGAs to provide a minimum mapping unit for the Assessment of flood Risk in the study area.
2. **Thematic maps:**
   These are representation of specific maps and data that focuses on Relief and drainage and 2006 population data.

2.5 GIS DATA PROCESSING AND DATABASE CREATION

All the datasets were captured in the GIS environment by scanning, Geo-referencing and digitizing and projecting to the US WGS 84. Attribute tables were created using Arc map 9.2. Datasets were re-projected to UTM zone 32N and rasterized using the data management tool and conversion tool of the Arc map 9.2 software.

2.6 GIS ANALYSIS OF FLOOD RISK ASSESSMENT

Assessment of Flood Risk was conceptualized in a GIS environment, using Arc map 9.2 for data manipulation and analysis.

2.6.1 Flood Hazard Mapping:

Weights were assigned to the rasterized data layers and using map Algebra in the spatial Analyst tool to run a multi-criteria Analysis. That is Flood hazard map was generated combining drainage, elevation and vegetation rasterized datasets as shown on the sub-schema in figure 5.

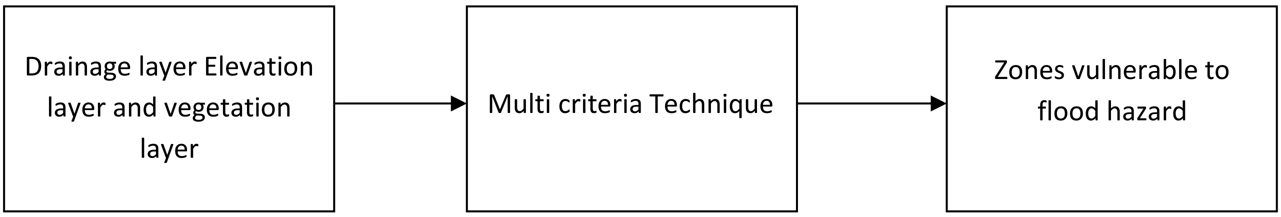

Figure 5: Sub-schema Flood Hazards Mapping Analysis

2.6.2 Flood Vulnerability Mapping:

This was generated by the combination of the flood hazard layer and population map using the spatial Analyst Tool of the Arc map 9.2 as shown on the sub-schema in figure 6

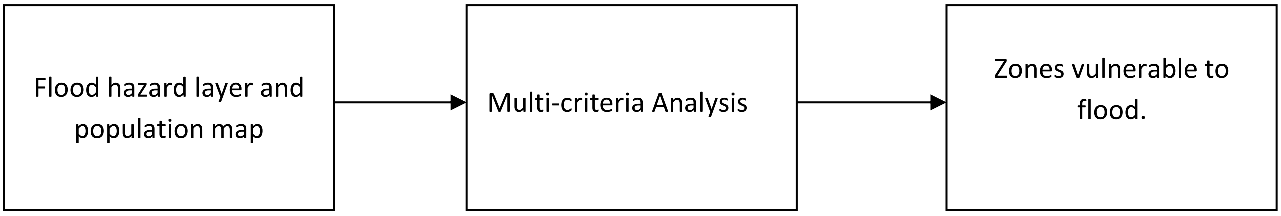

Figure 6. Subschema Flood vulnerability mapping Analysis

2.6.3 Flood Risk Mapping:

This was generated by the combination of the flood hazard layer and flood vulnerability layer as shown on the subschema in figure 7.

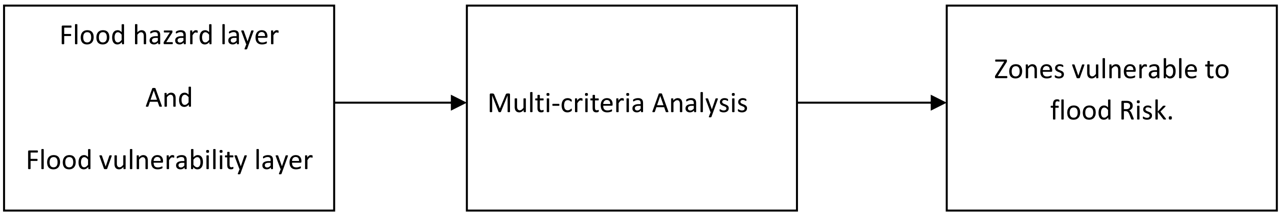

Figure 7. Subschema Flood Risk mapping Analysis

This section dealt with manipulation and GIS procedural analysis made in the light of the main purpose this research sought to address. It has put forward the stage for Result and Discussio.

3.0 RESULTS AND DISCUSSION

3.1 Presentation of Findings and Analysis:

The three of flood hazard surface layers in the study area was generated and illustrated using Drainage layer, Elevation layer and vegetation layer.

Table 4.1: weight Assignments for Flood Hazard Layers.

S.N	**Data layers**	**%**	**Decimal Weightage**
1	Drainage	40	0.4
2	Elevation	35	0.35
3	Vegetation	25	0.25
	Total	100	1.0

The 3 layers were weighted as presented above in table 4.1 and combined using single output, map, algebra of spatial Analyst extension, a multi-criteria Analysis in Arc map 9.2 environment to generate flood hazard layer. This is analyzed using three (3) classes to show low, moderate and high areas of flood hazard disaster as shown in figure 8

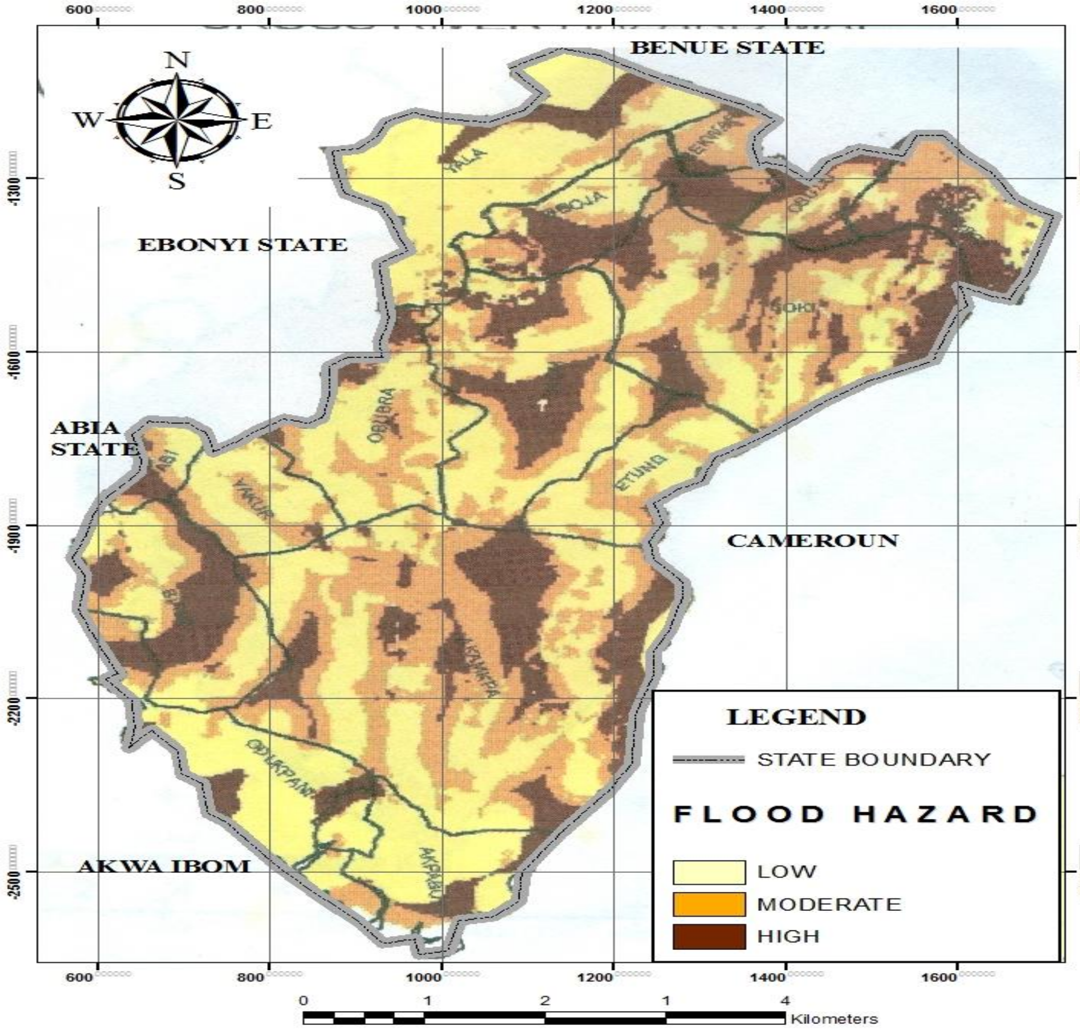

Figure 8: Flood Hazard Map of Cross River State

3.2 Flood Vulnerability Presentation Analysis:

The two (2) flood vulnerability surface layers in the study area was generated and illustrated using, Flood hazard layer and population layer.

Table 4.2: weight Assignments for flood vulnerability layers

S.N	Data layers	%	Decimal Weightage
1	Flood hazard layer	60	0.6
2	Population payer	40	0.4
	Total	100	1.0

The two (2) layers were weighted as presented above in table 4.2 and analyzed in a GIS environment.

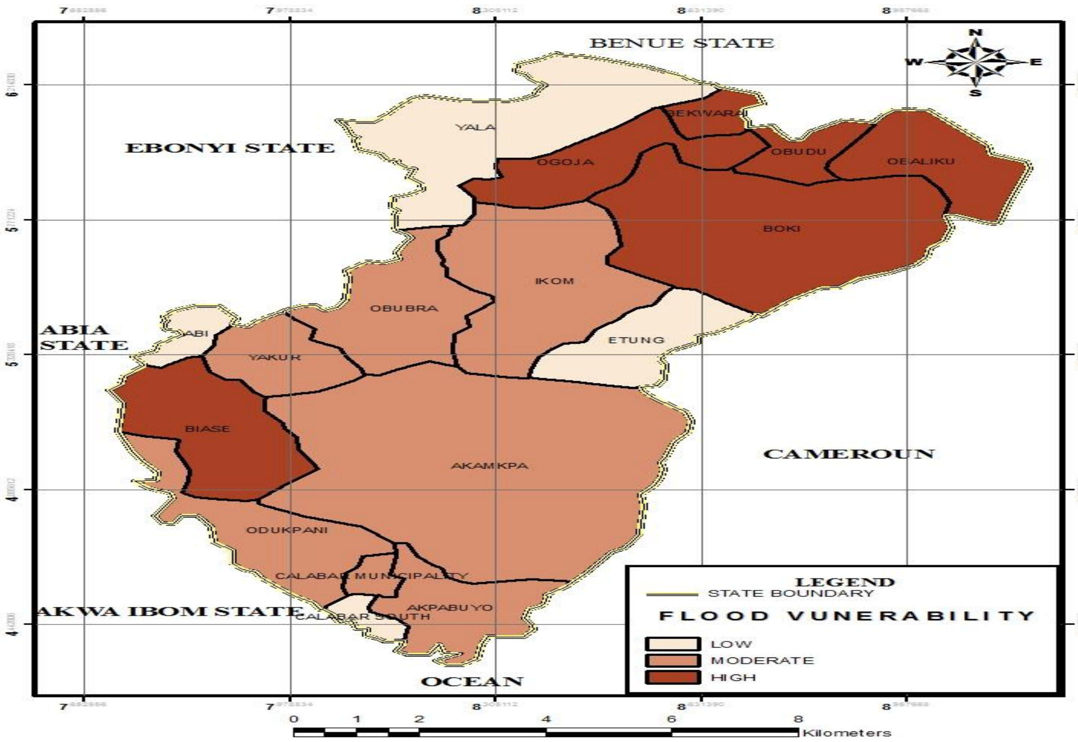

Figure 9: Vulnerability Maps of Cross river state

3.4 Flood Risk Presentation Analysis:

The two Flood Risk surface layers in the study area was generated and illustrated using Hazard layer and Vulnerability layer

Table 4.3: weight Assignments for Flood Risk layers

S/N	DATA LAYER	%	DECIMAL WEIGHTAGE
1	Hazard Layer	50	0.5
2	Vulnerability Layer	50	0.5
	TOTAL	100	1.0

The two layers were weighted as presented above in table 4.3 and analyzed in a GIS environment. The flood risk map like the hazard and vulnerability maps also has 3 classes, namely Low, Moderate and high Flood risk areas respectively as shown in figure 10.

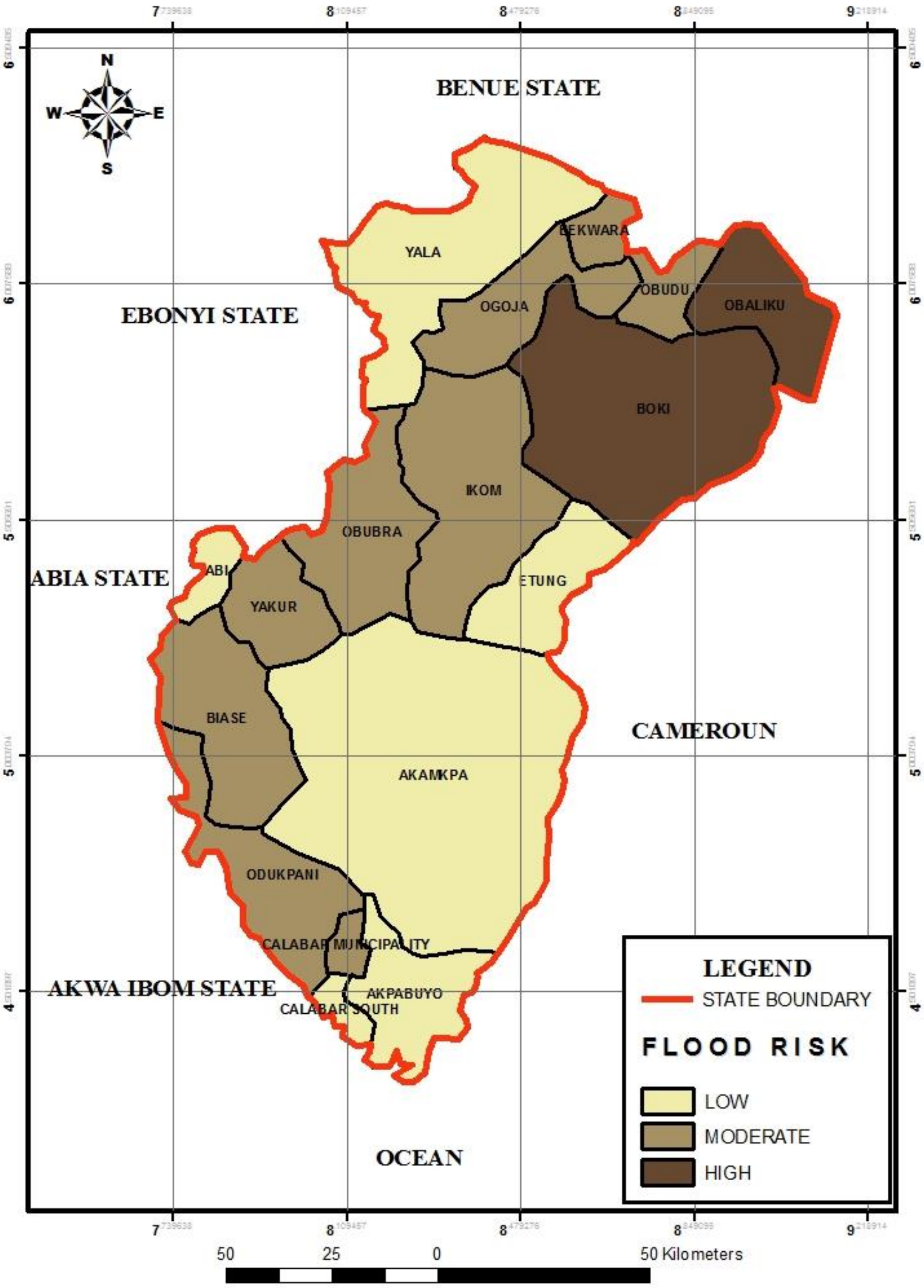

Figure 10: Flood Risk Map of Cross River State

4.0 DISCUSSION OF FINDINGS

Flood Risk Assessment and Cross River State Environment:

Based on the foregoing map-based GIS analysis, this study has shown that Cross River State Environment is prone to Flood risk. This is due to extreme intensity of rainfall events, wide spread of severe poverty and threatened by urbanization (Ekpenyong, 2010). Besides, basic adaptation needs/resolutions remained low or not available.

This section dealt with results and discussions and set the final stage in section 5.

4.1 SUMMARY, CONCLUSION AND RECOMMENDATION

This section presents summary of the major findings, Conclusion and Recommendation for this study area as well as areas where attention are needed.

4.2 SUMMARY OF FINDINGS

Floods are one of the most common and widely distributed natural hazards to life and property worldwide. This research represents an attempt to understand the dynamics of GIS/RS technology. The findings demonstrated that flood hazard and vulnerability maps are used for improved communication about risk and what it threatens. It shows that it is possible to monitor and control urban growth /expansion, deforestation and loss of biodiversity that always lead to flooding.

4.3 CONCLUSSION

GIS technology should be employed for effective and efficient flood management in the study area. That is the study proved GIS/RS technology as tools which can be deployed in the assessment of flood risk in the study area.

4.4 RECOMMENDATIONS

I. A GIS implementation strategy will help in effective and efficient flood control measure in the state to target areas of high flood risk.
II. Map-based flood risk assessment provides information that leads to disaster reduction.
III. Other flood control measure can be integrated into field enterprise with GIS technology. E.g. financing, Emergency Response measure and Government and legislature.

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