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Multi Hazard Risk Assessment Using GIS Techniques in the Mbo Area of Nigeria

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Abstract

The study area Mbo and environs of South Eastern Nigeria are experiencing frequent inundation by flood and erosion hence this research is aimed at generating vulnerability hazard and risk maps as decision support tools for policy makers. Rainfall, elevation, slope, soil association and hydrology were used as input layers to model the hazard layers while population density, vegetation and Normalized Difference Vegetation Index (NDVI) were used to model the vulnerability layers. Risk maps were generated weighting and combining the Hazard and vulnerability layers using the Single Output Map Algebra function of Arcmap soft ware. The final multi hazard risk map , derived by combining the flood and erosion risk maps shoed that 119.62km^2 (15.12%), 193.94km^2 (24.52%), 292.33km^2 (36.95%) and 185.20km^2 (23.41%). The study, using GIS, has revealed an objective way of understanding and dealing with the impact of hazards in the study area.

Keywords: Hazard, Vulnerability, Risk assessment, GIS, AkwaIbom State.

1. Introduction

Natural hazards including erosion and flooding are part and parcel of the environment in which we live. They do not discriminate between people or countries. However, no disaster is entirely natural. For an example, although erosion is a natural process, it has increased dramatically by human land use, especially industrial agriculture, deforestation and urban sprawl. Land that is used for agricultural generally experience a significant greater rate of erosion than that of land under natural vegetation, or land used for sustainable agricultural practices [1]. Equally, floods are caused by a variety of factors, both natural and manmade. Apart from the obvious causes of floods like heavy rainfall, melting snow and ice, and frequent storms within a short period of time duration; the common practice of humans to build homes and towns near rivers and other bodies of water have contributed to the disastrous consequences of floods. Generally, increased urbanization, the settlement and industrialization of highly exposed regions, the vulnerability of modern technologies and anthropogenic changes in the environment, have led to increased levels of disasters globally [2]. Risk is the expected lose as a result of potentially damaging phenomena within a given time period and within a given area [3]. It can be analyzed by assessing three major components – the probability of an event with a certain magnitude (hazard); the vulnerability of the elements at risk that are exposed to the event to the event with a certain magnitude (vulnerability); and, the costs relating to these elements at risk (risk).

Risk assessment forms an important input in disaster management, in the design of development plans and in emergency response planning. It combines information on the nature hazard with information on vulnerability of the targets. It is helping to clarify decision making and the development of mitigation strategies [2]. Vulnerability is an important concept in hazard research and is central to hazard mitigation strategies. Within the framework of the United Nation's International Decade of natural Disaster reduction (IDNUR), for an example, vulnerability assessments are used to determine the potential damage and loss of life from extreme natural events. They are important as well in proposing hazard reduction alternatives where mitigation normally takes the form of structural (engineered) approaches to hazard reduction [4].

Most of the data required for disaster management have spatial components and also change over time. Hence, remote sensing and Geographic Information System (GIS) are very useful for analyzing various components of risk. While remote sensing help collect environmental data, the GIS helps store, integrate and display the data. Various GIS based studies exist on hazard, vulnerability and risk assessment. Examples include, multi-hazard risk assessment in urban areas [5]; landslide hazard zonation and analysis [6] and, vulnerability to environmental hazard [7].

2. Aim and Objectives

The aim of this work was to carry out a multi - hazard risk assessment using GIS techniques in Mbo and environs in Akwa Ibom State of Nigeria. Specific objectives of the study include: to quantify and model hazard and risk; make an inventory of these hazards; map the elements at risk; and, produce a multi – risk map that would inform the decisions and developments of effective response measures, for the study area

3. The Study Area

The study area (Fig.1) is the south eastern Akwa Ibom state comprising four local government areas (LGAs) – Mbo, UdungUko, Oron and Urue Offong Oruko. It lies within latitude 4^0 30^I - 5^0 0^I North and longitudes 8^0 0^I - 8^0 20^I East. With a total landmass of $791.1m^2$, it is bounded on the north by Okobo LGA and on the South by Ibeno LGA, to the south by Cross River and to the west Esit Eket and Eket LGAs as shown in Figure 1. It has a population density 399.33 people per square kilometers with the people being predominantly fishermen and farmers.

The landscape of the study area comprises of generally low lying plain and riverine areas with no portion exceeding 175meters above sea level. The area is traversed and criss-crossed by a large number of creeks, rivers, streams and canals. The likelihood of erosion and flooding is high in the study area because of the intricately woven network of creeks, rivers and inlets. Rich in crude oil and gas, the area is noted for its wetlands, sandy coastal ridge barriers, brackish or saline mangroves, fresh water swamp forests as well as lowland rainforests.

4. Methodology

Analogue maps on vegetation and land use, soil association, hydrology, rainfall, relief and drainage, and population density were scanned into a computer, opened on a GIS environment and digitized to create a digital map layers that were used for the analysis. Equally, Landsat TM of 2003 with 30m x 30m resolution were used to extract the vegetation and Normalized Difference Vegetation Index (NDVI) used too for the analysis. The Digital Elevation Model of the study area was used to extract slope, elevation and aspects also used as input in the analysis. Hazard and vulnerability analysis are needed to model risk.

4.1. Vulnerability Modeling

For risk assessment to be valid, certain elements must be critical to that assessment. In carrying out multi – hazard risk assessment of the study area, what are likely to be affected by the hazard is of prominence to the study. Population; vegetation and land use, and NDVI were identified and used as the vulnerability elements at risk to the hazards. The vulnerability layer was modeled by weighting and combining the elements using the Single Output Map Algebra function of Arcmap soft ware thus:

Vulnerability layer = (population density x 0.4) + (vegetation & Land use x 0.2) x (NDVI x 0.4).

The vulnerability map displayed in Fig. 2 was the resultant output.

4.2. Multi - Hazard Modeling

Hazards for this study were limited to flood and erosion. In the absence of data for these hazards, the following were used as proxies to model them: slope, rainfall, hydrology soil association and elevation. The elements were weighted and used to model the hazard as follow:

Erosion hazard = (Rainfall x 0.3) + (Slope x 0.25) + (Soil association x 0.20) + (Hydrology x 0.25)

Flood hazard = (Rainfall x 0.3) + (Elevation x 0.25) + (soil association x 0.20) + (Hydrology x 0.25)

4.3. Risk Layer

The final risk layer of the study area (Fig. 5) was gotten by deriving, combining and classifying the erosion and flood risk layers of the study area using the Single Output Map Algebra function of Arcmap soft ware as follows:

Erosion Risk layer = (Erosion Hazard x.05) + (Vulnerable layer + 0.5)

Flood Risk layer = (Flood Hazard x.05) + (Vulnerable layer + 0.5)

The resultant output were Erosion (Fig. 3) and Flood risk (Fig. 4) maps respective. These were combined to form the multi – risk map as follows:

Multi – hazard risk map = (Multi hazard layer x.05) + (Vulnerable layer + 0.5).

Fig.1: Vulnerability locations in the study area

Fig 2: Erosion Hazard Zones of the study area


Fig. 3: Flood Hazard Zones of the study area

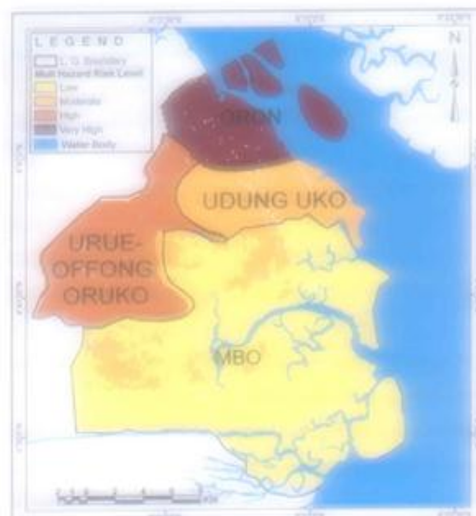

Fig. 4 Multi Hazard Risk Zones of the study area

The vulnerability, hazard and risk maps were all classified into Low, Moderate, high and very high zones. The multi risk classification of the zones is displayed on Table 1 to show the areal extent of each zone in the study area.

Table-1. Tale showing the multi risk classes

Risk class	Area (km^2)	%
Low	119.62	15.12
Moderate	193.94	24.52
High	292.33	36.95
Very High	185.20	23.41
Total	**791.09**	**100**

Source: Analysis by researchers.

5. Discussion

This study generated a multi-hazard risk map of Mbo and environments in a GIS environment using a data base created with vegetation and land use, soil association, hydrology, rainfall, relief and drainage, and population density data of the study area. Generally, GIS based risk is assessed by combining vulnerability and hazard layers as no risk is encountered if there hazard events but no vulnerable population or if there is a vulnerable people but no hazard event. Hence risk is a function of a varying degrees of hazard and varying degree of vulnerability [8].

The study has revealed risk zones in the study area that would help policy makers identify specific risk zones for intervention measures. For an example, the High and Very High risk zones being 60.36 % it means that there is need for mitigation measures in order to preserve the study area from the harmful effects of erosion and flood. The study area being in a low – lying coastal needs such measures as the erosion and flood maps have shown that these hazards are found in all the 4 LGA’s located here. The study has also shown that the areas of moderate (24.52%) and low (15.12%) risk have to be preserved and well maintained so that erosion and flood does not spread.A combination of remote sensing and GIS techniques was used in the risk assessment. Remote sensing LANSAT imagery and DEM data has been used in providing timely information on the state of the environment hence making the monitoring and detection of environmental hazards easier than conventional text based methods. The remote sensing and other spatial data of the study area were stored and integrated in a GIS data base for subsequent analysis and presentation.

6. Conclusion

The study has revealed the use of GIS for multi – hazard risk assessment for effective management of the study area. Risk, hazard and vulnerability maps were generated that could serve as useful decision support system for planners and policy makers. With these, areas for mitigation measures could easily be identified and tackled easily.

7. Dedication

This paper is dedicated to the memory Okpo O. Ekere, the co-author who died before the publication of this work.

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