Flood Risk Assessment using Geographic Information Systems (GIS) in Uyo, Nigeria

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Abstract: This paper discusses the application of Geographic Information System (GIS) in the assessment of flood risk and sensitivity for Uyo urban, Nigeria. Data for the study were obtained from field measurements and observation as well as archives of relevant agencies. The data include GPS coordinates, base maps and rainfall. The data was manipulated using GIS techniques to generate geospatially-referenced information which was further used to develop cartographic and hydrological models suitable for flood sensitivity mapping and risk assessment. Onscreen digitization overlay and query operations were performed by orthophoto manipulation. Results indicate that a greater portion of the landuse pattern of Uyo urban is residential mostly constructed across natural drainage routes resulting in serious erosion menace in the city particularly within the residential areas.

Key words: Geographical Information System; Flood Risk Assessment; Uyo, Nigeria

Introduction

Flood basically means a large body of water covering an area after its optimum capacity is reached. It follows that in the event of flood, the water covers the area longer than necessary. Gobo (1988) defines flood as any high stream flow that overtops natural or artificial banks of streams. It is theoretically the greatest depth of precipitation for a given duration that is physically possible. There are various types of flooding, which according to Gobo (2006) and Teme and Gobo (2005) include;
- Backland or Back Swamp Flooding
- Tidal Flooding
- Channel Flooding
- Coastal Flooding
- Flash Flooding and
- Petters et al. (1994) lists flooding and erosion amongst other phenomena as deforestation, loss of fauna, pollution, diseases prevalence etc, among major environment hazards Akwa Ibom State including Uyo urban. According to Gobo and Abam (1991) and Gobo (2006), the Niger delta area where Uyo is located suffers from regular flooding as a result of its flat terrain and high rainfall. Flooding is accentuated in the area because its river banks are made up of levees bordered by areas consisting mainly of backswamps and numerous lake-like water logged depressions where surface flow can hardly be drained by gravity.

Man’s quest to control flood and its impact has led to the development of technologies for analysis and assessment of floods and flood risk zones. According to Sharma and Sham (2000) new technologies include automation of data collection and telemetry to base stations, measurement of rainfall, stream discharge and soil moisture by radar, remote sensing by camera and geophysical sensors from aircrafts and satellites, automation of data storage, processing and retrieval by use of digital computers, electric analogs (Geographic Information Systems, GIS) to simulate hydrological systems.

Geographic Information Systems (GIS) is a highly technical computer-based system that combines layers of information about any given geographic location in order to provide a better understanding of that location (HCFCD, 2006). The layers and the data that are combined depend on the type of information needed and may include review of population statistics, analysis of environmental conditions, evaluation of urban development trends, etc.

Geographic Information Systems (GIS) are used for capturing, storing, processing analyzing and visualizing geo-referenced data. A GIS is not just a data base management system (DBMS) since in addition to the storage capabilities it includes spatial operators, which permit the manipulation of spatial data.

GIS in the past have been used primarily for the production of digital maps for resources management and management of land information systems. However, in the last 10 years with the wide availability of digital map data and the emergence of desktop mapping systems, GIS are applied in many different fields ranging from marketing to
environmental planning and from city planning to water resources management. The Niger Delta basin (where Uyo is located), has been investigated using remotely sensed data to evaluate the hydrological impact of canals, (Abam, 2004).

GIS has been employed in number of environmental, telecommunications, tourism sectors as well as in the management of Electricity Distribution Facilities in Nigeria. For example, Environmental Systems Research Institute; ESRI (1997) noted that a GIS software, Land Related Information System (LRIS) provides access to all relevant documents available for each parcel of land for a portion of Lagos., where current records are poorly kept and the communications infrastructure is unreliable. Reid Crowther (GIS solution consultants) has developed a PC-based system that allows query and update of land records from either a form-based approach or a map-based approach.

Igbokwe and Emengini (2002) developed an automated system for Power Holding Company Of Nigeria (PHCN) installations and transformers in Onitsha District of Anambra State using GIS. In the tourism sector, Ayeni et al (2004) have developed a multimedia GIS database for tourism industry in Nigeria.

In this study, GIS, is intended to provide a broad range of tools for determining flood vulnerable and damage areas amongst others and thus assist policy makers, town planners, environmentalists, engineers, governments, academics and stakeholders alike in solutions to flooding menace.

Data collection and analysis

Study location

Uyo located within the Niger-delta sedimentary basin is the administrative capital of Akwa Ibom State, south-south Nigeria. Uyo is located between latitudes 5° 58’ and 5° 08’N and longitudes 7° 47’ to 8° 02’ E (Fig. 1). Like most part of Nigeria the area is characterized by two seasons, namely, the wet or rainy season and the dry season. The rainy season occurs from March to April and the dry begins around mid November and lasts till March.

During the rainy season the major streets of Uyo become un-useable (Mendie and Akpan, 1999). At the beginning of the dry season is a brief period of hamattan. During this brief period, the whole Continental Tropical air mass and its accompanying north-easterly winds and their associated dry and dusty hamattan haze blow over Nigeria. However, as a result of the proximity of the study area to the ocean, the hamattan dust haze, (locally known as “ekarika”) is not usually too severe as in the Sahelian zone of northern Nigeria. Sometimes it lasts for only a few weeks between December and January.

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The 1991 census puts the figures for Uyo council at 293,870 (Ekpo, 2005). The population has been projected to reach 483,959 by 2005. Uyo being a state capital and a regional commercial nerve centre, the rate of rural urban migration is expectedly high.

Uyo lies on flat terrain with natural drainage channels in the north-easterly direction and much further away in the southerly direction (Ideal Concepts Engineering, 2004). Although nature provided tributary channels and ravines to collect stormwater runoff for discharge into major waterways, uncontrolled erection of buildings and other facilities, dumping of refuse in drainage facilities, lack of drainage maintenance and general disregard for building codes among others, cause water to collect in troughs and pools in several locations within Uyo urban, thereby constituting hazards. These hazard points easily identifiable as shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Identified hazard points within Uyo Metropolis</th>
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<tbody>
<tr>
<td>Along Nwaniba Road</td>
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<tr>
<td>---------------------</td>
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<tr>
<td>Udo Iwng/ Nwaniba Junction</td>
</tr>
<tr>
<td>Enig Offot and Nsikak Eduok/Oron Road Crossing (Methodist Church Area)</td>
</tr>
<tr>
<td>Ekpi Nsukara Mbiabong Primary School</td>
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Data for this study were collected directly from the field and records from relevant agencies. The data include pictures, GPS coordinates from selected locations and rainfall data. Required instrumentation which included computer systems and GIS software was used to generate geographically or geo-spatially referenced data culminating into models; cartographic and hydrological models. On-screen digitization overlay and query operations were carried out by orthophoto manipulation and analyses.

Creation and Design of Database

Igbokwe and Emengini (2002) listed four basic steps in the design of a GIS database. These include articulation of reality, translation of reality to conceptual model, translation of conceptual model to logical design and physical design. During this research, the database was designed in such a way that it facilitates the storage, organization and retrieval of flood analyses in the under mentioned processes.
Articulation or View of Reality

This refers to the mental abstraction of the objects in the study area, as they actually exist. These objects include roads, drainage routes, buildings, landuse, soil, population statistics etc; as they are in real life. These perceived realities are often causes of flood problems. A school of thought does not regard articulation of reality an integral part of the database design phase in GIS applications; it is however a useful tool in the design phases.

Translation of Reality to Conceptual Model

The vector data modeling was adopted. The realities were represented and displayed as points, lines or area (polygon), with their attributes defined by pair of plane coordinates (X, Y). The objects together with the spatial relationships among them were carefully identified and analysed. The representation of realities by point, line and polygon (area) objects as the case maybe in conceptual design model is illustrated in fig.3 below.

Translation of Conceptual Model to Logical Design

Translation of conceptual model to logical design involves representation of the designed data model to reflect the recording of the data in the computer, (Igbokwe and Emegini, 2002). The data were structured to describe logically the organization of data in a database system or scheme. Fig.4 below shows a typical example of schematic representation of a spatial database in DIS (Drainage Information System).

Physical Design

This is the representation of internal storage structures and file organizations for database in the format for instrumentation implementation, (Olabanjo, 2004). During physical design, the designed data structure was represented in a form that is acceptable to the available instrumentation; i.e. implementation hardware and software. The software of course, allows for GIS to be run on the computer hardware via data acquisition, manipulation, analyses and display.
Overlay Operations

Here, the orthomap of the study area was superimposed on the grid vector map, generated using SURFER7.0 GIS Software. Again, according to Igbokwe and Emengini (2002), the essence of overlay operation is to superimpose two or more data layer that occupies the same location.

<table>
<thead>
<tr>
<th>Spatial data base</th>
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<tr>
<td>Point data</td>
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<tr>
<td>Catch pit</td>
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<tr>
<td>Man holes</td>
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<td>Parks</td>
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<tr>
<td>Piles</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Point coverage</td>
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**Fig. 4:** Schematic Representation of Spatial Database in DIS (Drainage Information Systems).(Olabanjo, 2004)

Query Operation / Spatial Search

Retrieval operations of spatial and attribute data involves the selective search manipulation and output data without resultant modification of the geographic location of features or the creation of new entities. These work with the spatial elements as they are entered in the database. Information from the data can be accessed directly through the map or the attributes data.

Landuse Map

The landuse map is a cartographic model and a graphical representation of the pattern of land usage in the study area. The landuse map is geo-referenced (geo-rectified) using observed GPS point coordinates. These contours are then overlain on aerial photo of Uyo to produce the orthomap (rastermap). This pattern could be grouped into residential, commercial, governmental institutions and farmlands.

Flood Vulnerability Map

This is produced by cartographical modeling, similar to that of the Landuse map. However, one more theme is created for recognizable flood vulnerable positions observed.
Runoff Flow Direction Map

The Landuse Map is used in combination with relevant GIS software as a basis for the generation of the flow direction map. The map shows a real life pattern of surface runoff.

Digital Elevation Model (DEM)

A map showing a three dimensional model of surface runoff pattern for Uyo was also developed using the Surfer 7.0 GIS software.

Results and Discussion

Geographic (geospatial) analyses allows for the study of real world processes by developing and applying models. Such models illuminate underlying trends in geographic data by providing tools, which can be combined in meaningful sequences to develop new models. These models may reveal new or previously identified relationships within and between data sets, thus increasing the understanding of these models represent.

Landuse Map

Figs. 5 and 6 show the analysis for the landuse map. The map indicates that a greater portion of the landuse pattern of Uyo is mostly residential, often constructed across natural drainage routes. Therefore more dwelling structures and roads (which reduce percolation) are constructed to accommodate the growing population. This increases the chances of flooding.

![5m Contour Map Graduated by Colors](image)

Fig. 5: Contour lines of the study area
Fig. 6: Orthophoto of study area overlaid with 5m contours

Fig. 7: Landuse map of study area
Flood Vulnerability Map

According to Nawaz (2003), vulnerability is defined as the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude. It is expressed on a scale from 0 (no damage) to 1 (total damage). From the vulnerability map (Fig. 8), the areas very vulnerable to flooding are the residential areas.

Runoff Flow Direction Map

Fig. 9 shows the flow direction of runoff from the study area. This is indicated by the direction of the arrows. The runoff follows the natural water ways which flow from highland to lowland or depressions. The general direction of flow is towards the ravine and depression spots.

Digital Elevation Model (DEM)

Fig. 10 shows this DEM revealing the flow patterns of surface runoff, major depressions, ravines and the major existing roads in Uyo Urban.
Fig. 9: Runoff flow direction of the study area

Fig. 10: Digital elevation model (DEM) of the study area
Conclusion

Flood is destructive and a frequently occurring phenomenon in the study area. Geographic Information Systems (GIS) will however provide proper warning information and risk assessment about the flood hazard to the people living in the flood prone area if communicated effectively. Simply put GIS is a vital tool before, during and after flood cases. The GIS provides flood management that can prove very useful tool for advance planning and decision making. At this point the researchers will commend the laudable effort of the government of Akwa Ibom State, which in the last couple of year embarked on the Aerial survey of the state and in that course providing vital geo-information.

Although flooding is sometimes a natural phenomenon we cannot completely stop it but we can minimize its adverse effects by better planning. For reduction of vulnerability in the study area to flood hazard there is urgent need to adopt long-term strategies by skilfully combining the engineering devices with proper planning.

References