Journal of Applied Sciences Research, 4(12): 1822-1833, 2008

Flood Inundation Hazard Modelling of the River Kaduna Using Remote Sensing and Geographic Information Systems

[1]Mr. David Nyomo Jeb and Dr. [2]S.P. Aggarwal

[1]National Centre for Remote Sensing, KM 11, Jos-Bukuru Expressway, P.M.B. 2136, Jos Plateau State, Nigeria.
[2]Water Resources Division, Indian Institute of Remote Sensing, 4, Kalidas Road, Dehradun, Uttaranchal, India.

Abstract: The hazard of and damage caused by flooding cannot be overemphasized in terms of loss of life, property, displacement of people and disruption of Socio-economic activities as well as the loss of valuable agricultural land due to the attendant inundation of flood plains from floods. Urban flooding is gradually becoming a serious ecological problem in Nigeria. Several areas along the coast of the Atlantic ocean and along major river valleys are affected by floods every year. To gain better understanding of the flood problem especially for planning purposes, flood risk maps are often required. A combination of recent data on flood plains such as land use/cover, river/flood stage, and digital elevation models are used to predict future flood stages and likely impacts. In addition, extreme value statistical models such as the Gumbel's, distribution are used to determine flood frequencies and different return periods of flood hazards of certain magnitudes. Remote sensing and GIS and results of analysis of flood stage data using Gumbel's Extreme distribution model and a combination of Digital elevation model and land use/land cover data were used to estimate the extent of flood inundations in different flood return periods in Kaduna Metropolis. Areas under high risk due to flooding were also determined. The study revealed that most of the areas lying close to the River Kaduna's flood plain are under severe threat to flooding in different flood return periods.

Key words: Flood Inundation, hazard, remote sensing, geographic information system, flood frequency analysis

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. Flooding phenomenon is considered the world's worst global hazard in terms of magnitude, occurrence, and geographical spread, loss of life and property, and displacement of people and socio-economic activities. In the tropical and sub-tropical regions, severe flooding hazards of grave consequences resulting from heavy thunderstorms, torrential monsoon downpours, hurricanes, cyclones and tidal waves surges in coastal and estuarine environments are yearly occurrence. Flood disasters are said to account for about a third of all natural catastrophes throughout the world (by number and economic losses) and are responsible for more than half of the facilities damage. Worldwide, flooding is a leading cause of losses from natural disasters and is responsible for a greater number of damaging events than most other types of elemental perils. At least one third of losses due to nature's forces can be attributed to flooding.

Flood damage has been extremely severe in recent decades and it is evident that both the frequency and intensity of floods are increasing. In the past ten years, losses amounting to more than 250 billion dollars have had to be born by societies all over the world to compensate for the consequences of floods. Trend analyses reveal that major flood disasters and the losses generated by them have increased drastically in recent years. (Berz, G.) Analysis of worldwide loss events shows that there are distinct increases in respect of the economic losses, but also the rising number of events represents a worrying trend.

Corresponding Author: David Nyomo Jeb, National Centre for Remote Sensing, KM 11, Jos-Bukuru Expressway, P.M.B. 2136, Jos Plateau State, Nigeria.
Email:jebtiya@yahoo.com

In Nigeria, most floods occur because of excessive rainfall and dam failures. It has been estimated that more than 700,000 hectares of useful land for agricultural and human settlements are rendered useless due to annual floods. For example, in August 2001, excessive flooding caused severe devastation on land property and human life in Kano and Jigawa States when rivers Challawa and Kano were flooded[11]. It was reported that twenty people died in Kano, and a further 48,500 were displaced. While in Jigawa, 180 deaths were registered, 800 people were injured and 35,500 displaced. The total number of people affected, including those whose farmlands were washed away, exceeded 143,000[16].

As a result of eight hours of heavy rains that occurred On 7 August, 2005 the heaviest and worst floods in 40 years occurred in Jalingo, the state capital of Taraba (north-east of Nigeria, bordering Cameroon), killing over 100 people and displacing more than 50,000 others. By 26 August 2005, 40 bodies had been recovered and five people were rescued. The most affected areas were Mafindi, Nunkai, Magami, Lamurde, Mallam Gabdo and Sabon-gari where about 80 houses were totally swept off, 410 houses extensively destroyed, and 2,661 families displaced[9].

On Saturday afternoon, September 30, 2006 following more than 24 hours of heavy rain, a barrage dam located outside the Zamfara state capital, Gusau, gave way. The heavy rainfall swelled the reservoir to critical levels, causing the dam to collapse and send a barrage of water through villages. More than 500 houses were washed away, over 1000 families were affected, and property worth over 3 billion naira ($35.45 million) destroyed. Although there were no reports of loss of life, it was however reported that more than 98 people, mainly women and children, remain unaccounted for in the worst hit village of Birnin Ruwa[4,13,12].

Indeed, annual floods occur along Rivers Niger and Benue causing severe damages in parts of Niger, Adamawa, Benue, Kogi and other States. As a result, of the flood events every year, Government spends huge sums of money on compensation and rehabilitation, yet the problems are unabated. It is therefore necessary to use scientific methodology such as flood risk modeling to provide a basis for concerted action-plans to be carried out in flood plain planning, flood structures or hazard mitigation, warning systems and rescue operations by either government or non-governmental agencies as applicable.

In Kaduna metropolis and environs, flooding is not a regular annual phenomenon but the potential risk is very high in the low-lying settled flood plains. In addition, rapid urban expansion and encroachment of settlements into the areas liable to flood is also continuing rapidly and unabated. More so, recent floods especially of August 23, 2003 caused inundation of huge areas on the flood plain and as a result, cultivable lands and human dwellings were adversely affected and several thousands of people rendered homeless. It was estimated that about 30,000 houses were destroyed in 12 local government districts and at least 5,000 were left homeless and 2 people dead along the course of River Kaduna from its upper reaches, while more than 1,500 people in Kaduna Metropolis were affected. The areas that were most affected were Malali, Barnawa, Angwan Rimi and other areas of Kaduna Metropolis along River Kaduna[11].

While monitoring flood hazards and processes that lead to them form the bases for early warning systems, flood hazards zoning, assessment and risk analyses often provide the major prerequisite components for flood disaster management before any assessment of the impact of a flood event can begin. Decision makers need to know the magnitude of flooding[17]. Utilization of flood stage or river gauge levels in the land are essential for hazard zoning with Remote Sensing, modeling and GIS as major tools. The incidences of these flood events and associated hazards of profound magnitudes and disastrous consequences can be monitored effectively using either real time satellites or multi-date satellite imageries. Different flood scenarios can easily be mapped and the risked associated presented in a timely manner.

Aim and Objectives: The major aim of this study is to apply remote Sensing and GIS in the analysis of flood risk in Kaduna Metropolis, Kaduna, Nigeria.

Specific Objectives: The above stated aim were achieved through the following specific objectives;

- Determine the return periods of extreme flood events in the study area given a time-series data of the maximum year flood levels.
- Determine the extent of flood inundations given different flood levels of different return periods.
- Determine at the Land uses that would mostly be affected by flooding in different return periods.
- Proffer options to flood hazard mitigation in the area

Flood Inundation Mapping: Flood inundation mapping provides flood risk maps that represents the characteristics of a hypothetical flood graphically from a synthesis of past flood events. With sufficient long term and accurate records, flood extents drawn from the empirical results become very powerful prediction tools because the flood risk map is often a map of more than one flood event. Flood risk maps are therefore the basic tools and starting point of regional flood intervention policy. Flood risk maps can be used for various purposes:

- Flood inundation/hazard maps are used to determine the areas susceptible to flooding when discharge of a steam exceeds the bank-full stage.
- They provide basic initial information for land use planning.Allow correct development plans for new urban areas.Enable adequate evaluation of costs of flood and flood reduction benefits.
- They help to identify the worst affected areas or otherwise due to flooding and provide a guide for better planning and rescue operations and allocation of resources.
- The feasibility of non – structural flood control measures such as flood proofing can be correctly assessed.
- They can form the basis of any insurance plan.
- They serve as a logical basis for investment planning and priority setting.
- They increase the overall public awareness on flood risk and hazards.

Applications of Remote Sensing and GIS in Flood Inundations: The complexity of global flood disasters requires an integrated approach in studies that may lead to the effective management and reduction of the flood problem. Usually, latest information on flood plain dynamics such as flood plain characteristics, and flood duration in addition to intensive fieldwork, are required to prepare flood risk maps using hydrological and hydraulic mathematical formulae and stream geometry.

Remote sensing provides synoptic data of the area either in real-time or near real-time in different spatial or temporal resolutions for different magnitude of flood so that the flood extent can be related to the flood magnitude. The duration and recession of floodwaters can be estimated using multiple imageries of the same area for few days. On the other hand, GIS provides the environment for the combination of the remote sensing data and different spatial and attribute datasets to delineate the flood affected areas under different magnitudes of floods or flood scenarios such as breach in the embankment, overtopping and unprotected rivers[7].

Remote Sensing and GIS enable the collection of data about natural phenomena over very large areas and the assessment and monitoring of natural resources and the prediction of natural phenomena such as flooding. In particular, Remote Sensing enables the collection of on-going natural phenomena instantaneously.

In many countries, remote sensing is being applied to flood inundation management, analysis and rescue operations. For example, during the flooding in Mozambique (January – March 2000), Radarsat-1 images and Ikonos imagery were used to monitor the flooding. In India for example, National Remote Sensing Agency (NRSA) sends regular flood maps along with data obtained through Radar satellite/microwave satellite for assessing the intensity of flood situations in various States of India,

Near Real Time Flood Mapping, using Satellite Remote Sensing is gradually becoming operational in many countries. Operational satellites such as MODIS Terra/Aqua, RADARST, NOAA/AVHRR, ERS, Landsat ETM, IRS-1C, SPOT and others are currently in use. Data derived from these satellites are used for deriving inputs for preparation of risk zone maps. The MODIS Rapid Response Team provides regular data on the extent of floods of high magnitudes for different parts of the world in near-real time mode.

Aim and Objectives: The major aim of this study is to apply remote Sensing and GIS Techniques in modeling plans for flood abatement in Kaduna Metropolis, Kaduna, Nigeria

Specific Objectives: The above stated aim shall be achieved through the following specific objectives;

- Determine the return periods of extreme flood events in the study area given a time-series data of the maximum year flood levels.
- Determine the extent of flood inundations given different flood levels of different return periods.
- Determine at he Land uses that would mostly be affected by flooding in different return periods.
- Proffer options to flood hazard mitigation in the area.

Study Area: The study area is part of Kaduna Township, located between latitude 10°27′15″N - 10°13′5″N and longitude 7°21′48″E - 7°29′36″E in the High plains of Hausaland, Northwestern Nigerian Region. It is the administrative capital of Kaduna

State and center of commercial activities in the state. The general relief is an undulating plain land at a height between 582m to 640m. The bedrock geology is predominantly metamorphic rocks of the Nigerian Basement Complex consisting of biotite gneisses and older granites. In the southeastern corner, younger granites and batholiths are evident. Kaduna State experiences a typical continental climate with distinct seasonal regimes, oscillating between cool to hot dry and humid to wet. These two seasons reflect the influences of tropical continental and equatorial maritime air masses, which sweep over the entire country. However, in Kaduna State, the seasonality is pronounced with the cool to hot dry season being longer, than the rainy season. Again, the spatial and temporal distribution of the rain varies, decreasing from an average of about 1530mm in Kafanchan-Kagaro area in the Southeast to about 1015mm in Ikara, Makarfi district in the northeast. High storm intensities (ranging from 60mm/hr) plus the nature of the surface run off build up the good network of medium sized river system. High evaporation during the dry season, however, creates water shortage problems especially in Igabi, Giwa, Soba, Makarfi and Ikara Local Government Areas.

Generally, the soils and vegetation are typical red-brown to red-yellow tropical ferruginous soils and savannah grassland with scattered trees and woody shrubs. The soils in the upland areas are rich in red clay and sand but poor in organic matter. However, soils within the “fadama” areas are richer in kaolinitic clay and organic matter, very heavy and poorly drained, characteristics of vertisols. Fringe forests (“Kurmi” in Hausa) in some localities, and especially in the southern LGAs of the state, are presently at the mercies of increasing demands for fuel wood in the fast-growing towns and urban centres.

MATERIALS AND METHODS

Materials and Software Used: The materials and data used for this study are as follows:

Hardware and Software:
Hardware:

- High speed memory digital electronic PIV computer.

Software:

- ERDAS Imagine 8.6 for data pre-processing and Water depth simulation with given return periods.
- ILWIS 3.3 (Integrated Land and Water Information System) for digitization of Land Use and Contour Maps, Map calculations and all GIS analysis with spatial and attribute data.
- MS Excel for flood frequency analysis.

Data Used:
Topographic Map: The topographic maps used were the Nigerian survey Topographic Map Series of Nigeria; NIGERIA 1:50,000, Kaduna S.E. Sheet 123 and Kakuri N.E.Sheet 124.

Satellite Imagery: The satellite image (Figure 2) used was Landsat ETM of November 11 2001. This image was downloaded from the Global Land Cover Facility (GLCF) Earth Science Data Interface (ESDI)[15].

Digital Elevation Model (DEM): The DEM for the study was created from the digitized contour lines of the topographic map sheets of the study area.

Hydrologic Data: Multi-Temporal Rainfall data, Discharge levels, and Stage heights data were provided by the Kaduna State Water Board Headquarters, Kaduna.

Methodology:
Image Classification: The Landsat Enhanced Thematic Mapper (ETM) satellite imagery of the study area was used to create a land use/cover map because the available topographic map of the area was old. The land use/cover themes were generated through Manual interpretation because more than half of the densely settled area in Kaduna Metropolis is also heavily vegetated. Six general land use/land cover classes were generated: flood plain agricultural land, built-up, River, Cultivation, Gully, park, and scattered cultivation, shrubs and orchards.

Statistical analysis: Flood frequency analysis was applied in this study by selecting annual maximum gauge levels at Kaduna South water Works Gauging point (Datum at 582.96m) located in the study area. In our attempt to find out water levels at different return periods, the Gumbel’s extreme value distribution was used by selecting peak gauge level data for 21 years (1974-1994). It is one the most widely used probability analysis for extreme values in hydrologic and meteorological studies for prediction of flood, rainfall etc. Gumbel defined a flood as the largest of the 365 daily flows and the annul series of flood flows constitute a series of largest values of flows. Other statistical methods used in flood frequency studies

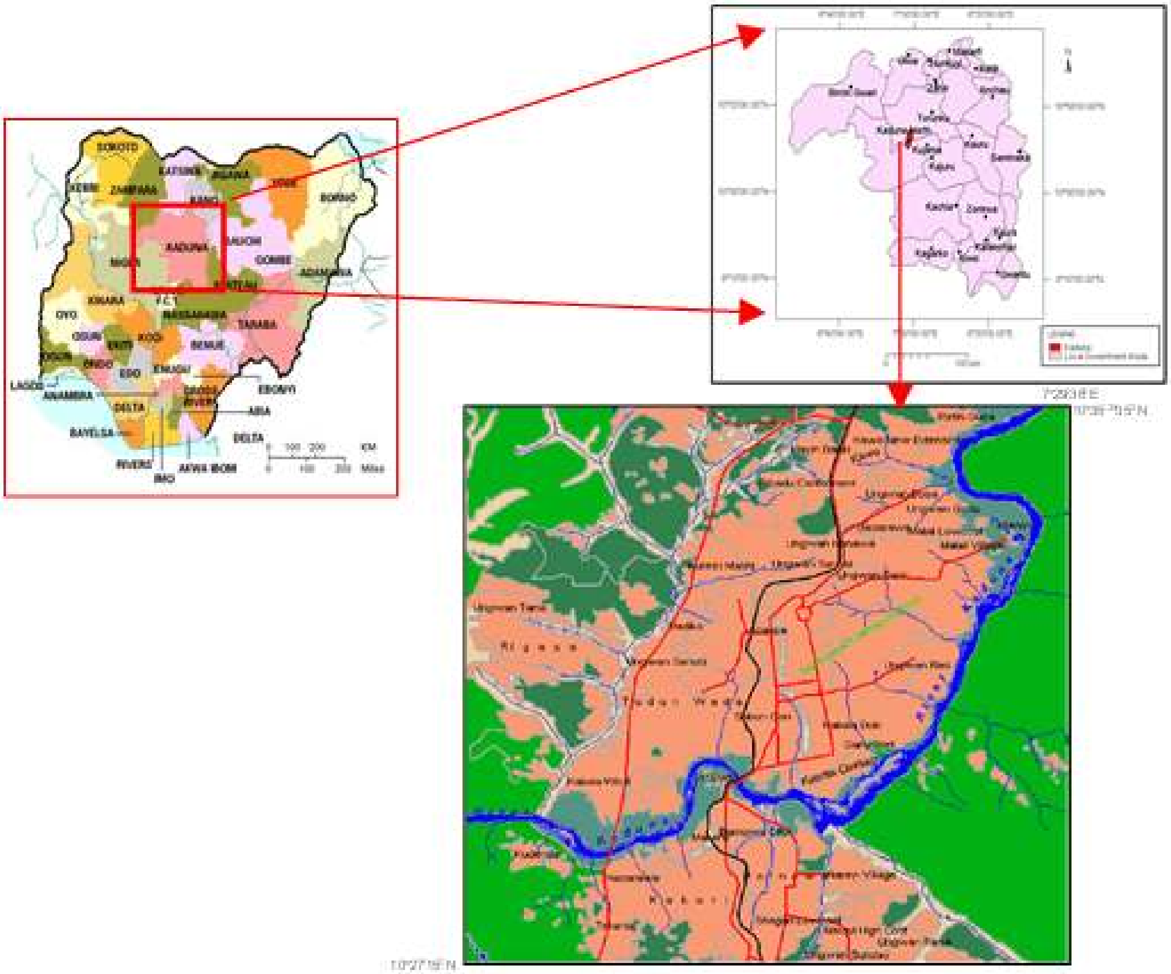

Fig. 1: Location of Study Area

include Graphical Method, the Log Pearson Type III, Weibul's Method, California Method, Foster Method, Ven Te Chow method, Hazen Method among others,[6,8,5,1]. The results of flood frequency analysis can be used for many hydrological engineering purposes, for the design of dams, bridges, culverts and flood control structures, to determine the economic value of flood control projects; and to delineate flood plains and determine the effects of encroachment on the flood plain. The Gumbel's Extreme Value Statistical Distribution equation is given by:

$S_T = x + k * SDV$

where,

S_T = Value of variate with a return period 'T'

x = Man of the variate

SDV = Standard deviation of the sample

k = Frequency factor expressed as

$k = (y_T - y_n) / Sn$

y_T = Reduced variate expressed by:

$y_T = (LN*LN) (T/T - 1)$

where:

T = Return period

Yn = Reduced mean from table

Sn = Reduced standard deviation from table

Flood Frequency Analysis: Flood Frequency Analysis is the determination of flood flows at different recurrence intervals. The standard procedure to determine probabilities of flood risk consists of fitting the observed stream flow record to specific probability distributions. However this procedure only works for basins that have 'long enough' stream flow records to warrant statistical analysis; where flood flows are not

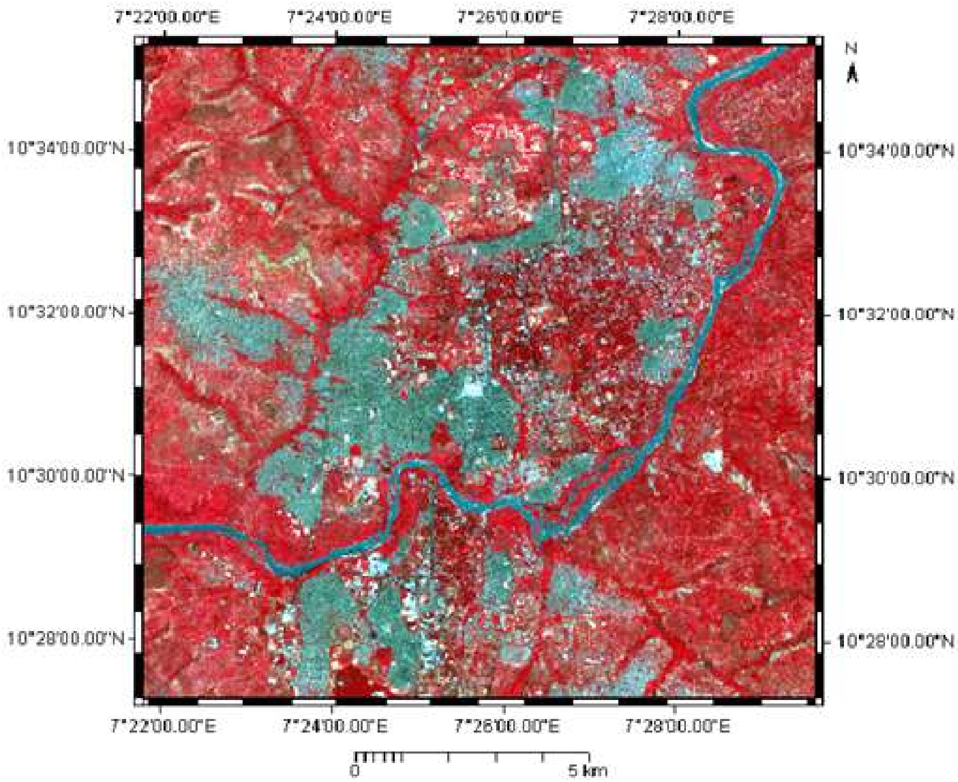

Fig. 2: Landsat Etm of the Study Area

appreciably altered by reservoir regulation, channel improvements (levees) or land use change. The objective of frequency analysis of hydrologic data is to relate the magnitude of extreme events to their frequency of occurrence using probability distributions. The hydrologic data analysed are assumed to be independent and identically distributed, and the hydrologic system producing them (e.g. a storm rainfall system), is considered to be stochastic, space independent and time independent (i.e. the hydrologic processes evolve in space and time in a manner that is partly predictable, or deterministic and partly random) in the classification scheme[3]. The frequency or probability of a flood usually is described by assigning a recurrence interval to the flood at each gauging station. This is accomplished by statistically evaluating long-term annual peak stream flows at a station. For example, a 100-year flood-recurrence interval means that, in any given year, a flood of a specified stream flow magnitude has a 1-in-100 chance of happening.

Selection of the Hydrologic Data: Chow, *et al,*[3] have suggested that the hydrologic data for flood frequency analysis should be carefully selected so that assumptions of independence and identical distributions are satisfied. In practice, this is often achieved by selecting the annual maximum of the variable being analysed (e.g. the annual maximum discharge, which is the largest instantaneous peak flow occurring at any time during the year) with the exception that successive observations of this variable from year to year will be independent.

Using DEM and the Landuse/Landcover Map: To create a flood map using the DEM that was generated, the flood stage at each return period were use. An ILWIS Command was used to derive the area of inundation from DEM if the areas lie below the height of the river stage of the given return period. The total areas generated from the DEM were crossed with the land use/cover maps to generate the total areas of inundations for the given return periods.

Creation of flood Maps and Determination of the Flood Risk: Fixed maps of the study area were created separately using the DEMs and the land use/cover map derived from the satellite image. These were combined to create/generate the total flooded area. To determine the flood risk, a simple technique of Map Crossing in a GIS was used. The total areas of the land use classes

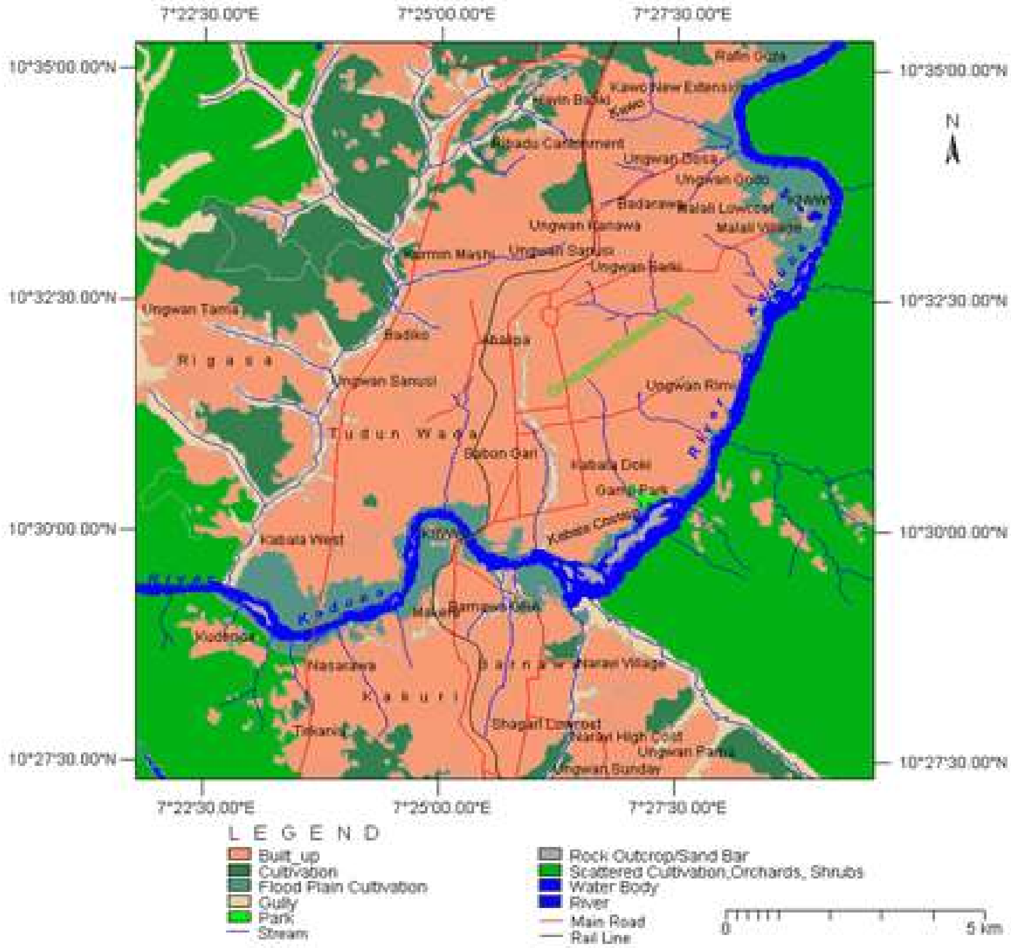

Fig. 3: Classified Land use/Cover of Study Area

were determined and then for each individual land use type. Then the total land use map was crossed with the flood map. After which the following were calculated:

- The percentage of the total area inundated.
- The areas inundated by water for each land use class (e.g. cultivation, Built-up, etc.) All the procedures in the methodology are shown in Figure 4.2

RESULTS AND DISCUSSIONS

The results obtained from the statistical analysis of the flood data using the Gumbel's Extreme Value distribution for different flood return periods and the results of the analysis of the extent of flood inundations in different return period using remote sensing and GIS within the study area are presented in this section.

Results of the Statistical Analysis: The results of the statistical analysis of flood stage in different flood return periods using the Gumbel's statistical distribution are presented in Table 1 below.

The table shows that there is a gradual rise in flood stage 589.80m in the 5-year return period to 593.57m in a 100-year return period. This represents a rise in flood stage of about 5.84m above a Datum of 583.96m in the 5-year return period and about 3.84m higher than the minimum contour level (equivalent to the flood plain level) of 585.96m. In the 100-year return period, the expected flood level will be about 8.61m above the Datum at 583.96m and 6.61m above the flood plain level.

Areas Under Flood Hazard in Different Return Periods: The results of crossing the land use/land cover map with the maps of the extent of flood in different return periods is presented in Table 2.

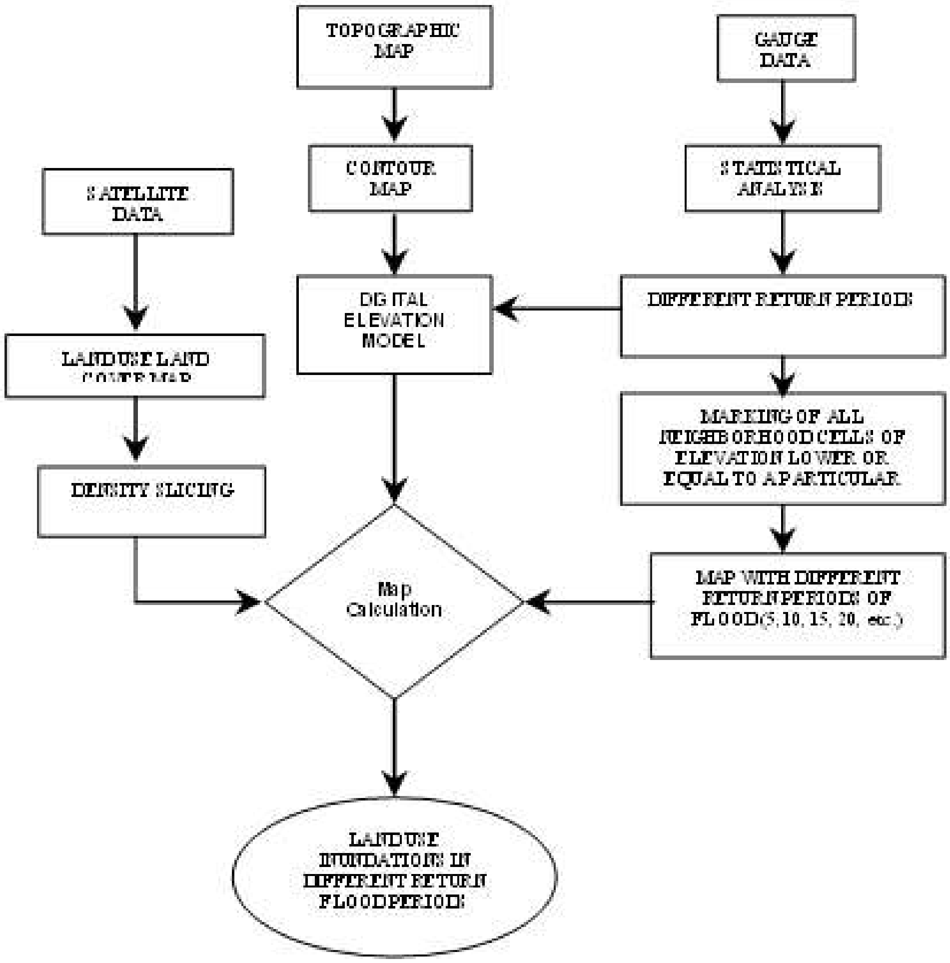

Fig. 4: Schematic Diagram of the Methodology

Table 1: Flood Stage in Different Return Periods (m)

Return Period	Flood Stage(m)
5	590.80
10	591.47
15	591.81
20	592.11
30	592.48
50	592.94
100	593.57

Table 2: Areas under Flood Hazard in Different Return Periods (Km^2)

Land Use/Land Cover Type	Return Period						
	5yr	10yr	15yr	20yr	30yr	50yr	100yr
Built-up	3.06	3.56	3.79	4.04	4.3	4.66	5.15
River	6.17	6.18	6.18	6.18	6.18	6.18	6.18

Table 2: Continued

Water Body	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gully	0.6	0.65	0.66	0.68	0.69	0.71	0.75
Scattered Cultivation, Orchards, Shrubs	6.05	6.64	6.92	7.17	7.45	7.86	8.38
Flood Plain Cultivation	5.88	6.22	6.39	6.53	6.68	6.9	7.18
Park	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Rock Outcrop/Sand Bar	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total Area	22.65	24.14	24.83	25.49	26.2	27.21	28.54

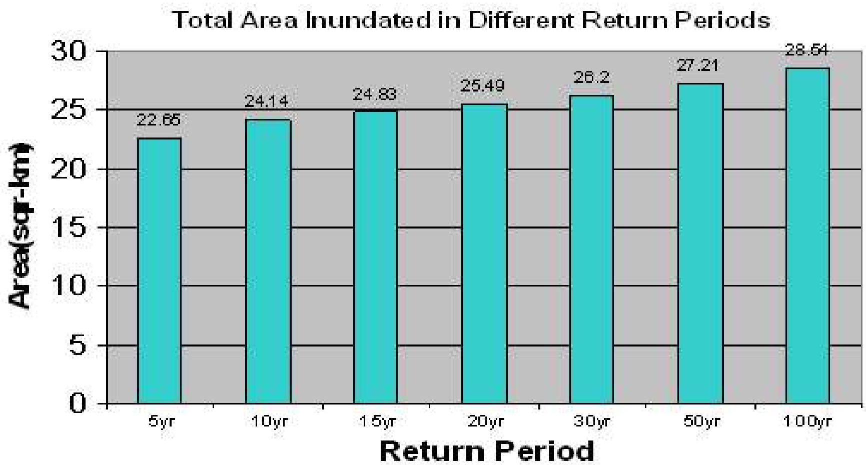

Fig. 5: Total Area Inundated in Different Flood Return Periods

The results show that there would be a general increase in the areas that would be flooded in a 5-year return period to the 100-year return period. For the built-up areas (59.42%), scattered cultivation, shrubs and orchards (72.20%) flood plain cultivation (81.89%). There were no significant changes in areas that would be flooded in the Park, and Water Body. Although the water body shows no general increase in area, it means that such water body will completely be inundated in the 5-year return period. It is important to note that this water body is the Reservoir at the Kaduna North Water Works Treatment Plant, Malali, Kaduna. The river and the rock out crops are part of the Kaduna River System.

The results of the study also revealed a general increase in the area extent of flood inundation in different return periods. In a 5-year return period, the area extent of flood inundation would be approximately, 22.65 percent of the study area, 24.14% in a 10-year return period, 24.83% in a 15-year, 25.49% in a 20-year return period, 26.2% in 30-year return period, 27.21%in a 50-year return period and 28.54% in a 100-year return period. Figure 5 is a histogram of the Total Area that would be inundated by flood in different return periods while Figures 46A, B,C,D,E,F and G are graphic presentations of the GIS analyses of flood inundation in the study area in different return periods.

Areas under Risk of Flooding in the Different Return Periods: The study reveals that all the land use/ land cover classes are under the threat of flooding in the different return periods. However, it is important to note that Built-up areas, scattered cultivation, shrubs and orchards, flood plain cultivation and the water body at Malali are under severe flood risk.

The results of crossing the land use/land cover map with map of the different flood return periods also showed areas under severe threat to flood in Kaduna Metropolis given different return periods. These include; Ungwan Guza, Kawo New Extension, Ungwan Dosa, Badarawa, Malali (at Ungwan Godo), Kaduna North Water Works' Treatment Plant, Ungwan Rimi (South of Ungwan Kudu), Kabala Costain, Kabala West, Gamji Park, Barnawa, Stadium, parts of Makera and Nasarawa, and Kudenda Village. Most of these areas are dense settlements with equally high population densities. The above-mentioned areas also correspond to the areas that were affected by the August 2003 flood that affected Kaduna Metropolis. These Areas are depicted in Figure 7.

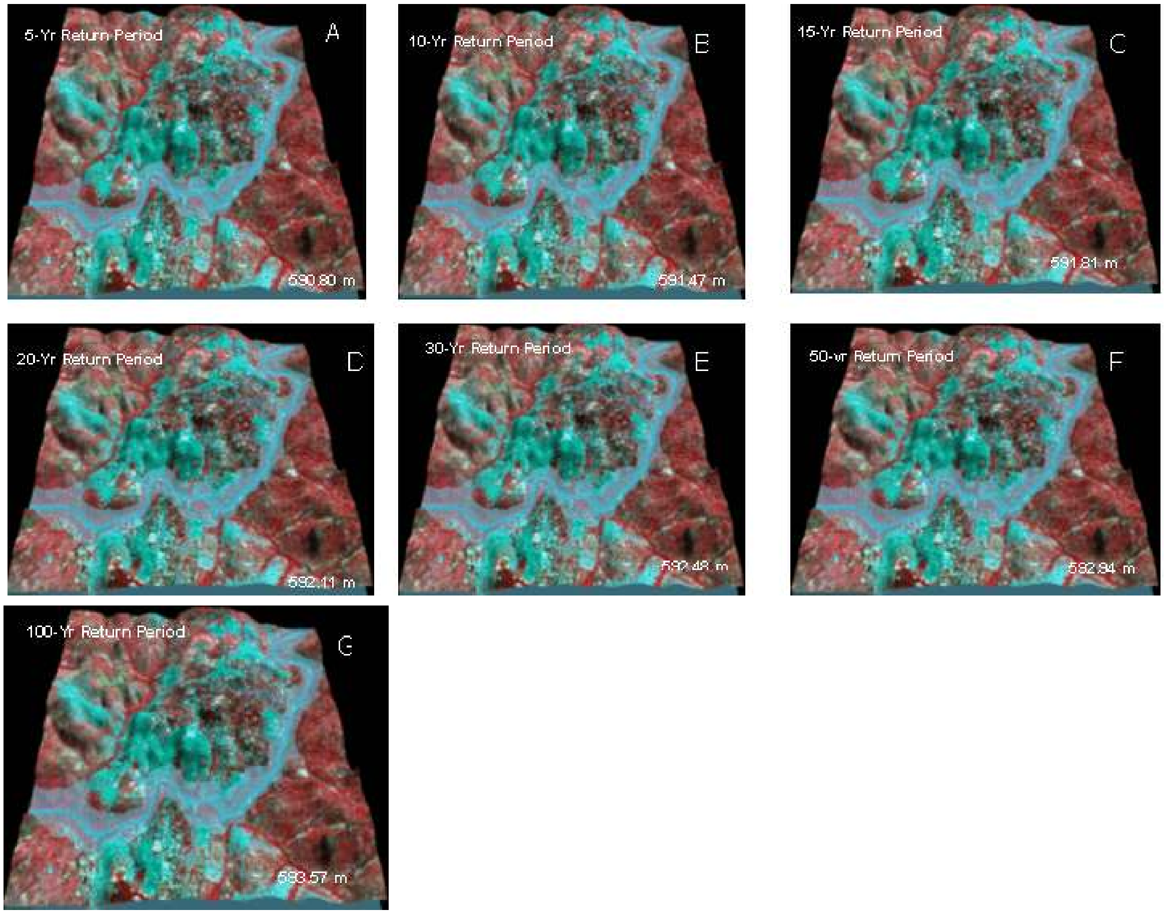

Fig. 6A-G: Land Use/Land Cover Area Inundated in Different Flood Return Periods

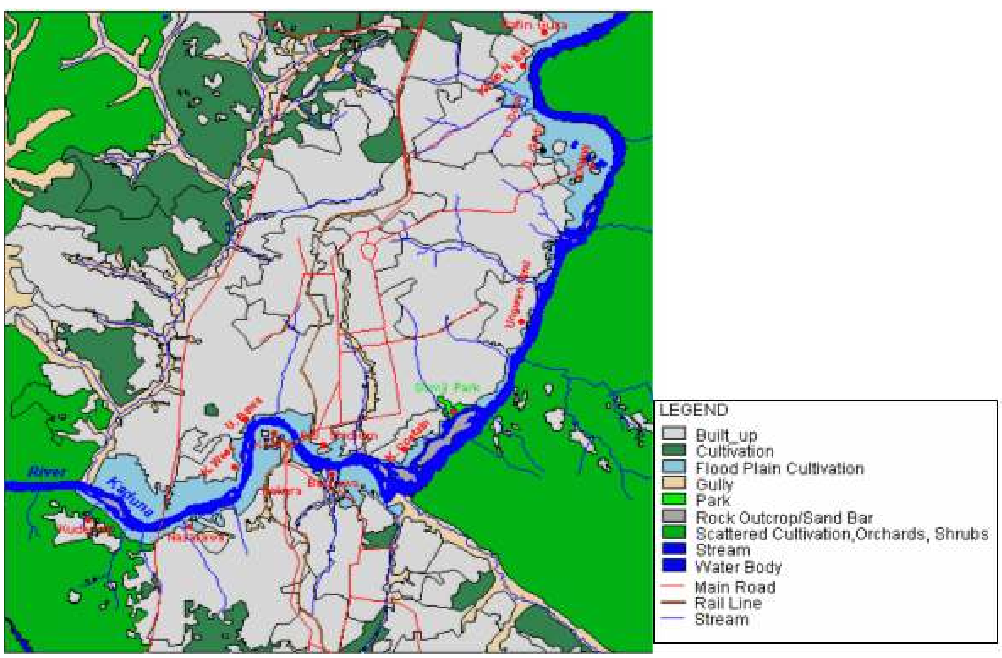

Fig. 7: Areas under Risk of Flooding

The area under flood plain cultivation (known as *Fadama*) is under serious threat and is often flooded under normal peak flows of River Kaduna every year, especially in the months of July – September. Often, farmers experience losses as their cash crops are washed away by the floods. For the 100-year return period, the study reveals that almost all of the flood plain cultivable area would be submerged or flooded.

Summary: This study utilized log-term river stage data to generate flood inundation scenarios for 5, 10, 15, 20, 30, 50 and 100 year return periods for Kaduna metropolis. A combination of DEM and Landuse/cover map enabled us to generate or estimate area extents of different land uses/cover types that may be flooded.

The study revealed that areas that are at higher risk to the flood hazard include Ungwan Guza, Kawo New Extension, Malali at Ungwan Godo, Ungwan Rimi, Kabala Costain, Kabala West, Stadium, Gamji Park, Parts of Barnawa, Makera, Nasarawa and Kudenda. In addition, the Kaduna North and South Water Works would face maximum flood threat with increase in flood stage from the 5-years return period.

Recommendations: Based on the findings of this study, the following are therefore recommended:

- There is need for urgent and thorough hydrological modeling of the Kaduna River or the whole catchment to its outlet at the Kaduna South Water Works and beyond.
- The Kaduna State Urban Development Environmental Protection Agency most ensure full compliance of development guidelines for the Kaduna Metropolis as regards the encroachment of flood plains especially at Malali, Ungwan Rimi, Barnawa, Ungwan Bawa, Kudenda and Kawo New Extension including Ungwan Dosa.
- The Kaduna State Government should provide flood warning systems.
- Flood control structures should be constructed in areas of high vulnerability.
- There is need for consistent flood stage monitoring by the Kaduna State Water Board.
- Given the nature of the flood problem in Kaduna Metropolis, a quantitative methodology is required using very high resolution satellite imagery to:

- Estimate the lives at risk due to flooding at each of the subject communities and comparison of the lives at risk with available guidelines or criteria if any.
- Prioritization of the risks to facilitate the development of a defensible and transparent risk management plan.

Conclusion: The threat of flooding in Kaduna Metropolis and environs have been highlighted in this study. Remote sensing and GIS technologies provide effective means of studying the flood problem. A combination of flood stage data and digital elevation models enabled the estimation of area extent of flood in different return periods and areas under high risk to flooding. Therefore, to enable proper understanding, management and mitigation, flood inundation and risk maps are required. Long-term flood data in addition to discharge and rainfall data are required to generate flood models and scenarios for given flood return periods. Considering the magnitude of the 2003 flood in Kaduna and the fact that floods occur unexpectedly, there is need for an effective risk mapping and risk management strategy to abate the problem.

REFERENCES

1. Ayoade, J.O., 1988. Tropical Hydrology and Water Resources. Longman Pub., London and Basingstoke.
2. Berz, G., 1999. Flood Disasters: Lessons from the Past – Worries for the Future. Geosciences Research Group, Munich Reinsurance Company, D-80791 Munich, Germany.
3. Chow, V.T., D.R. Maidment and L.W Mays, 1988. Applied Hydrology, New York: McGraw-Hill Book Company.
4. Johnson, T., 2006. Northern Nigeria hit by floods. *Article*- World Socialist Web Site of October, 2, 2006. Published by the International committee of the Fourth International (ICFI).
5. Raghunath, H.M., 1995. Hydrology: Principles Analyses and Design. New Age Intl. Pub. (P) Ltd New Delhi.
6. Sharma, R.K. and T.K. Sharma, 2000. A Textbook of Hydrology and Water Resources Engineering. Dhanpat Rai Publications (P) Ltd.; India. Fifth Ed.
7. Sharma, P., 2004. Flood risk zone mapping of Dikrong sub-basin in Assam. A paper presented at the Map Asia Conference, 2004 at Beijing International Convention Centre, Beijing, China.
8. Singh, P.K., 2000. Watershed Management: Design and Practice. E-Media Pub,. Udaipur, India.
9. International Federation of the Red Cross and Red Cresent Socites, 2005. Nigeria: Floods. Minor Emergency No. 05ME 51, 29 August, 2005
10. Punch Newspapers, Lagos Nigeria, August 31, 2001.
11. Punch Newspapers, Lagos Nigeria, August 27, 2001.
12. The New Zealand Herald, 2006. Dam Collapse washes away 1000 homes in Nigeria. *Article*; APN Holdings, NZ., 02 October, 2006.

13. United Nations Networks Office for the Coordination of Humanitarian Affairs, 2006. Nigeria: Collapsed dam sweeps away 500 houses - Integrated Regional Information (IRIN), 02 October, 2006.
14. http://www.tulane.edu/sanelson/geol204/floodhaz.htm.
15. http://glcfapp.umiacs.umd.edu.8080/esdi/index.jsp.
16. http://www.wsws.org/articles/2001/oc2001/nig-o05.shtml (5 October 2001)
17. http://www.earthsat.com/wx/flooding/harrisco_flood_tx.html