Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.13, 2014

Multicriteria Flood Risk Analysis of Lower Ogun River Basin

Raji, Saheed Adekunle[1*] Adeniyi, Peter Olufemi[2] Odunuga, Shakirudeen[2]

1. Laboratory for Remote Sensing and Geographic Information Systems (GIS), Department of Geography, University of Lagos, Akoka-Yaba, Lagos.
2. Department of Geography, University of Lagos, Akoka-Yaba, Lagos.

* E-mail of the corresponding author: rsa_seun@yahoo.co.uk

Abstract

Issues pertaining to flood and flood-related damages always generate global interest in different circles. This study utilised remote sensing techniques to develop flood risk map of Lower Ogun basin in Southwestern Nigeria. Microscale environmental variables of landuse and landcover typologies, rainfall, NDWI, DEM, slope, geological formation, and population density were used as input for weighted overlay multicriteria modelling using Idrisi Taiga and ArcGIS 10.0. These environmental variables were used to generate flood hazard map. Flood risk map was developed in which flood hazard map was combined with population data. Inter-parameter and intra-parameter modeling techniques were used to generate the flood risk based on flood-stimulating coefficient values. Results showed that about 77.62% of Lower Ogun lies within flood hazard zone (with 53.24% under high flood hazard intensity and 24.38% under very high flood hazard intensity. Further, flood risk intensity showed that 60.62% of the area is highly risky to flood occurrence. Therefore, it was recommended that a green belt buffer of 65 metres on both sides of the main river should be established for proper flood zone delineation.

Keywords: Flood modeling, environmental variables, water level, flood hazard, Remote Sensing and GIS

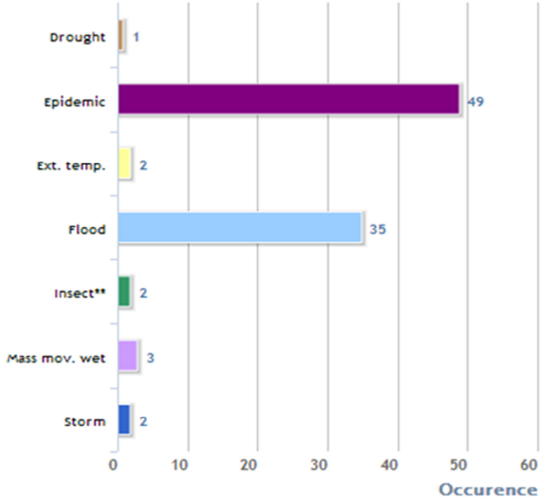
1. Introduction

The fascinating speed and rapidity with which extreme events occur nowadays is alarming. Extreme events such as cyclones, hurricanes, storm surges, earthquakes now occur beyond predictions and projections (Iyanda, 2003; IPCC, 2007; IPCC, 2012a). Flood, irrespective of the dimension and direction, is gradually taking the same pattern (IPCC, 2012b). To wit, a flood scenario is succinctly captured by IPCC (2012b) as *the overwhelming of the normal confines of a stream or other body of water, or the accumulation of water over areas that are not normally submerged*. This simply interprets that flood is an anomaly scenario of water flow beyond the original confines of a defined water body (Middleton, 2003). Different typologies of floods often typify the global environmental landscape, each with definite place-based and contextual occurrence scenarios. As such, floods could be urban floods which is usually associated with urban areas; flash floods; pluvial floods, river floods, and floods could occur owing to the glacial lake or dam operations and management upstream which releases large quantum of water leading to flooding affecting the downstream communities.

Statistics have shown that flood intensity and associated impact is on the rise globally. Smith and Ward (1998) stated that the decade of the ‘80s had more than 60 flood-related disasters globally with antecedent loss of lives and properties. Subsequent years had a more intensified account. In 2004, the European Space Agency (ESA) reported that flood events accounted for almost 55% of all disasters recorded leading to about 73% economic losses on a global view (ESA, 2004). The annual disaster review indicates that flood has increased drastically almost 10-fold in the last fifty years, from just 20 events in 1990 to about 190 in 2005 (Scheuren et al., 2008). These figures represent the spatial distribution of global occurrence across several continents with spatial differences. Although Asia is the most flood-affected continent, others areas in Africa, Europe and North America have had different account of flooding which is mostly seasonal particularly with respect to river flooding.

The scenario of river flooding in Nigeria is a microcosm of the global view and a mirror of the situation in the study area. In terms of frequency of occurrence of extreme events, flood is rated only next to epidemic with 35% of annual occurrence irrespective of place and season (Figure 1). Also, the cumulative number of people that have been affected by flood disaster is much more than any environmental malaise. Most of these arose owing to river systems flowing beyond their defined boundaries. Middleton (2003) and Iyanda (2003) agreed conscientiously that most rivers depict either single flood regime or double flood regime. In Nigeria, Rivers Benue and Kaduna are typologies of river systems with singular flood regime while River Niger depicts a double flood regime (Iyanda, 2003). Most river systems in Nigeria have the potentials of annual flood event with different river networks having different flood values. According to Iyanda (2003) the Cross River flood of 1970, the Lower Ogun River annual flood and the effervescent Ogunpa River in Ibadan are key examples. Further the researcher documented specific flood events in Nigeria such as River Niger flood (1964, 1988, 1994, 1998 and

1999) with its antecedent devastating impact on human lives, socioeconomic life of dwellers of the affected area and ecological distortions. In addition, Eludoyin et al (2007) noted that enormous river flooding which have occurred in specific areas of the country; examples include; Ibadan (1985, 1987. 1990), Oshogbo (1992, 1996, 2002), Yobe (2000), Akure (1996, 2000, 2002, 2004, 2006) and the coastal cities of Lagos, Port Harcourt, Calabar, Uyo and Warri among many incidences that have claimed many lives and properties. Urbanization is another phenomenon that contributes immensely to the occurrence of flood. Alayande and Agunwanba (2010) emphasised that population growth and expansion of structural developments into flood-prone areas can escalate the incidence of flood in such areas particularly in Kaduna and other northern cities with similar ecohydrological characteristics as Kaduna. Similarly, Balzerek et.al (2003) stated that flooding in Gombe northeast of Nigeria is stimulated by poor urban planning perspectives and the challenges of the savanna environment owing to limited water availability often leads to flooding during the wet season. A recent example is the July 10 2011 devastating flood in Lagos which led to destruction of public infrastructure, closure of schools, and loss of valuables beyond computations.



Top 10 Natural Disasters Reported

Affected People

Disaster	Date	Affected (no. of people)
Drought	1983	3,000,000
Flood	2010	1,500,200
Flood	1994	580,000
Flood	1988	300,000
Flood	2003	210,000
Flood	2009	150,000
Flood	1998	100,000
Flood	1999	90,000
Flood	2001	84,065
Flood	2007	50,000

Figure 1*:* Natural disaster occurrence Reported in Nigeria
Source: http://www.preventionweb.net/english/countries/statistics/?cid=126

This study is therefore essential as river flooding is on the rise in Nigeria. The United Nations Platform for Space-Based Information for Disaster Management and Emergency Response (UN-SPIDER) conducted a technical advisory mission in Nigeria in June 2011. The study revealed that there is a dearth of satellite-based geospatial information for flood management and mapping particularly in flood-sensitive areas. It is on this background that the study area was selected for potential study of flood hazard and risk mapping. Also, the basin falls within the conterminous Lagos megacity which is highly flood-prone especially during the wet season when the Ogun River flows within its banks. The aim of this study is to map the flood risk within the lower Ogun basin of southwestern Nigeria. The respective objectives are; (1) to identify the drivers of flood occurrence in the study area, (2) to map the flood hazard areas and (3) to map the flood risk areas with a view to recommend environmentally sustainable mechanisms for flood management and mitigation.

2. The Study Area

According to Oyebande et.al (2003), the study area falls within the lower hydrologic landscape of River Ogun, referred to as Lower Ogun Basin. It lies within parts of Lagos and Ogun States in southwestern Nigeria (Figure 2). It lies within longitude 3°22´E to 3°39´E, and latitude 6°3´N to 6°39´N occupying an approximate area of 361.02 km2.

Topographically, the area of study is low-lying with traces of undulating terrain. Due to the presence of the Ogun River and the Lagos Lagoon, the altitude of the study area varies from sea level to about 78 metres above sea level. Hydrologically, the study area is traversed by the sinuous the Ogun River. This geomorphologically defines the age of the river with traces of connecting streams, wetlands, coastal marsh and hydrophytes. The drainage pattern is dendritic in morphology. The climate of the area is influenced by two air masses, namely; Tropical maritime and the Tropical continental air masses. The tropical maritime air mass is warm and wet originates from the Atlantic Ocean. The tropical continental air mass is warm, dry and dusty originates from the Sahara desert. Hence, the climate of the area is similar to that of the other coastal region of the tropical West Africa with tropical sub-equatorial climate. The temperature is seasonal, relatively high and ranges between

220C and 320C. Two seasons are distinguishable in Ogun river basin, dry season from November to March and wet season between April and October. Mean annual rainfall ranges from 900 mm in the north to 2000 mm towards the south. The two major vegetation zones that can be identified on the watershed are the high forest vegetation in the north and central part, as well as swamp/mangrove that cover the southern coastal and floodplains next to the Lagos lagoon.

The population of the study area shows a dramatic increase within intercensal period of 1991 and 2006. According to 1991 census figure, the population of the study area was 1,634,356. This increased to 3,447,909 in 2006 indicating an annual growth rate of 7.40%. The indigenous dwellers of the area are mainly the Ijebus (a Yoruba sub-group). People from other parts of the country, as well as foreigners also inhabit the area. The major settlements within the study area include Ikorodu, Ebute-Ipakodo, Owutu, Ijede, Egbin, Ajegunle, Owode-Onirin, Magodo, Ketu, Kosofe, Mile 12, Alapere, Ogudu, Osolo, Majidun and Oworonshoki.

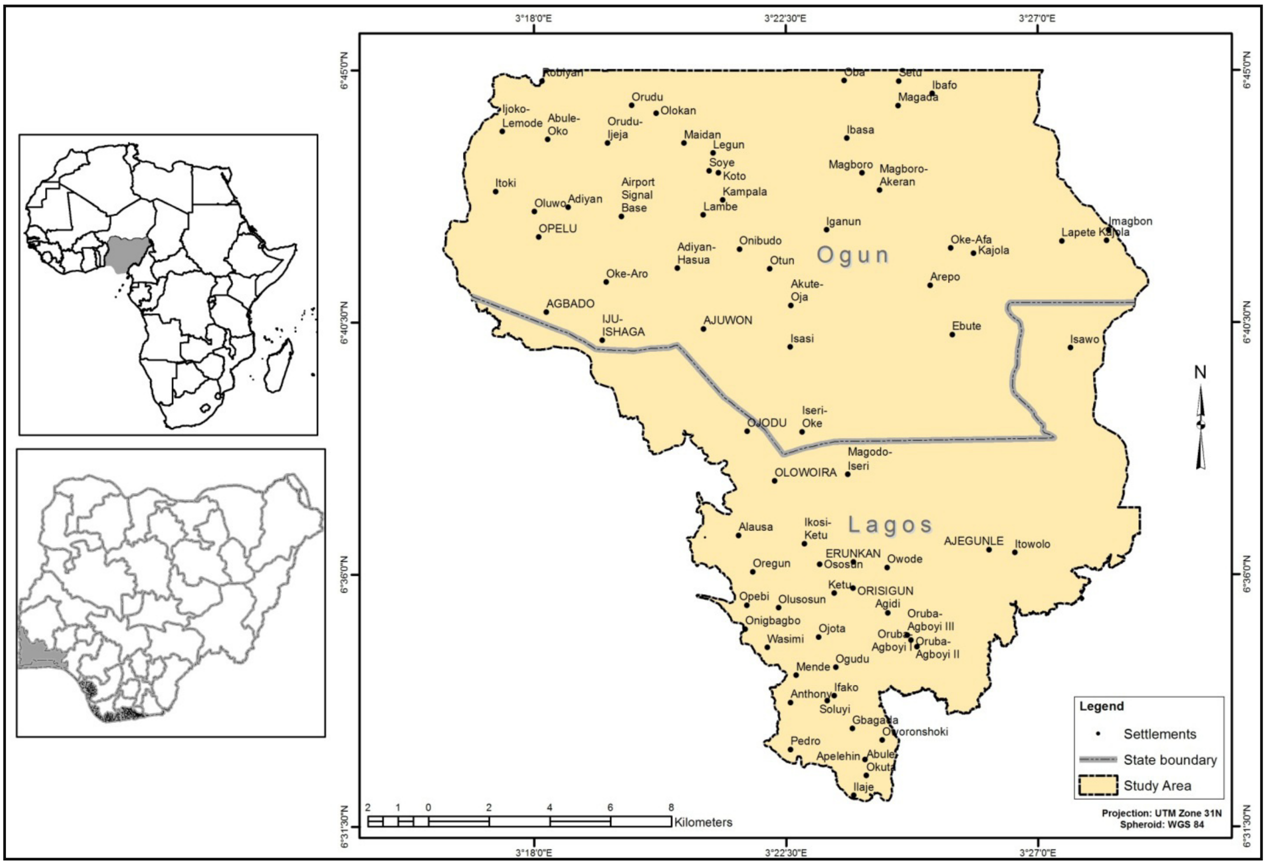


Figure 2: The Study Area

3. Methodology

3.1 Data Sources and Characteristics

Remotely sensed data is the main data source used for this study. Table 1 provides the details of the data used and associated characteristics. Basin boundary was delineated using the contour values and spot heights values extracted from the topographic map (1:25,000) sheets of Ilaro SE 1 through to 4. Landsat ETM+ was used for landuse and landcover classification based on the adaptation of Level I schema provided by USGS (Anderson, 1976). These images (band 2, 4 and 7) were downloaded from the internet portal of Global Land Cover Facility of University of Maryland. The selected bands were used due to their composited functionality and suitability for landuse and landcover mapping. Rainfall data across areas located both within and abut the study area were sourced from Nigerian Meteorological Agency (NIMET) for the year 2000 to 2007. Demographic data of the two census periods 1991 and 2006 were sourced from National Bureau of Statistics. Geological formation data were obtained through the Atlas of Nigeria published by the Federal Surveys Department for the year 1978 at the scale 1:2,000,000.

Table 1: Data and associated Metadata used

s/n	Data	Scale and Resolution	Data Source	Date	Data extracted
1	Topographic maps of Ilaro SE 1, 2, 3 & 4	1:25,000	Federal Surveys Department	1982	Study area outline (basin boundary)
2	Landsat ETM (p191r055 of 7th December)	30 metres	GLCF (Department of Geography, University of Maryland)	2006	Bands 2, 4, and 7 for specific landuse and landcover and NDWI
3	Rainfall Data (Ikeja, Lagos-Roof, Ijebu–Ode and Abeokuta)	Point-based	NIMET (Nigeria Meteorological Agency)	2000 – 2007	Spatial distribution of rainfall
4	Lagos State and Ogun State (Local Governments) Population Data	Intercensal period	National Bureau of Statistics	1991 and 2006	Population density computations
5	Geological Map	1:2,000,000	Federal Geological Surveys Department	1978	Geological formation of the study area

3.2 Flood hazard and risk analysis

A critical aspect of the determination of flood risk of Lower Ogun is the initial definition of flood hazard. This entails the assessment and development of parameters for flood hazard which is presented in section 3.1.1 below. However, it should be noted that the extent of modeled inundation area is a pointer to the nature of the environment and its susceptibility to flood occurrence particularly the spatial relationship between the elevation and the water surface levels.

3.2.1 Development of environmental parameters and data layers

Owing to the knowledge of the environment gathered from literature and fieldwork, seven parameters were selected for flood modelling; landuse and landcover, NDWI (normalized difference water index), geology, slope, elevation, and rainfall. Population factor is considered germane for the production of flood risk map. These environmental variables were converted to digital format from the original analogue format. Thus, in GIS environment using ArcGIS 10.0, these data were converted into appropriate data layers for use within the specified environmental modeling and statistical software packages. The raster data format was used as the principal spatial data model for the entire modeling of the environmental parameters. This was to ensure interoperability and suitability. The details of the data layers are described succinctly in the subsequent section with the weighting/scoring system listed in Table 2.

Landuse and landcover (LULC); The 2006 landuse and landcover (LULC) output used for the study was based on landuse and landcover dynamics conducted for the study area by Raji (2011). Five LULC themes were developed. The subsequent ranking and scoring of the LULC themes is centred on inherent capacity to stimulate flood.

NDWI (Normalized Difference Water Index); The NDWI, as a derivative of NDVI (Normalized Difference Vegetative Index), was used to map the different categories of water with respect to LULC themes. It was selected as a tool in order to separate water-bearing features from non-water bearing features with a view to identify open/permanent water body, moist soil/vegetation, area liable to flood as well as areas without any proportion of water that could lead to flooding. The NDWI as defined by McFeeter (1996) was utilised based on Landsat data of the area. This is defined as;

$$NDWI = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}}$$

where:
Green is the reflectance in the green wavelength band 2 of Landsat ETM+ (0.525– 0.605 µm); NIR is the

reflectance in the near infrared wavelength band 7 Landsat ETM+ (0.775– 0.900 µm). Image processing module of Idrisi ® Taiga is used for the implementation and derivation of the NDWI.

Slope; Slope is generated from DEM of the study area which is created from spot heights and contour. The spatial analysis sub-suite of ArcToolbox in ArcGIS 10.0 was used to create TIN. The TIN was converted to raster which was used as the main data input for slope generation. The principle of slope analysis used in this study is based on the analogy "*the gentle the slope, the higher the probability of the area to be flooded*".

Geology; There are five geological formation identified within the study area. As observed, these were structurally arranged with respect to proximity to water body hence the propensity to stimulate flood occurrence. The allocation of score was therefore conducted according to characteristics of these geological formations.

Elevation; Elevation analysis is based on the outcome of the development of the DEM (Digital Elevation Model). However, the scoring analysis for elevation reclassification is based on the influence of elevation on flood. The analysis scoring system shows that there is an inverse relationship between elevation and flood event.

Rainfall; Using the rainfall data acquired from NIMET, a spatial interpolation technique – kriging was used to create a raster dataset to map rainfall distribution. The outcome shows that high quantum of rainfall is directly proportional to high flood hazard within the basin.

Population density; This is principal factor used for flood risk mapping. Population factor is based on local government population density values computed from the population statistics. This was further subjected to Inverse Distance Weighted (IDW) statistic in ArcGIS ArcToolbox.

Table 2: Weighting/scoring system for variables used for multicriteria evaluation

S/n	Main Layer	Layer typologies/categories	Scores (weights)
1	2006_LULC	**Landuse/landcover themes**	
		Waterbody	100
		Swamp	80
		Forest	60
		Scattered cultivation	40
		Built-up Areas	20
2	NDWI	**Index values**	
		2.8 – 3.5	100
		2.1 – 2.8	80
		1.4 – 2.1	60
		0.7 – 1.4	40
		0 – 0.7	20
3	Slope	**Values in (^{0})**	
		0 – 0.457	100
		0.457 – 1.129	80
		1.129 – 2.070	60
		2.070 – 3.414	40
		3.414 – 6.855	20
4	Geology	**Geological formation**	
		Recent Alluvium	100
		Miocene	80
		Eocene (Ilaro formation)	60
		Paleocene (Ewekoro formation)	40
		Senonian (Abeokuta formation)	20
5	Elevation	**Values in (^{0})**	
		1 – 9.256	100
		9.256 – 25.682	80
		25.682 – 44.863	60
		44.863 – 59.868	40
		59.868 – 78	20
6	Rainfall	**Mean monthly (mm)**	
		1482.4 – 1537.6	100
		1445.3 – 1482.4	80
		1410.7 – 1445.3	60
		1379.1 – 1410.7	40
		1336.5 – 1379.1	20
7	Population	**Density (p/km^2)**	
		47,437.64 – 69,465.34	100
		28,6673.31 – 47,437.64	80
		17,251.54 – 28,6673.31	60
		8,821.18 – 17,251.54	40
		118.88 – 8,821.18	20

3.2.3 Multicriteria modeling technique

The overall evaluation technique used for this is study depicted in Figure 3, which integrates the parameters selected for the study and the procedures used to derive the flood hazard map and the flood risk map.

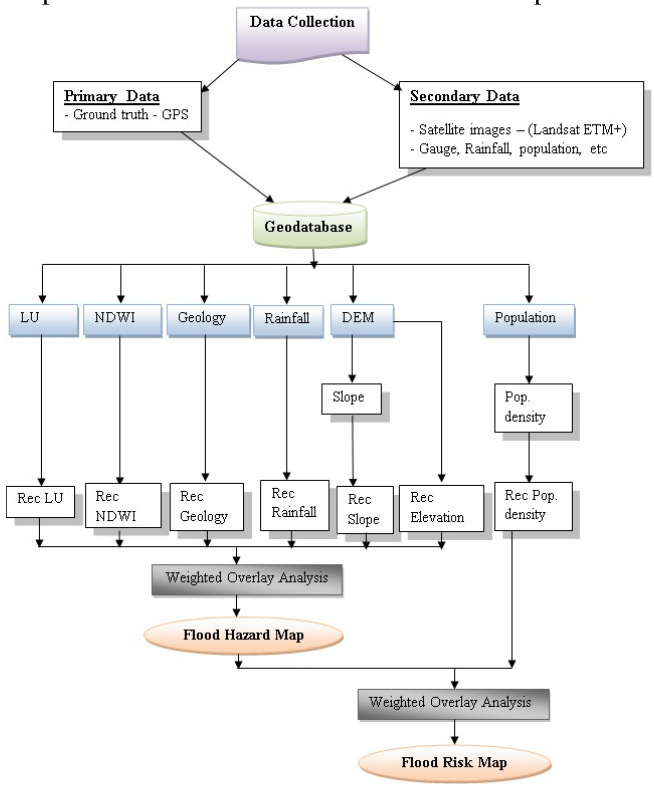


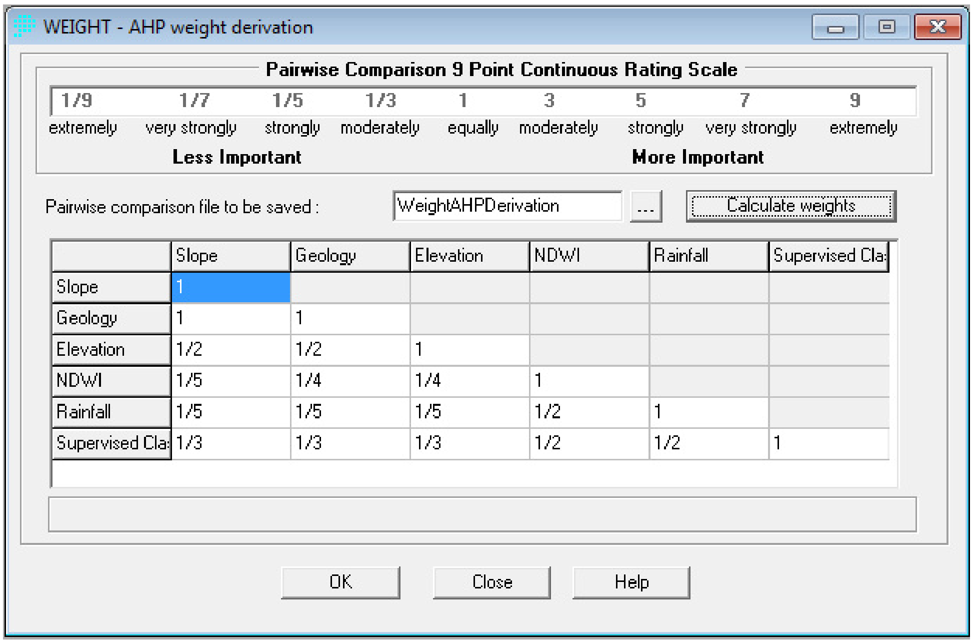
Figure 4: Methodological flowchart for the study

The flood hazard map was developed using the expression in equation (1).

$$\beta = f\,(\alpha, \upsilon, \varphi, \varpi, \vartheta, \psi). \ldots\ldots\ldots\ldots \quad (1)$$

where b is the flood hazard intensity value, α is the slope in degrees, υ is elevation, φ is the typology of geological formation, φ is the index of NDWI, ϖ is the index of range of landuse and landcover classification, and ψ is rainfall value.

This mathematical relationship was defined digitally using the weighted overlay analysis module. Weighted overlay analysis entails the development and attachment of weights to pairs of environmental variables via the use of confusion matrix. The pair comparison matrix in was developed using the WEIGHT–AHP (Analytical Hierarchy Process) weight derivation module in Idrisi Taiga. Based on software-derived consistency ratio and its associated acceptability, weights were derived for each of the six variables for weighted overlay analysis. Figure 5 shows the pair comparison matrix and the rating scale used to define variable-variable relationship. The derived weight values were used in ArcGIS 9.3 ModelBuilder, which was used to generate the flood hazard map (Figure 6).



	Slope	Geology	Elevation	NDWI	Rainfall	Supervised Cla:
Slope	1					
Geology	1	1				
Elevation	1/2	1/2	1			
NDWI	1/5	1/4	1/4	1		
Rainfall	1/5	1/5	1/5	1/2	1	
Supervised Cla:	1/3	1/3	1/3	1/2	1/2	1

Figure 5: The pairwise comparison matrix of the flood hazard inducing parameters

Figure 6: Schematic layout of ModelBuilder analysis used for mapping flood hazard

The flood risk map was developed through the inclusion of the population factor to the already created flood hazard map. The flood risk is mathematically therefore defined as;

$$\Phi = f(\beta . \eta) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where Φ is the flood risk, β is the modeled output of flood hazard intensities, and η is the vulnerability which is based on the population distribution across space.

4. Results and discussion

4.1 Environmental Factors stimulating Flood Occurrence

Figure 7 shows the entire factors considered for the modelling of flood hazard and flood risk in Lower Ogun basin. Each of the mapped variables depicts the varying degree of intensity on the landscape. The NDWI shows that the blue footprints which indicates the intensity of water. The deep blue areas indicate high water availability thus showing the potential of the areas to flood event. The variation in geological bed formations shows proximity with water formations as displayed by the dominance of recent alluvium. Slope values shows that the area is quasi-flat with highest value of 0.4^0 and lowest value of 6.8^0. Similarly, elevation values show a range of 1 metre above sea level to 78 metres above sea level. Rainfall is spatially distributed from the areas proximate to the Lagos lagoon to hinterland showing a northwards decrease in values from 1,538 mm to 1,337mm. Five landuse and landcover classes were established. This includes built-up areas, forest, scattered cultivation, waterbody, and wetlands. The population density distribution shows that the most densely populated areas are close to the waterbody while the sparsely populated areas are located further inland the study area. The values obtained showed an overall range of 8,821 – 69,465 p/km^2.

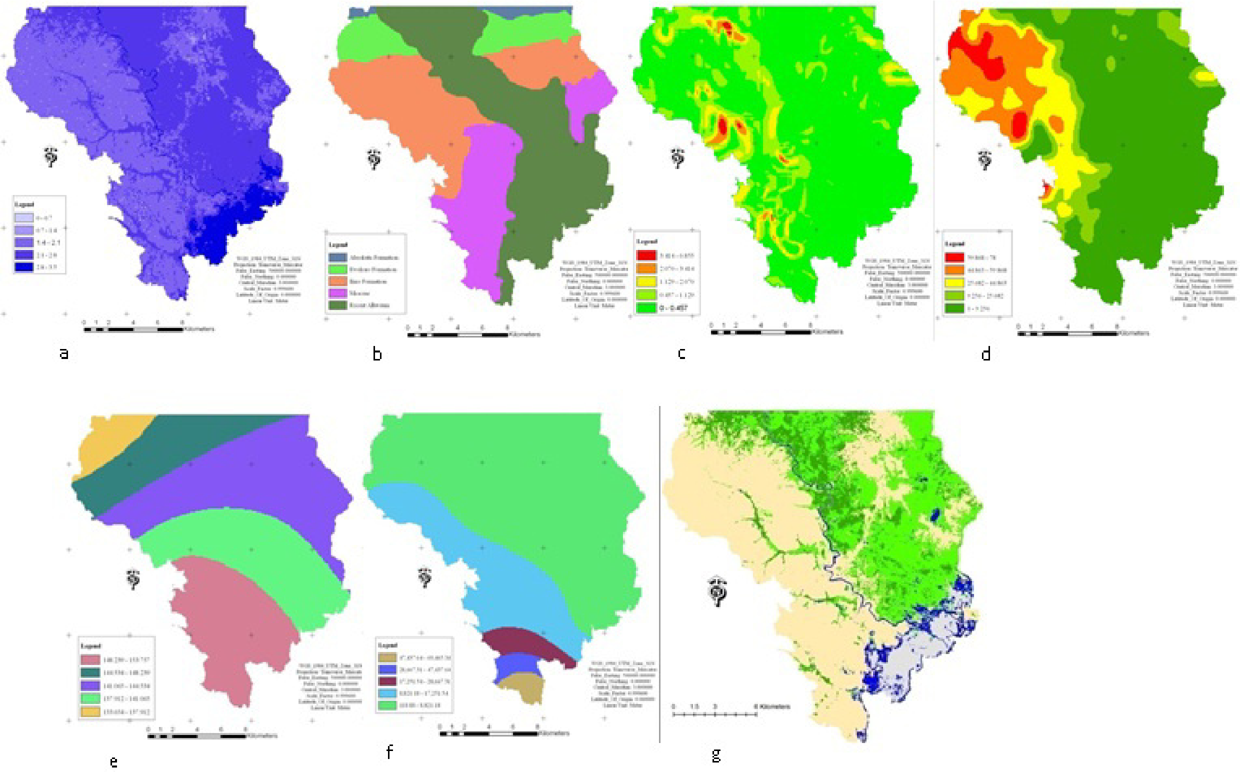


Figure 7: The environmental parameters stimulating flood occurrence in Lower Ogun basin (a) NDWI (b) Geology (c) Slope (d) Elevation (e) Rainfall (f) Population density (g) 2006_LULC

Figure 8 displays the result of the pairwise comparison matrix. It indicates the extent of influence a particular environmental factor exert to stimulating the occurrence based on the eigenvalues returned. With a consistency ratio of 0.06, the modeled environmental variables are sufficient to detect the impact of the variables on flood, thus validating the procedure. With weight value of 0.3000 (30%), slope is the most critical environmental variable with the highest potency to stimulate flood in the area. This is total accordance with field observations as most flooded areas are plain with little or hilly or undulating surfaces. Geology, elevation, NDWI, 2006_LULC, and rainfall have weight value of 0.2872, 0.2081, 0.0809, 0.0629 and 0.0610 respectively. These weight values were further integrated into weighted overlay analysis in ArcGIS to generate the flood hazard map.

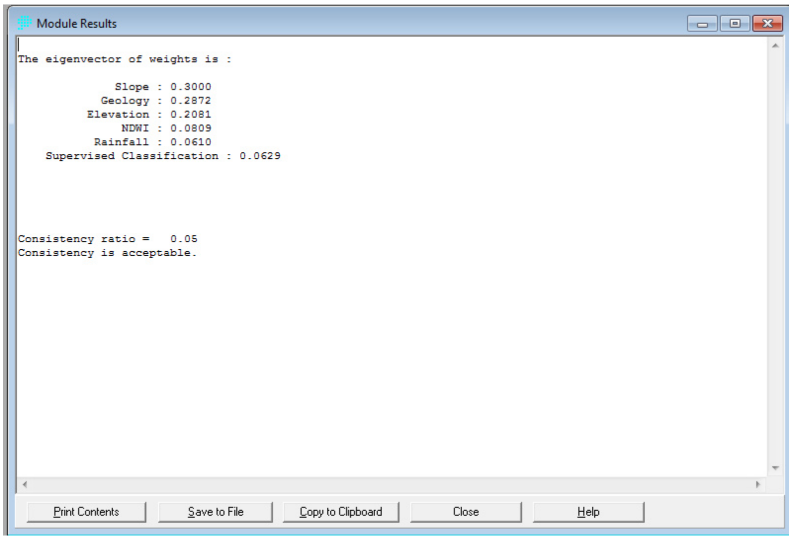


Figure 8. IDRISI output of the principal eigenvector of the pairwise comparison matrix

Flood hazard

The dynamics of the modeled environmental variables and their cognate relationship with respect to flood occurrence makes it paramount to capture the flood sensitivities of the Lower Ogun basin. The flood hazard map, as depicted in Figure 9 shows the overall nature of the environment as regards flood occurrence. It succinctly presents a snapshot of the propensity to flood as regards the key settlements. The concomitant hazard intensities are presented in hierarchical order of impact in Table 3. About 77.6% of the area is liable to flood hazard making the area highly susceptible to flood incidence while the remaining 22.4% have lesser propensity to flood event.

Most of the study area particularly areas lying adjacent to the Lagos lagoon have inherent potential for flood occurrences due to their spatial location, nature of geology, water availability, elevation and slope. Settlements such as Ajegunle, Itowolo, Agidi, Oruba Agboyi I, II, and III, parts of Owode have very high flood hazard intensities. Areas with high flood hazard intensity include such as Ilaje, Abule Okuta, Apelehin, Ketu, Ikosi-Ketu, and Olusosun, up to Akute-Oja, Magboro, and Iganun covering about 181.24 km^2 (53.24%). Medium flood hazard intensity is observed in areas such as Ojodu, Ajuwon, Oke-Aro, Agbado, and Lambe. And, low flood intensity was detected in areas such as Opelu, Oluwo, Itoki, and Ijoko-Lemode and Abule-Oko covering about a tenth of the study area.

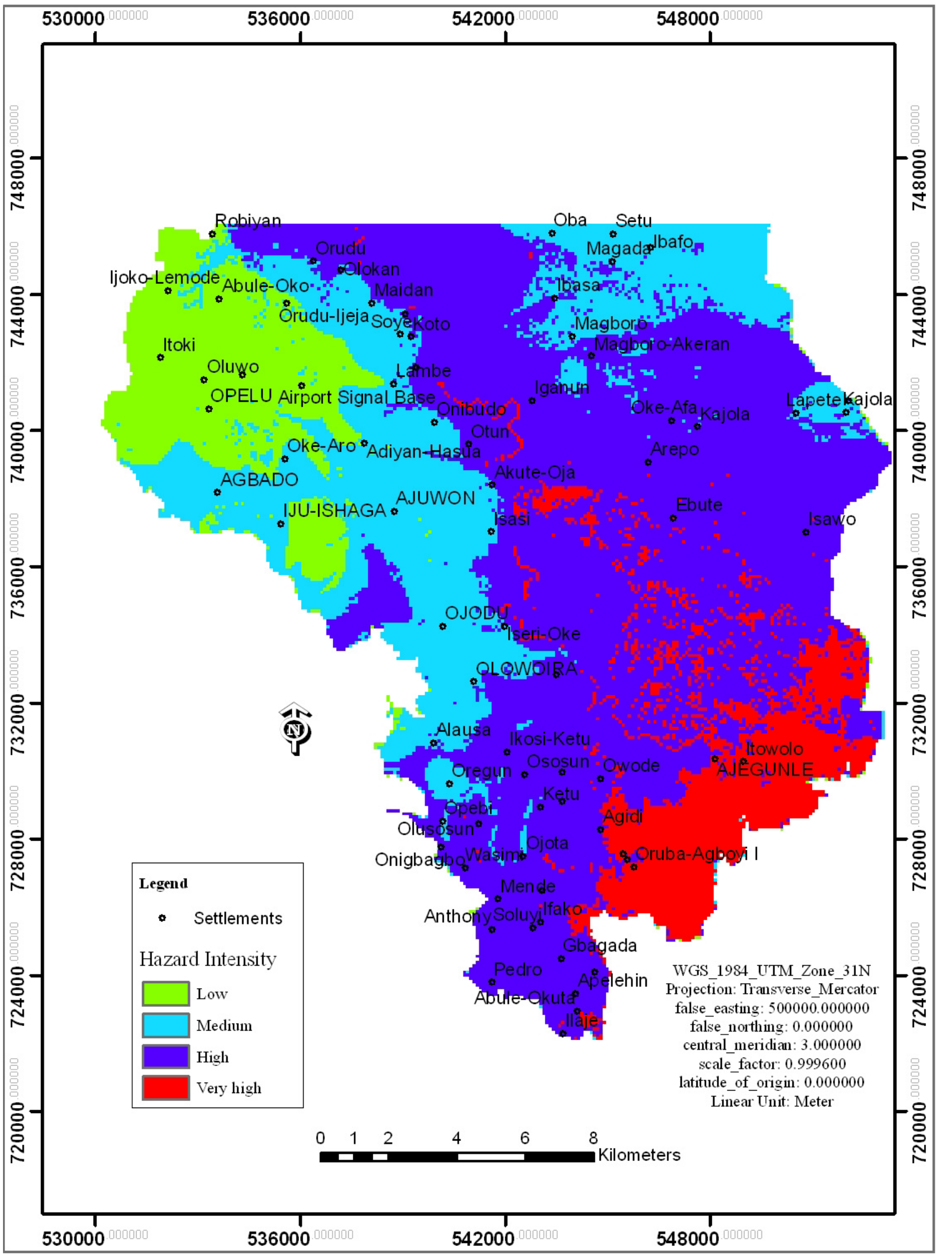


Figure 9. Spatial extent of flood hazard with differentiated intensities

Table 3. Statistical distribution of flood hazard intensity

s/n	Hazard Intensity	Land Area (km^2)	Proportion (%)
1	Low	37.19	10.92
2	Medium	38.99	11.46
3	High	181.24	53.24
4	Very high	82.97	24.38

In assessing the spatial association of the flood hazard with landuse and landcover, built-up areas will be mostly affected (Table 4). Going by the nature of urban expansion detected in the Lower Ogun basin (Raji, 2011), this is not unexpected. 77% of the built-up areas are highly volatile to flood event. Similar statistics were recorded concerning lower intensity levels. Conversely, forested areas have the least proportion of land exposed to flood event. Virtually all of the swamp areas are within the high intensities as the few land area are threatened by a high likelihood flooding activity. Expectedly, the water footprint lies within the high flood hazard intensities. The implication of these observations shows that most of the built environment and natural ecological systems are within the flood zone.

Table 4. Landuse and landcover under flood hazard

	Landuse and landcover [Area (km^2) / Proportion]				
Flood hazard intensity	Built-up Area	Scattered Cultivation	Forest	Swamp	Waterbody
Low	24.06 (64.71%)	0 (0%)	13.12 (35.29%)	0 (0%)	0 (0%)
Medium	36.58 (93.81%)	1.00 (2.56%)	1.40 (3.58%)	0 (0%)	0.02 (0.04%)
High	140.93 (77.76%)	27.04 (14.92%)	12.89 (7.11%)	0.11 (0.06%)	0.27 (0.15%)
Very high	33.36 (40.21%)	35.16 (42.38%)	13.36 (16.10%)	0.18 (0.22%)	0.91 (1.10%)

Flood risk

Exposure to danger by human beings is determined by the degree of risk. Similarly, flood risk is a measurement of exposure of man to the imminent environment-driven flood hazard in the study area. Thus, it is more than estimation but a measurement of likelihood and extent of loss related to flood-driven damages and destructions.

The varying degree of spatial intensity of flood risk in Lower Ogun basin is visually displayed in Figure 10. The flood risk map shows the spatial modelling of population cum environmental variables in which the former defines the number of human lives likely to be exposed to the danger and the later the earlier modelled flood hazard. Risk intensities were modelled based on the nature of exposure of the risk observed. Compared to the flood hazard map, it shows increase in the nature of susceptibility to flood occurrence.

Statistical variables of the risk intensities from high to low flood risk intensities were recorded in Table 5. Over 60% (123.21 km^2) of Lower Ogun basin lie within the high risk intensity. Spatially, this impact is detected in most part of the area; particularly areas abutting the River Ogun, and other parts of the northern fringe including areas previous detected as having low hazard intensities. About 36% of the land area (206.35 km^2) was detected under medium flood risk intensity. This constitutes areas in the northeastern, parts of the east and southern axis with lower hazard intensities. It could be explained that the likelihood of local factors stimulating this development is quite high. Low flood risk intensities were detected in about 3% (10.83 km^2) of the study area. thus, there exists few areas that are potentially flood safe in Lower Ogun basin.

Table 5. Statistical distribution of flood risk intensity

s/n	**Risk Intensity**	**Land Area (sq. km)**	**Proportion (%)**
1	Low	10.83	3.18
2	Medium	123.21	36.20
3	High	206.35	60.62

A closer and deeper view into the relationship between the computed flood risk intensities and landuse and landcover of the study area will present a synoptic view of the potential danger the risk poses to human life in Lower Ogun basin. Over 60% of the inhabited areas have high flood intensity indicating a sparse areas for safety. This shows the natural flood hazard system have been intensified further by human activities. It is now a common development for land developers to find wet areas particularly swamps and shallow water bodies to be reclaimed for construction of houses and industries. It further goes to show the nature of scarcity of land in the area. The exposure of over two-thirds of the study area to flood risk is a manifestation of the continuous human interference with the natural ecosystems and the feedback has resulted in intensification of flood events. Other landuse such as agriculture areas 27.3% (33.67 km^2), and forest footprint 9.7% (11.9 km^2), have high degree of exposure to flood impacts.

Table 6. Landuse and landcover under flood risk

	Landuse and landcover Area (sq. km^2)/Proportion				
Flood risk intensity	Built-up Area	Scattered Cultivation	Forest	Swamp	Waterbody
Low	5.21 (48.12%)	2.79 (25.80%)	1.48 (13.620%)	0.87 (8.04%)	0.48 (4.42%)
Medium	100.63 (48.77%)	55.44 (26.87%)	26.86 (13.01%)	14.25 (6.91%)	9.18 (4.45%)
High	73.03 (59.28%)	33.67 (27.33%)	11.90 (9.66%)	0.28 (0.23%)	4.32 (3.51%)

Flood-safe areas are relatively small in land area. For instance, human settlements (5.21 km^2), cultivation (2.79 km^2), and forest area (0.87 km^2) occupy very little modelled space for safety, hence the need for proper flood zonation and delineation in the study area.

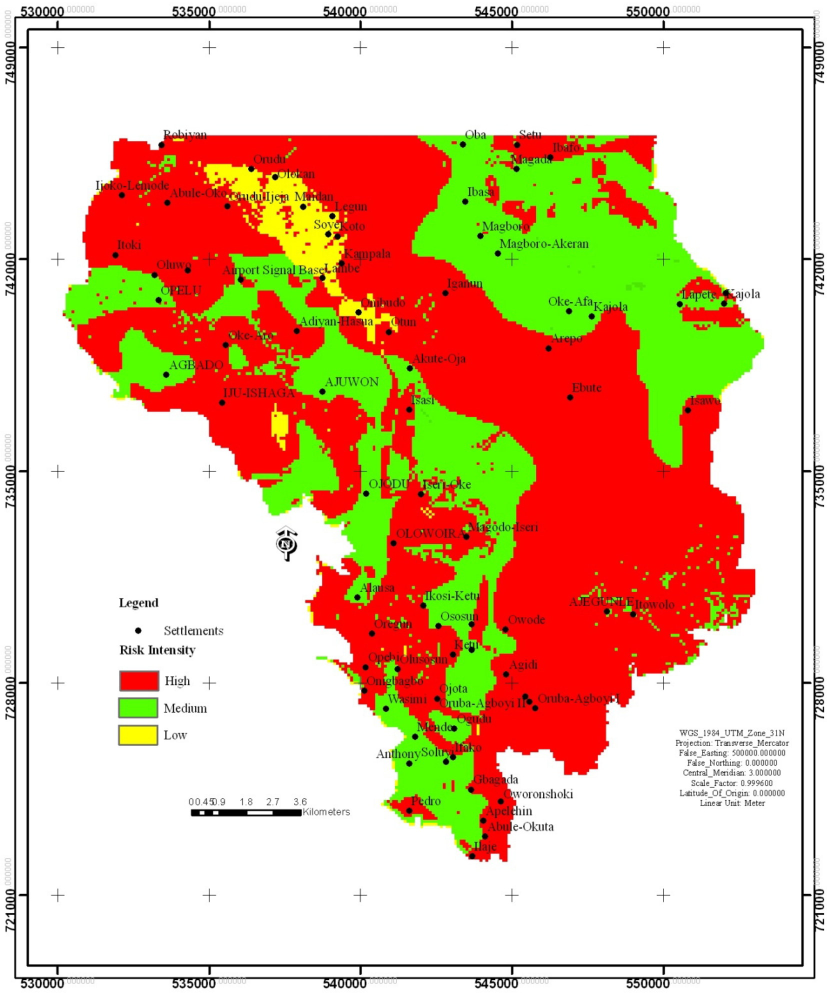


Figure 10: Flood Risk and associated Intensities of Lower Ogun Basin

Conclusion

In this study, the development of flood hazard and flood risk maps for Lower Ogun basin is carried out based on multicriteria evaluation of selected environmental parameters using remote sensing techniques and GIS. The selected environmental parameters covers aspects of environmental and human drivers of flood occurrence, thus,

they are suitable to model the probable flood hazard and risk of the study area.
The results presented provide a medium for proper flood disaster management, flood prediction and mitigation of flood-related damages. More appropriately, the study revealed that land surface configuration i.e. land slope is the most germane environmental parameter for flood assessment. Therefore, in flood disaster management for urban planning, slope should be considered paramount in delineating potential flood zones.
The study also revealed that most of the built-up areas particularly settlements along the Ogun River could be inundated owing to low elevation as well as proximity to wetlands and high water footprints. This is a remarkable change compared to the landuse and landcover scenario of the base year (1984). In order to curtail the potential risks that this portends, a green zone should be designed in form of buffer of about 65 metres. The green zone should be restricted from human occupation but small-scale recreational activities could be permitted. This zone should be established for assessment of rising water levels, thus performing the role of flood observation zone. The development of such green zone will fill the lacuna identified by IPCC (2012a) in designing and implementation of disaster risk profiles of extreme events zones in developing countries.

References

Alayande, A. W. and Agunwamba, J. C. (2010). "The impacts of urbanization on Kaduna River flooding," *Journal of American Science*, 2010; 6(5) pp 28 – 35.
Balzerek, H.; Fricke, W.; Heinrich, J.; Moldenhauer, K.; and Rosenberger, M. (2003). "Man-made flood disaster in the savanna town of Gombe / NE Nigeria; the natural hazard of gully erosion caused by urbanization dynamics and their peri-urban footprints", *Erdkunde*, pp 94 – 109.
Eludoyin, A. O. Akinbode, M. O. and Okuku, E. (2007). "Combating flood crisis with geographical information system: An Example from Akure, Southwestern Nigeria", *International Symposium on New Directions in Urban Water Management*, UNESCO Paris.
European Space Agency (2004). "Space and Public Safety, Civil Protection Assistance", Available online http://www.esa.int/esaeo/SEMQFF3VQUD_environment_0.html viewed on 25 November 2010.
IPCC (2012a). "*Summary for Policymakers*". In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19.
IPCC (2012b). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C. B., V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp.
IPCC, (2007). Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. Van Der Linde, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK, pp. 7-22.
Iyanda, I. A., (2003). *River Niger Flood and Flood Management for sustainable Hydroelectric Power Generation at Kainji Dam*. Unpublished MSc Research. Federal University of Technology, Minna).
McFeeters, S. K., (1996). The use of the normalized difference water index (NDWI) in the delineation of open water features. *International journal of remote sensing*, 17 (7), 1425-1432.
Middleton, N., (2003). An Introduction to Environmental Issues: The Global Casino. New York. pp 366-372.
Oyebande, L., Obot, E. O. and Bdiliya, H. H. (2003). *An inventory of wetlands in Nigeria*. Report prepared for World Conservation Union–IUCN, West African Regional Office, Ouagadougou, Burkina Faso.
Raji, S. A. (2011). Flood Risk Mapping of Lower Ogun River Basin. Unpublished M.Sc. thesis, Department of Geography, University of Lagos.
Scheuren, J. M.; De Waroux, O.; Below, R.; Guha-Saphir, D.; and Ponserre, S. (2008). Annual Disaster Statistical Review, *CRED*, Brussels.
Smith, K., and Ward, R. (1998). Floods; Physical process and human impacts, John Wiley & Sons Ltd, Chichester.
Yahaya, S. (2008). Multicriteria analysis for flood vulnerable areas in Hadejia-Jama'are River basin, Nigeria, *ASPRS Annual Conference Portland*, Oregon.