Delineation of Flood Vulnerable Zones and Disaster Risk Management Along Asa River: A GIS Approach

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Key words: Flood, Vulnerable, Disaster, Buffering

SUMMARY

This research work was designed to map the areas that are vulnerable to flood along the Asa river plain in Ilorin. Defining the level of vulnerability and delineating risk zones can help in understanding the best option in managing, mitigating and adapting to the impact of flood hazard. The study area was divided into three buffered zones based on Town and Country Planning Regulation (1986) and the previous extent of flooding experienced in the area. The buffered distance was used to classify the area into high (30m buffer), moderate (50m buffer) and low (70m buffer). Based on planning regulations, buildings must be at least 30meters away from the river. A total of 1259 buildings were vectorized, of these 211, 122, and 120 falls within the 30m, 50m and 70m buffer zones respectively. The digital elevation model of the study area was generated from the contour lines extracted from a topographical map of Ilorin on a scale of 1:50,000. The raster output was used to generate the flow accumulation map of the study area. The flow accumulation map was classified and used to identify run-off accumulation points. Four accumulation spots were identified close to densely populated areas around Amilengbe, Opomalu, Unity and Cocao cola area. The overlay of the classified flow accumulation spots and the buffered zones were used in determining vulnerable areas within the study area. It was revealed that 51 buildings are highly vulnerable,22 buildings are moderately vulnerable while 30 buildings are less vulnerable. The population density and coverage of the study area was used to calculate the number of population that are at risk to flood. A total of 2693, 3609 and 4518 people for high, moderate and low buffered zones respectively could be vulnerable to flood.

ABSTRACT

The spatial analytic capacity of GIS was employed in this research to identify the areas that are at risk to flood along the Asa River in Ilorin. The different datasets used in this research were extracted from Ikonos Imagery (one meter resolution) of the Study Area and Topographical map of Ilorin on a scale 1:50,000. ArcGIS 9.3b was used for the spatial analyses. Buffering, overlay operations, and 3D Analysis were among the spatial analysis that were carried out. The result revealed that the study area is situated on near uniform lowland with the vulnerable zones located on the lowest part of the plain which is responsible for the high flood vulnerability experience in this area. Flow accumulation spots, coupled with refuse dumps which hinder free flow of water were identified as important factors that heighten the level of flood susceptibility in the study area. . It was revealed that 51 buildings are highly vulnerable,22 buildings and moderately vulnerable while 30 buildings are less vulnerable.

Using the population density of the study area and the total area of each of the vulnerable zones, it was projected that 2693, 3609, 4518 people could be at risk to flooding for high, medium and low buffered zones respectively. It is believed that the result of this research can be used as a means of regulating development along the plain and also serve as a decision support when making policies relating to flood management around the Asa flood plain.

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1. INTRODUCTION

In recent years, floods have become increasingly significant as an environmental hazard. This is due to the devastating impact it has on the human and physical environment. Floods are mostly associated with; excessive rainfall beyond which the soil can absorb thereby causing surface water accumulation and an overflow of water into areas which are normally dry. Flood is enhanced when many drainage channels empty into a single collector, indiscriminate waste disposal which is a characteristic of most third world cities and collapse of dam embankments all results in flooding. In recent times, Nigeria has experienced a lot of flood incidences and the impact of flood has also increased due to population growth coupled with uncontrolled developmental practices which has resulted in pressure and congestion on urban land. This forces a considerable number of people to settle in unsafe areas with inherent risks. Low purchasing power also motivates people to acquire cheap land regardless of inherent risk involved. Climate change which culminates into rising sea level is another causative factor. Flooding poses a tremendous risk to the human and physical environment. Flooding is a potential harm to residences along the Asa river channel because of it severity, magnitude of its impact and frequency of occurrence. This calls for a systematic management of the disaster. Defining the level of vulnerability and delineating risk zones can help in understanding the best option in managing, mitigating and adapting to the impact of flood hazard (Bahaeldeen, 2006). The viability of Geographic Information System was adopted in this study for delineation of flood vulnerable zones and management. Geographic Information System is a computerized tool for capturing, storing, checking, integrating, manipulating, analyzing and display of data which are spatially referenced to the earth for solving complex planning and management problems (Kufoniyi, 1998). Geographic Information System is viable for preparedness, prevention, responses and post disaster recovery activities.

2. STATEMENT OF PROBLEM

Flooding along the Asa river in Ilorin is an annual occurrence. The unsafe condition of lives and properties along the river has over the years become an issue of serious concern to individuals, local, state and the federal government. Properties amounting to billions of Naira are damaged yearly. The government disburses lots of resources to resettle flood victims and to provide relief materials. A viable tool for decision making in risk reduction is geo-spatial information. This technology is being deployed in the delineation of flood vulnerable zones and disaster risk management along Asa River in Ilorin.

3. AIM OF THE STUDY

This research is aimed at delineating features that are susceptible to flood disaster along the Asa river in other to provide ameliorative and mitigating measures.

4. OBJECTIVES OF THE STUDY

The aim of this research will be achieved through the following objectives:

i. Database design
ii. Capturing the spatial data within the study area using Ikonos Imagery (One meter Resolution).
iii. Create an attribute database for all elements at-risk.
iv. Generate the Digital Elevation Model of the study area.
v. Production of risk map which will capture the at-risk elements and delineate risk zones.
vi. Perform some spatial analysis such as buffering, overlay operation and 3D analyses.

5 STUDY AREA

Ilorin is located between latitude 8.425N to latitude 8.530N and longitude 4.494E to longitude 4.647E. The foundation rock of Ilorin is the crystalline rock of the pre-Cambrian age, while the major highland noticeable is the Sobi hill which is an isolated hill located to the north of the city.The major river in Ilorin is the Asa river. It occupies a fairly wide area and flow in a south-north direction. The river divided Ilorin into two parts: a western part representing core of indigenous area of Ilorin and the eastern part where the GRA is located. Other rivers that drain the city include: Oyun, Aluko, Okun, Amule, Alikeke, Agba and Alalubosa. Asa and Agba rivers are dammed and used for different industrial and domestic purposes. Most of the small streams dry up during the dry season while rivers shrink leaving sand on their banks. The annual flash flood normally experienced along the Asa river is a product of excessive rainfall and waste disposal along drainage channels. Flooding is usually experienced along the Asa river in the month of September which is the month with the highest amount of rainfall. Table 1 shows an increase in the total amount of rainfall in the past four years which is likely to be the impact of global change in climate. If the trend persists, then there will be an increase in flood occurrence. This calls for intensification of efforts geared towards flood prediction, warning, prevention and management.

Table 1 Summary of Annual Rainfall At Ilorin (2000-2009). All Readings in (MM). Lower Niger River Basin Development Authority

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
2000	-	-	93.1	206.4	207.4	375.2	158.8	107.6	224.4	115.3	15.0	-	1503.2
2001	-	0.75	17.1	73.9	159.6	132.3	58.5	170.9	224.8	140.0	-	-	977.9
2002	-	32.5	54.9	67.1	143.3	244.9	195.6	85.7	265.6	182.5	22.8	-	1294.9
2003	-	2.2	2.4	22.8	68.2	262.2	93.4	163.9	268.0	9.0	-	-	892.1
2004	18.2	-	18.0	45.0	139.0	121.8	138.7	44.5	176.4	60.8	-	-	762.4
2005	-	-	59.4	163.2	57.2	97.8	180.8	182.7	144.5	176.7	6.5	-	1068.8
2006	1.2	14.0	12.4	93.9	124.5	360.7	123.2	130.9	176.2	140.5	46.7	-	1224.2
2007	-	33.1	4.0	67.0	260.5	159.2	211.4	145.4	243.5	111.2	31.6	-	1266.9
2008	-	5.5	25.5	75.7	187.6	171.0	130.2	93.6	282.6	109.8	10.5	-	1092.0
2009	-	16.1	27.5	106.6	163.7	259.6	224.1	88.2	276.2	190.0	-	-	1352.0

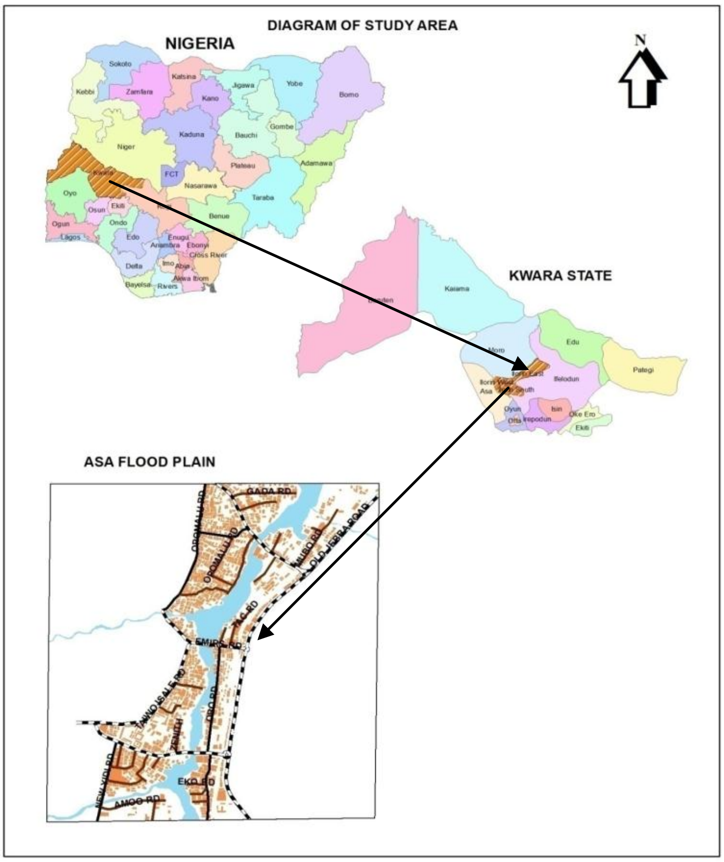

Figure 1: Location of the study area

6. METHODOLOGY

This section deals with database design, collection of geometric and attribute data and database creation.

6.1 Database Design

Database design is categorized into three stages, i.e. the conceptual design, logical design and the physical design phase.

Conceptual Design: This is a representation of human conceptualization of reality. At this stage of the database design, decisions were made on how the view of reality will be represented in a simplified manner and still satisfy the information requirements of the users. For this research, vector data model was adopted and the represented realities were treated as points, lines and polygon feature classes. The following entities were identified: River, represented as line feature, Access roads, represented as line feature. Buildings, represented as polygon. Boundary of study area, represented as polygon.

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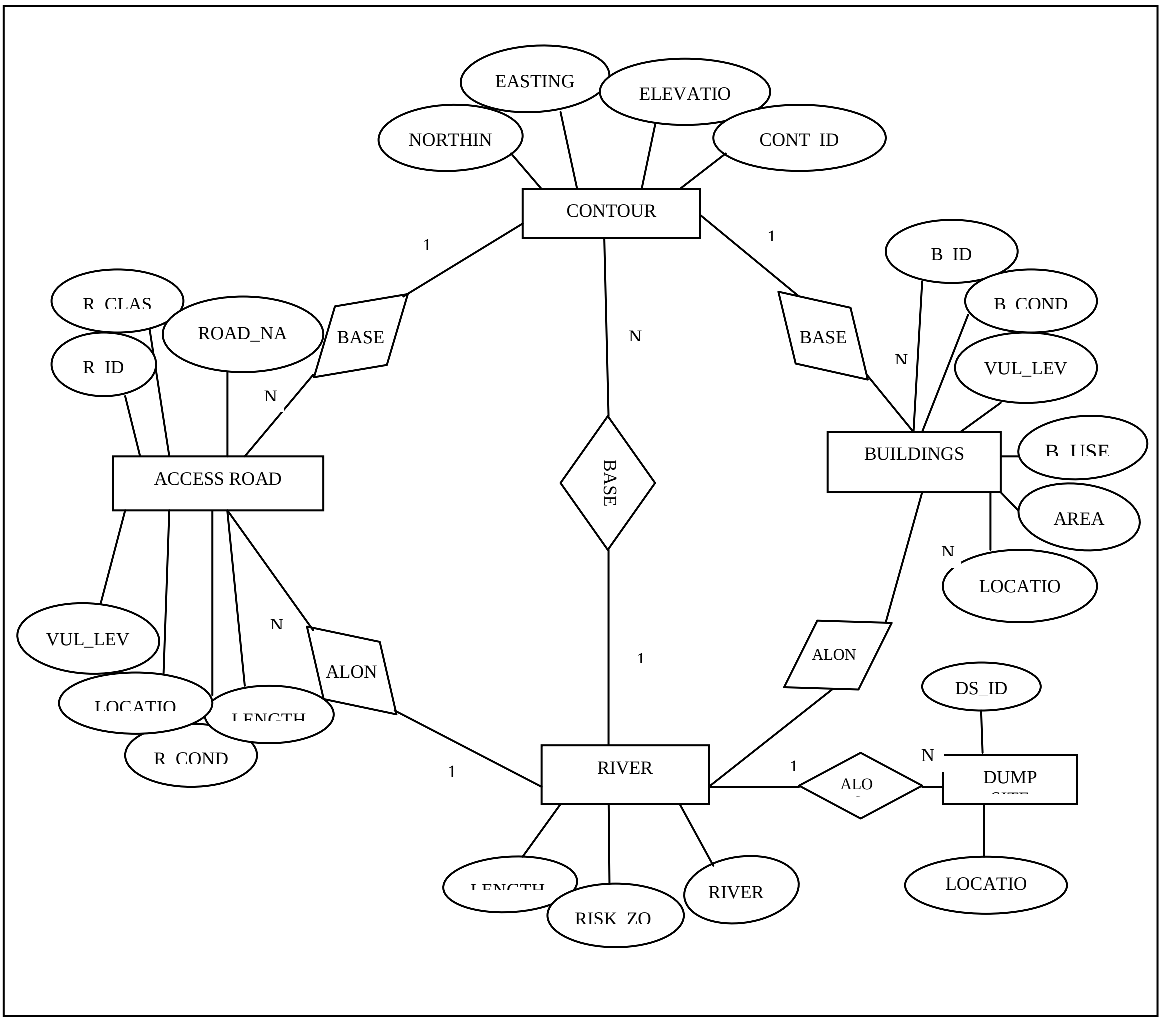

Figure 2: Entity Relationship diagram of the study area

Logical Design: The logical design is a phase in database design where the conceptual data model is transformed into data structure capable of being represented in the computer. In a relational data model, the data are separated into tables. Each table contains item called fields. Fields are objects (attributes of entities). The conceptual data model in figure 2 was translated into a relational data model.:

Table 2 Building Entity and Attributes

FIELD	DESCRIPTION
B_ID	Building Identification Number
LOCATION	Precise Address of Building
B_USE	Building Use
B_TYPE	Building Type
B_COND	Building Condition
VULN_LEVEL	Vulnerability Level of Building base on its location

Table 3 Dump Site table and attributes

FIELD	DESCRIPTION
DS_ID	Dump Site Identification Number
Location	Precise Location of Dump Site

Table 4 River table and attributes

FIELD	DESCRIPTION
RIVER_ID	River Identification Number
LENGTH	Length of River
RISK_ZONE	Risk Zone along the River

Table 5 Contour table and attributes

FIELD	DESCRIPTION
CONT_ID	Contour Identification Number
EASTING	The Easting Coordinate
NORTHING	The Northing Coordinate
ELEVATION	Height Value

Table 6 Road table and attributes

FIELD	DESCRIPTION
R_ID	Road Identification Number
ROAD_NAME	Road Name
R_CLASS	Road class
R_COND	Road Condition
LOCATION	Location of Road
LENGTH	Road Length
VULN_LEVEL	Vulnerability Level of Road

6.2 Dataset Required

The primary data acquired for this study include: Some points coordinated using Global Position System (GPS) to geo-reference the topographic maps, attribute data was collected through social survey and direct interview with residence of the area. The secondary data include: Ikonos Image of Ilorin (One meter resolution) covering the project area obtained from the Office of the Surveyor General of Kwara State, topographical map (1:50,000) covering the study area from the Office of the Surveyor-General of Kwara State, Rainfall data for a period of ten years (2000-2009) from Lower Niger River Basin Development Authority, Ilorin and population data from National Population Commission, Ilorin.

Physical Design

This stage has been described by Kufoniyi (1998) as the representation of the data structure in the format of the implementation software and it is usually done at the beginning of the database creation.

Table 7 Attributes and their Declaration

ENTITY	ATTRIBUTE	DESCRIPTION	DATA TYPE	WIDTH
BUILDING	B_ID	Building Identification Number	Short Integer	10
	VULN_LEVEL	Vulnerability Level of Building	Text	20
	B_USE_TYPE	Building Use	Text	20
	B_TYPE	Building Type	Text	10
	LOCATION	Precise Address of Building	Text	50
	B_COND	Building Condition	Text	10

ROAD	R_ID ROAD_NAME R_CLASS LOCATION LENGTH R_COND VULN_LEVEL	Road Identification Number Road Name Road Class Location of Road Road Length Road Condition Vulnerability Level of Road	Short Integer Text Text Text Double Text Text	10 30 20 30 10 10 30
RIVER	RIVER_ID LENGTH RISK_ZONE	River Identification Number River Length Risk Zone Along River	Short Integer Double Text	10 10 20
CONTOUR	CONT_ID EASTING NORTHING ELEVATION	Contour Identification Number The Easting Coordinate The Northing Coordinate Height Value	Short Integer Short Integer Short Integer Short Integer	10 10 10 10
DUMP SITE	DS_ID LOCATION	Dump Site Identification Number Precise Location of Dump Site	Short Integer Text	10 20

6.3 Database Creation

The tables were created and populated in ARCGIS 9.3 and the attribute tables were linked with geometric data.

Table 8: Sample of Building table created in ArcGIS 9.3

BUILDING_H

OBJECTID *	SHAPE *	VULN_LEVEL	LOCATION	B_USE	B_CONDITION	SHAPE_Length	SHAPE_Area
1	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	87.024101	324.98747
2	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	97.88275	534.533854
3	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	108.844256	582.215977
4	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	142.539256	1247.457146
5	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	113.169933	647.986943
6	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	103.487402	551.786091
7	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	62.458038	238.827257
8	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	106.729948	544.154875
9	Polygon	HIGH VULNERABLE ZONE	COCOA COLA R	RESIDENTIAL	WATER LOGGED/CRACKING/SINKING	159.859759	1545.570856

6.4 SPATIAL OPERATIONS

The spatial data acquired in this research were linked to the attribute data and used to demonstrate how GIS as an analytical tool is used to answer the basic generic questions of; "what is where", "where is what", and "what is the pattern?".

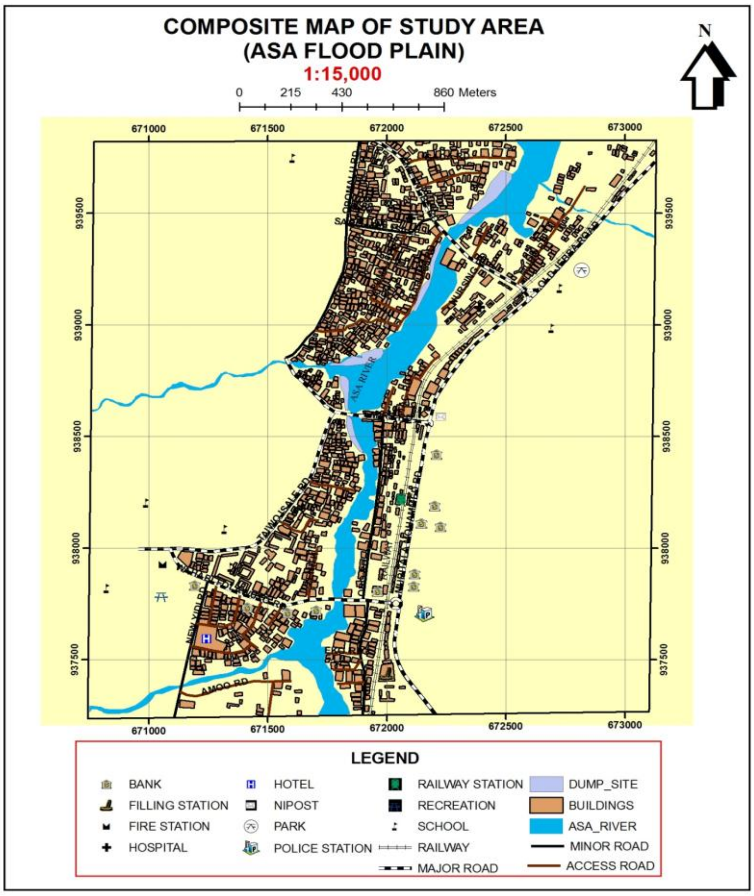

Figure 3: Composite Map study area

6.4.1 Buffering Operation

Buffering is the process by which zones of influence/interest around an entity or set of entities are created. It is often used to delineate areas not affected by a spatial activity or to show extent of coverage of an activity. With respect to this research, buffering as a spatial analytical function was used to classify the Study Area into low (30m buffer), moderate (50m buffer) and high (70m buffer) buffer zones respectively - product one

CRITERIA FOR THE BUFFER OPERATION

- Buildings must be at least 30meters away from the course of the river; Town and Regional Planning (Building Plan) Regulation, 1986.
- Fifty meters (50m) away from the river. This criterion was based on the previous flood extent experienced in the study area.
- Seventy meters (70m) away from the river. This criterion was included in this study to give room for eventualities “what if flood extends beyond the previous extents”. Which areas will be affected under such circumstances?.

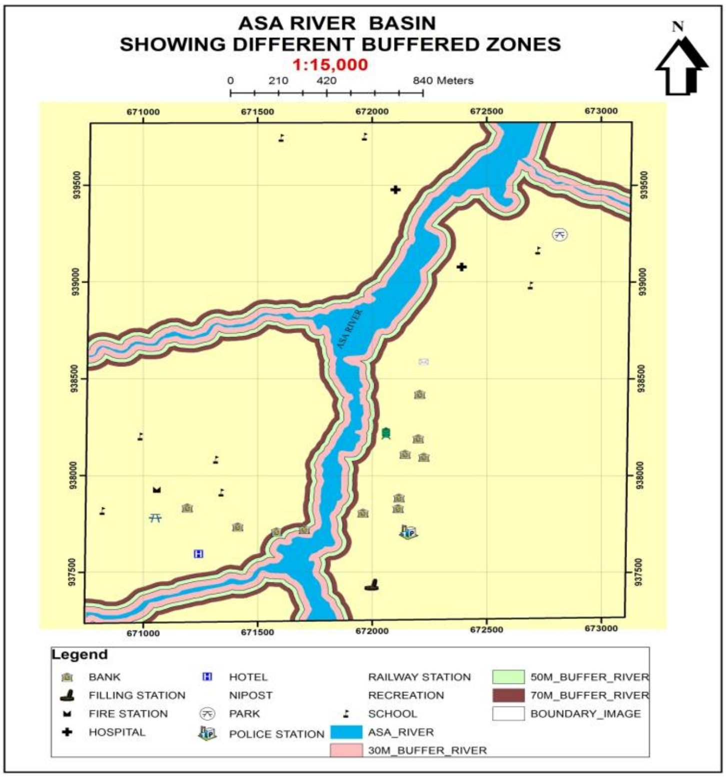

Figure 4: Buffered zones along the Asa flood plain.

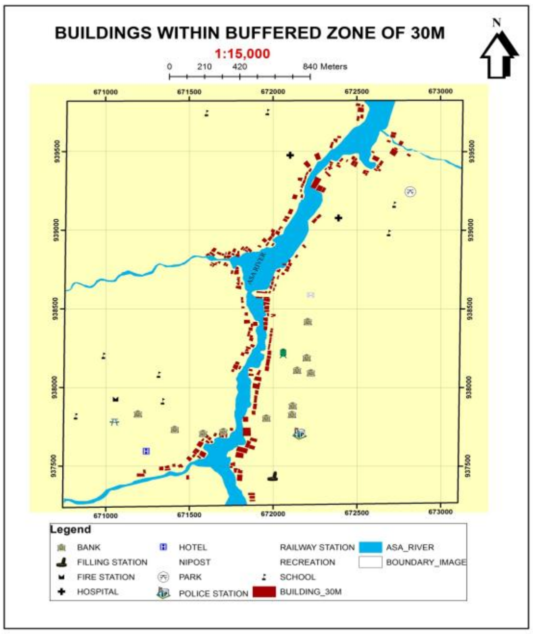

Figure 5: Buildings within 30m of buffered zone

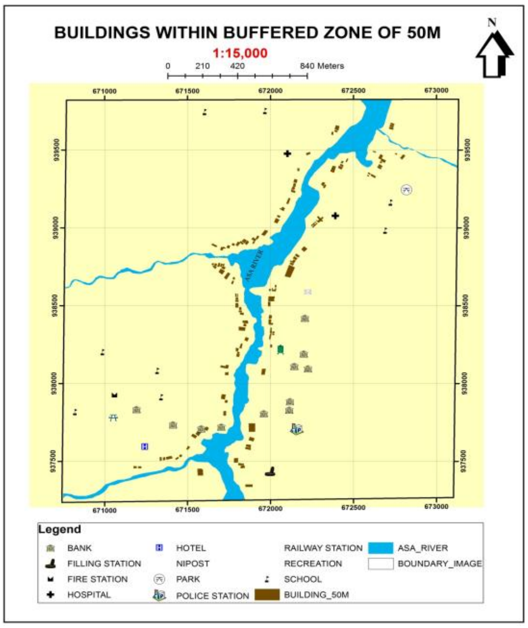

Figure 6: Buildings within 50m of buffered zone

Figure 7: Buildings within 70m of buffered

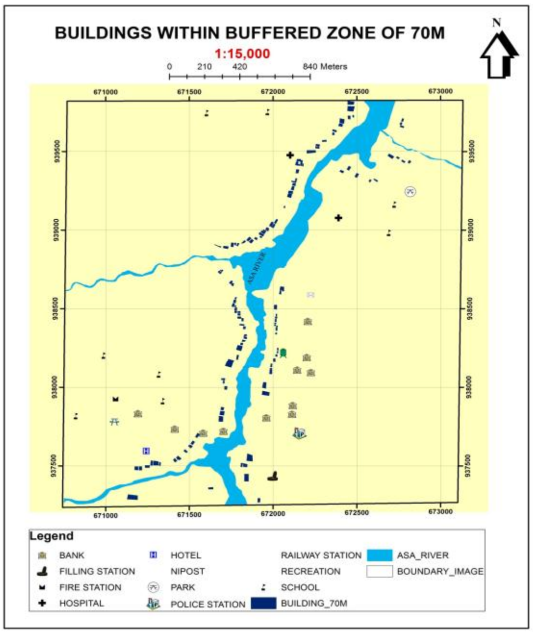

Figure 7: Buildings within 70m of buffered zone

6.4.2 Overlay Operation

The ability to integrate data from two sources using map overlay is perhaps a key GIS analytical function. Using GIS, it is possible to take two different thematic map layers of the same area and overlay them one on top of the other to form a new layer from which a set of information can be generated. In this research, the buildings and roads were overlaid on the buffered zones - see figure 8

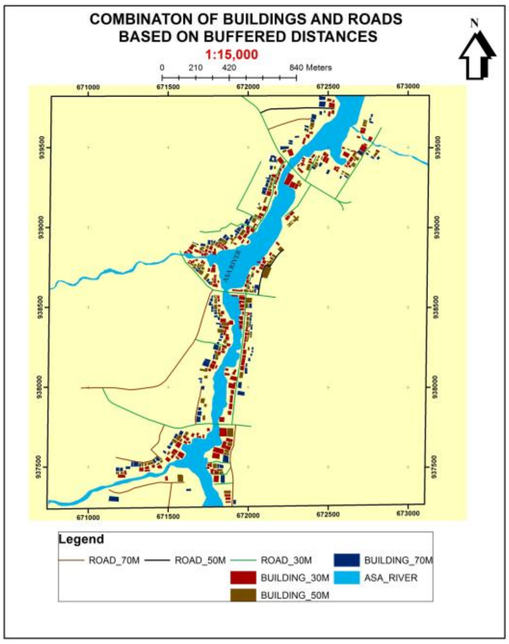

Figure 8 Combination of buildings and roads based on the buffered distances

6.4.3 3D Analysis

The shape of a surface determines the direction of water flow. The most common digital data of the shape of the Earth's surface is cell-based DEMs. A DEM is a raster representation of a continuous surface, usually referring to the surface of the earth. The digital elevation model of the study area is given in figure 9.

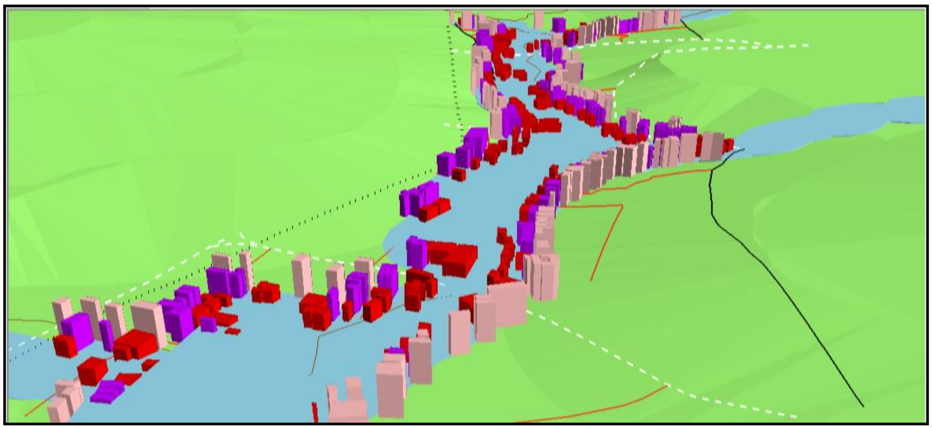

Figure 9 3D Scene of Buildings in ArcScene. The building area extruded based on the buffered distances of 30m (Red), 50m (Purple), and 70m (Brown).

6.4.4 Assessing the level of vulnerability using flow accumulation

In this research, the Flow Accumulation Function was used to generate the convergence point for the surface run-off. The buildings and other functions concentrated around these areas are naturally more vulnerable to flood - product 2

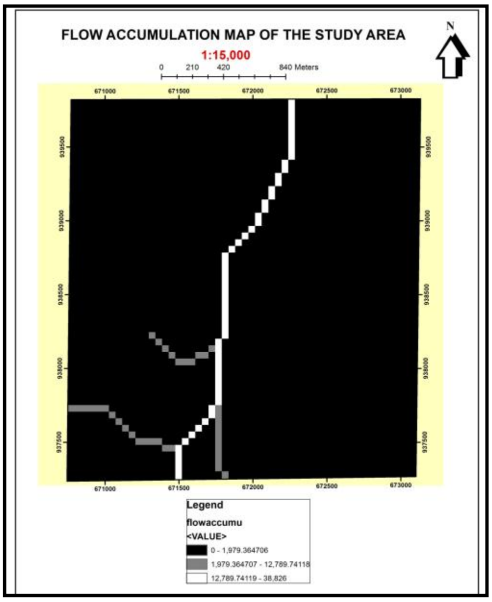

Figure 10: Flow Accumulation Raster. (*There is high cccumulation rate around the white areas*)

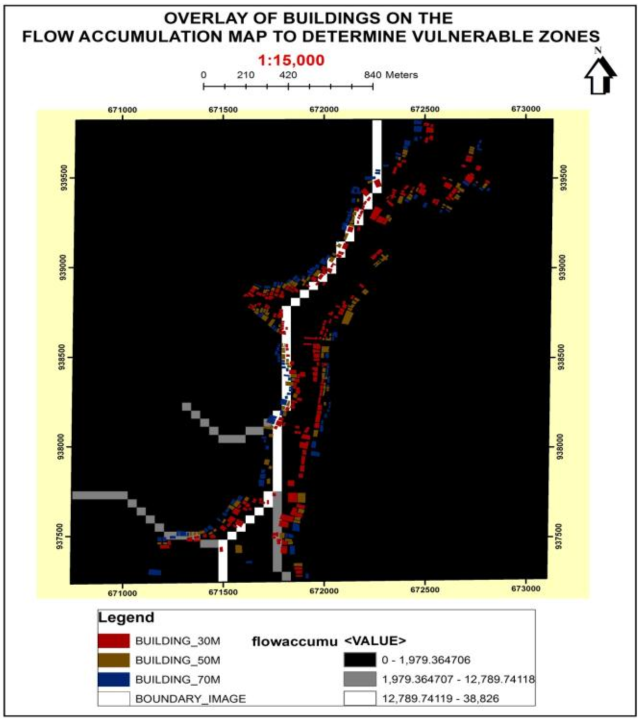

Figure 11: Overlay of buffered buildings (30m,70m,70m) on flow accumulation map

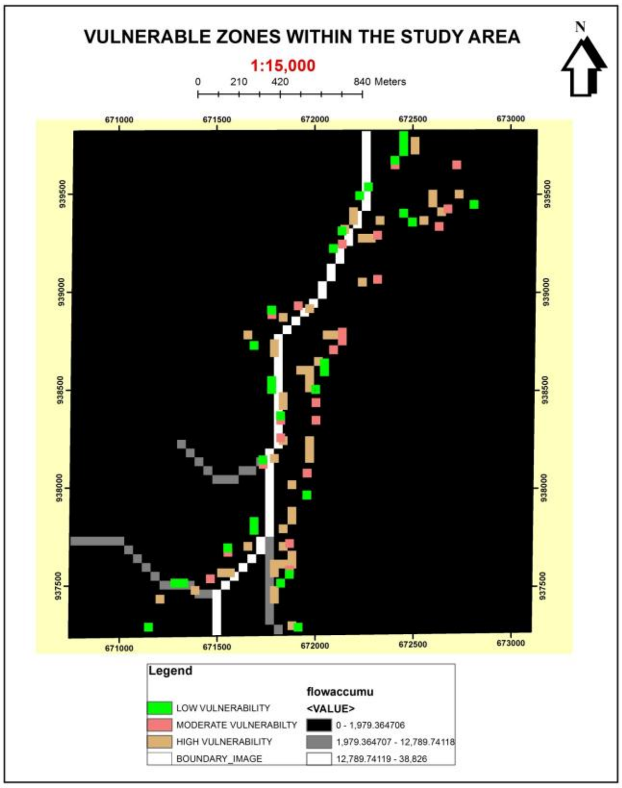

Figure 12: Vulnerable zones within the study area

Table 8 Categories of buildings at risk

ZONE	TOTAL
HIGH	51
MODERATE	22
LOW	30
TOTAL	103

6.4.5 Estimated population vulnerable to flooding

The study area is located in Ilorin West Location Government Area with a total population of 364666, land area of 98.4 Km^2 and population density of 3706 persons per square Kilometer (National Population Commission, 2006). Since personal geodatabase was used to create the themes, ArcGIS 9.3 automatically calculates the area of each of the buffered zones. The population density of the study area was used to multiply the areas of each zone to arrive at the population of the study area. The total population per group is shown in Table 9

Table 9 Population Vulnerable to flood based on the buffered distance.

ZONE	AREA (M^2)	AREA (KM^2)	POPN DENSITY	POPN AT RISK
30m buffer	726728.4	0. 7267284	3706	2693
50m buffer	973814.6	0.9738146	3706	3609
70m buffer	1219013.9	1.219013	3706	4518

6.4.6 Analysis of Results

Figure 3 shows the composite map of the study area which combines all the feature classes. Figures 5,6 and 7 shows the buildings within the buffred distancesof 30m,50m and 70m respectively. The vulnerable zones were determined in this study based on the overlay of buildings on the classified buffered distances and the classified fow accumulation map - See figures 11 and 12 and Table 8

7 CONCLUSION

Flood is an inevitable occurrence but it could be prevented and damage reduced through effective management and mitigation measures and giving sufficient information to residence and prospective developers. Geographic Information System is embedded with analytical capacity which can be used as a decision support system for prevention/mitigation, preparedness, response, recovery and also planning for operational activities; immediately before, during (taking initiative to evacuate people to save places) and after flood (reconstruction activities). This spatial analytical capacity was utilized for this study. To reduce the impact of flooding, adherence to appropriate building set back along Asa river corridor and dredging was recommended.

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BIOGRAPHICAL NOTES

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