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Urban Flood Risk Information on a River Catchment in a Part of Ilorin Metropolis, Kwara State. Nigeria

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Abstract

This study identifies areas at risk to urban flood along Aluko river channel in Ilorin and provides information on flood risk implications on the city dwellers. Data sets on roads, river, dump sites and contour lines were extracted from Ikonos Imagery and Topographical map of Ilorin. The study area was demarcated as high, moderate and low flood risk zones, based on approved setbacks and previous flood extent. Buffering, Overlay Operations, Digital Terrain Modeling, Flow Accumulation and Spatial Search were the spatial analyses carried out using ArcGis 9.3b. The digital terrain model revealed that the study area is situated on near uniform lowland, with the vulnerable zones located on the deepest part of the plain, and this is responsible for the high flood vulnerability of this area. Flow accumulation spots, coupled with refuse dumps were identified as key factors that heighten the level of flood susceptibility in the area. About 288 buildings contravene the setback rule and a total of 10,820 people were estimated to be at risk of urban flood in the three zones. The study recommends adoption of Geographic information system for policy formulation and decisions making on planning, regulation and development along streams in urban centers.

Key words: flood, Geographic Information, spatial analysis, vulnerable, flood risk

1. Introduction

A recent report in the Saturday Tribune (2012) on flooding in Nigeria was that flood sacked communities, some were totally wiped out, buildings submerged, properties destroyed, wiped out farmlands, and caused incalculable and irreversible damaged to food and cash crops, rendered hundreds of thousands of citizens homeless and caused death of many citizens. This is not strange in communities at the bank of major rivers and coastal communities in Nigeria, more importantly when the Nigeria Emergency Management Agency (NEMA) predictions and warnings about the flood in many parts of the country early this year 2012 were ignored. The NEMA(2008) traced the cause of the devastating flooding in the country to the release of large volume of water from the Goroyo dam in Sokoto State and warns that so far, other rivers and streams on the routes may be affected, especially communities in Niger and Kwara States that host the Kainji dam. The hinterland cities cannot be totally excluded from flood disasters because most of them are vulnerable and at risks.

As rightly observed by Oriola (1994) and Jeb and Aggarwal, (2006), floods in Nigerian cities are caused by excessive and intensive rain storms, rapid urbanization, urban expansion and encroachment of flood plains, dam failures, agricultural activities in river beds, blocked drainages and poor solid disposal habits (Oriola, 1991). The unsafe condition of lives and properties along the river has over the years become an issue of serious concern to individuals and government at all levels. Properties worth millions of Naira are damaged yearly. According to Rosenberg (2008) urban floods are a great disturbance of daily life in the city (see also flood Consortium, 2009). Roads can be blocked; people cannot go to work or to schools. The economic damages are high, but the number of casualties is usually very limited (Floodsite Consortium, 2009 and Oblack, 2012), because of the nature of the flood. The water slowly rise on the city streets. When the city is on flat terrain the flow speed is low, and people can still drive through it. The water rises slowly, and the level does not usually reach life endangering heights.

In contemporary time, there has been increasing concern that human actions and natural catastrophes have been adversely impacting the environment and posing serious ecological and health hazards. These concerns have led to increased emphasis on environmental risks assessment studies all over the world (Olorukoba, 2009). It is expedient for development managers to introduce vulnerability reduction criteria in every activity because; development without considering risk management cannot be sustained. Therefore, development along flood plains must be regulated to reduce flood risk. This paper therefore, evaluates Aluko river catchment area for flood risk information and the implications on the city dwellers.

2. The Study Area

Ilorin, the capital of Kwara state Nigeria, is the study area for this investigation. As reported by Oyegun (1983), Ilorin lies between latitude 8^{O} 24’ N and 8^{O} 36’ N and longitude 4^{O} 10’ and 4^{O} 36’ E (Fig 1).

The first population estimate of Ilorin after the establishment of the British Colonial Administration in 1911 was put at 36,343. In 1953, the figure rose 40,994. In 1963 population census, it was 208,546 and in 1991, it rose to 532,088. The latest population census conducted in 2006 put Ilorin at 777,667 (N.P.C 2008). It is evidently clear that there has been rapid population increase and areal expansion. The city has grown from what can be described as a “Foot City” with residential houses located around the Emir’s Palace to an automobile city. Flood and flooding activities have increased due to population growth coupled with uncontrolled physical developmental practices which has resulted in pressure and congestion on urban land (Bolaji, 2012). This forces a considerable number of people to settle along flood prone areas.

The Indigenous part of Ilorin is drained mainly by the Aluko River which is the most urbanized. The River originates from Kuntu area and empties into Asa River (Fig 2). Ajewole (2010) reported that the basin covers an area extent of 9.3km^2 lying at the western part of Asa River. Also, the basin stream frequency is about 0.66 channels for every km^2 and the drainage density is 0.956. Its percentage built up-area is 97.8%, and vegetation is virtually absent in the basin. Aluko River is active mainly during the rainy season and dormant during the dry season.

According to Oyegun (1983), the city has a humid tropical climate which is characterized by the wet and dry seasons. He further observed that raining season in the city begins towards the end of March and ends in October with two peak periods in June and September (Osoba, 1980). Dry season is experienced between November and March of each year. Temperature is uniformly high throughout the year, and open air isolation can be uncontrollable during the dry season. Flooding along Aluko river basin is experienced during the raining season particularly at the second maxima (September).

Oyegun (1983) reported that Ilorin is underlain by Precambrian Igneous metamorphic rock of a basement complex, which is neither porous nor permeable except in places where they are deeply weathered or have zone of weakness. Substantial area of the town is also underlain by sedimentary rock, which contains both primary and secondary lateritic and alluvial deposit. As reported by Oloru (1998), low permeability level of the old Precambrian rocks in the city increases surface water accumulation and run off after rainfalls which in turns lead to a flood. Olaniran (1983) described the soils of Ilorin as sandy and clayey deposits lying on top of each other. The characteristic nature of the sandy deposit include low water holding capacity, which encourages infiltration, while the clayey deposit beneath results in water logging during rainy seasons, and thus, encourages run-off generation in the city. Urbanization process is vastly replacing the Guinea Savannah vegetation in Ilorin with artificial (paved) surfaces with consequent effect on run-off generation as noted by Oriola (1994) hence, frequent occurrence of flooding.

3. Materials and Methods

This study employed Geographic Information System as a tool to delineate the areas that are vulnerable to flood risks in Aluko River catchment, based on the stipulated setback by Town Planning Authorities, the extent of flood experienced in the past, slope pattern and flow accumulation of Aluko flood plain. Data sets on roads, river, dump sites and contour lines were extracted from Ikonos Imagery (one square meter resolution) of the study area and Topographical map of Ilorin on a scale 1:50,000. Using approved Town planning setbacks and previous extent of flood as the yard stick, the study area was divided into high, moderate and low vulnerable zones. ArcGis 9.3b was used for the spatial analyses. Buffering, Overlay Operations, Digital Terrain Modeling, Flow Accumulation and Spatial Search were among the spatial analyses that were carried out.

Buildings along the basin were randomly sampled to gather information about their conditions, distance from the river (a criterion used to measure the level of vulnerability based on distance from the river), building type (residential, commercial, educational, and religious among others) and address of the properties. A hand held GPS was used to pick coordinates used to geo-reference the topographic map of the area. To generate the terrain model of the area, the map was scanned, digitalized on screen and the contour lines extracted for the model. Buildings, Aluko River, Roads and Dump Sites were digitized from Ikonos Imagery of November, 2005. These layers were used to perform the various spatial operations for this study.

3.1. *Overlay Analysis*

One of the most valuable GIS features is its ability to combine information from one data layer with data on another layer. At its simplest, this over process can be visualized as laying a transparent map of an area over a map of the same area with one map displaying the census blocks of the area and the other showing soils types. However, in order to perform analytical operations, the attribute tables tied to these layers were joined as well. New layers became easy to create.

3.2. Database and query analyses

A search operation was used to test the database created. This phenomenon is a common feature in Geographical information system. Search operation is used to identify a particular area of interest. It is used in the processing and manipulation of data to generate information which can be used in decision support system.

The basis of all tools provided or available in Geographical information system is those marked with database query. Queries are specific question asked; what is where? , where is what?. Answers are provided through manipulation and processing of the spatial database. All these are made possible as a result of the link between the graphic (geometric) data and attribute being acceptable to the implementing software (Arc VIEW). Graphic and database for query operation are linked together with their unique identifier towards answering question such as, Highly vulnerable area, Moderately vulnerable area, Low vulnerable, Non vulnerable area.

4. Results and Discussion

4.1 Assessment of Flood Vulnerability using Buffer Analysis

4.1.1. Buffer generation

The river was buffered at a distance of 500m using multiple rings of 20 and distance between rings 30m. The operation was performed using the distance operation in the operation list. The area was classified into four flooding zones namely: highly vulnerable, moderately vulnerable, lowest vulnerable and not vulnerable, using buffer distance as the only flood zoning parameter. These criteria were set in line with town and country planning building Regulation of 1996. The classification arrived at are highly vulnerable: 30m moderately vulnerable: 50m, Low vulnerable: 75 and Not-vulnerable; 100m.

4.1.2. Overlay Operations

First Overlay: the building theme was overlaid on the high flood vulnerable zone (30meter buffer away from the Aluko River). Spatial query was used to select by location, buildings that intersect the high vulnerable zone. Erase function was used to extract the buildings within the highly vulnerable zones and to generated a new theme called outside high vulnerable zone. Figure5 clearly depicts the elements that fall within this category, 288 buildings of the

3730 buildings vectorized from the flood plain are highly susceptible to flooding Table1. Most buildings close to the river are dilapidated, and some totally abandoned due to the severity and intensity of flood along Aluko River (see plates 1 and 2).

Second Overlay: The theme called outside high vulnerable zone was overlaid on the moderate flood vulnerable zone (50meter buffer away from the river) to show buildings that are within this flood vulnerable zone and was erased to generate the theme tagged outside moderate vulnerable zone. Figure 6 clearly shows the elements that fall within this category. The map revealed that 207 buildings were found in this group.

Third Overlay: The outside moderate building theme was overlaid on low flood hazard zone to show low vulnerable buildings and roads. The result is illustrated in (Fig 7). The low vulnerable zone was erased from the outside moderate vulnerable zone for proper delineation of the buildings within this zone. The analysis revealed that 220 buildings were found within this zone.

4.2 Flood Vulnerability Using Digital Terrain Model (DTM).

Digital terrain model (DTM) was used to classify the Aluko flood plain for better visual perception of the configuration of the study area. The contour layer was extracted from a Topographical map covering the study area on a scale of 1:50,000 with an elevation ranging from 900m and 1150 at an interval 50meters. The 3D Analytical tool in ArcGis was used to generate the terrain model. The analysis revealed that the Aluko flood plain is located on a graduated plain. The elevation model shows that the highest point along the basin is between 983-1011 meters and this is the source of the river, while the point of entry into the Asa River is between 900-928 meters. The decreasing nature of the elevation of the flood plain has a direct implication on speed, intensity and erosive capacity of the flood water along the plain as shown in Figure 9. Buildings that fall within the high, moderate and low vulnerable zones based on the buffered distance criteria were draped on the DTM. This revealed the exact location of all the building along the plain. The declining nature of the slope increased the vulnerability level to flooding especially in the event of flash flood.

4.3 Flow Accumulation and Level of Vulnerability

The Flow Accumulation Function was used to generate the convergence point for the surface run-off in Aluko river basin. The buildings and other structures that concentrate within the basin are naturally more vulnerable to flood. There is High Accumulation Rate around the White Areas (Yellow Circle) while The Black Surrounding stands for low Accumulation Rate. Areas where flow accumulation is high are usually at higher risk and more vulnerable to flood. Such areas serve as a convergence point for surface run-off. Figure 10 shows a virtual overlay of buildings and roads on the flow accumulation map. The area with highest accumulation is found around Eruda area demarcated with a yellow circle. Experience shows that these areas experience flash flood annually.

Dumping of wastes (mostly domestic wastes) on the drainage channels is an identified flood enhancement factor in the study area. Plate 3 shows heaps of refuse (dump site) around the river corridor. They block the passage of water and make the areas more prone to flood.

4.4 Estimate of the Population at Flood Risk in Aluko River Catchment.

The study area has a total population of 364,666 and the land area is 98.4 Km^2 and population density of 3706 persons per square Kilometer NPC (2008). Since personal geo-database was used to create the themes, ArcGis 9.3 automatically calculates the area of each of the buffered zones around the river in meters, that is high vulnerable zone (30meter buffer), moderate vulnerable zone (50meter buffer), and low vulnerable zone (70meter buffer). ArcGis, Convert, version 4.08 (1996) was employed to convert the area to km^2. 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 vulnerable per group is shown in Table 2.

5. Conclusion

Flooding cannot be completely avoided, as long as physical development extends to river channels traversing urban centers, but with effective flood prevention programmes, damages from severe flooding can be reduced if not eradicated. Mitigation is hence the cornerstone of emergency management as rightly observed by Olorukoba (2009). The non-structural methods of mitigation of flood hazards are often less expensive as compared to structural ones (dams and dikes). Among the non-structural methods, modern flood forecasting and real-time data collection system have become the practice in countries prone to flood hazards. As reported by Olorukoba (2009) in a similar study, this study has provided information that would be of help in regulating development in a flood plain, identified the number of buildings that are exposed to flood risk and their level of severity. It also serves as a template for evaluating urban streams vulnerability to flood.

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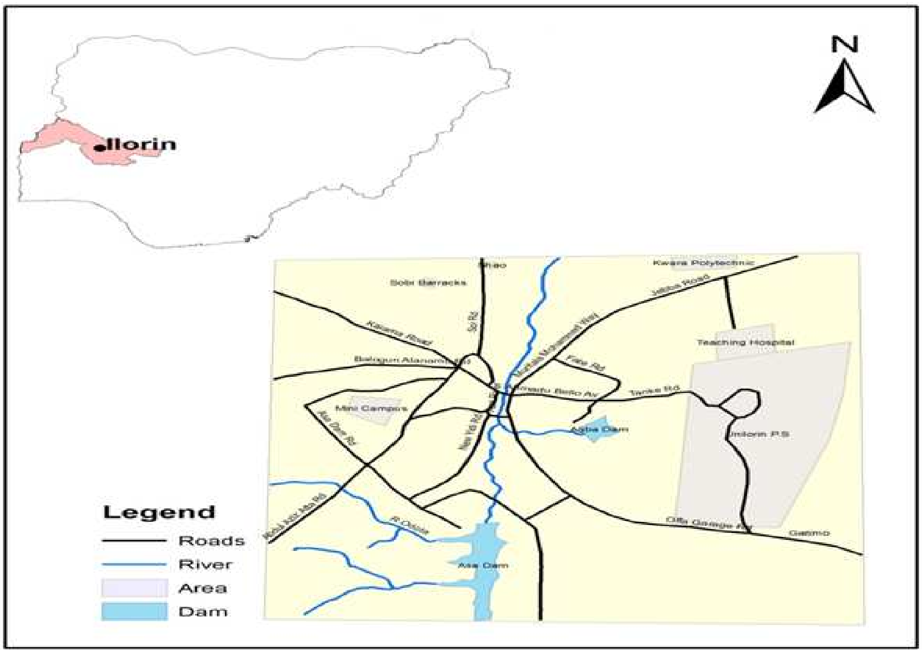

Figure 1. Map of the Study Area

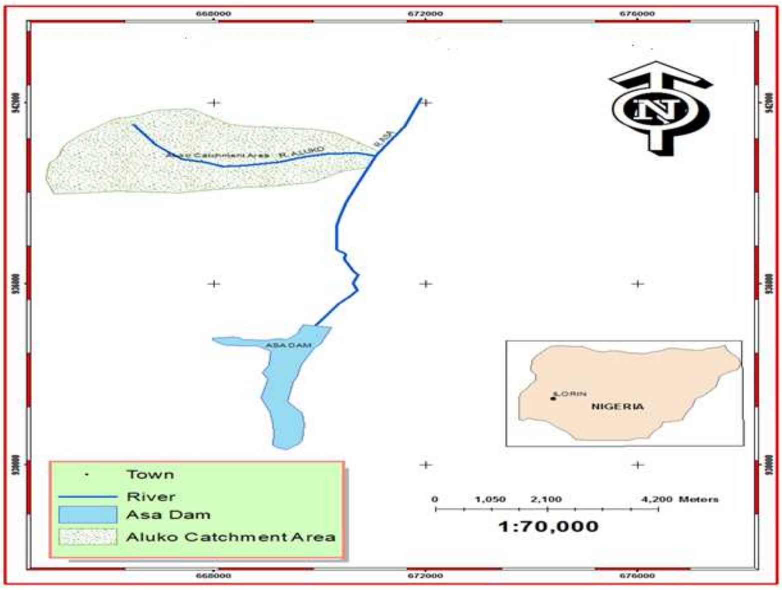

Fig. 2 Aluko River Catchment Area

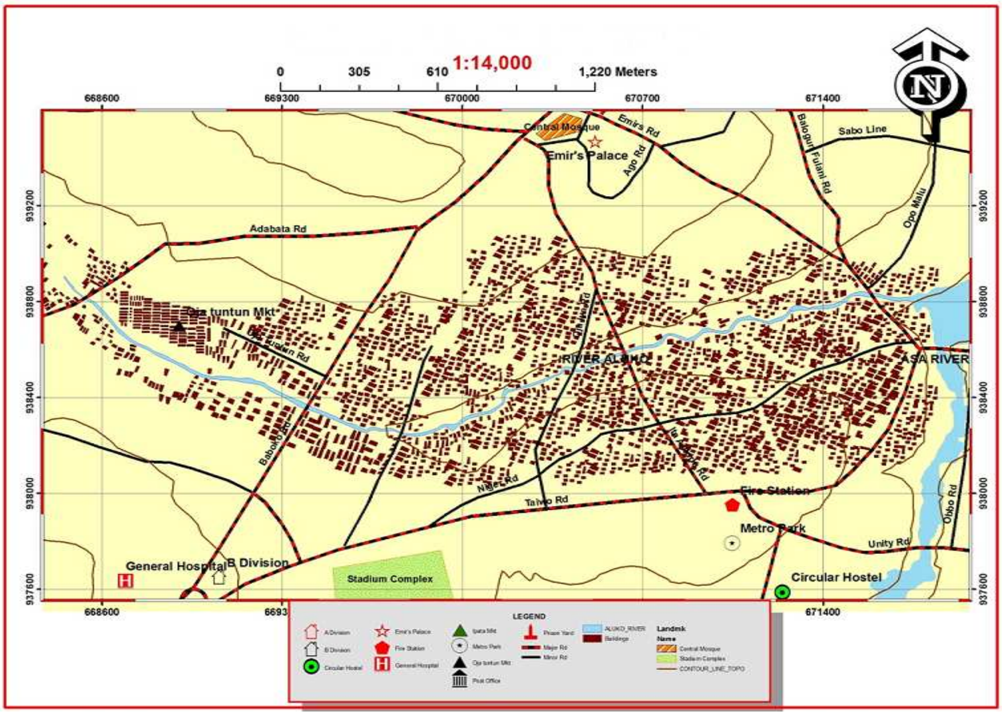

Figure 3. Composite Map of the Study Area

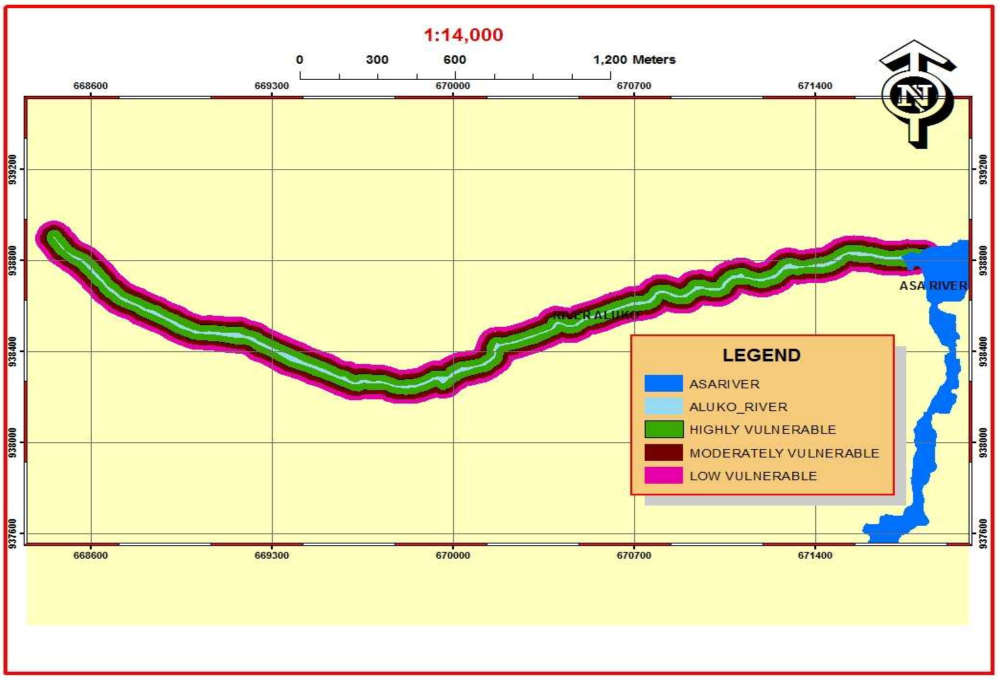

Figure 4. Different Flood Vulnerable Zones in Aluko Flood Plain.

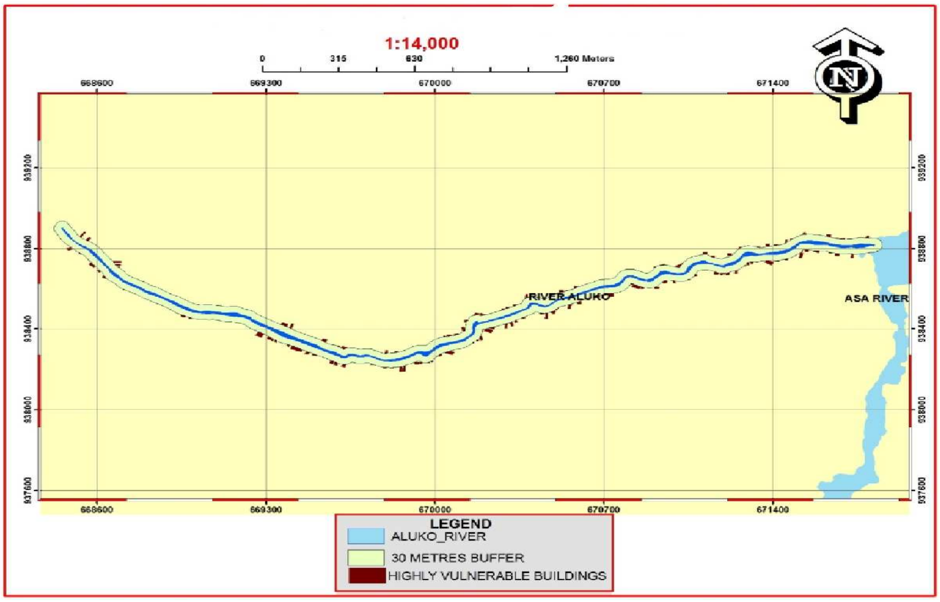

Fig.5.Areas Highly Susceptible to Flood (30m Buffer).

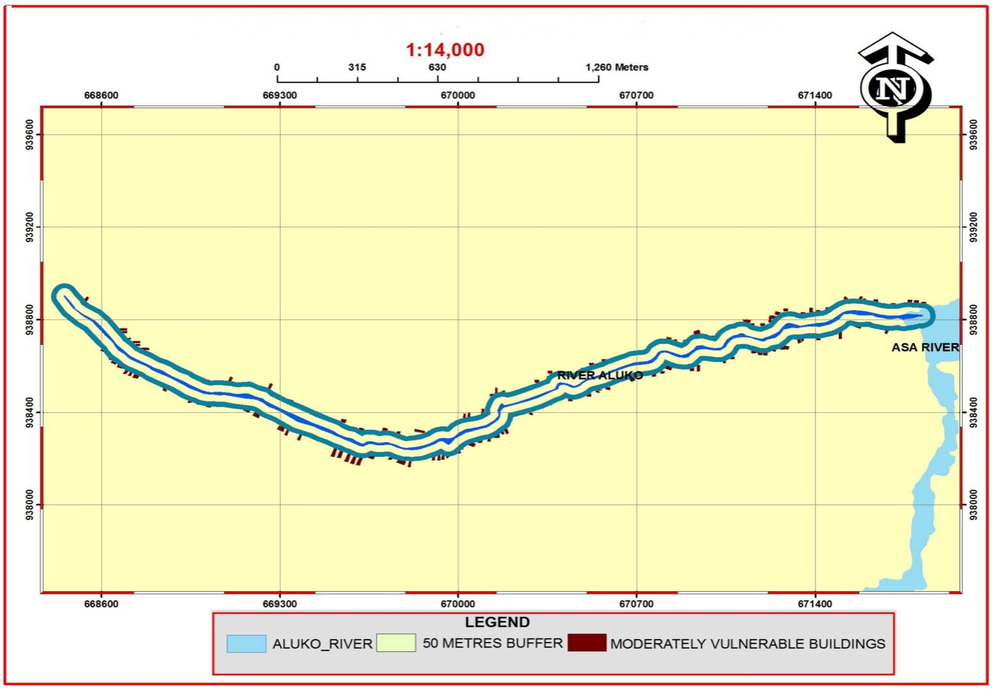

Fig.6 Areas that are Moderately Susceptible to Flood (50m Buffer).

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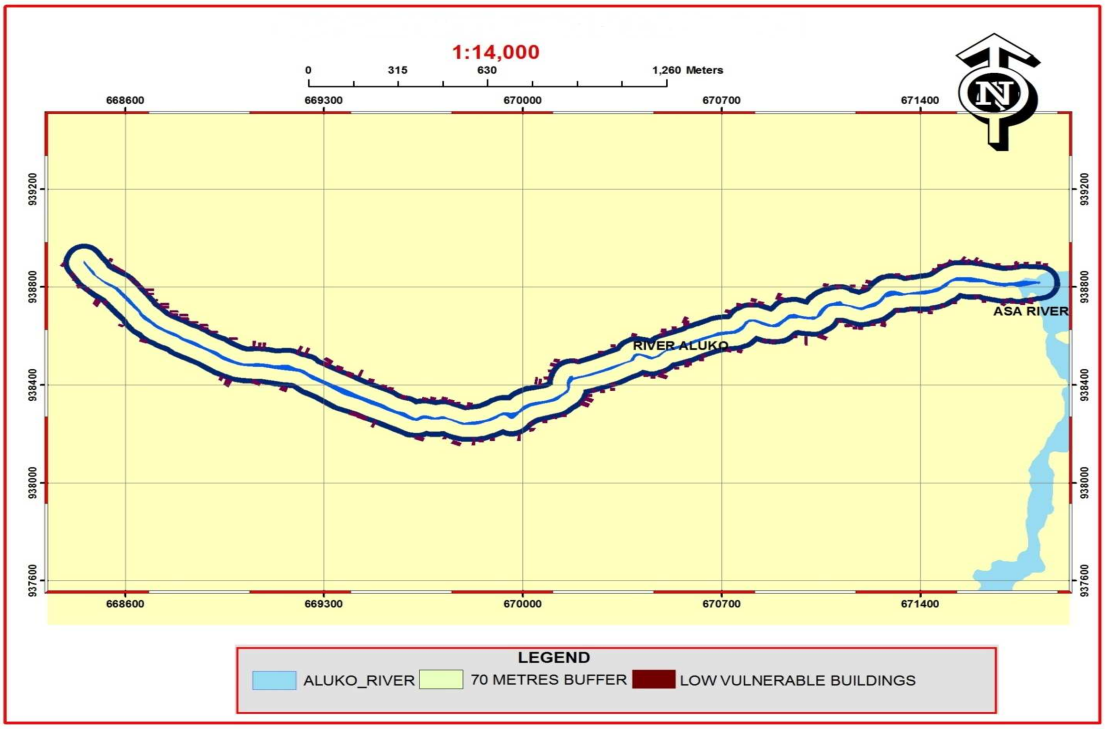

Fig.7 Areas with Low Susceptibility to Flood (70m Buffer).

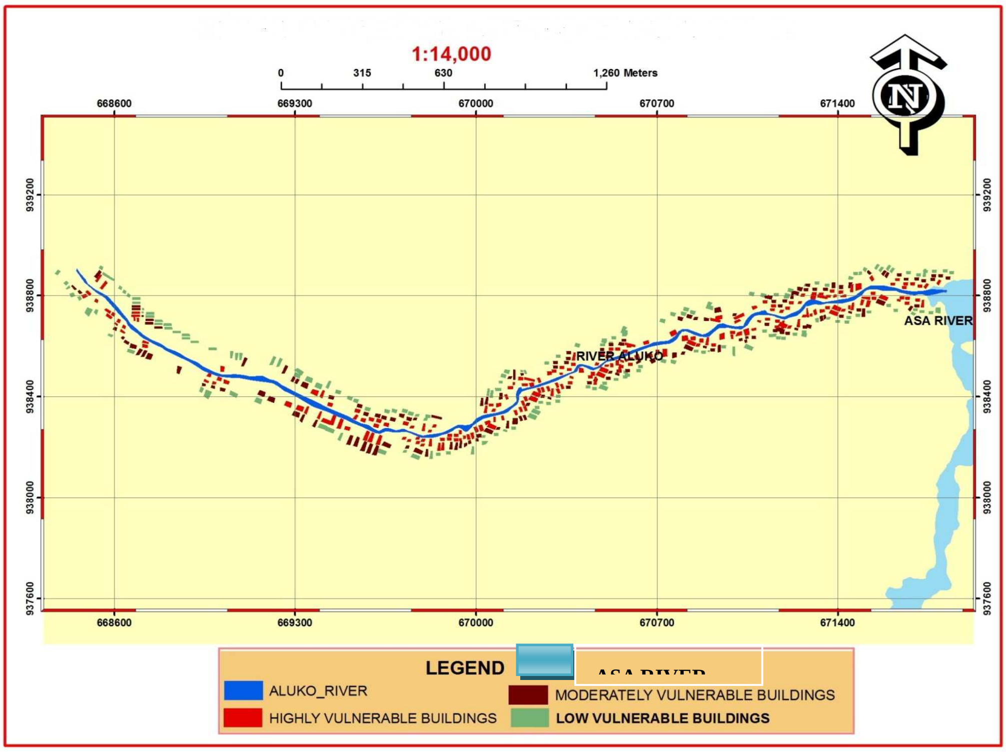

Fig . 8 Buildings at Flood Risk in Aluko flood Plain within the Buffered Distances.

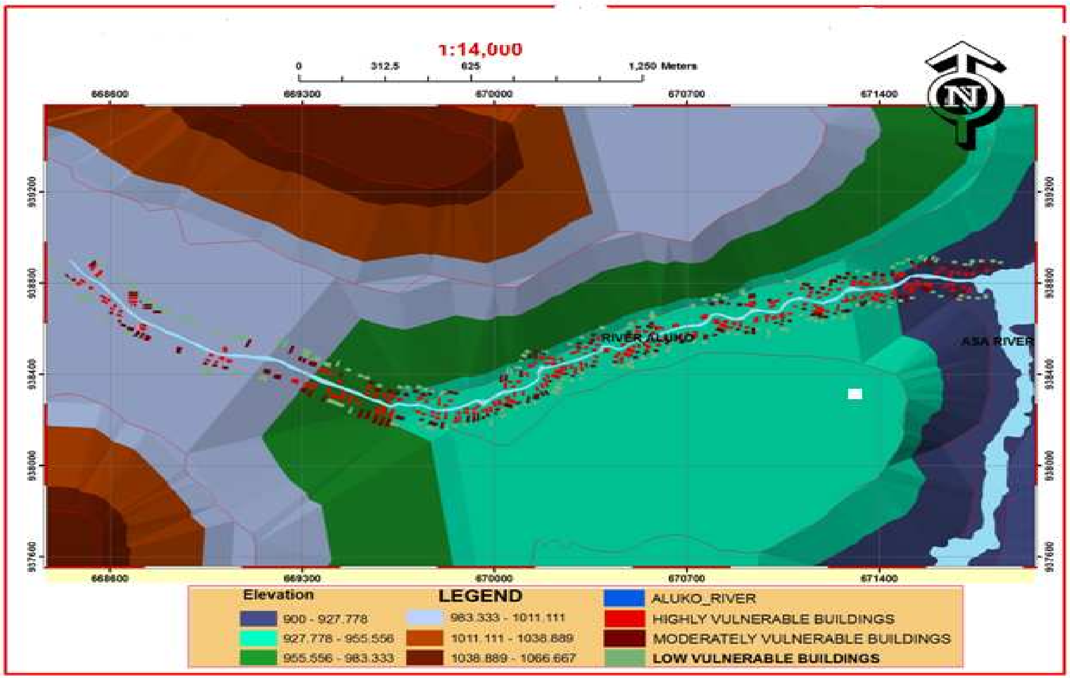

Fig.9 Digital Terrain Model of Aluko Flood Plain and Buildings at Flood Risk.

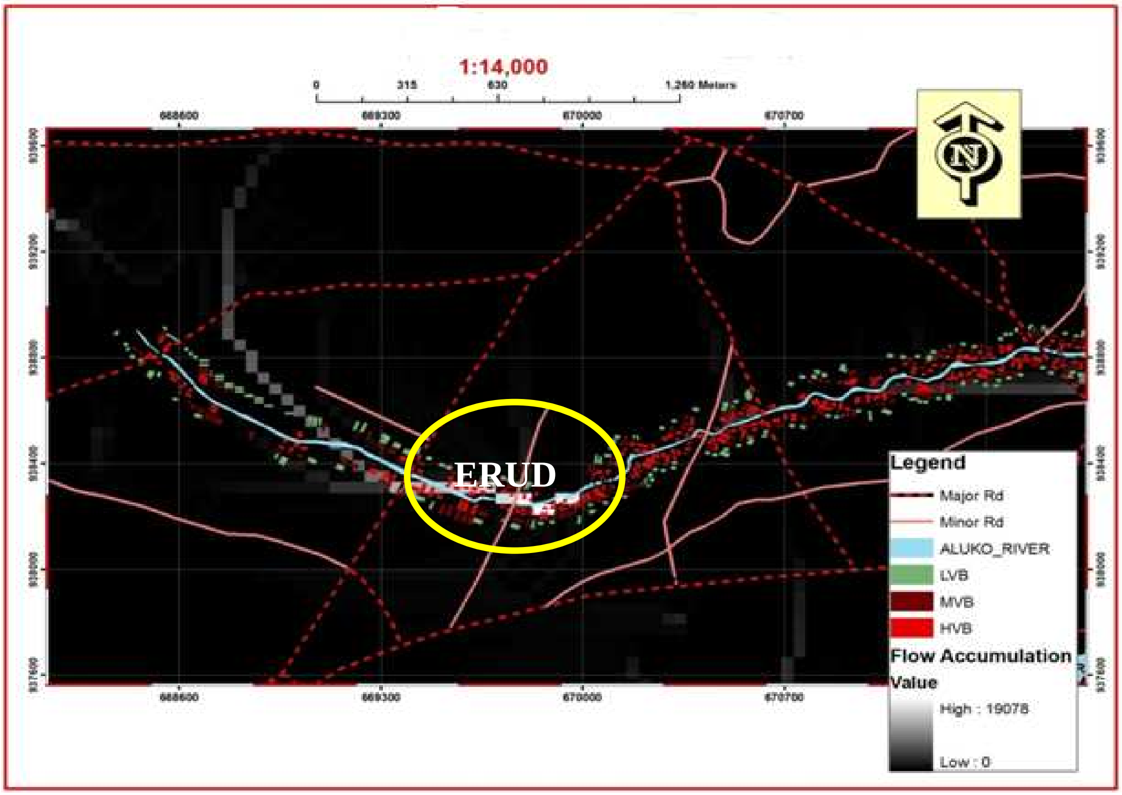

Fig 10 Flow Accumulation Map of Flood Risk Areas.

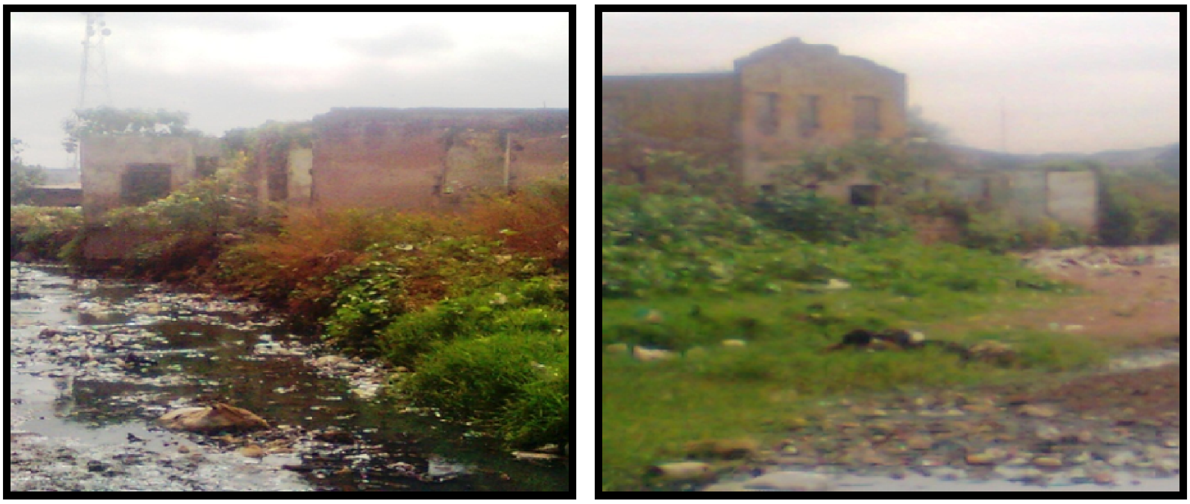

Plate 1 and 2 Parts of Buildings within` 30meters of Aluko River at Emirs Road, Ilorin.

Plate: 3 Refuse Dumps at Emirs Road, Opoo-malu Junction, Ilorin

Tale 1: Number of Buildings at Risk of Flood Based on the Three Buffered Distances.

ZONE	RESIDENTIAL	COMMERCIAL	EDUCATIONAL	RELIGIOUS	TOTAL
HIGH (30m)	207	66	1	14	288
MODERATE (50m)	144	59	-	4	207
LOW (70m)	177	35	3	5	220
TOTAL	528	160	4	23	715

Source: Author's Field Survey, 2011

Table 2: Population Vulnerable to Flood in Aluko River Catchment Area

ZONE	AREA (Km^2)	POPN DENSITY	POPN AT RISK
High	0. 73	3,706	2,693
Moderate	0.97	3,706	3,609
Lower	1.22	3,706	4,518
Total	2.92		10,820

Source: Author's Field Survey, 2011