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Flood Vulnerability Study in Parts of Oyo Township Using GIS and Remote Sensing

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Abstract: **Flooding has been a major environmental disaster frequently occurring in the cities of Tropical African countries differing solutions because of human dimension difficulty to be modelled. The analysis of flood events, the resulting damage and its causes are basis for the development of risk prevention and mitigation measures. The aim of this research is to empirically investigate the vulnerability towards flood in parts of Oyo Township as one component of flood risk assessment with the integration of Geographic Information Systems and Remote Sensing to investigate the contravention level of people in a rapidly urbanizing settlement of Oyo Township to building ethics and rules, which is a tool for rational decision making. It is therefore revealed that the methodology adopted produced and classified buildings in the study area according to their vulnerability levels to flood and the results are presented in maps. The generation of vulnerability maps representing the two different perspectives of local decision makers (experts) and affected households is discussed using the methodology.**

Keywords: **BED, SRTM, Land-uses, urbanization, fill, sink.**

1. INTRODUCTION

Alterations on the surface of the earth for more than 50 years have been linked to human activities notably agriculture, deforestation and urbanization (Lo, and Yeung 2003) and urbanization appears to be contributing greater than expected. For instance, it has been noted that more than 50% of the world's 7 billion population already live in cities and this figure is expected to rise to over 70% by 2050 when the world's population will just be under 9 billion (Noorazuan *et al*., 2003). As population increases and more people migrate to the urban centres, the demand for housing, roads, business, industrial and retail land uses and ancillary infrastructure rises. Thus the cities begin to sprawl; lands earmarked for agricultural purposes and zoned wildlife sanctuaries are over taken by urban expansion. As Tang *et al*., (2005) puts it, many social and economic benefits may be derived from change in land use pattern but come at a cost to the natural environment.

With urbanization comes degradation of urban natural environment and intensification of impervious surfaces (built-up, bare soil and other impermeable artificial and natural surfaces), which leads to modification and replacement of the cover of the land surface, loss of bio-diversity, and agricultural land. In addition to this there is usually a change in micro-climatic conditions such as rise in temperature, drought, and intense rainfall coupled with flooding events. Environmental pollution in terms of ground water pollution is also a regular occurrence. These are all signs of a degraded and fragmented natural habitat which has undergone the process of urbanization.

The process of urbanization and its attendant consequences are a daily occurring phenomenon around the world. It influences the nature of runoff and other hydrological characteristics, delivers pollutants into rivers and control rates of erosion. This trend of urbanization in Nigeria will continue for a long time with attendant consequences. Flooding and other forms of land degradation are some of the consequence of urbanization in Nigeria. Past flooding events of 2009 in Abeokuta, 2010 in Lagos, Jigawa and Sokoto and 2011 in Ibadan etc., which are linked to heavy precipitation and opening of dams are reminders. The latest event was between July and September 2012 in the Nigerian states of Adamawa, Taraba, Benue, Plateau, Kogi, Delta, Enugu, and Anambra and unreported occurrence of floods along major

Akunlemu stream outlet at Oroki junction in Oyo Township are signals for flood occurrence in major Nigerian cities. When occurred, these events showed the displacement of people and properties worth billions were destroyed. Urbanized land are characterized by a decrease in surface roughness. Most surfaces in urban areas are replaced with hard road and concrete drainage system which greatly shorten the time of runoff confluence. Worse still is the fact that buildings and structures are erected at, near or close to drainages which increase the increases the vulnerability of such area(s) to flood and its hazards. Therefore, urbanized area would become more susceptible to flood hazard under intensive precipitation and, erosion if the terrain is undulating. Nwilo *et al*., (2012) has estimated direct runoff produced by precipitation in the Ogun sub-watershed as the first input for water resource management. Also, Sobowale and Oyedepo (2013) evaluated the problem of flooding and flood vulnerability in the Ogun basin with the help of hydrologic simulation methods (Oretade, 2014).

Sun *et al*., (2011) used a long term hydrologic impact assessment (L-THIA) model to evaluate the effect of land use land cover in Beijing City. The datasets used were land use land cover maps, derived from long-term Landsat Imagery (1992, 1999, 2006 and 2009) using support vector machine method, soil type classification data, daily precipitation data from two synoptic weather stations and daily river discharge data. The L-THIA model estimates runoff by SCS-CN method and it was subsequently calibrated by observed daily runoff data.

In addition, Aisya and Mazlan (2014) in their work "change detection of runoff – urban growth relationship in an urbanised watershed in Kuala Lumpur and its impacts on surface runoff" estimated runoff based on the soil conservation service curve number method without additional processes. This procedure used was similar to SCS model used by Weng (2001). Subsequently, the relationship of runoff with urban expansion was examined. However the number of meteorological station records used was not stated. The SCS model used in this work involves the calculation of runoff from curve numbers that relates to land use, soil type, hydrological conditions and soil moisture.

Statement of the Problem:

Changes brought about by uncontrolled urban development in the study area have negatively altered hydrologic regimes, and exposed open spaces to erosion. For example, removal of the top soil and intensive agriculture coupled with sand mining is a regular occurrence in the undeveloped fringes of Oyo e.g. Boroboro, Sabo, Low cost and several other parts of the areas under study. The natural vegetative cover has been removed leaving the subsoil exposed, at the mercy of erosion during heavy rainfall event. In addition, rise in population, and development of houses and other supporting infrastructures without due regard for planning rules and ethics are contributing factors to be considered in the modification of land cover in the study area. Human activities such as deforestation, expansion of residential areas and agricultural land have been linked to the alteration of the hydrologic regime in the watershed (Aawon). Also, deforestation has exposed the watershed to erosion and it is said to have aggravated land cover and land use changes. The change in land cover is said to have impacted and altered the water balance of the area by changing the magnitude and pattern of stream flow and as such this has made the effective management of water resources problematic.

The growth of Oyo in the recent years, therefore, will continue as long as the population increases and the quest for living a sustainable life increase among the inhabitants of the study area. With this in mind, it is therefore essential to model urban growth with a view to understanding the trend and evaluates its impact on surface runoff so as to manage and mitigate its adverse effects on people as this will be useful for land use planning and management.

2. AIM AND OBJECTIVES OF THE STUDY

The central aim of the study is to integrate Geographic Information Systems and Remote Sensing techniques to evaluate properties and elements vulnerable to flood hazards in the study area with a view to providing mitigation measures that will help forestall the risk associated with flood hazards. To achieve the above aim the following objectives are set to be examined

Identify properties and elements threatened by flood hazards in the study area and recommend appropriately.

Identify the hydrologic patterns in the study area and the impact of man on such pattern.

Predict hydrologic patterns in the study area.

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Create spatial database for features of interest in the study area.

Perform spatial analyses on the database and

Present information for Spatial Decision Support Systems.

The Study Area:

Oyo state in the south-western part of Nigeria is one of the component states which make up Nigeria; the study area is the south- eastern part of Oyo Township comprising parts of Oyo east and Atiba local governments. The study area lies between longitude $3^0 45^1$ - $4^0 00^1$E and latitude $7^0 45^1$ – $8^0 00^1$N. The entire area is carved out of the two local governments and has enormous human activities which greatly impacted on the on the hydrologic status of the study area. The area is bounded in the south by Akinyele Local Government, in the east by Osun state, in the west by Iseyin local government and in the north by the rest of Atiba local government. The study area is carved out of Oyo Township which an estimated area of about 6,500sq km and drained by numerous streams and rivers which had impacted seriously on both the topography and hydrology of the area. The area belonged to a rural settlement and its people are predominantly farmers who live a subsistence level. Being a local setting, flooding occur primarily due to literacy level of the people of the area who might in one way or the other do not build in accordance with building regulations and are also ignorant in their waste disposal and management practices. See the map below

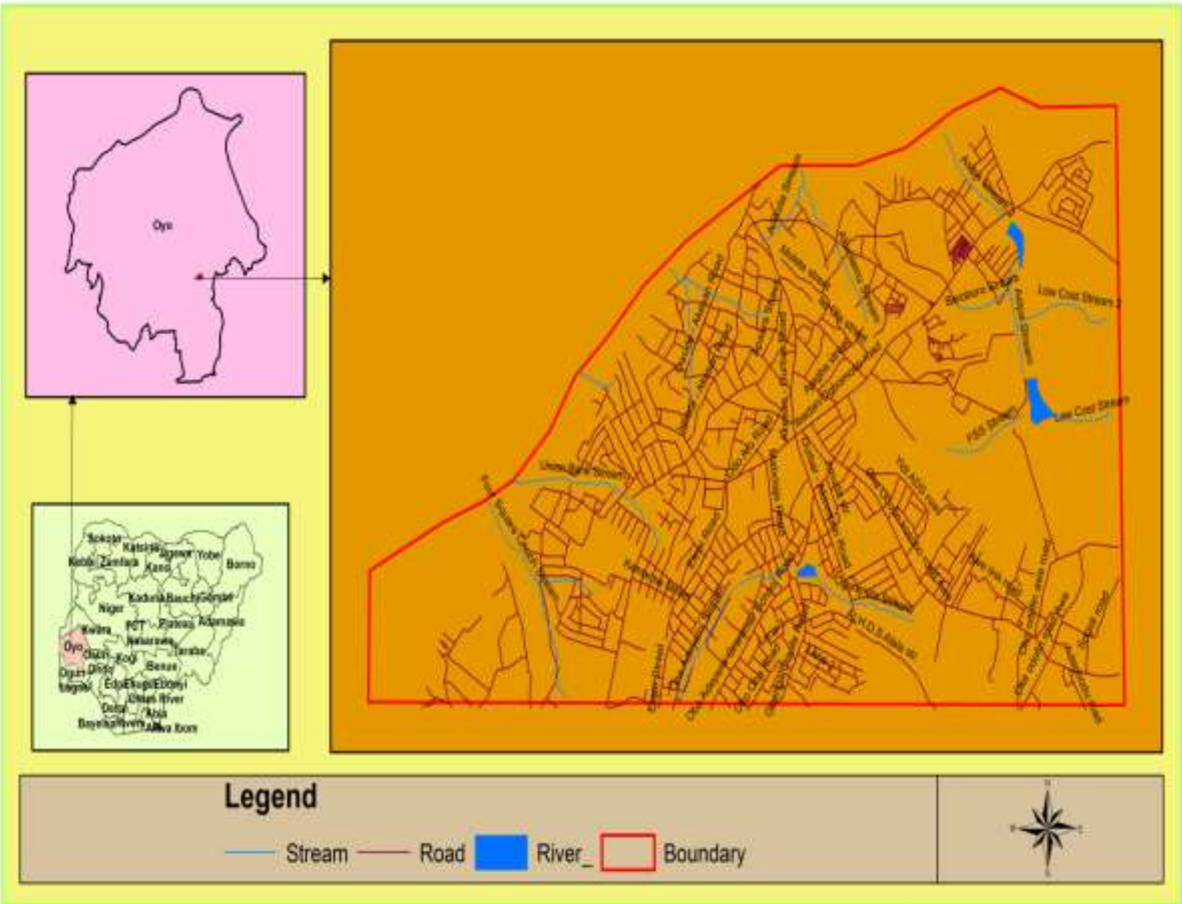

Fig1.1 Location of the study area

Since the area is part of Oyo Township, the people are homogenous in culture and ethnic affiliation. They are predominantly farmers and produce such crops like yam, cassava, maize and other seeds. Fish and poultry farming are known to be an increasing practice among the people of the study area. Light weighted industries and agro-allied industries also have its own share of the economy of the people of the study area.

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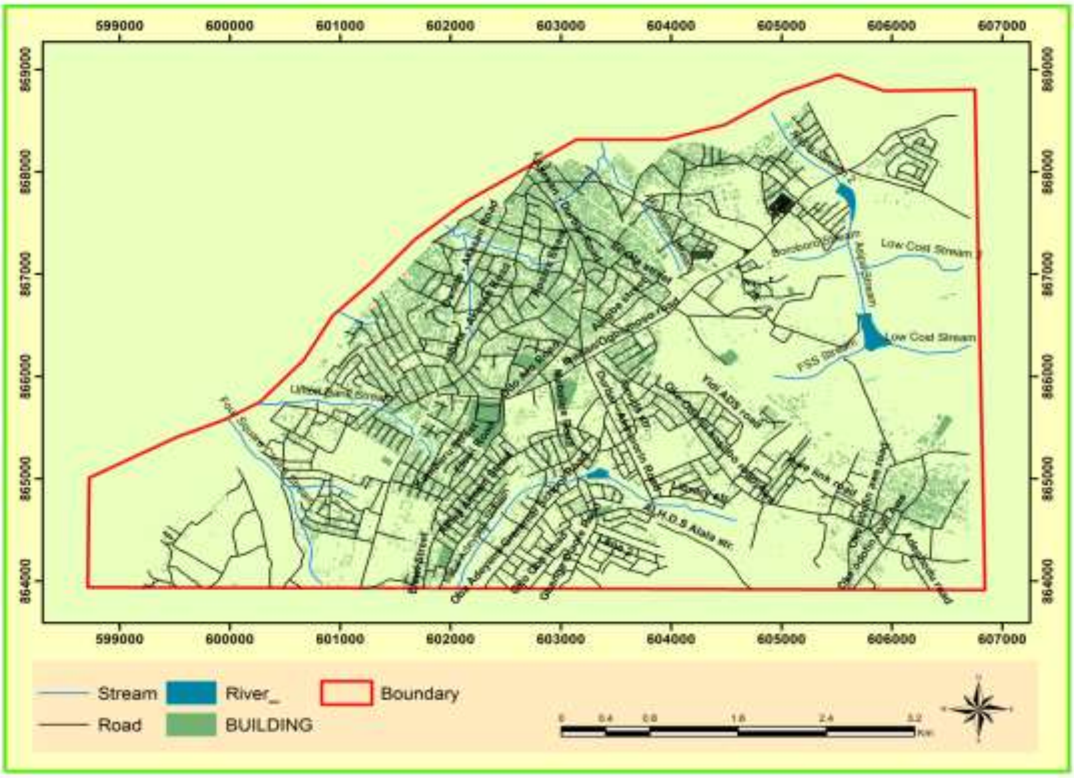

Fig 1.2 Composite map of the study area

Significance of the study:

The study shows the effectiveness of GIS technology and its capabilities in solving spatial problems and its aids as decision making tool for organization that are in charge of flood controls and mitigation against the hazards and emanating risks at the local, state and national levels of decision making.

3. METHODOLOGY

Environmental and resource managers require reliable mechanisms to access and monitor land-uses and its implications on planning related problems which flood exemplify. Management and planning of urbanization related problem require, current accurate and reliable information about the causes of, and elements threatened by flood related problems. Vulnerability analysis using satellite imagery and SRTM (shuttle Rader Topographic Mission) provides an effective method for flood studies; It analysis and predictions in the study area. The integration of remote sensing and Geographic Information Systems (GIS) has been widely applied and recognized as a powerful and effective tool for risks and disaster management as well as decision support systems (Sowton, 1991).

In order to indentify vulnerability levels of areas of the city of Oyo flood hazard, satellite imagery of the study area which shows various land-uses and streams within the area of the study and SRTM of the area which are useful component of BED analysis of flood were acquired for the present study: The use of BED analysis was based on simplicity of use and its availability for flood analysis as compared to other methods of analysis of flood which required real time climatic data which is not usually available; More importantly, since one of the objective of this study is to analyze vulnerability potential of different area within the study to flooding using medium resolution satellite imagery like IKONOS will give an accurate overview of flood potentials of streams in the study aarea and reveal streams that are encroached and their levels of encroachment.

The data used for the study comprised 30m resolution IKONOS image of Oyo townships (2003) and SRTM covering the entire area of study. The images are first registered to the universal Traverse Mercator (UTM) Projection Zone 31 North.

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A total of four registration points coinciding with the edge of the image was used to geo-referenced the image covering the entire Oyo township. The study area was later extracted from the mosaic image and data relating to BED analysis of flood was extracted from the image through vectorization in Arc GIS 10.2.2

Analysis performed on the vectorized map include proximity analysis (buffering), overlay spatial search and hydrologic analysis (fill and sink). The process is shown below in the cartographic model.

Sequel to the created databases of elements in the study area which may be threatened or which act as threats (streams and rivers) are created and spatial operations (query) are performed on them.

4. RESULTS AND DISCUSSION

GIS is different from every other information systems by the reason of its spatial analytical capabilities. It integrates both the spatial and non-spatial data to answer questions relating to spatial problems in which location is a critical factor. There is a wide range of functions for data analysis in most GIS packages which distinguishes it from other information systems. These capabilities use the spatial and non-spatial data in the spatial database to answer locational specific questions and solve problems which will be used as decision support systems. With all relevant and necessary data acquired, the Geographic Information Systems operations performed in the present study are: Proximity analysis (Buffering), Classification, Overlay and Hydrologic operations

Proximity analysis of buildings to streams in the streams in the study area. Fig 4.1 shows the composite maps of the study area where structures are erected along drainage channels at specified distances of 7.5m, 15m and 25m either sides of the streams which shows the extent of buildings encroachments to the streams. It is revealed that highly vulnerable buildings in study numbered 484 out of the entire 19,557 buildings captured for the study and the streams that are highly encroached are Adikuta and Akunlemu streams which produces the result of about 4.2% of the total. More importantly the result is as shown in the table below and the map of the affected building at that levely vulnerability is as shown below.

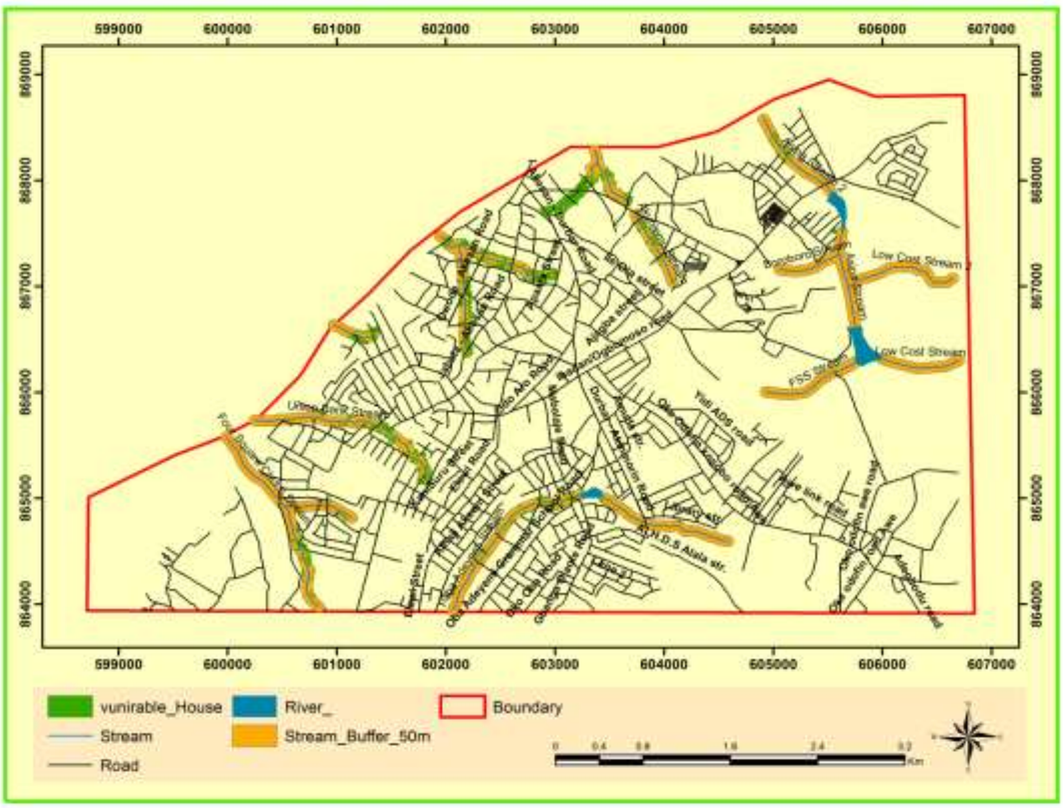

Fig 4.1 Buffer of Streams by 50m to determine buildings within marginal level of vulnerability to flooding

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Spatial Analyses and Product Generation:

Heywood (1998) says that GIS takes the user from data to information and ultimately to decision making, this mean that GIS packages address both general and the specific needs of the user. The measurement techniques in GIS, the attribute queries capabilities, the overlay operations, buffer spatial search potentialities are the various advantages to the user of GIS package.

Spatial Analyses:

The GIS operations analysis performed for the project is spatial search, order by Classification, Buffering, Hydrologic analysis and Overlays. Overlays operations were one to integrate two themes to produce a new one involving operations like union and intersection. Classification, based on the vulnerability of buildings to floods in the area, and classified as highly vulnerable, vulnerable, marginally vulnerable and non vulnerable zones were classified. Neighbourhood operation involving what surrounds what? Or what is in the vicinity of what was carried out while buffering operations were used to show zone of interest at specified distance and features to produce a new theme.

GIS is different from other information systems by the reason of its spatial analytical capabilities. It integrates both spatial and non-spatial data to answer questions relating to spatial problem in which location is a critical factor (Ibe, Alagbe and Ejiro, 2012). There is a wide range of function for data analysis in most GIS packages; this is what distinguishes GIS from all other information systems. The GIS capabilities use the spatial and non-spatial data in the spatial database to answer questions and solve problems that will be used as decision support system. Having acquired all the necessary data, the Geographic Information System operation performed within the study area are: Buffering, Classification, Intersect and 3D Analysis.

Buffering Operation:

Buffering is an important analytical function in GIS. It is an aspect of proximity analysis in GIS. A buffer is also called the zone of influence, spread, search or corridor. It is used to identify areas that are vulnerable to flood within the study area. According to the space standard of development in urban area, The rivers are buffered at specified distance that is nationally accepted depending on the size of rivers or streams and specified by Oyo State building regulation recognized for setback provision for roads and streams which are put at 15, 30 and 45 metres respectively depending on the earlier mentioned specifications. In this regard, streams in the study area are buffered at the distances specified above to determine the levels of vulnerability of buildings or properties at the verge of been affected by the streams in case of emerging situation. Figures 4.1a, b, c and d show the results of the operation.

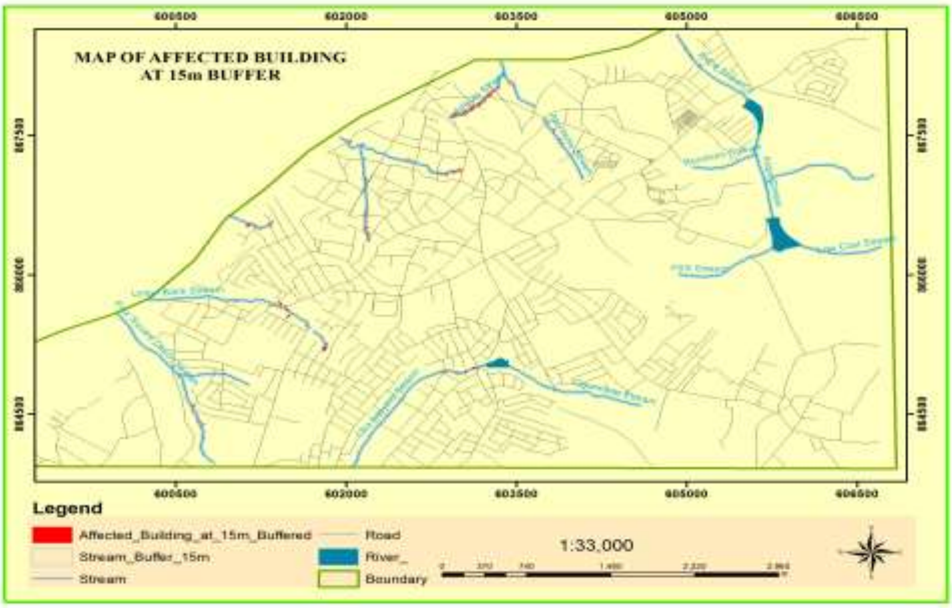

Fig. 4.2a Map of affected buildings at 15m Buffering

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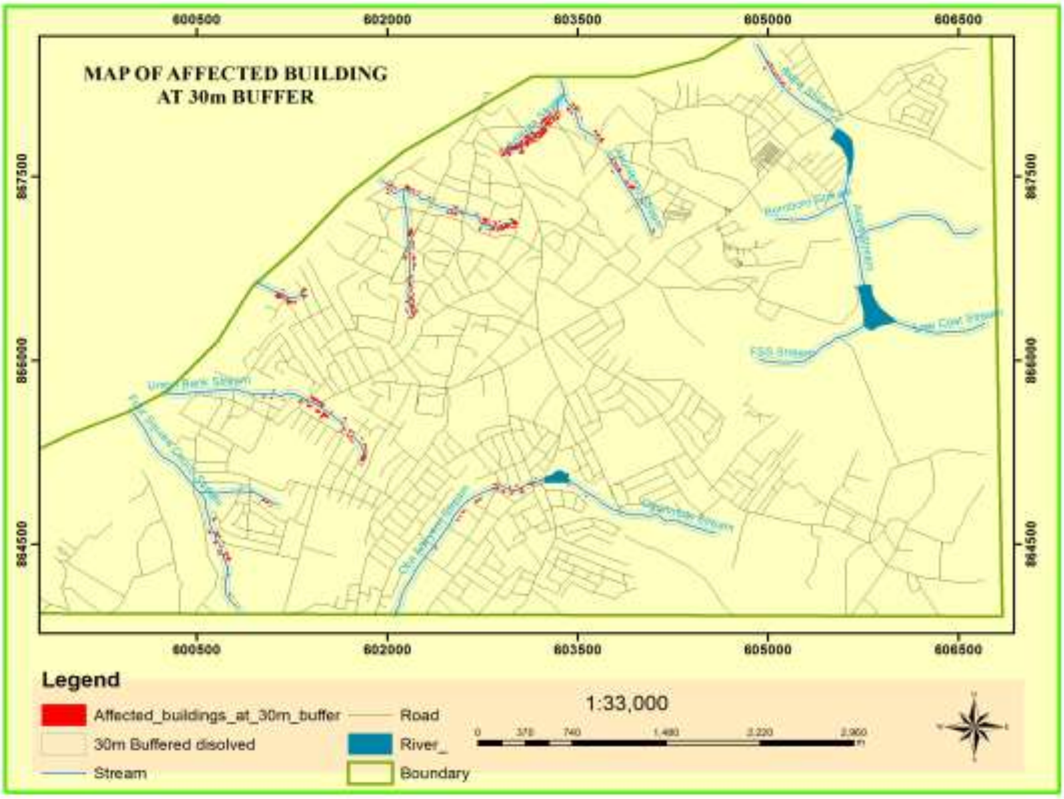

Fig. 4.3b Map of affected buildings at 30m Buffer

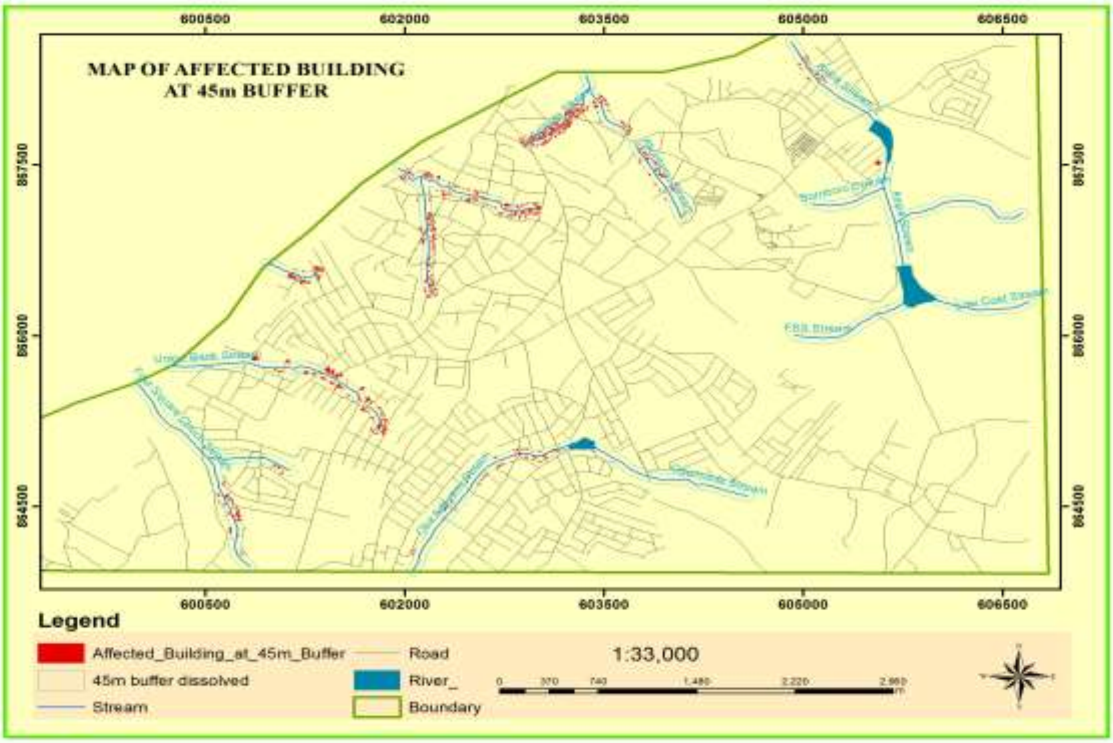

Fig. 4.4c: Map of affected buildings at 30m Buffer

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Overlays:

Interactions of SRTM converted to Grids in Suffer 10 environment and stream map were done to obtain common areas that are likely to be affected for rational decision to be made to mitigate the impact of flood occurrence within the study area. This after accomplished is then intersected with buildings to identify elements which may likely be threatened so that impact reduction steps will be taken. In this regards Erase operation was also performed to determine elements within the study area that are marginally vulnerable to flood hazards. The map below show the result of the overlay operation.

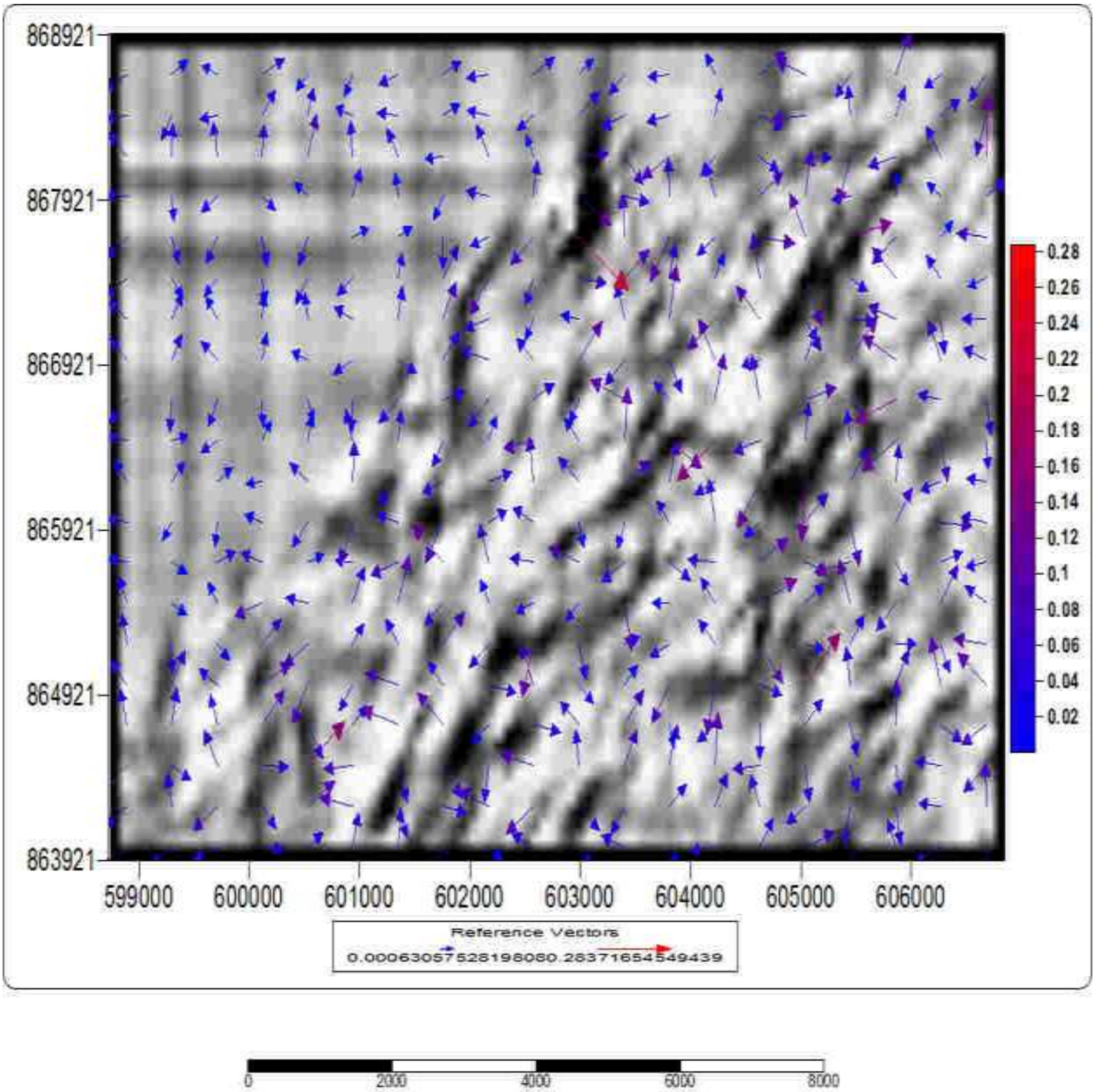

Fig 4d: Overlay of vector flow direction and SRTM (shaded relief)

Hydrologic Analysis:

Apart from the above analyses, other analysis of interest in the present study or which proves useful in flood vulnerability study are the fill/sink, flow direction and flow accumulation analysis. They are useful in identifying the natural course of a stream or the course of human impacted streams. The figures below help explain this analysis. The flow accumulation derived from the analysis performed revealed the pattern of water flow in the area. See the figure below

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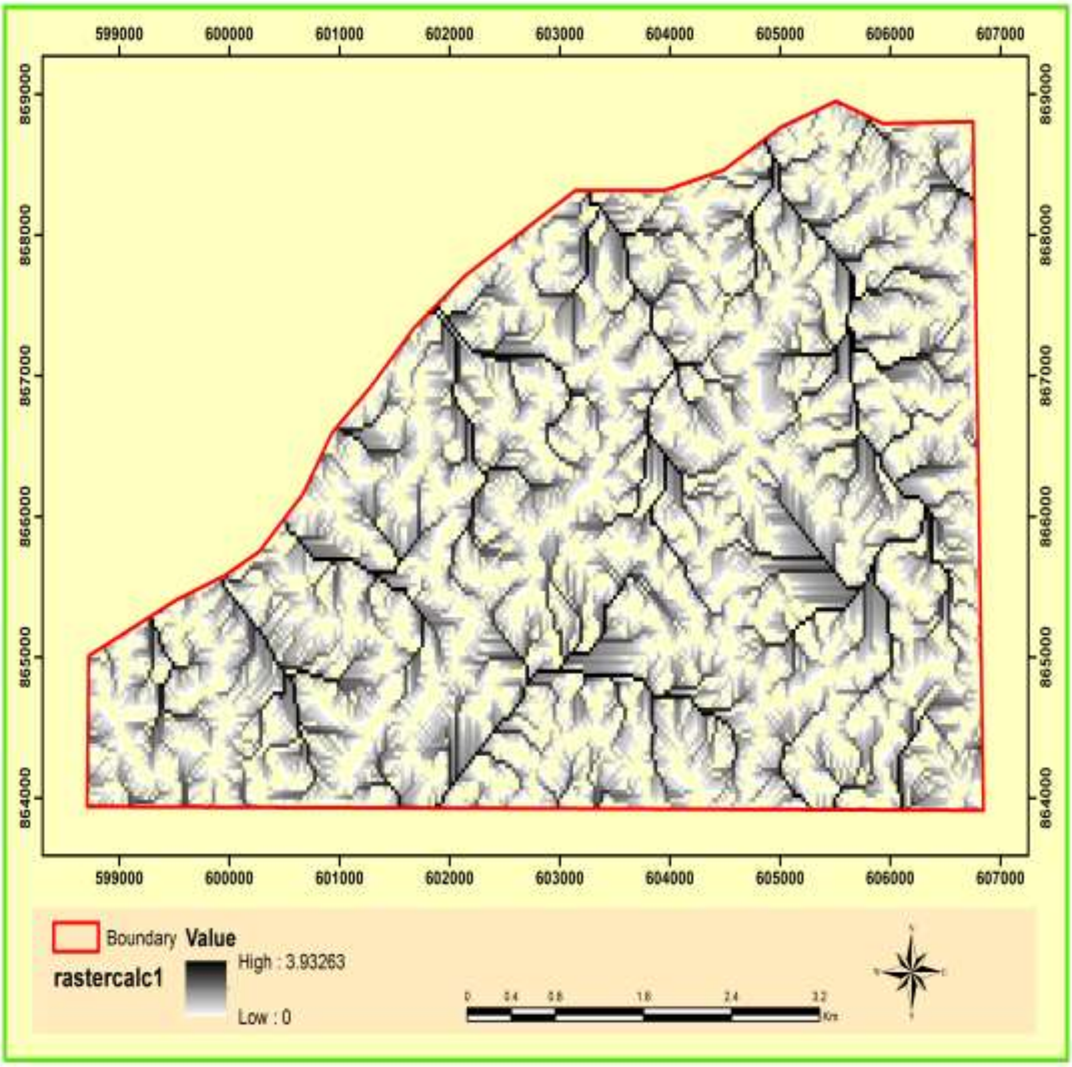

Fig. 4e: Map showing flow direction in the study area.

Flow accumulation is a flow direction raster with streams and their tributaries having tree-like appearance. It a raster records which records how many upstream cells will contribute drainage to each cell. A flow accumulation raster can be interpreted as cells having high accumulation values that generally corresponds to stream channels with cells having zero accumulation value corresponds to ridgelines. If multiplied by the cell size, the cell value equals the drainage area.

Classification:

Classification was carried out to determine the level of vulnerability and susceptibility of the various areas within the study area which led to demarcation of the area into zone of highly, moderately, marginally and non vulnerable areas to flood and related hazards. This therefore lead to generating map of the area in accordance to the level of vulnerability as identified.

Table 6: Classification of buildings according to vulnerability rate

Buildings	**Number of Buildings in each category**	**Vulnerability rate**
First Category	194	High
Second Category	287	Moderate
Third Category	347	Marginally
Fourth Category	18,723	Non Vulnerable

Analysis of Results:

Two type of analyses were carried out the proximity and intersect with various GIS operations and hydrologic analysis led to hydrologic conclusion that predict the various attribute of the surface water and its potentials with the flood water in the study area base on the hydrological investigation, data collection from satellite image data with other data like SRTM and map were used in the study.

The previously mentioned GIS operation was performed on the data collected from the study area, to predict the vulnerability of the study area flood hazards.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

Summary:

Spatial problem are problems associated with location over space that are determined by locational answer and provision of explanations to problems bordering humans in space. These problems with specific area or location are therefore identified as a spatial problem. This work was conceived to predict the vulnerability potential of different areas within the study area to flooding with a view to provide a spatial explanation. The work could therefore be used as a Spatial Decision Support System (SDSS) which provide an aid to effective decision making.

The various GIS operation performed on the entities and spatial relationship between the entities with results shows parameters to determine flood vulnerability potentials of areas within the study area which could be listed and used in cartographic models representation. Database was designed and created for the study area. Though the study use basically GIS application with spatial analysis carried out to determine the flood vulnerability potential of areas, scientific work and other computer interpretation done with empowering details and socio economic and political consideration overlooked.

Conclusion:

The studies has shown the usefulness of GIS in solving hydrologic problem and determine some naturally occurring phenomena, surface water runoff prediction, given various criteria that can be considered in order to arrive at optimum prediction and potential derivation.

This has shown the extent to which the technology can solve natural problem, provide answer to unknown, values to unseen and of great benefit to decision makers. GIS has provided precise information about buried treasure (water) in the study area, it has also proved beyond reasonable doubt that it can be used for timely information and be more cost-effective.

The problem of flooding and other naturally occurring hazard require an integrated approach for effective conclusion to be drawn, but poor technology and poor funding of studies as shown possible impediments in the application of GIS to determine the vulnerability potential of area to flooding and in developing a prototype system to solve its spatial problem.

Though GIS has been used to explore flood vulnerability, determine its potential and predict its susceptibility, further engineering work like flood gauging, sediment material studies and groundwater intrusion in to surface water sources, and construction work couple with political decision and adequate funding in producing geographic explanations to flood hazards and mitigation strategies. Outlets when added to the earlier mentioned will provide required solution to flood water contamination and disease mapping to both rural and urban area and people in the study area.

By and large, the aim of the project to determine the vulnerability potentials of different sections of the study area by applying GIS has been achieved. Maps are produced which has shown cartographic visualization of flood vulnerability of different areas within the study area.

Recommendation:

Base on the achieved result on this project as well as solutions provided for the various problem encounters, the veracity of GIS operations in providing hydrologic information and enhancing the required decision making make the system "one solution to problems approach" not only to the Hydrologist and Earth Scientists but to all. The operations are to be embraced by all and the software acquired for effective and comprehensive work and analysis hence the sustainability and continuity must not be compromise.

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Application of GIS to solve scientific problem (natural and physical) and in providing solution to spatial problem is hereby recommended to Decision Markers and stakeholders.

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