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Flood vulnerability assessment and disaster risk reduction in Kubwa, Federal Capital Territory, Nigeria

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Abstract
Disaster occurrences are on the increase all over the world and large numbers of people are constantly exposed to the risk associated with these disasters including flooding. Urban areas, especially in developing countries, are highly vulnerable with increasing threat of flood; there is therefore need for an assessment of flood vulnerability and capacity for implementing disaster risk reduction (DRR) programmes in communities. The study focuses on the use of Remote Sensing and Geographic Information System technology to propose an effective assessment of the vulnerability of Kubwa town to flooding and the capacity for implementing a DRR programme in the area. Satellite imageries for three periods: 1987, 2001 and 2006 were used for an overall assessment to produce a contemporary land use maps. Comparative analyses of the old land use map, the master plan and the derived land use map shows that there has been consistent changes in the original land use compared to the current, evidenced in the increase of areas allotted for residential purposes (20.54% to 75.6%). Buffering analysis was carried out to determine areas that fall within the floodplain. Digital Terrain Modelling (DTM) and slope analysis were used to re-classify the area into different levels of vulnerability. The analyses showed that the central part of Kubwa, which is the most populated area, is most affected by flood incidences due to soil sealing resulting to infiltration. Other features of this area are encroachment on the flood plains, clogging of the drains and lack of land use planning. The study therefore recommends the need for improved land use planning, enforcement of standards and codes, Community Education/ participation, among others.

1. Introduction

Every year, more than 200 million people worldwide are affected by disasters such as droughts, floods, cyclones, earthquakes, landslides and other natural phenomena. Global warming, environmental degradation, rapid urbanization, increased population densities and their concentration on hazard prone areas make the impact of natural disasters even worse. The consequences of these trends are especially important for Least Developing Countries (Nigeria inclusive), land locked countries and Small Island Developing States (SIDS), which are often affected disproportionately by such disasters [1].

Flood has the greatest damage potential of all natural disasters worldwide and affects the greatest number of people. On a global basis, there is evidence that the number of people affected and economic damages resulting from flooding are on the rise at an alarming rate. It has claimed many lives, displaced millions and resulted to the destruction of properties and degradation of contiguous farmlands. It is the most frequent and devastating natural disaster in the world [2].

Urban flooding is a global phenomenon and has caused devastation and economic losses. According to the Centre for Research on the Epidemiology of Disasters (CRED), flooding in 2010 affected 178 million people and amongst all natural disasters the occurrence of floods is the most frequent. In the last century based on International Strategy for Disaster Reduction (ISDR) statistical analysis, the total numbers of hydro-meteorological events was 7,486 [3].

Flood hazards are natural phenomena, but damage and losses from floods are the consequence of human action like urbanization, which aggravates flooding by restricting where flood waters can go, covering large parts of the ground with roofs, roads and pavements, obstructing sections of natural channels and building drains that ensure that water moves to rivers faster than it did under natural conditions. Many of the devastating disasters, including flood, can however, be pre-empted and averted, if relevant government departments would form synergy with the Non Governmental Organisations and other concerned stakeholders to address the risks of natural disasters through effective preparedness, forecasting, early warning, and prompt response. Flood disasters commonly lead to immediate responses by institution saddled with the responsibility, but as time passes, the memory and need for preparedness fades leaving communities unprepared the next time around. To develop safer, sustainable communities it is necessary for communities to become more knowledgeable about dealing with disasters, floods and storing their accumulated knowledge [4]. Society must therefore move from the current paradigm of post-disaster response. Plans and efforts must be undertaken to break the current event-disaster cycle. More than ever, there is the need for decision makers to adopt holistic approaches for flood disaster management [5].

A major gap in disaster reduction in Africa is weak knowledge management. There is inadequate attention to information management and communications, training and research; consequently, there are gaps in knowledge about disaster risk. The ultimate aim of Disaster Risk Reduction (DRR) is to empower people to take timely and adequate actions to protect themselves, their livelihoods and ecosystem against disasters, disaster risk reduction is a shared responsibility and partnership between the state and the people [6].

Nigeria has got her own share of flood disasters, which is evident in the recent widespread devastating flood disaster that hit the country cutting across major cities in about 31 states in the country from June to September 2012. The worst affected states are those that are at the borders of the Niger-Benue River and those around the Niger Delta area, they are, Adamawa, Taraba, Benue, Niger, Kogi, Anambra, Bayelsa, Delta, Edo, Rivers, Cross River and Akwa Ibom. This flood incident has been characterised as the most devastating since the last 40 years. The flood submerged houses, severed transportation routes throughout the affected areas. Overall, an estimated 1.3 million people were displaced and about 431 people lost their lives. In addition, over 1525 square kilometres of farmland were destroyed [7]. Although, the National Emergency Management Agency (NEMA) predicted the imminence of the flood disaster and advised the relocation of activities and residence from the floodplain to the upland, but spatial and synthesized information was not made available. Such information involves the detection of the areal extent along the Niger and Benue rivers that is at risk or vulnerable to flooding [8].

Also in 2007, the exceptionally heavy rains in Sub-Saharan Africa throughout July, August and September 2007 resulted in severe flooding, leading to loss of life and extensive displacement of families across the region. The nine most seriously affected states in Nigeria were: Lagos, Ogun, Plateau, Nasarrawa, Bauchi, Sokoto, Yobe, Borno and Kebbi. By August 2007, more than 46 people had lost their lives and more than 2,500 families had been displaced. In addition, the flood waters destroyed a number of homes, contaminated farmland and crops, and depleted livestock and other household assets. Poor drainage systems, the untimely release of water from dams and the indiscriminate building of houses on river banks all contributed to exacerbating the effects of the flooding [9].

Since its inception in 1984 when the Federal Capital Development Authority (FCDA) evolved a master plan designating Kubwa as a resettlement town, the town had been growing rapidly and this was not without the attendant problem that goes with such development. Residents for some years now have been losing houses, businesses and personal belongings to flooding that accompany some down pours in the areas. The degrees of losses are always estimated in the millions of naira. The flood most often than not, submerge houses and vehicles and sweeping debris along the channel, the personal tragedies of those who were affected are deeply heart-wrenching.

The importance of the application of geo-information technologies in flood studies cannot be over emphasized. Cinque *et. al.*,[10] contributed that the use of Geographic Information System (GIS) technology has contributed with other technology in Flood intelligence and the result is the product of a process of gathering and assessing flood related data to enable emergency managers to determine the extent of actual or likely effects of flooding on a community. Remote sensing technology produces an authentic source of information for disasters mitigation, preparedness and management as a whole. The response or action taken during and immediately following a disaster can also be enhanced by Remote Sensing. During floods, timely and detailed situation reports are required by the authorities to locate and identify the affected areas and to implement corresponding damage mitigation. It is essential that this information be accurate and timely in order to address emergency situations. Flood hazard mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily-read, rapidly-accessible charts and maps which facilitates the administrators and planners to identify areas of risk and prioritize their mitigation/ response efforts [11][12].

Over the years, many writers have made some research on Flood Vulnerability Mapping and Risk Assessment in Nigeria, using Remote Sensing and GIS techniques; it is not just enough to create maps showing the flood prone areas and how low or highly susceptible an area is to flooding, there is the need to go a step further, to reduce the risks of such places. This research therefore assesses the vulnerability of Kubwa to flooding as well as suggests ways of reducing the risk of the area to flooding by mapping out the areas as they influence the distribution of the floodwater; developing flood mitigation measures using geo-information technologies that will cater for the mapped area as well as determine an effective approach to effect disaster risk reduction (DRR) in Kubwa.

1.1. The Study Area

Kubwa is one of the strategic satellite towns of the FCT. It is located within Bwari Area Council, one of the six areas councils of the FCT. It lies between longitude $7^{0}18^{I}$ E and latitude $9^{0}11^{I}$ N of the equator. Kubwa satellite town is located on the northern fringes of the FCT along the Outer Northern Expressway. It is bounded by the Bwari-Aso hill ranges, stretching for about 4km in the North, whilst the East is bounded by Dutse Alhaji – Lower-Usuma dam road and towards the West by Jibi resettlement scheme. The area covers about 3,326.29 hectares [13]. The area is generally low, undulating and dotted with rock out crops. The heights of which, range from 406m along the river valleys to 448.8m at the highest points. Generally, the entire area slopes in a south ward direction [14]. Kubwa area records the highest temperatures which range between 37^{0}C and 30^{0}C during the dry season months. During the rainy season, the maximum temperatures range between 25.8^{0}C to 30.2 ^{0}C [15][16]. The area has a yearly and monthly mean annual rainfall of approximately 1391mm and 118mm respectively [17].

Figure 1. *Landuse map of Kubwa Settlement Source: Fola Konsult Nig. Ltd, 2004.*

The study area is traversed from the north east to south west by the Usuma River and its numerous tributaries which provide natural drainage channels from north to south throughout the area. The Usuma River, dammed upstream, provides water to Abuja City but despite this, the down flow of the River is still remarkably heavy especially during the rainy season [14]. Kubwa area has valleys that are well developed and are susceptible to flooding during periods of heavy rainfall. These areas were likely to be undevelopable because of their slope gradients and drainage characteristics [13]; but the areas referred to above, are now developed. The nature of the terrain and human activities in the study area has contributed to flash flood which is characteristics of River Usuma and most streams in the study area particularly during the rainy season causing a major environmental hazard threatening the area and this danger and threat is increasing every year.

Kubwa was designated for those displaced by the development of Phases 1 and 2 of the Federal Capital City. Over the years, Kubwa has been transformed from a resettlement town, into a modern one. In fact, the town has one common feature with the Federal Capital City; this is in the sense that it is, like the city, a planned, new town, without strong roots in the Nigerian urban tradition [16]. The rapid increase in population in Kubwa, large scale urbanization, increase in sizes of the settlements as well as expansion of farmlands and fuel wood extraction has resulted in the degradation of the physical environment. The environment has had to bear with severe deforestation among other problems. The provision of infrastructure, especially roads, which have ensured accessibility, as well as easy distribution and evacuation of farm inputs and products have also left its impact on the physical environment as there has not only been loss of vegetation, but also biodiversity. The implication of these developmental activities has been that areas intact with vegetation, including the river valleys and other water courses, have now been replaced with other structures. Consequently, the area is seasonally flooded and most times this leads to the loss of lives and properties [18].

2. Materials and Methods

2.1. Data Acquisition

Some of the materials acquired for this research includes Landsat satellite imagery for 1987, 2001 and 2006 (30m resolution) (ETM) and Spot 5 imagery for 2006 (5m resolution) were also used. Others include the Landuse Map of Kubwa (scale 1: 25000); and Height Information (Contour) which was extracted from the height information of Nigeria. It was used to create the Digital Elevation Model (DEM) of the project area using contour interpolation, after which a slope map was created of same area.

2.2. Map Preparation

(a) Image Pre-processing: The Pre-processing of satellite images prior to image classification is very essential. The goal is to achieve as much as possible the status of image normalization such that all images appear as if they were acquired from the same sensor.

(b) Geometric correction: This improves the positional accuracy of the satellite imageries. The Clarke 1880 Spheroid and Minna datum was used to define the common geo-reference system for all the images. This was to ensure that all maps and imageries fit perfectly when overlaid.

(c) Image Subset: This was done to eliminate extraneous data in the satellite image file, and also speeds up processing by making the amount of data to be processed smaller.

(d) Projection: This enables geographic datasets to use common locations for integration.

(e) Creation of shape files: Geographic features in a shape file can be represented by points, lines, or polygons (areas). For the purpose of this project, the shape files were in form of areas viz: Built up areas, drainage /rivers, floodplain, major roads and minor roads.

(f) Conversion of Landuse map: The land use map was in "DWG" format and it was converted into an ESRI shape file so that it could be used in ArcGIS environment.

(g) Digitizing: After all the procedures above, the features on the imagery were digitized based on the various shape files created.

(h) Editing of the digitized features.

(i) Ground Truthing: This is a field checking exercise that was conducted in some locations that corresponds to some sites in the study area. A hand held GARMIN III GPS receiver was used to facilitate the navigation and identification of such locations on the ground in the area. The ground truthing exercise was taken to confirm features that are still retaining the original use they were meant for.

2.3. Data Processing and Analysis

(A) Database creation: This was done using ArcCatalog, a subset of ArcGIS 9.2.

(B) Data Processing, Analysis and Manipulations: This was done using Spatial operations such as:

(i) Buffering Operations: Buffers are usually used to delineate protected zones around features or to show areas of influence.

(ii) Overlay Operations: This was done by Clipping, using the Clip tool of ArcTool box of the software. The floodplain was buffered at 30m and 50m distance. The various buffered meter was overlayed on the landsue to know the areas that would be affected.

(iii) Digital Terrain Model (DTM): The height information of the area extracted from the height information of Nigeria was used to create the Digital Elevation Model (DEM) of the project area using Spatial Analyst tool of ArcGIS.

(iv) A slope map of the area was also created same way as above.

(C) Landuse Map: The land use map was digitized using information from the Spot 5 and the database created from ground truthing.

3. Result and Discussion

3.1. Terrain of the Area

A good representation of the topography of an area is an important asset in flood forecasting, emergency action and mitigation. Digital terrain model (DTM) or digital elevation model (DEM) can be used to show this representation. Figure 3 shows the vector map of kubwa town overlaid on the contour map.

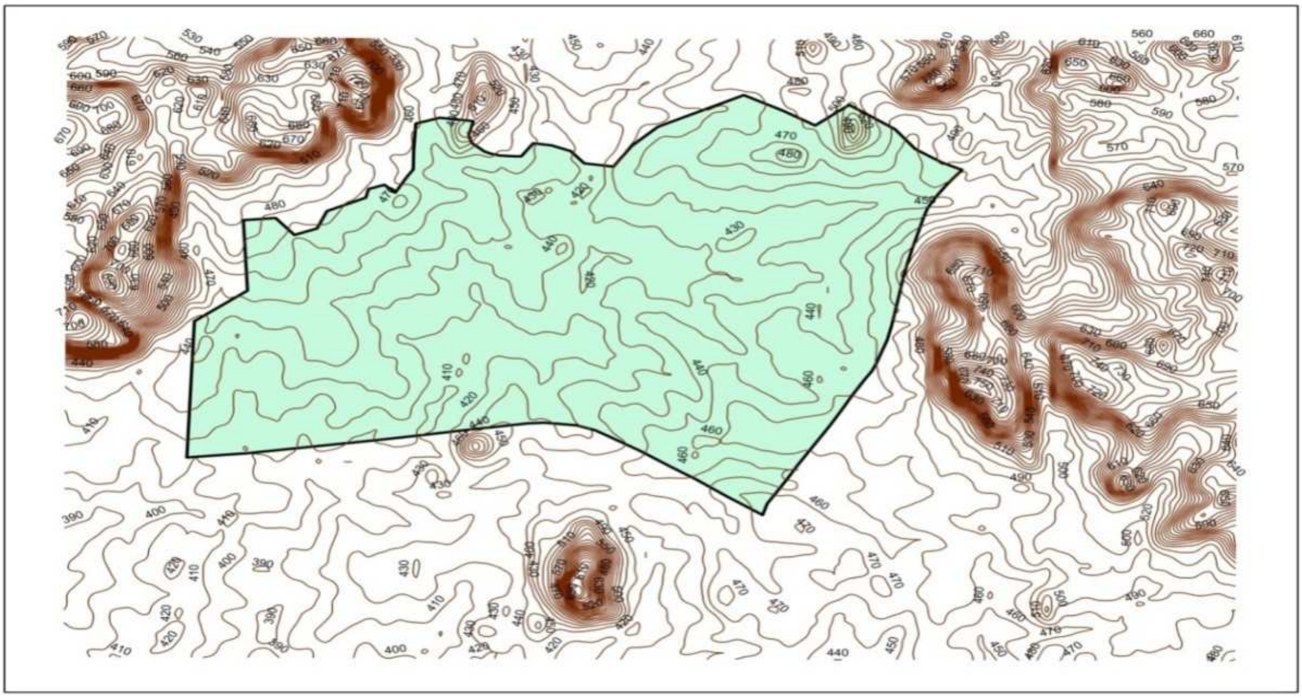

Fig. 2. *Vector map of Kubwa town overlaid on the contour map. Source: NARSDA, Abuja.*

The figure above depicts the nature of the terrain of the study area. The contour lines are mostly well spaced out but with close knitted contours bounding the area on the North West (NW) and North Eastern (NE) area of the figure. The close knitted contour lines are typical of outcrop of hills and high terrain.

Figure 4 below shows a digital elevation model (DEM) of the same study area. The DEM was enhanced with a vertical exaggeration showing in three Dimension (3D) giving a close to real life view thereby giving a better understanding of the terrain of the study area.

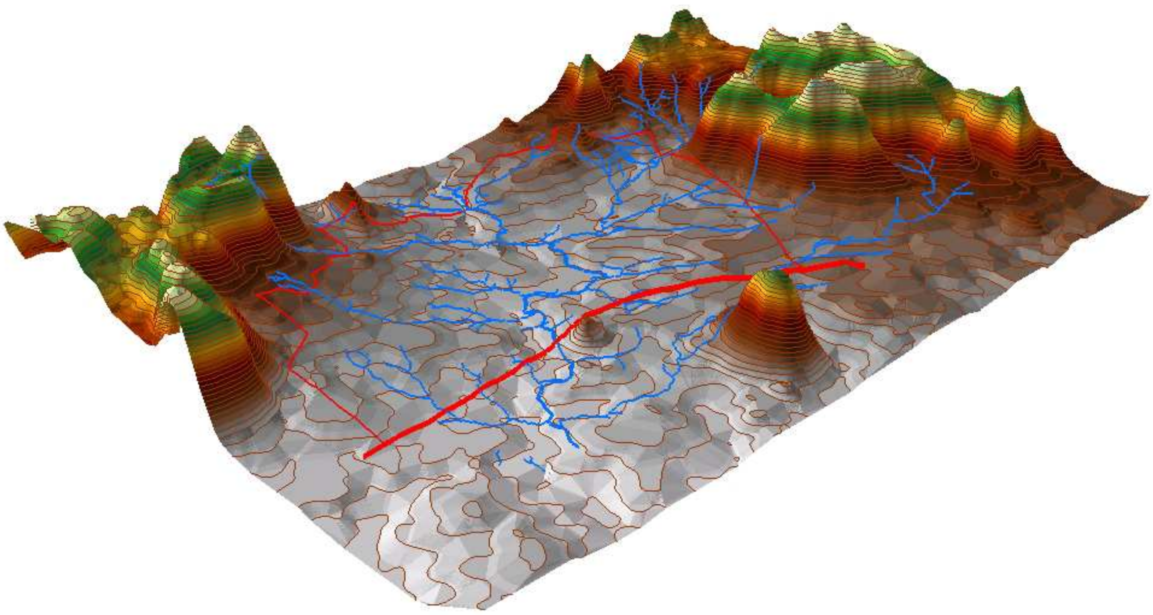

Fig. 3. *Digital Elevation Model (DEM) of Kubwa showing in 3D. Source: Field work*

From the figure above, a view of the terrain is done with the main populated areas serving as a collecting point. Water flowing from the surrounding hills, the runoff that could not be properly infiltrated into the soil due to soil sealing and the water runoff from blocked drains due to development, all finds their place of rest in the valley of the study area. The same area serves as the most populated region in Kubwa town. One would expect nothing than for the massive water coming from all these sources to find their ways. This influx of water affects animals, crops, commercial activities, and virtually all aspect of life has their share.

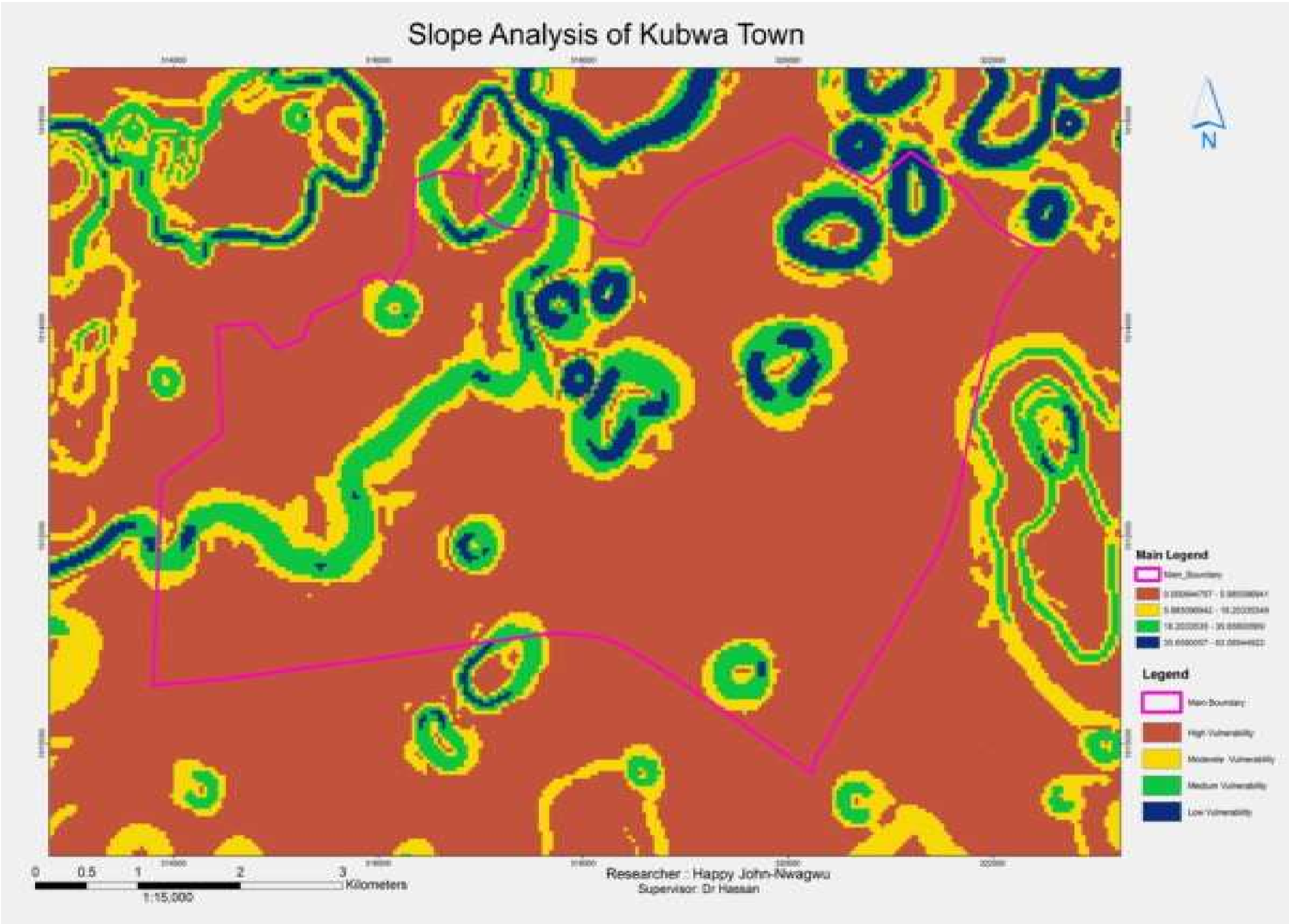

Fig. 4. *Slope Analysis of Kubwa Source: Field work*

Table 1. *Vulnerability Levels of Kubwa*

Elevation	Level of Vulnerability
0.0006-5.9851	Highly vulnerable
5.9851-18.2034	Moderate Vulnerability
18.2034-35.6580	Medium Vulnerability
35.6580-63.5854	Low vulnerability

The slope analysis of Kubwa town in figure 5 derived from the DEM also confirms the terrain of the study area. There are pockets of slight elevation just within but with the high peaks surrounding the study area. The slope analysis clearly confirms the position of Kubwa town as being in the valley surrounded by hills. This makes it easy to also serve as a collection point for water draining down the surrounding hills. From the analysis done, kubwa can easily be divided into 4 groups of elevation depicting four different levels of vulnerability as shown in Table 1.

Some of the areas in the NW, Central and NE region of Kubwa fall in the category of areas with their elevation between 0.006 and 5.98metres above mean sea level. The areas mostly hit according to the terrain model, the slope analysis and the field work done lies mainly in the central part of the town. Areas like Phase 4, Phase 3, Phase 2/1, Phase 1 and their surrounding areas suffer from flood and its reoccurrence because of the peculiarities of their terrain.

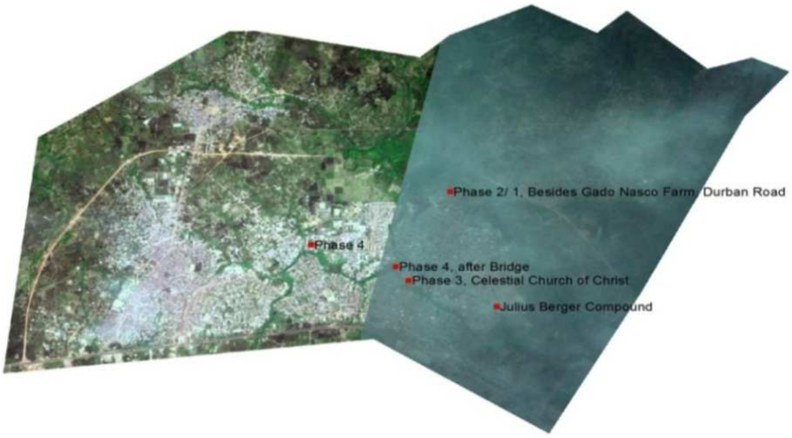

Figure 5. *Showing some location on ground.*

All the areas shown above are in the highly vulnerable region of Kubwa town. The implication of this finding to scientific community is confirmed by Alho *et. al* [19] in a related study in SW Finland where he stated that the emerging technology of the high-resolution DTM (Digital Terrain Model) and DEM (Digital Elevation Model) makes a detailed analysis of overland flow achievable, thereby being an effective tool in flood forecasting, emergency action and mitigation.

3.2. Encroachment on the Flood Plain

This is any action or development within the limits of the floodplain that could obstruct flood flows, such as fill, a bridge, or a building. This is another factor seen as contributing to the event of flooding in Kubwa. During the field work, the researcher observed that buildings were erected at the edge of the river bank, vegetation surrounding the river is cleared for illegal building purposes and some buildings are found to be on natural water ways as reported by Ishaya *et al*, [20]. Figures 7 and 8 are maps showing the buffered region surrounding the floodplain of Kubwa drainage network at 30m and 50m intervals respectively. The rivers naturally have their various floodplains, so a buffer of the dimensions stated above was used to build a block round them.

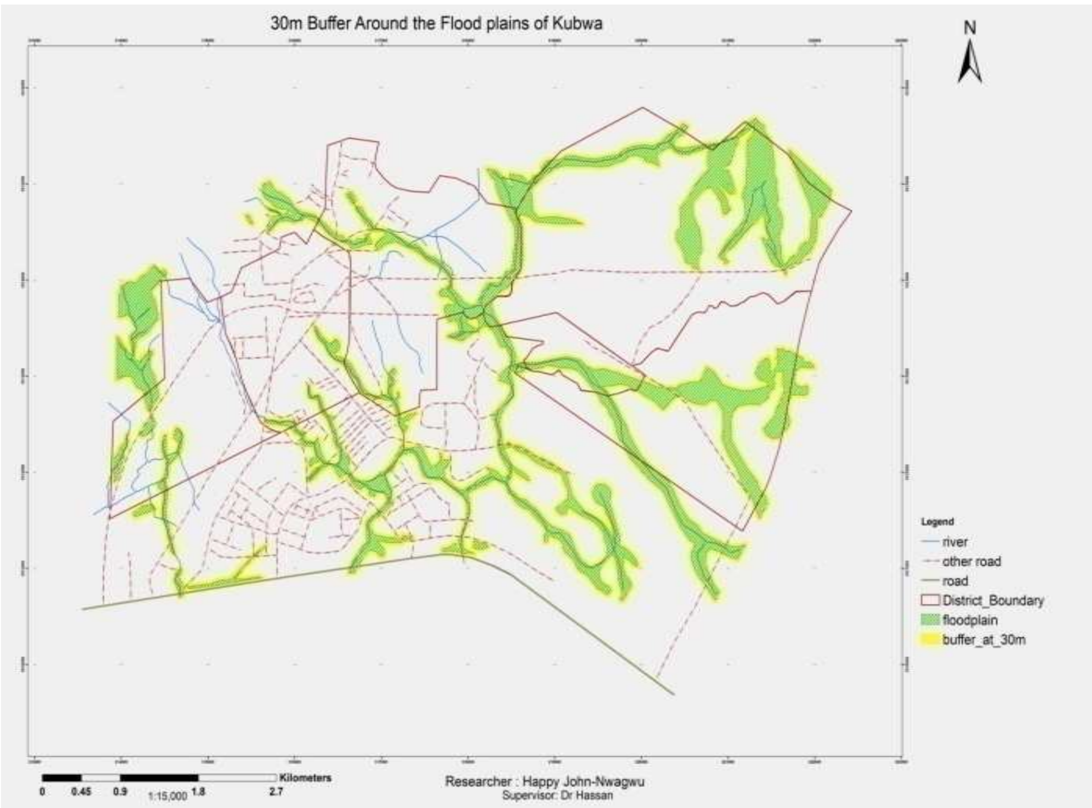

Figure 6. *30meters buffer around the floodplain*

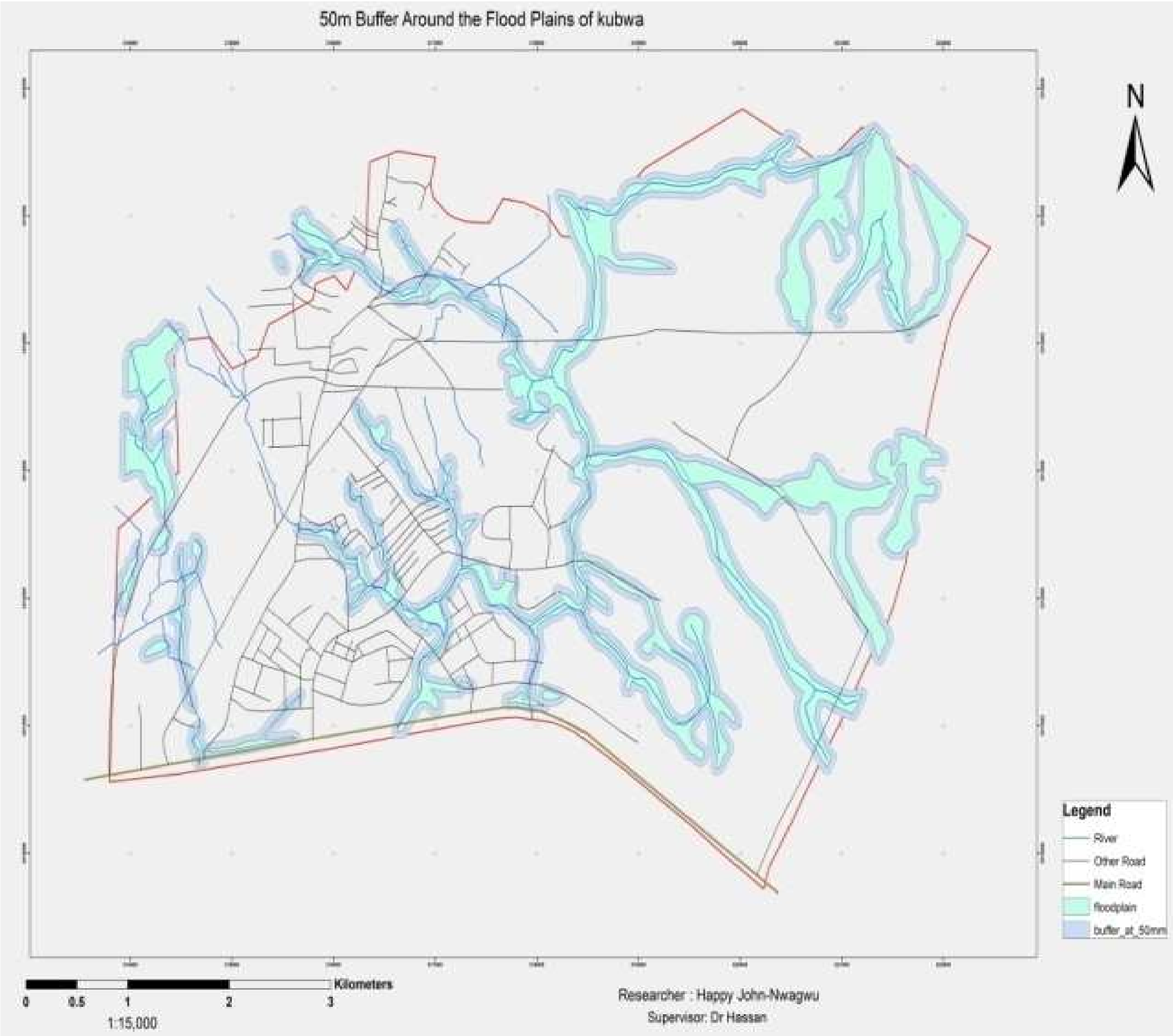

Figure 7. *50meters buffer around the floodplain*

Normally the floodway can be characterized as that part of the flood-prone area having high velocities, high potential for erosion, and high exposure to significant flow of debris. No structures, other than critical infrastructure such as bridges, are allowed in the floodway. In simple terms, the floodway is reserved for the river, not for humans. The buffer can be likened to be a prohibited area if one is staying or carrying out any activity close to a river. Any breech of this rule, should be seen as moving out of one's protective zone to danger. Areas within the 30m and 50m demarcation or buffering, falls within the floodway and floodplain of this study area, and they are the most vulnerable areas, while areas other than these are free from flood threat. Buffering helps in carrying out vulnerability analysis. This analysis considers the population and structures at risk within the flood-prone area. It analyses and also evaluates the potential costs of flooding in terms of damages to buildings, crops, roads, bridges and critical infrastructure, such as utilities. Vulnerability analyses are also valuable for making a decision on the level of flood protection.

After the buffering, the result of the 30m and 50m buffering is shown in figures 9 and 10 respectively

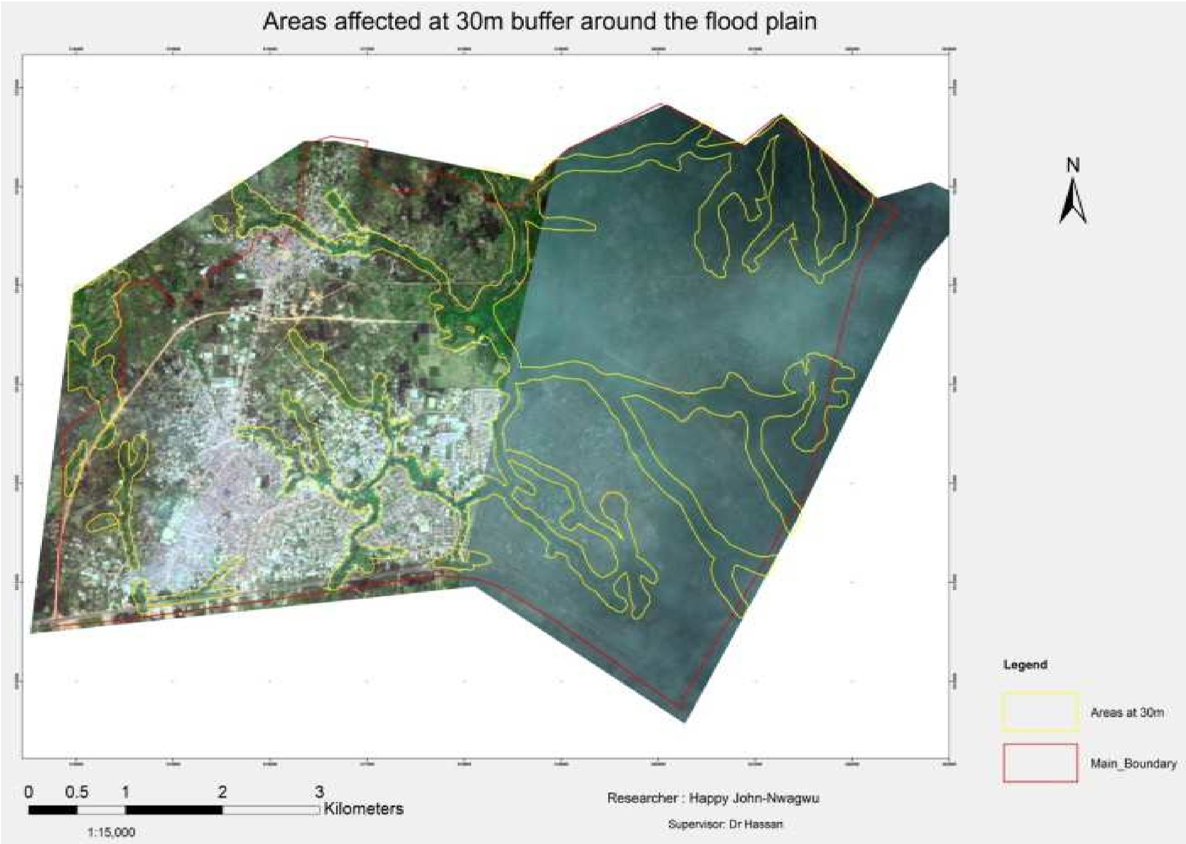

Fig. 8. *Areas affected by 30m buffer*

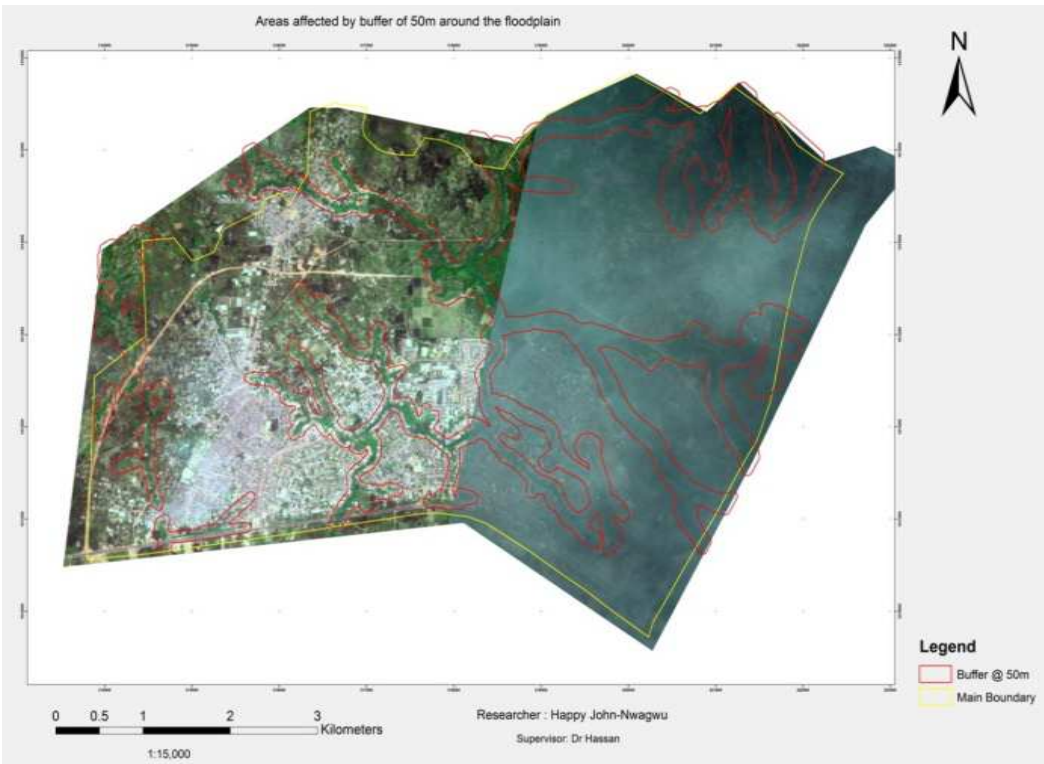

Fig. 9. *Areas affected by 50mbuffer*

The buffered zones are placed on the satellite imagery of the study area. According to the legend, the areas within the yellow and red lines in figures 9 and 10 respectively are within the floodplain and all actives within this zone are interpreted as encroached into the floodplain areas. There were lots of encroachments on ground as identified by the researcher during the Ground Truthing exercise, these includes buildings as well as fences of buildings as shown in plates 1 and 2 in Phase 3 and Phase 2/1.

Plate 1. *Building's fence in the river at phase 3*

Plate 2. *House encroaching on the river at phase 2*

Plates 2 and 3 shows buildings along Phase 3. The fence of the buildings encroached on a river and the fact that the house was marked for demolition by virtue of its location on the floodplain. These encroachments may result in a high probability of loss of human life, will likely cause future damage that could be substantial in cost or extent, including interruption of service or loss of vital transportation facilities, or will cause a notable adverse impact on natural and beneficial floodplain values. Figure 11 shows a building within the flood plain and some within the 30m buffered zone.

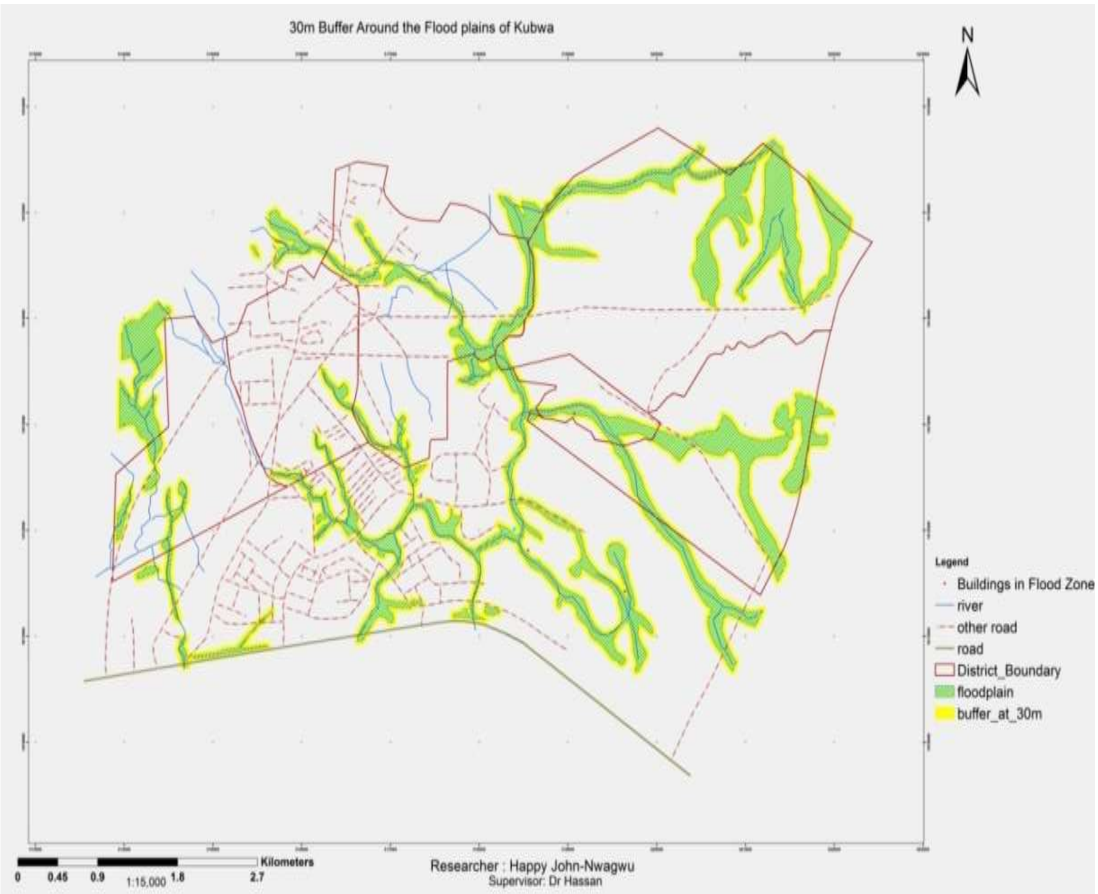

Figure 10. *Building within the flood plain*

3.3. Clogging of the Drains

Other means of disturbance of the smooth flow of floodwater is clogging of the drainage with debris. Plates 4 and 5 show refuse dumps at the edge of a bridge by Phase 3; and along a river channel at Gado Nasco in Phase 2/1 respectively. During the recent 2010 and 2012 flood, the bridge was blocked, with water submerging the surrounding areas including the road and all other available space.

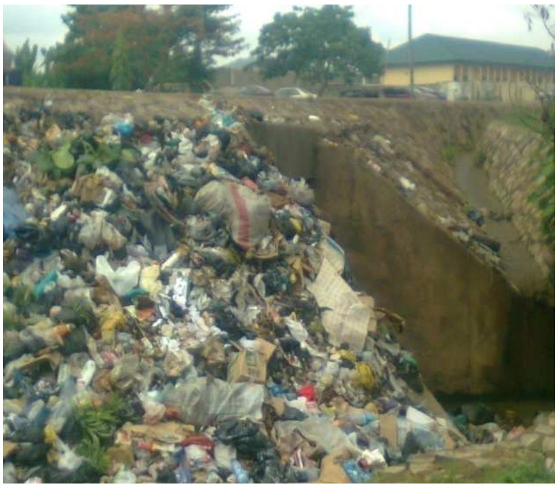

Plate 3. *Debris by the bridge edge along phase 3.*

Plate 4. *Debris along floodplain by Gado Nasko phase 2/1*

The implication of this finding as confirmed by Afeku [21] in a related study, is that massive expansion in the built-up area of Accra due to government developmental program, the impact of the increased impervious surface due to urban growth, poor land tenure and land delivery system, poor garbage collection and disposal, have been identified as contributors to flooding in Accra.

3.4. Mapping Critical Zones and Mitigation Method Using Geo-Information

Mapping defines the area at risk and should be the basis for all flood damage reduction programmes and subsequent actions. To effectively carry out the mapping of the areas that are within the critical zones, the buffering along the floodplain using a 30 meter buffer distance and the ideal distance of 50m is used as shown in figure 7 and 8 respectively. The essence of such analysis is to show at a glance, features, items, properties that are at risk and also an estimation of the life at risk can also be deduced from this. Figures 9 and 10 are the result of the buffered zone overlaid on the Spot 5 imagery of the area, and the areas that fall within the buffered zone are seen and they are the critical areas. Maps become the common element in terms of identification of flood-prone areas, perhaps their greatest value is as an educational and communications tool and they should be readily available to the public as well as to emergency response agencies at all levels of government.

From the field work, about 75% of the areas occupied presently as residential area is affected by the 30m buffer on the floodplain as shown in Table 2. This shows the potential rate of risk and consequent loss of lives and damages to property. With all the convincing results, wise decision should be made for a change of attitude.

Table 2. *Areas Affected by 30m Buffer*

SN	Type of Landuse	Percentage
1	Public utilities	9
2	Commercial activities	5
3	Residential use	75
4	Open space, Agricultural areas	11
	TOTAL	100

4. Conclusion

With the results obtained from this research, it can be concluded that areas lying in the central part of the town and mostly highly populated, are the most affected by flood; the flood vulnerability in the town decreases towards the upper section of the town; development level in the study area is changing some land uses affecting the infiltration level of the area, thereby leading to large runoff after even slight rainfall; lack of landuse planning, population growth and the old nature of the drainage channels affects the vulnerable nature of the area; encroachment on the floodplain is done without caution and recklessly to maximize the use of land; and the clogging of the drains in the area also contribute to the incident of flood problem in Kubwa. There is therefore the need for improved land use planning, enforcement of standards and codes, Community Education/ participation, improved functionality of the National Emergency Management Agency (NEMA), inclusion of DRR in school curriculum; development of a GIS data base for the town and the country as a whole as well as the need for flood proofing of new and existing structures.

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