Land Use and Land Cover Change Analysis along River Kaduna Floodplain Using Geospatial Techniques

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ABSTRACT

In recent years, incidence of flooding have become a recurring phenomenon in River Kaduna; several instances include the year 2003, 2009, 2010 and most recently in September 2012. Although these occurrences may be attributable to climate change and extreme weather conditions, however, human activities along the floodplain have only gone further to increase the devastation on human lives and property in addition to an alteration of the ecological and environmental equilibrium. This study is aimed at understanding the problem and suggesting long term solutions by looking at human conversion and modification of the floodplain area over a defined period and as shown by changes in land use and land cover observed from three (3) satellite images of the study area. Using Remote sensing and Geographical Information System techniques a temporal land use land cover analysis was conducted in order to observe the pattern of change. Visual interpretation methods and manual on-screen digitizing were used to map land use and land cover into six classes. The result of the analysis of the imageries shows a considerable change in the pattern of land use land cover classes among the three (3) time points. The trend of change indicates a progressive conversion of natural vegetation areas into farmlands and finally into built up lands. . It was concluded that the floodplain areas have undergone considerable changes due to human activities with dire consequences. The research finally recommends relocation, resettlement and effective floodplain management as against dredging and relief, as long term solutions to ensure environmental sustainability and forestall recurring damages due to floods.

KEYWORDS: *Land use; land cover change; floodplain; flood; river Kaduna; remote sensing; Geographic Information System*

INTRODUCTION

Floods are natural processes where rising inland or tidal waters inundate dry land. Over geological time frame, the erosional and depositional processes that occur during floods create floodplains. Floodplains are valuable natural resource areas, which play a major role in ecological function of rivers and coastal ecosystems. For example, they provide a storage area for flood waters, which reduces downstream erosional forces and improves downstream water quality by removing pollutants from the water. In addition, floodplains allow infiltration and the recharge of ground water aquifers. They also provide critical habitat necessary for the survival of many invertebrate, fish and wild life species (Bolton and Shellberg, 2001).

In developed areas, floodplains are a natural extension of streams, rivers, lakes and wetlands that create them. Although flooding should not be seen as an entirely destructive natural phenomenon, historically, the Nile river floods in Egypt has since ancient times to the present served as an economic life blood of that region through irrigation agriculture. However, it is only when human development encroaches on a floodplain that flood damages are induced and humans become concerned about controlling the flooding or questioning why development has been allowed within the floodplain (Mark *et al*, 2001).

To successfully protect the environmental functions of floodplains, minimize or forestall disastrous flood damages and provide land use planners, emergency management agencies and developers with a suitable basis for making decisions, it is necessary to acquire timely and reliable information about flood prone areas.

Remote sensing, by virtue of its data transmission capabilities, can provide comprehensive, synoptic, multi-temporal coverage of large areas in real time and at frequent intervals, which are valuable tools for continuous monitoring of atmospheric as well as surface parameters related to floods (Jensen, 1996)

This study explored the vast capabilities of remote sensing and GIS in analyzing land use and land cover changes in the floodplain of River Kaduna within the metropolis.

THE RESEARCH PROBLEM

Along River Kaduna floodplain, the current extent of encroachment of infrastructure, homes, businesses, utilities and industries and the degree to which productive agricultural land is in close proximity to the river are significant. The floodplain continues to experience development pressures at such an alarming rate. This is not however surprising considering the fact that in recent years, the metropolis have experienced a population explosion and urban expansion partly as a result of the city being previously the capital of the northern region and presently the capital of Kaduna state (DFID, 2003)

The close proximity of the city to Abuja, the federal capital of Nigeria, rather than reduce this urban growth, increases the demand for space partly due to the high cost of living in Abuja. There is thus a high demand for land. Consequently the available spaces are so overstretched that areas which were previously considered dangerous and which are very close to the floodplain and in some instances even within the river corridors and floodplain are being used for development (DFID, 2003)The situation is particularly disturbing around areas such as Ungwar Rimi around low cost, Malali around Kaduna water works, Rafin Guza in Kawo, Kabala and Abubakar Kigo road new extension The presence of government agencies such as

Kaduna State Urban Planning and Development Authority (KASUPDA) which are saddled with the responsibility of ensuring that building codes and regulations are strictly adhered to, do not help matters. Observations have shown that developers are building structures dangerously close to the floodplain all of which increases the severity of hazards and damage to lives and property when the River overflows its banks during floods.

The overall result is the series of flood cases and damages which occur at the peak of the rainy season. For instance, devastating floods have occurred in recent years with serious effects which affect especially those investments and structures in close proximity to the floodplain.

Several examples and cases abound, a few of which include; the 9th of September 2003 flood, as reported by the United Nations (UN) Humanitarian Affairs division - At least 80,000 people living in and around the northern Nigerian city of Kaduna have been displaced by flooding following torrential rains on a Sunday that forced the Kaduna River to burst its banks. Property worth several hundred thousand dollars was destroyed by the worst floods ever to hit the town, officials said. The most affected districts included Barnawa, Kabala, Nassarawa and Tirkania. There was however no reports of deaths. Many homesteads were washed away. Several plots of farmland along the river bank were also submerged. It was assumed to be the worst flood in the last 20 years (IRIN, 2014). In September of 2009, another devastating flood disaster reoccurred, submerging several areas within the metropolis including Kigo road new extension, Nasarawa, Kabala Doki, and Rafin Guza in Kawo (IRIN, 2014).

In all these situations the government had always been up and doing in providing succor to the affected victims through the efforts of Agencies such as National Emergency Management Agency (NEMA) and their state counterpart. It is, however, instructive to state that those efforts are curative and not preventive.

In advanced countries such as the United States of America, the Federal Emergency Management Agency (FEMA) has a standard framework on floodplain protection and restoration. They also provide flood insurance through in-depth Studies on flood hazards, flood inundation mapping, floodplain zoning, flood risk and vulnerability studies. Updates are also made regularly to go with changing conditions and time (flood plains are dynamic systems). Sadly, in Nigeria such studies are rarely done by the relevant government authorities. Previous studies by Ndabula (2006), focused on the analysis of land use land cover change using five quantitative indices in the whole metropolitan area, while David *et. al.* (2008) also carried out a Flood Inundation Hazard Modeling of the river Kaduna, both studies though very promising, have not paid much attention to the floodplain area. There is however the need to improve our understanding of the problem through comprehensive studies and regular updates, knowledge about land use and land cover changes in the floodplain area will help in understanding the dynamics of changes and why there is an increase in flood damages due to increased exposure and vulnerabilities caused by encroachment of human uses into the floodplain. Since total flood prevention is not feasible (Green *et. al*. 2000), the outcome of this study is hoped to bridge existing gaps and to serve as an aid to mitigate future flood disasters along river Kaduna floodplain.

AIM AND OBJECTIVES

The aim of this study is to carry out a temporal land use and land cover change analysis along River Kaduna floodplain. The aim was achieved through the following objectives:

1. To determine the boundary of the floodplain of river Kaduna within the metropolis.
2. To map and characterize the major land use and land cover categories along the floodplain.
3. To generate statistics of the changes that occurred in the area using remotely sensed images of 2001, 2005 and 2009.
4. To identify problems arising from observed changes in land use and land cover and to make sustainable recommendations.

THE STUDY AREA

LOCATION AND EXTENT

The Study Area lies within the Kaduna metropolis between latitudes

10^{0}26‟30”N and 10^{0}35‟30”N and longitudes 7^{0}22‟30”E and 7^{0}29‟30”E. Kaduna River is a river in north central Nigeria, a long tributary of the Niger River. The river is 550 km (340 mi) long. From its source along the western margin of the Jos Plateau, the river flows northwest across the Kaduna plains. Just before it reaches the city of Kaduna, it turns to the southwest, cutting several gorges through rugged terrain between Kaduna and Zungeru. Finally, the river flows south through the broad, level Niger valley, and enters the Niger River opposite Pategi. Major tributaries joining River Kaduna along its course include the Mariga, the Tubo, the Sarkin, the Pawa,and the Galma (Encarta encyclopedia, 2009).

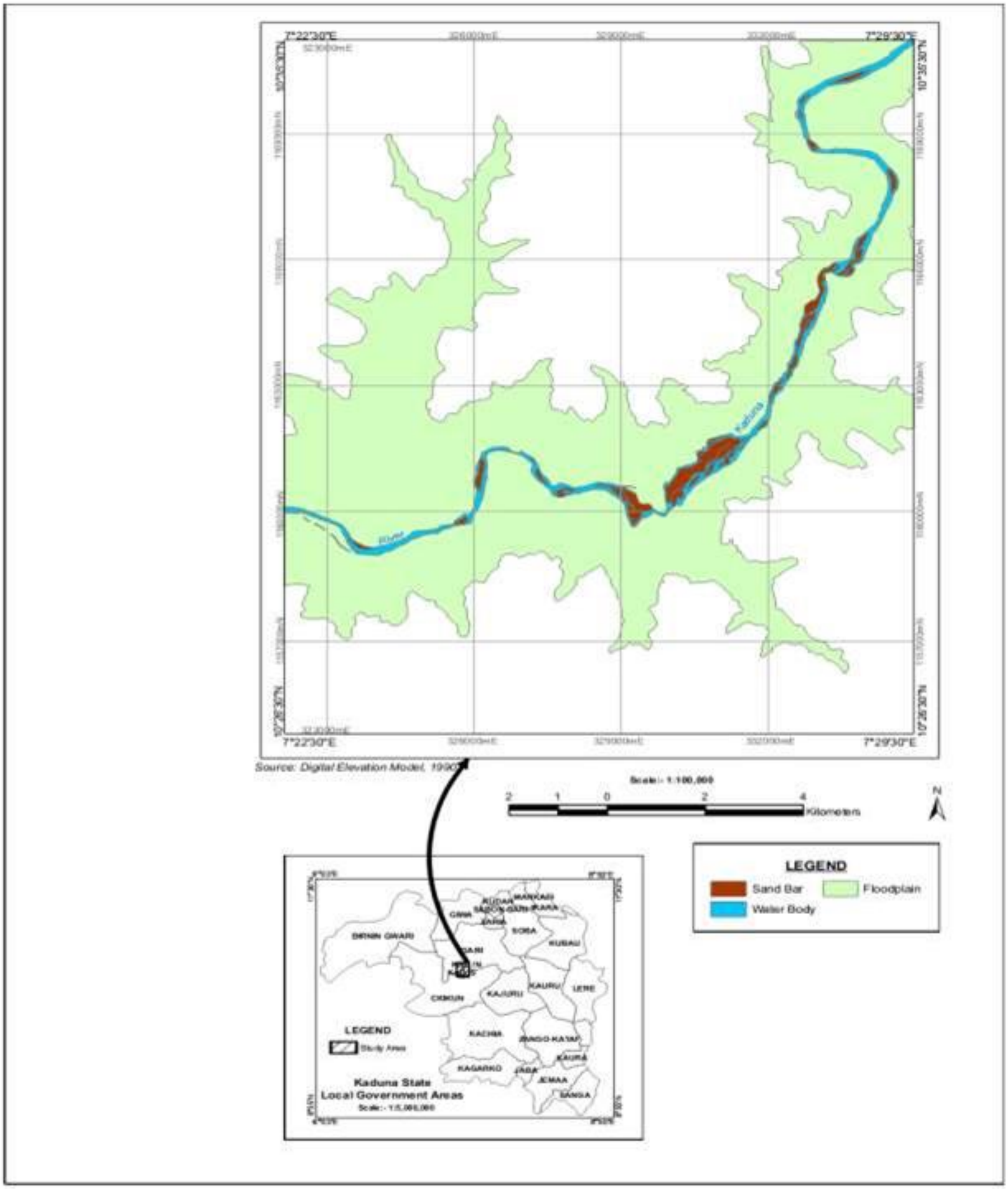


Figure 1: The Study Area

Figure 1.1: The Study Area

Source: Digital Elevation Model, 1990

MATERIALS AND METHODS

DATA TYPES AND DATA SOURCES

The high resolution satellite imageries were used for the study and include IKONOS and QUICKBIRD imagery for the three (3) time periods. The imageries were acquired from Dynamic Digital Technologies and are considered appropriate for this study because of their high resolution which clearly show details that aided the visual interpretation and classification of land use land cover for the study. The *Quick bird* is an excellent source of environmental data useful for the analysis of changes in land use, agriculture, environmental studies, oil and gas exploration/production, and engineering construction (Digital globe, 2004). The imageries have the following characteristics:

IKONOS: With an acquisition date of August 2001; it has a spatial resolution of 1m, spectral resolution of 450-900nm and temporal resolution of < 3 days revisit time (Digital globe, 2004)

QUICKBIRD: With an acquisition dates of June 2005 & March 2009; it has a spatial resolution of 0.6m, Spectral resolution range of 445-900nm and temporal resolution of approximately 3.5 days revisit time (Digital globe, 2004).

Other Data included:

- A Topographic map of Kaduna metropolis, sheet 32 scale; 1:250, 000

MATERIALS AND INSTRUMENTS

The materials and instruments used included**;** a windows Vista 32-bits operating system, a HP Desk jet 1500 series printer, Garmin 76CSX GPS hand held receiver, CD – ROM and Flash Drive.

Other Software used included; Arc GIS version 9.3, ERDAS imaging version 9.1, Google Earth version 5.3 and a Geographic Calculator (Geo Cal)

METHODS

In order to achieve the stated aim and objectives, the visual interpretation methods and on-screen digitization techniques are used for; determination of the boundary of the floodplain area, mapping and characterization of land use land cover classes and generation of areal statistics.

Preliminary classification

A land use land cover classification was done based on the available data source or images observed. The Anderson *et al.* (1976) classification scheme was used as a guide in grouping the features on the images into six (6) general or major classes. These included; bare surface/rock outcrop, Built up land, farmlands, vegetal cover, water body and wetlands. Each of these classes was further defined and described.

Pre-field interpretation

The visual interpretation technique was used as it is the most intuitive way to extract information from remote sensing images based on human ability to relate colors and patterns in an image to real world features. Thus the usual interpretation elements such as; shape, size, pattern, texture, tone and association as well as the familiar previous personal local knowledge of the area under study was used by the interpreter to extract relevant information from the image and in identifying the features and their locations. Features that were unclear were marked for field verification.

The visual interpretation technique was considered appropriate for this study because dominant or major land use/ land cover categories are being considered for the study. According to Jensen (1996), the method is accompanied in the same fashion as photo-interpretation, where 2 images (or photographs) are registered to a common base map and visually compared to manually identify changes based on interpretation elements such as shape, size, pattern, texture, shadow, in other words, implementing on- screen digitizing of changed areas using visual interpretation based on images of different dates. The method is often considered the most feasible change detection method especially when other techniques fail to accurately identify changes (Jensen, 1996). Its main strength lies in human experience and knowledge which are useful during visual interpretation and the analyst uses interpretation elements to make a decision on land use/ land cover change. 2 or 3 image dates can be analyzed at one time (Jensen, 1996)

The methodology flow chart in fig.2.1 is in a nutshell, a chart depicting, in sequence, the procedures followed in conducting the temporal change analysis which is the main objective of the study. Starting from acquiring the images, import into system software, measurement of floodplain area boundary, pre-field/ post-field classification of images, on-screen digitization, ground truth to verify doubtful classes of features on ground, areal calculation, mapping of uses into six classes and finally, the temporal analysis in order to identify the pattern and trend of changes among the 3 periods studied.

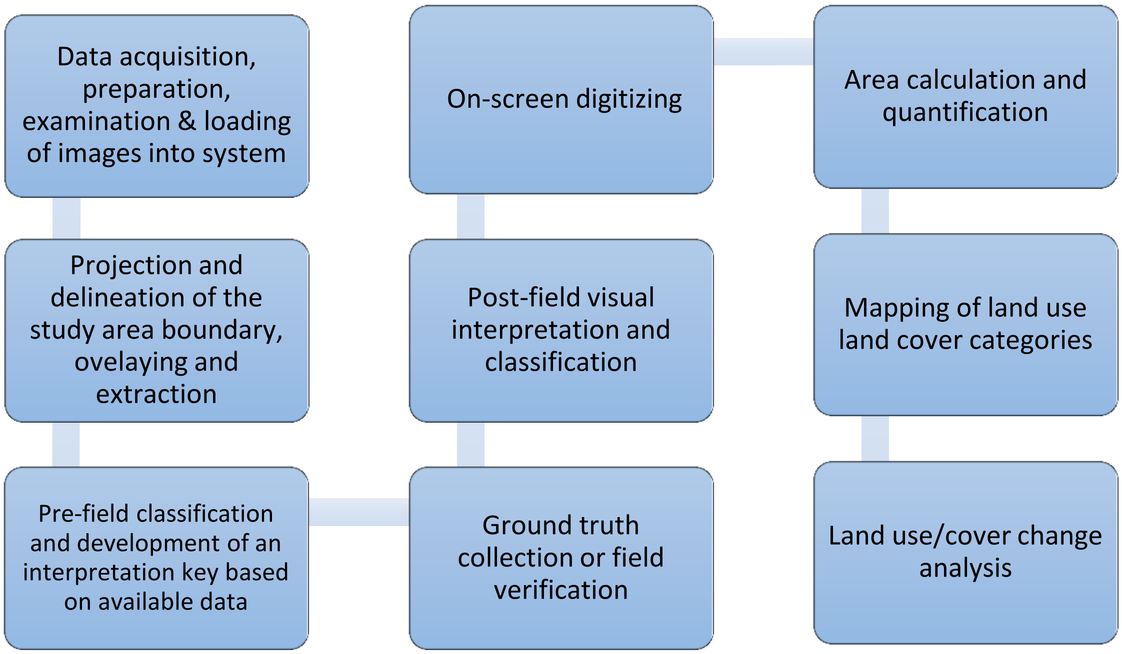


FIG 2.1: Methodology flow chart for temporal land use/cover change analysis

(Source: modified from Chaudhary et al. 2008)

Field Verification

During pre-field interpretation of the 3 data sets (2001, 2005 and 2009 image) after careful examination by the interpreter it was observed that 2 features were confusing and unclear to the interpreter and as such their actual use could not be presumed. This necessitated a ground truth or field verification so as to resolve these doubtful cases. This verification was done using the most recent image of 2009. The Garmin 76CSX hand held GPS receiver was used for the survey to take two points on the ground, the area which appears to be like a farmland because of its geometrical shape was observed on the ground to be the main cemetery at Tudun Wada. Thus 2 GPS point readings were taken at the cemetery; Point 1: 327157 (easting) 1161665 (northing) and Point 2: 327203 (easting) 1162351 (northing). The cemetery was thus included as a bare surface in the classification.

Another doubtful feature was around Ungwan Muazu in the western part of the metropolis. The GPS was also used to take readings at Point 3: 322643 (easting) 1163018 (northing) and Point 4: 323505 (easting) 1162175 (northing). The feature was also observed to be a bare surface and included in the classification.

- The Three satellite imageries of the metropolis showing river Kaduna and the floodplain area were used both for analyzing land use/cover changes and for the determination of floodplain boundary area using remote sensing and GIS techniques.

Extraction of the floodplain boundary

In order to determine the boundary of the river Kaduna floodplain within the metropolitan area, (see fig. 1.1), a topographic map of Kaduna metropolis sheet 32 of a scale of 1: 250,000 was used to digitize contours which indicated areas liable to flooding, these are used as source of spot heights or Z-values. This was used to generate a digital elevation model (DEM) using Arc GIS 9.3 software. The DEM was then converted to a contour map and used to extract the boundaries of the river Kaduna floodplain. This was achieved by on-screen digitization to obtain the floodplain area.

Geo-referencing and post processing

The images acquired were already geo-referenced thus there was no need for geo- referencing. However, post processing was conducted which helped in data manipulation and included; Sub-setting, which was done in order to extract the study area out of the original imageries. This also made it possible for easy manipulation of images, saving of computer space and making image ready for the analysis. This was carried out using Earth Resource Data Acquisition System (ERDAS) imaging software version 9.1

IMAGERIES USED FOR THE STUDY

The plates numbered 3.1, 3.2 and 3.3 are the three imageries of the Kaduna metropolis showing the river Kaduna floodplain area captured at different periods and sourced from Dynamic Digital Technologies. Plate 3.1 is an Ikonos 2001 imagery, it has a spatial resolution of 1m thus it shows less detail when compared with the other two. The image was acquired in 2001, thus the meandering river appears greenish and larger possibly due to the peak of the rainy season and increase in discharge. Plate 3.2 and 3.3 are Quick bird imageries of June 2005 and March 2009 respectively. Both have 0.6 m resolution thus showing more detail. In the 2005 image, the river and features appear clearer when compared with the Ikonos image, However, the 2009 image appears sharper with the river looking darker, possibly because of the extreme dry season period around March and less discharge and less suspensions in the channel. The imageries were zoomed to the nearest detail during visual interpretation to aid visual analysis.

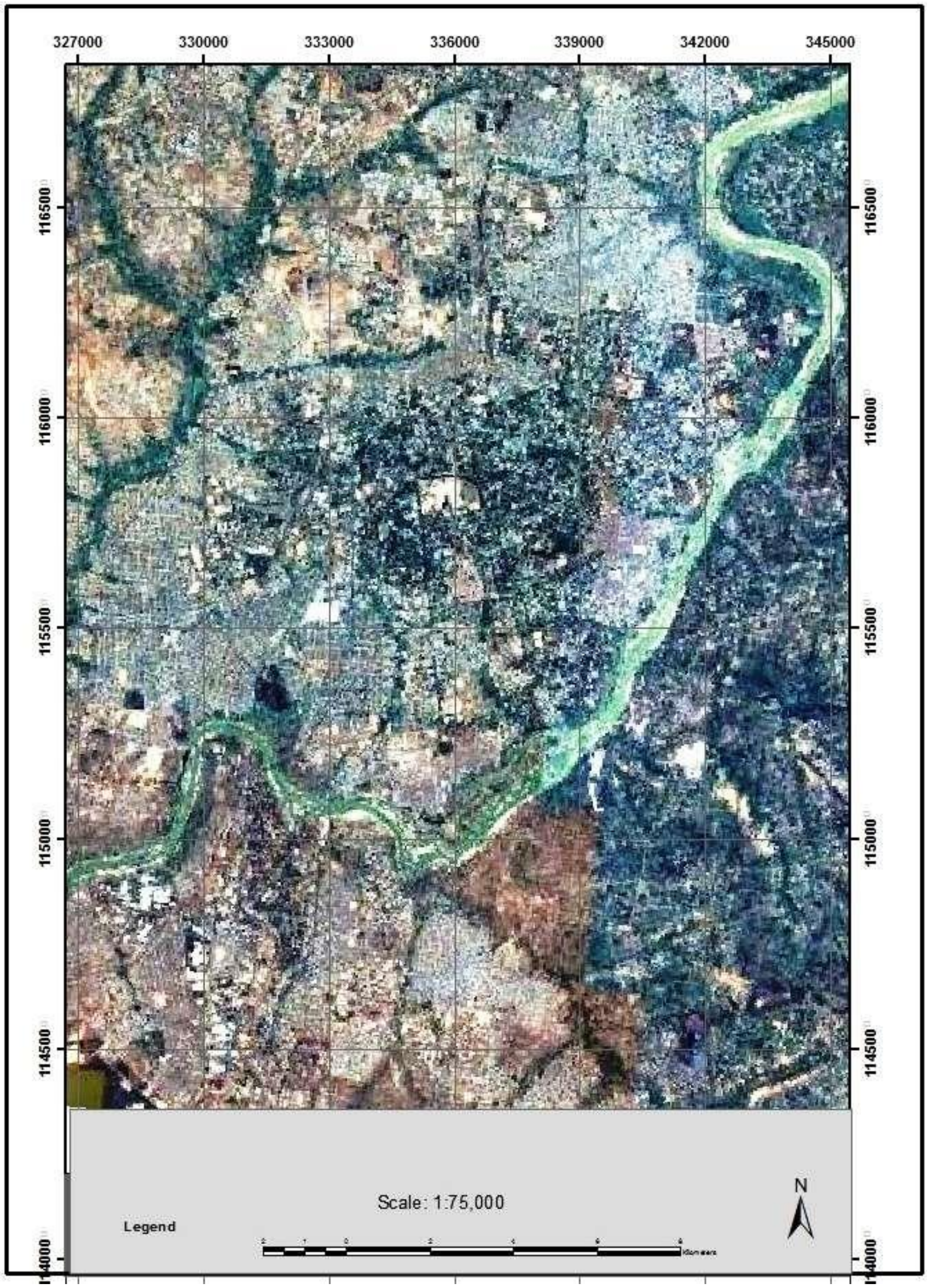


Plate 3.1: I k o n o s imagery of Kaduna metropolis in 2001

Source: Dynamic Digital Technology, 2012

Plate II: Quickbird Imagery, 2005

Plate 3.2: Quick bird imagery of Kaduna metropolis in 2005

Source: Dynamic Digital Technology, 2012

Plate III: Quickbird Imagery, 2009

Plate 3.3: Quick bird imagery of Kaduna metropolis in 2009

Source: Dynamic Digital Technology, 2012

RESULTS:

The result of the Visual Interpretation, Manual on-screen digitization and Mapping of the various Land use and Land Cover categories along the flood plain area of River Kaduna is indicated in the three 3 thematic maps in figure 4.2, 4.3, and 4.4 which show a considerable change. From the classification adopted, six (6) major Land use Land cover classes were mapped. The total area covered by the study is calculated to be 8124.9 hectares. A summary of the area statistics of the different Land use/cover types for the 3 consecutive years calculated from data input is shown in Table 4.1

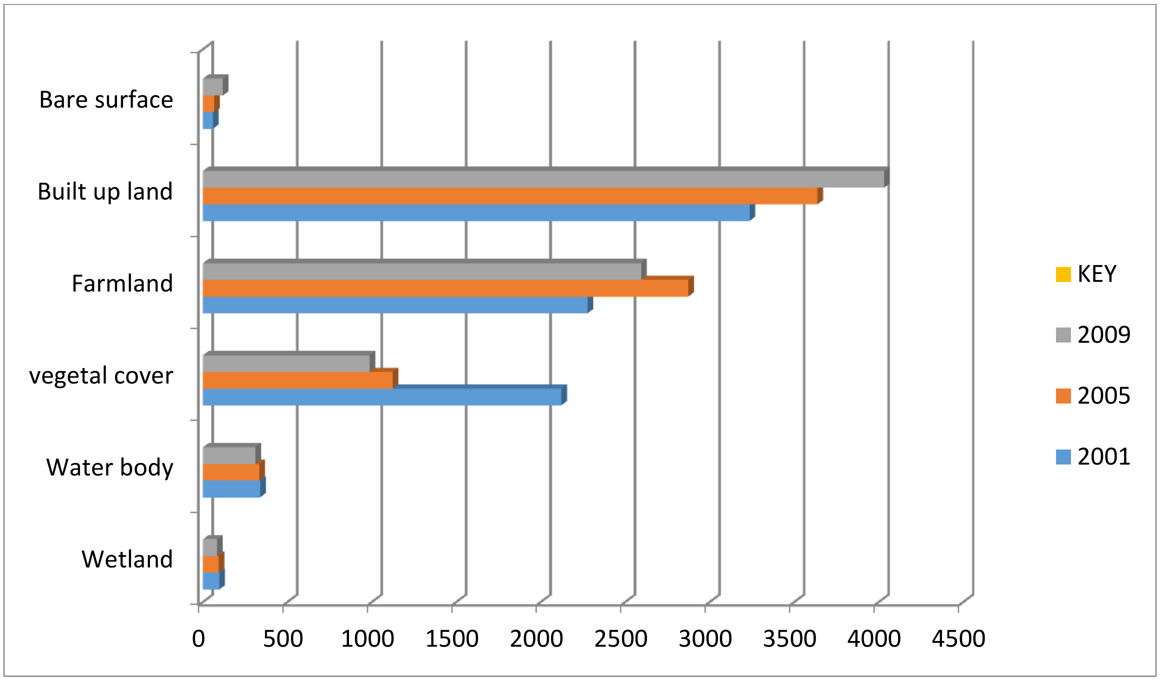
TABLE 4.1: SIZE OF MAJOR LAND USE/COVER TYPES OF THE FLOODPLAIN AREA IN 2001, 2005 AND 2009

Land use land cover category	2001 (August)		2005(June)		2009 (March)	
	Area (hectares)		Area (hectares)		Area (hectares)	
Bare Surface/Rock Outcrop	58.10		67.40		119.00	
Built-up land	3234.40		3637		4032.66	
Farmland	2276.20		2873.2		2592.80	
Vegetal Cover	2121.05		1122.30		985.40	
Water Body	338.05		332.30		310.40	
Wetlands	97.10		92.10		84.66	
TOTAL	**8124.9**		**8124.9**		**8124.9**	

Source: Author's field work, 2012

The results of the above described classes are graphically illustrated in the

Bar- chart on figure 4.1



Source: Authors field work, 2012

***FIG 4.1**: Multiple Bar Chart showing areas in hectares covered by land use, land cover categories among the 3 time periods. Note: Y axis = unit in hectares*

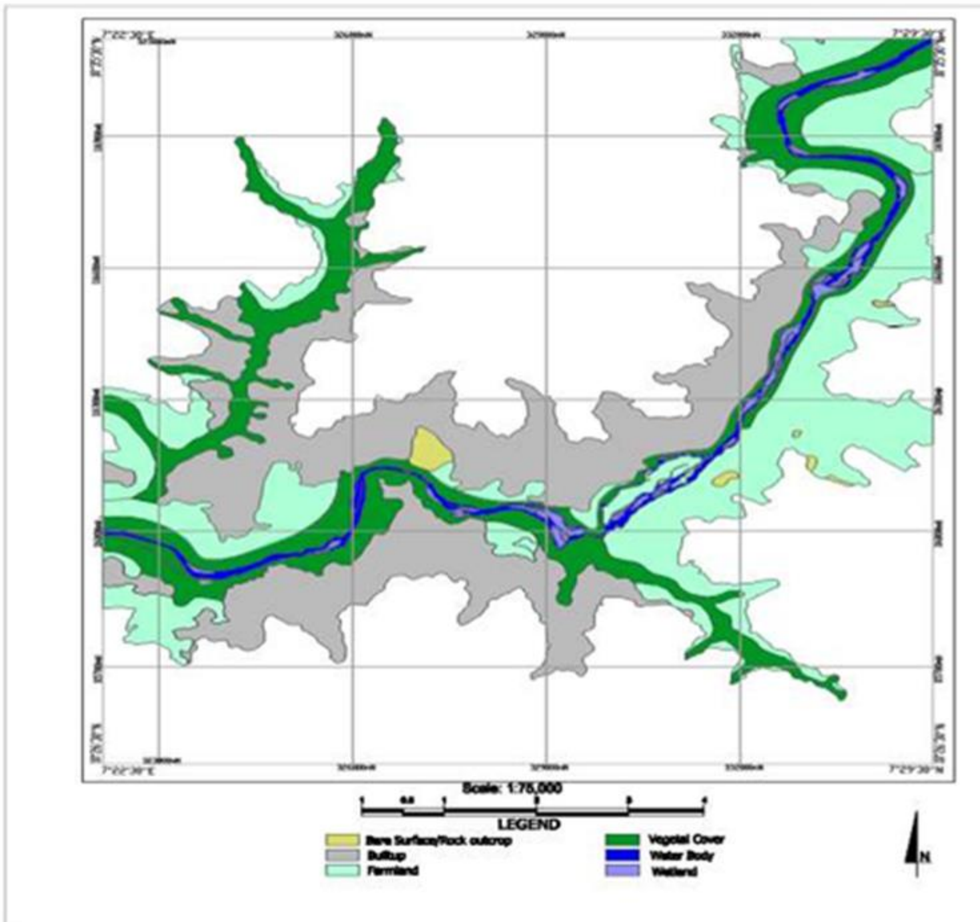


FIG 4: Land use Land cover Map of River Kaduna Flood Plain in 2001

FIG 4.2: Land use/land cover map of river Kaduna floodplain in2001

Source: Ikonos Image, 2001,

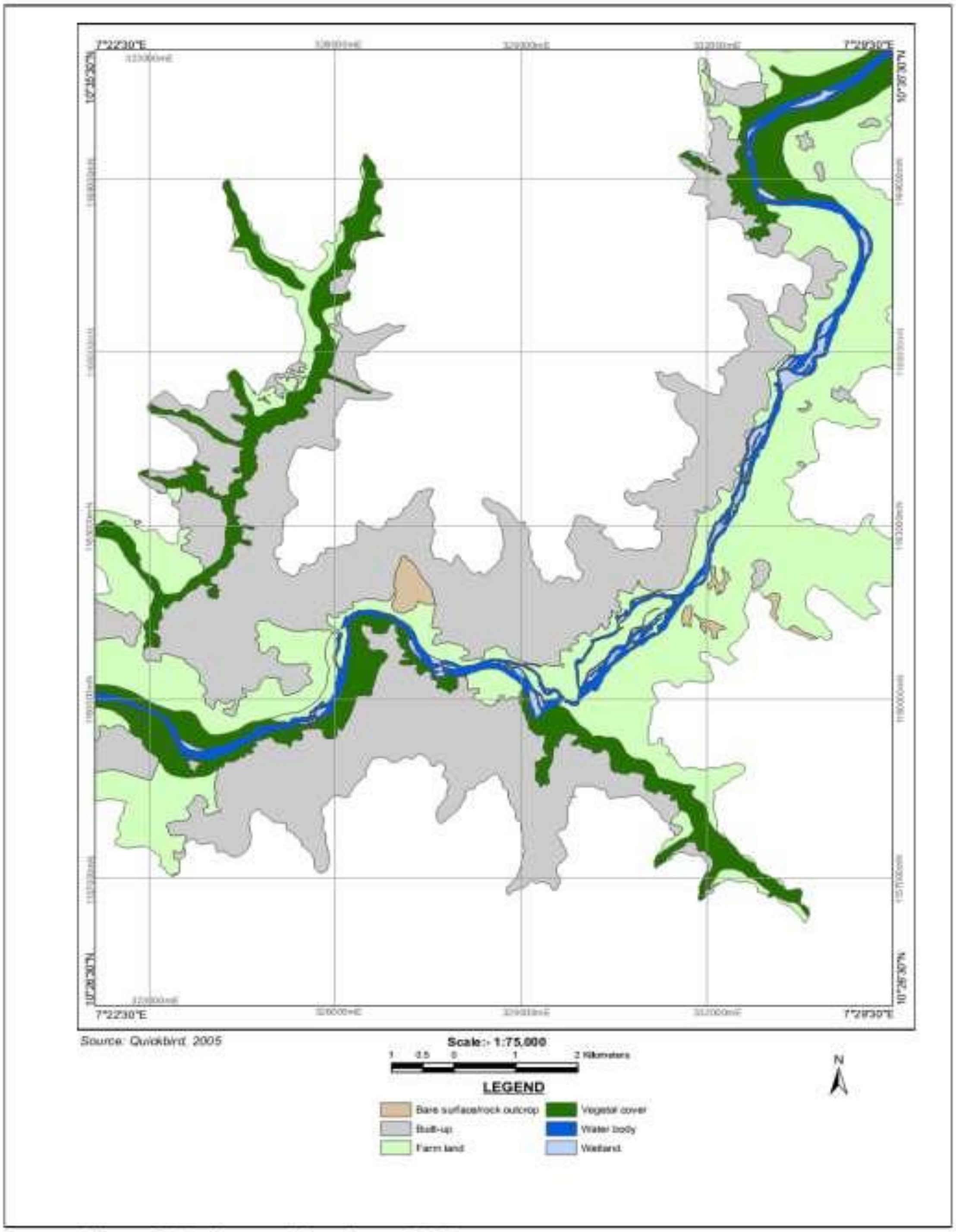


Figure 3: Landuse and Landcover 2005

FIG 4.3: land use/ land cover map of river Kaduna floodplain in 2005

Source: Quick bird image, 2005

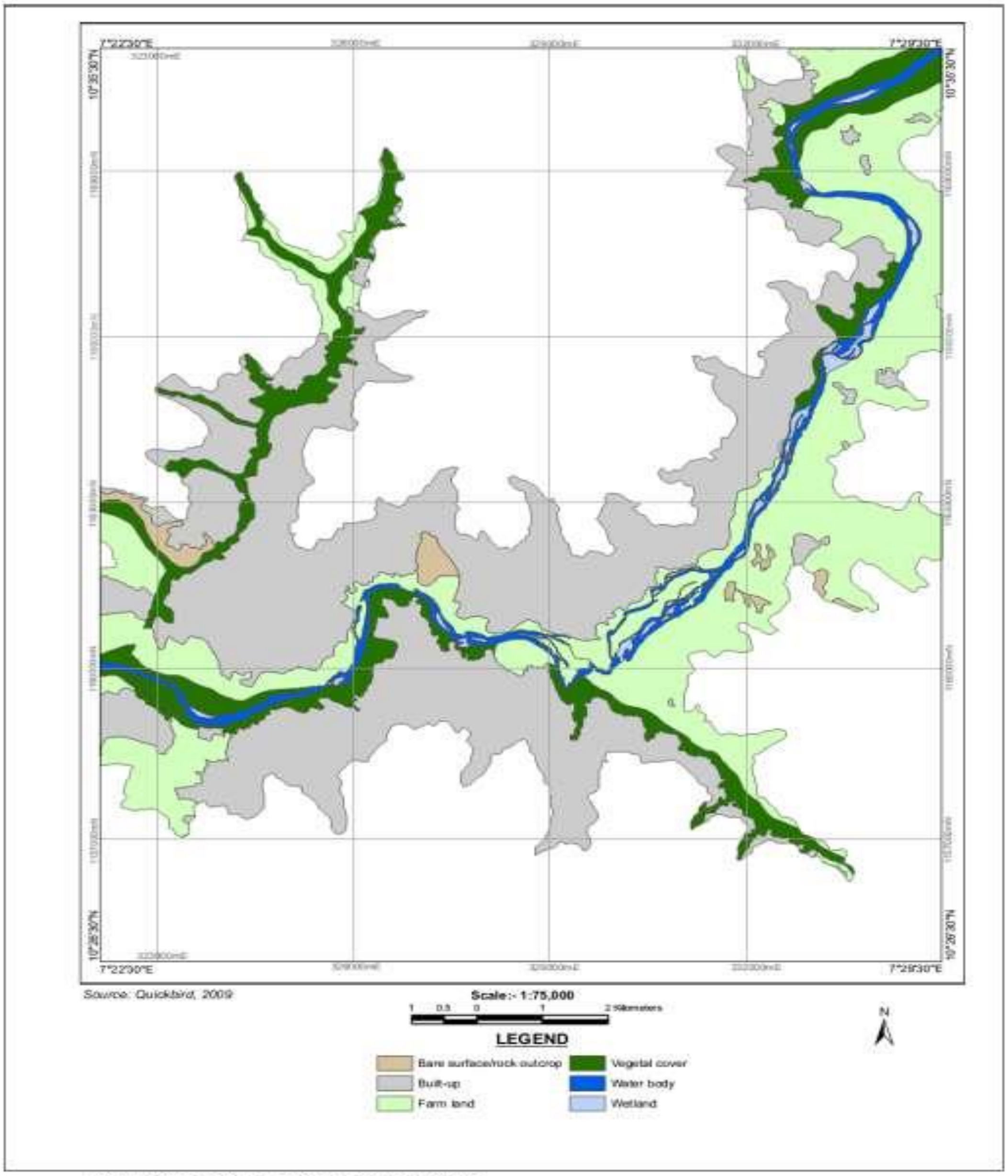


Figure 4: Landuse and Landcover 2009

FIG 4.4: land use/land cover map of river Kaduna floodplain in 2009

Source: Quick bird image, 2009

TABLE 4.2: COMPARISON OF AREAS OF LAND USE/COVER CHANGE BETWEEN 2001 AND 2005, AND BETWEEN 2005 AND 2009

Land use land Cover type	2001land cover area(ha)	2005 land cover area (ha)	2009 land cover area (ha)	Change in (ha) Between 2001-	Change in (ha) between 2005-
Bare Surface/Rock	58.10	67.40	119.00	+9.30	+51.60
Built-up land	3234.40	3637	4032.66	+402.60	+395.66
Farmland	2276.20	2873.2	2592.80	+597.00	-280.40
Vegetal Cover	2121.05	1122.30	985.40	-998.75	-136.90
Water Body	338.05	332.30	310.40	-5.75	-21.90
Wetlands	97.10	92.10	84.66	-5.00	-7.44
TOTAL	**8124.9**	**8124.9**	**8124.9**	-	-

Source: Author's field work, 2012

Note: ha= Hectares

Positive sign (+) indicates increase in area (ha) of land cover class

Negative sign (-) indicates decrease in area (ha) of land cover class

A comparison is made between the three periods of study, which also helped to determine the values in hectares either lost or gained among the six categories of land cover as shown in table 4.2. The proportion of change between the years under study was made to determine

The areas in hectares either lost or gained between the duration.
The result in table 4.2 indicated that from 2001 to 2005 bare surface/rock outcrop gained 9.30 hectares while between 2005 and 2009 it further gained 51.6 hectares. Built-up land from table 4.2 gained 402.60 ha of the study area between 2001and 2005; it also gained more area by 395.66 ha between 2005 and 2009. This signifies it as the most dominant land use encroaching into the floodplain area. Farmlands according to table 4.2, gained more of the total area by 597.00 ha between 2001 and 2005, but lost about 280.40ha between 2005 and 2009, signifying that more farmlands were changed and replaced by more built-up lands. Vegetal cover lost about 998.75 ha between 2001 and 2005 and also lost 136.9 ha between 2005 and 2009. This loss is mostly to both Farmlands and built-up land. Water body lost only 5.75 ha from 2001 and 2005 and 21.9 ha between 2005 and 2009 of the total area covered. Wetlands lost 5.00 ha of its area between 2001 and 2005, and also lost 7.44 ha of its area between 2005 and 2009.

TABLE 4.3: AREAS AND PERCENTAGES OF MAJOR LAND USE/COVER TYPES OF THE FLOODPLAIN AREA IN 2001, 2005 AND 2009.

Land use land cover category	2001		2005		2009	
	Area (hectares)	%	Area (hectares)	%	Area (hectares)	%
Bare Surface/Rock Outcrop	58.10	0.72	67.40	0.83	119.00	1.47
Built-up land	3234.40	39.81	3637	44.76	4032.66	49.63
Farmland	2276.20	28.02	2873.2	35.40	2592.80	31.91
Vegetal Cover	2121.05	26.11	1122.30	13.81	985.40	12.13
Water Body	338.05	4.16	332.30	4.09	310.40	3.82
Wetlands	97.10	1.20	92.10	1.13	84.66	1.04
TOTAL	**8124.9**	**100**	**8124.9**	**100**	**8124.9**	**100**

Source: Author's field work, 2012

DISCUSSIONS

A systematic way of analysis for land use change is first to have the total area for the different land use classes for the different durations and compare the various maps, in other words, this is referred to as temporal analysis. Accuracy in interpretation and measurement of these changes is thus very important.

To really understand the trend of change in the land use land cover classes the percentage of the uses was calculated as indicated in table 4.3.The composite maps in Fig 4.5, illustrate the pattern of changes and is used for the comparison. From the result in table 4.3, bare surface and rock outcrop increased from 0.72% to 0.83% and 1.47% in 2001, 2005 and 2009 respectively. Although bare surface and rock outcrop are classified together, it is not expected that the area of rock outcrop increased; rather it is the bare surface that must have increased as a result of clearing of areas of the Floodplain which are intended for future development.

The most glaring change and conversion is indicated by the result of built up land (table 4.3, Fig 4.5) which increased considerably from 39.81% in 2001 to 44.76% in 2005 and 49.63% of the total area in 2009. This means there has been a progressive expansion in structural development into the floodplain area thereby leading to reduction of the floodway and concretization of the natural surfaces which would have aided natural infiltration and decrease in run-off; it also means more property are in danger especially in an event of flood. The expansion of built up land into the floodplain areas of the river within Kaduna metropolis may not be unconnected with the city being a center and capital territory since colonial times to the present as a result of which it has experienced unprecedented growth and investment in industrial development and commercial activities and an influx of people from various parts of the country (DFID, 2003). It is estimated that the population in Kaduna has grown rapidly from 40,000 in 1952 to 149,000 in 1963 , to an estimated 150,000 in 1965(Kaduna 1917-1967-2017 Max Lock and Partners) and 500,000 in 1984. The final results of the 2006 census, puts the population of the metropolitan area at around 1,570,331 (Federal Gazette, February 2009).

Moreover, the significant intrusion of built up land as against other land uses with the attendant consequences conforms to the findings of Sheppard(2007) who presented a highly relevant information on built up areas of cities and their change over time. His work revealed that the spatial distribution of urban population in nearly 90 cities surveyed is by and large not the result of conscientious planning. One of the key messages is that cities in all regions must plan early and much more carefully to accommodate and disperse the impact of over concentration of people and economic activities in order to avoid large scale catastrophes that will otherwise ensue. Similarly, in the case of Kaduna metropolis, the intent of the proposals of the MAXLOCK and Partners (1967-2017) master plan of the city has not been effectively translated and implemented

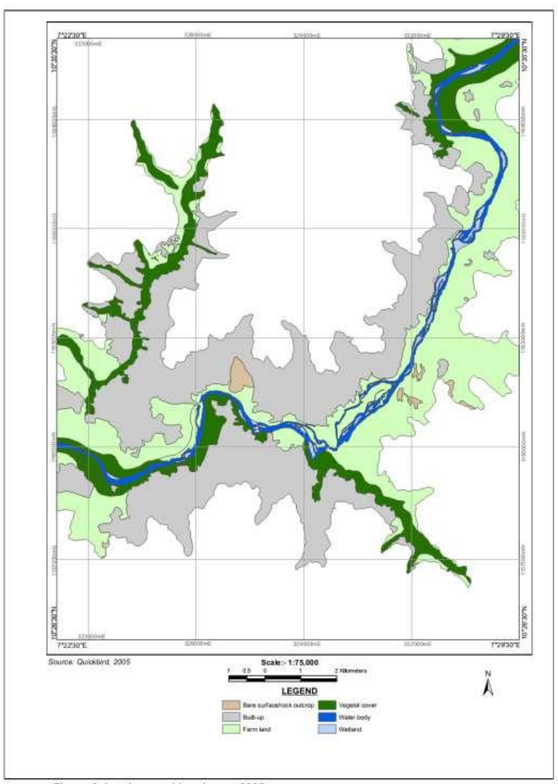


Figure 3: Landuse and Landcover 2005

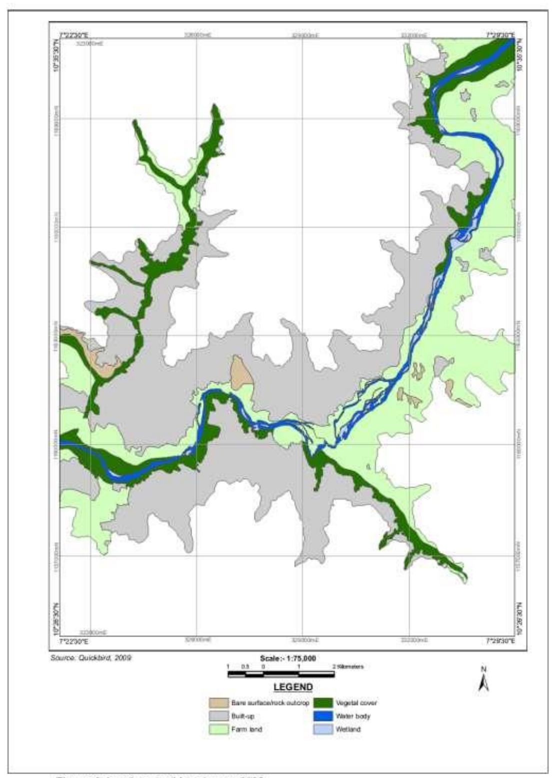


Figure 4: Landuse and Landcover 2009

FIG 4.5: Composite maps showing land use land cover 2001-2005-2009

Into an envisaged physical framework, partly due to institutional failure. This has, thus, resulted in creating an undesirable urban growth pattern (DFID, 2003).

According to the United Nations (2006), the total global urban population is expected to double from 2 to 4 billion over the next 30 to 35 years; an unwanted side effect of this process of rapid urbanization is the increased susceptibility towards flooding as a result of concentration of people and assets in flood prone areas – many urbanized areas are located along major water bodies, further more climate change may cause floods to occur more frequently and severely (Veerbeek *et al.* 2008).

Farmlands as indicated in table 4.3 covered 28.02% in 2001, it, however, increased to 35.40% in 2005 and then declined to 31.91% of the study area in 2009. The composite maps in Fig 4.5 illustrates this change clearly, and shows that initially vegetation along the floodplain area was cleared and replaced by farmlands which were later gradually phased out by built-up land especially in the Western part of the River. The maps in Fig 4.5 shows that there are more farmlands along the floodplain especially in the Eastern part of the metropolis and more built- up land in the northern, western and southern parts of the River Kaduna.

The invasion of flood plains by humans in search of new land for farming and homes is one of the most important drivers of flood losses in economically developing countries. For instance, in Bangladesh, flood plains occupy 80% of the country and annual flooding (locally known as *borsha*) is a part of peasant life to which people are resilient, since one-fifth of the country is regularly flooded (Mirza, 2003). Regular flooding is viewed as beneficial; it creates and maintains the high fertility of soils and supports the world's most densely populated country with average population density of 1209 persons/km^2 (World Bank, 2002).

The result in table 4.3 indicates a sharp decline in vegetal cover which decreased from 26.11% in 2001 to 13.81% in 2005 and 12.13% of the geographical area in 2009. This is clearly shown by the composite maps in Fig 4.5 in which more area were covered by vegetation in 2001 which were then modified and converted to other land uses especially built-up land and Agriculture in the preceding years, 2005 and 2009. This change has serious implications because the natural ecological balance within the floodplain is altered through human activities, natural habitats, vegetation and other species are gradually replaced by Farmlands and built-up land which leads to alterations in the natural beneficial functions of the Floodplain.

Water bodies from table 4.3 and Fig 4.5 indicated only a slight decrease in area covered, from 4.16% in 2001, to 4.09% in 2005 and 3.82% of the total area in 2009. This slight change may be due to variation between the imagery of the rainy and dry season which may differ.

Wetlands, from the result in table 4.3, cover a small area compared to other land uses. There is a gradual decline in wetlands from 1.20% in 2001 to 1.13% in 2005 and 1.04% of the area in 2009. In Fig 4.5 wetlands as illustrated are shown to occur mostly around areas of the braided channel of River Kaduna. It is, however, important to state that wetlands are crucial to the natural equilibrium of the floodplain in that, it absorbs flood waters, recharge ground water and filter impurities from water. They also serve as habitat for extraordinary diversity of birds, fish, insects and plant life (Encarta, 2009). Thus any decline, no matter how small, may offset the balance provided by these habitats. In Asia, more than 5000 km^2 of wetlands are lost every year because of agricultural development, urbanization and dam construction. If this trend continues, which is probable because of rapid economic and demographic development, by 2025 an additional 105,000 km^2 of wetlands will be converted to other uses, which means the ecological consequences for river-floodplain ecosystems are expected to be disastrous (Tockner *et. al*. 2008). Finally, the competing transitional changes, modification and conversion among the various land use land cover types by human activities in the floodplain alter the otherwise natural stable conditions provided by natural riparian vegetation and wetlands. This also induces instability in the river which results in floods. Consequently, several cases of floods have become a recurring incident in river Kaduna. Instances include the 2003, 2009, 2010 and most recently the September 2012 floods in which residents along the river Kaduna floodplain area were sacked by the flood, about 1500 residents were displaced while over 300 houses were submerged in various parts of the metropolis (Weekly Trust, 2012). All these points to the fact that issues on human activities along floodplains deserve serious attention.

CONCLUSIONS

From the findings of this study, it can be concluded that the River Kaduna floodplain area has:

- Undergone considerable alterations in its natural cover and conditions as shown by the competing transitional changes, modification and conversion in land uses caused by human activities and development. Since water will always have its course, the resulting floods have caused severe damages to life and property when it occurs. However, new strategies for floodplain management and restoration are imperative in order to save these sensitive ecosystems and avert future losses.

RECOMMENDATIONS

New development should be prevented from encroaching on to flood prone and environmentally sensitive areas, starting now; future development should avoid flood hazard and ecologically sensitive areas. Relevant agencies such as Kaduna State Urban Planning and Development Agency (KASUPDA) should have their regulatory programs identified and revamped by applying new land use planning and floodplain management techniques with emphasis on ensuring floodplain protection and restoration as against emphasis on damage reduction and construction standards and other regulations which assume that floodplain development is going to occur. Recent efforts by the Kaduna State government to embark on dredging of the river Kaduna to check silting and flooding is indeed commendable. However, such effort is only effective in the short term, as silting is a continuing geomorphologic process, meaning we are only delaying the disaster to a later date instead of solving the problem once and for all. This also negates what environmental sustainability is out to achieve, which is ensuring that the present generations achieve their needs without unnecessarily compromising the ability of future generations to achieve theirs.

Where possible, floodplain areas should be reclaimed through removal of existing development from flood prone and environmentally sensitive areas. There is the need to begin a collective pattern of gradual relocation of existing resident and businesses away from flood hazard areas; and also the need to begin a strategic retreat along the river floodplains. People should not be sitting ducks in those risky areas always assuming that floods are occasional occurrences or that hard engineering or reinforcing their structures through stone pitching and concretizing buildings will reduce damage, then when floods occur they await relief from government and then go back to the same flood prone area to wait for another round of floods and relief. The billions of naira that is spent on almost a yearly basis for relief can be used otherwise for relocation and redevelopment of new layouts away from flood prone areas. It has been tried in Nigeria, for example, after the floods of year 2010, the Sokoto State government planned to build 1000 units of houses to relocate and resettle the flood victims, 3.6 billion naira worth of houses are being built in 3 local governments of Goronyo (400 units) Gada (350 units) and Silame (250 units) (Weekly Trust Sept. 2012). It is, however, hoped that corruption and favoritism will not undermine this laudable objective. Although the cost implication and success of relocation and resettlement may seem prohibitive, however if we consider the cost in human lives and property then it is justifiable. Alternatively, reclaimed areas of the flood plain should thus be turned in to green areas or green infrastructure which would ensure environmental sustainability and ecological equilibrium

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