REMOTE SENSING AND GIS-BASED ANALYSIS OF URBAN EXPANSION AND ENCROACHMENT ON FLOODPLAIN IN KADUNA METROPOLIS, NIGERIA

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Abstract

The inadequate planning and control of the spatial growth of Kaduna metropolis has resulted in the encroachment of physical development on floodplain in the area with adverse consequences. The aim of this paper is to analyze the encroachment of urban expansion on floodplain in Kaduna metropolis. Landsat MSS imagery of 1973; Landsat TM captured in 1990; Landsat ETM+ of 2001 and Nigeriasat-1 image of 2009 were used to generate the built-up layer for the four epoch time series. Visual or manual image interpretation technique was used to extract the built-up landuse which was digitized to create segment maps. The segment maps were polygonized and rasterized. Using the Digital Elevation Model (DEM) constructed from the topographical map of the area, the floodplain was determined and digitized. The built-up area of the various periods was overlain on the floodplain and the extent and rate of built-up encroachment on the floodplain were determined. An interview was also conducted with the management of Kaduna State Urban Planning and Development Authority (KASUPDA) and Lands and Surveys in order to elicit information on the planning and management of urban expansion in the area. Coding and description were used to analyze the data from the interview. The findings reveal that 22.15% of the floodplain has been taken up by physical development as at 2009. The built-up land in the floodplain was increasing at the rate of 9.61% per annum. This paper recommends that: i) KASUPDA should engage adequate and well trained personnel in order to improve efficiency in the control of growth; ii) Remote Sensing and Geographic Information System (GIS) techniques should be adopted for proper monitoring of the rapid urban expansion.

Keywords: Built-up; Encroachment; Floodplain; Geographic Information System; Remote Sensing; Urban Expansion

1. Introduction

Urban land expansion is the most easily identifiable characteristic of urbanization process as it affects land cover/use at both regional and global scales. Although the definitions of urban land expansion tend to vary, the most commonly accepted one is that it is the spreading out of a city and its suburbs towards non built-up areas at the periphery of an urban area (Liu, Zhan & Deng, 2005). According to Liu, *et al*. (2005), this process involves the conversion of other land use categories into built-up developed land over time.

The built-up is generally considered as the parameter for quantifying urban expansion (Torrens & Alberti, 2000, Barnes *et al.*, 2001 & Epstein *et al.*, 2002 cited in Jat & Khare, 2008). It is quantified by taking into consideration the impervious or the built-up as the key feature of urban expansion (Jat,& Khare, 2008). The extent of urban expansion is one of the phenomena that drive the change in land use patterns.

Cities world-wide are experiencing rapid spatial growth. Liu, Zhan and Deng (2005) identified demography and economies as the most important driving factors for urban expansion. On the whole, urban built-up areas in the world consumed about 400,000 square kilometers in the year 2000 (about 0.3% of the total land area of the globe). This is projected to reach 1,100,000 (about 0.85%) by 2030 if the sane growth rate is maintained (Angel, *et al*, 2005). According to Angel, *et al.,* cities in the less developed countries would account for more of this growth. For instance, the built-up environment in Kaduna city was reported to be expanding at the rate of about 167.8ha annually between 1990 and 2000 (Ishaya, Ifatimehin & Okafor, 2008). Such rapid urban expansion could lead to uncoordinated growth and consequently, environmental problems may occur if proper planning and monitoring strategies are not adopted to control the growth.

One of the consequences of uncontrolled spatial growth in cities is the encroachment of physical development on floodplains. This could lead to disruption of the earth's ecological balance which could aggravate environmental problems in the city. Settlement of flood-prone areas is a major cause of flood damage (Prima on Natural hazard Management in Integrated Regional Development Planning, 1991). The occupants of the floodplains are exposed to high risk of flood devastation as being experienced in parts of Nigeria and Kaduna metropolis in particular.

Floodplains can be viewed from various perspectives based on the aim of the author. Topographically, floodplain is a flat land that lies adjacent to a stream. Geomorphologically, it is a landform composed mainly of unconsolidated depositional material derived from sediments being transported by the related stream. From hydrological perspective, floodplain refers to a landform that is subject to periodic flooding by a parent stream (Schmudde, 1968 cited in Primer on Natural Hazard Management in Integrated Regional Development Planning, 1991).

Most simply put, a floodplain is generally a strip of relatively smooth land adjacent to rivers and streams which is subject to recurring floods at periods of high water (Prima on Natural hazard Management in Integrated Regional Development Planning). They are therefore, "flood-prone" and are hazardous to development activities if the vulnerability of those activities exceeds an acceptable level (Prima on Natural hazard Management in Integrated Regional Development

Planning, 1991). Floodplains are a vital part of the river or stream ecosystem. They act as flood buffers, water filters, nurseries, and are major centers of biological life in the river or stream ecosystem (Floodplains, Not Dated).

The rapid uncontrolled spatial growth of Kaduna like most cities in Nigeria, is manifested in the encroachment of physical development or built-up land on flood-prone areas. The extent of built-up encroachment on floodplains in Kaduna metropolis has increased from 4.08% in the 1967 to 52.2% in 2001 (Ndabula, 2006). Kaduna has being experiencing devastating flooding events of varying magnitudes which destroy property worth millions of naira and displace thousands of people (Dartmouth Flood Observation (DFO), 2003). The residents occupying the floodplains have been mostly affected.

Remote Sensing provides a unique perspective of how cities evolve; it can be used to classify landuse in an economic and repetitive manner over large areas. Remote Sensing also has the capability to quickly identify and map floodplains (Fundamentals of Remote Sensing (not dated). Geographic Information System (GIS) has the unique capabilities to integrate data from different sources, store, manage, analyze, up-date, and quickly output information. Therefore, Remote Sensing and GIS are powerful technologies for effective monitoring and controlling of rapid urban expansion.

The aim of this paper therefore, is to analyze the spatial growth of Kaduna city and its encroachment on floodplain using Remote Sensing and Geographic Information techniques in order to provide information for proper planning and monitoring of the growth. The objectives pursued include to: i) extract the built-up area for 1973, 1990, 2001 and 2009; delineate the floodplain in Kaduna metropolis; and determine the extent and rate of built-up encroachment on the floodplain in Kaduna.

2. The Study Area

Kaduna got her name from River Kaduna known as *kogin kadduna* in hausa meaning "river of crocodiles". The name Kaduna was derived from the plural form of the Hausa word for crocodiles (*Kadduna)* which was abundant in River Kaduna (Oyedele, 1987). Kaduna metropolis is located between latitudes 10^{o} 20' N and 10^{o}37'N of the equator and longitudes 7^{o} 22' E and 7^{o}31'E of the Greenwich meridian. The city cuts across Kaduna North, Kaduna South, as well as parts of Igabi and Chikun local government areas of Kaduna state (see fig.1). Kaduna is mainly drained by River Kaduna which tends to divide the city into two unequal parts. The main tributaries of River Kaduna are rivers Rigasa, and Romi.

Lying under the Tropical Continental climate, Kaduna experiences seasonal alternation of moist maritime air mass and dry continental air mass. The rainy season begins in April and ceases in October while the dry season (hamattan) lasts from November to March (Bello, 1993). The temperature is high throughout the year with the peak in March and April (37^{o}c). Humidity is constantly high (above 60%) at mid-day and close to 100% at night during the rainy season (Ati,1998 in Ndabula, 2006).

The 1991 census puts the human population of Kaduna metropolis at 971,070 which comprised 515,373 males and 455,697 females (NPC, 1991). Based on projection, the population of the city in 2012 was estimated to reach 1,729,142 with 917,702 males and 811,440 females. The

movement of the West African Frontier Force between December 1912 and March 1913 and labourers from Kano province and Zungeru in 1913 and 1917 respectively as well as individual migrations marked the beginning of the urbanization process in Kaduna (Bello & Oyedele, not dated). Since then, the city has continued to grow in both population and geographical extent.

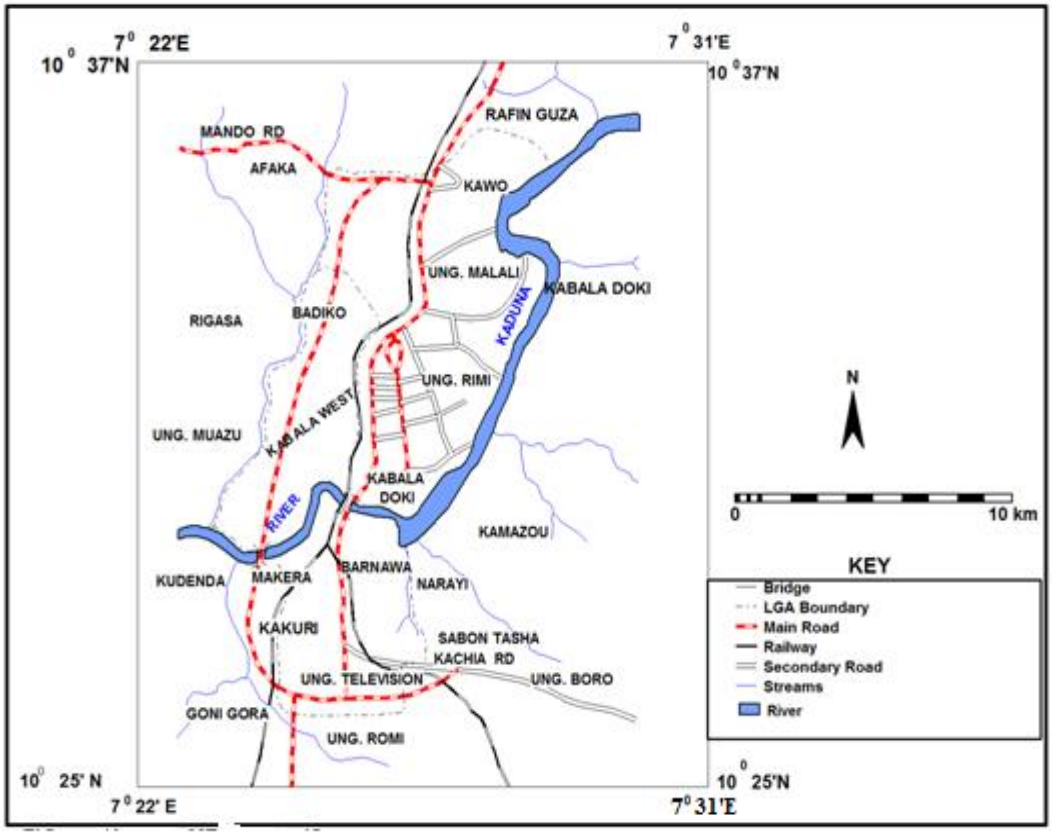


Fig. 1 Kaduna Metropolis
Source: Modified from Kaduna Environmental Protection Agency

3. Materials and Methods

Landsat MSS imagery of 1973 with 80m spatial resolution; Landsat TM captured in 1990 whose spatial resolution was 30m; Landsat ETM+ of 2001 with 30m spatial resolution and Nigeriasat-1 image of 2009 with 32m resolution were used to generate the built-up layer. Subsetting of the portion of interest (Kaduna metropolis) was done from each of the larger scenes using ERDAS IMAGINE 9.2 software. Since the data used were auto-rectified, there was no need for geometric and radiometric correction to be performed on them. However, the data sets were geo-referenced or geo-coded that is registered to a geographic coordinate system. The nearest neighbor resampling method was used to resample the 1973 and 2009 imageries to 30m

resolution in order to bring all the datasets to a common resolution and projections. This was necessary in order to make it possible for overlay and other GIS operations to be carried out.

Visual or manual image interpretation technique was used to extract the built-up or urban landuse which was digitized to create segment maps for the four epoch time series. The segment maps were polygonized and rasterized. These were done in ILWIS 3.3 environment. Using the Digital Elevation Model (DEM) constructed from the topographical map of the area, the floodplain was determined and digitized. With overlay analysis of the Geographical Information System (GIS) in ILWIS 3.3 environment, the built-up area of the various periods were overlain on the floodplain to ascertain the extent of built-up encroachment on the floodplain. The rate of encroachment was also calculated. An in-depth interview was also conducted with the managements of Kaduna State Urban Planning and Development Authority (KASUPDA) and the Planning Unit of Lands and Surveys in order to elicit information concerning the planning and management of urban growth in the area. The analysis of the unstructured interview data was done by coding and description.

4. Results and Discussion

The extent of built-up area in Kaduna in 1973, 1990, 2001 and 2009 is shown in table 1. The extent and rate of built-up encroachment on floodplain in the area for the four time period is shown in tables 2 and 3. The result is visually presented in figures 1-4 and further illustrated by plates 1 and 2.

Table 1: Extent of Built-up Area in Kaduna metropolis

Year	Built-up Area (Ha)
1973	6,410.4
1990	10,101.4
2001	12,965.4
2009	19,707.2

Source: Author's GIS Analysis, 2012

The extent of the built-up land as shown in table 1 reveals that about 6410.4 hectares of land in Kaduna was built-up in 1973. The built-up area more than doubled (12965.4 hectares) by the year 2001 (28years) and more than tripled in 2009. This implies that the city is experiencing a rapid spatial growth.

Table 2: Extent of Built-up Encroachment on Floodplain

Year	Total Floodplain (Ha)	Extent Encroached on Floodplain (Ha)	Proportion Encroached on Floodplain (%)
1973	4341.38	215.57	4.96
1990	4341.38	447.79	10.31
2001	4341.38	533.32	12.28
2009	4341.38	961.54	22.15

Source: Author's GIS Analysis, 2012

The analysis as shown in table 2 reveals that only a small proportion (4.96%) of the entire floodplain (4,314.38ha) was occupied by physical development in 1973. However, by the year 1990, the built-up area in the floodplain more than doubled (10.31%); and by the 2009, as much as 22.15% of the floodplain was already built-up.

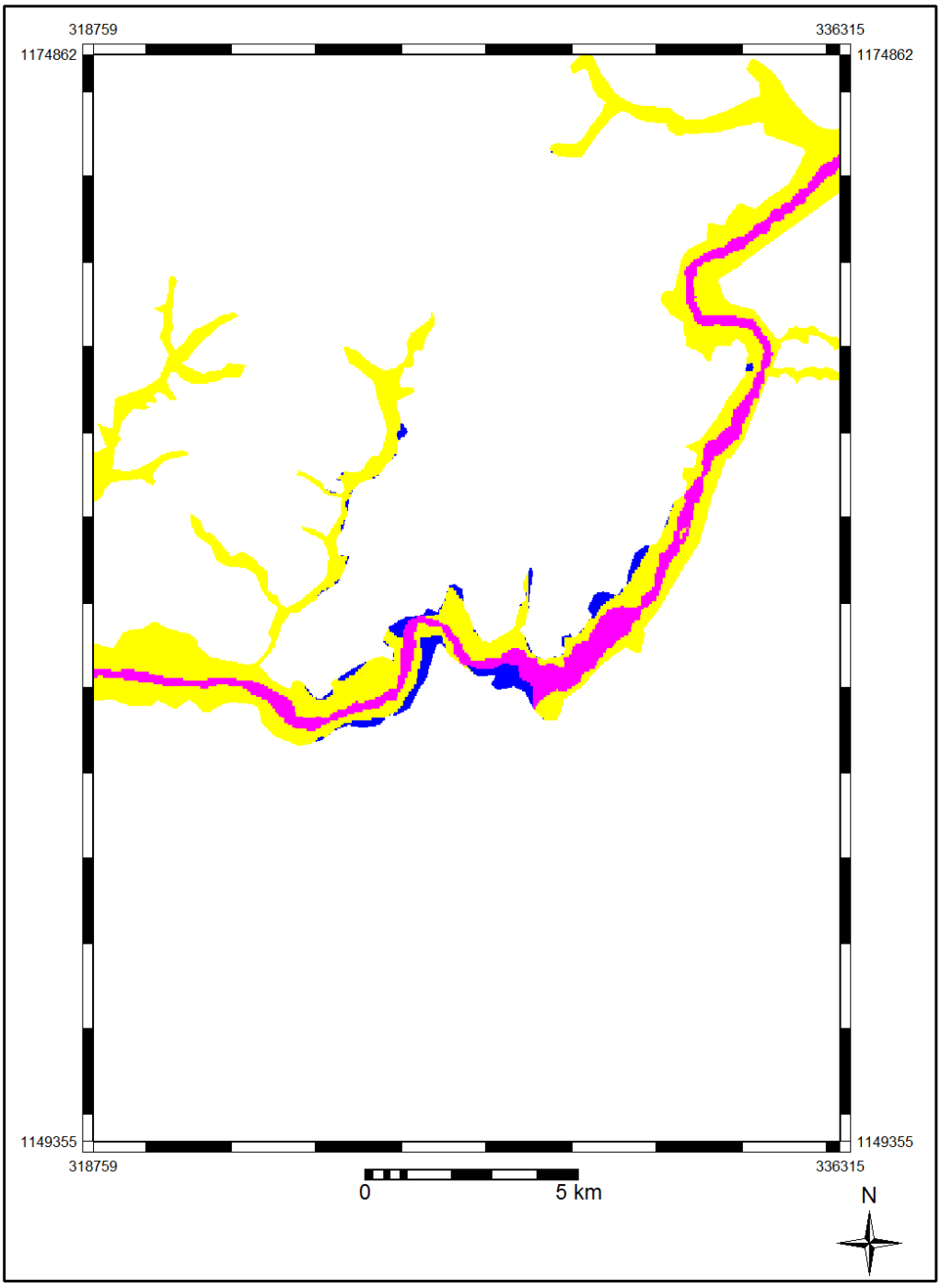
Table 3: Rate of Built-up Encroachment on Floodplain

Period	Year	Built-up on Floodplain (ha)	1ncrease		Arithmetic Mean (Rate of Increase)	
			Ha	%	Ha/Year	%/Year
1973-1990	1973	215.57	232.22	107.72	13.66	6.34
(17years)	1990	447.79				
1990-2001	1990	447.79	85.53	19.10	7.78	1.74
(11years)	2001	533.32				
2001-2009	2001	533.32	428.22	80.29	53.53	10.04
(8years)	2009	961.54				
1973-2009	1973	215.57	745.97	346.05	20.72	9.61
(36years)	2009	961.54				

Source: Author's GIS Analysis, 2012

About 215.57 hectares of the floodplain in Kaduna metropolis was occupied by physical development in 1973. This increased by about 107.72% in 1990 at the rate of 6.34% annually during that period. The period 2001-2009 recorded the highest growth rate (10.04%) of built-up land within the floodplain. In other words, about 53.53 hectares of the flood-prone area was transformed to built-up land every year during that period. This coincides with the period when the highest spatial growth rate was experienced in the metropolis (Akpu,2012). The growth was not adequately planned for and monitored hence, haphazard development occurred and consequently, encroachment on the floodplain. On the average, between 1973 and 2009, the built-up area within the flood-prone land was growing at the rate of about 9.61% annually. If this development of the floodplain continues at this rate, in no distant time, the entire floodplain would be lost to built-up land use which would be detrimental to the ecological system.

Some of the consequences of such development may include the occurrence of devastating flooding which may claim lives and property, as well as loss of biodiversity which is housed by the floodplain. Parts of the neighborhoods occupying the floodplain in Kaduna include: Kabala Costain,Kabala Doki, Barnawa, Nasarawa, Kakuri, Ungwan Rimi, Malali, Tudun Wada and Kudenda. These areas often experience flooding which destroy property and displace large number of people. Plates 1 and 2 show examples of houses built on a floodplain in Nassarawa and Kabala costain respectively. These buildings are at a high risk of been flooded due to its location. The extent of built-up encroachment on floodplain in Kaduna metropolis is shown in Figs. 1-4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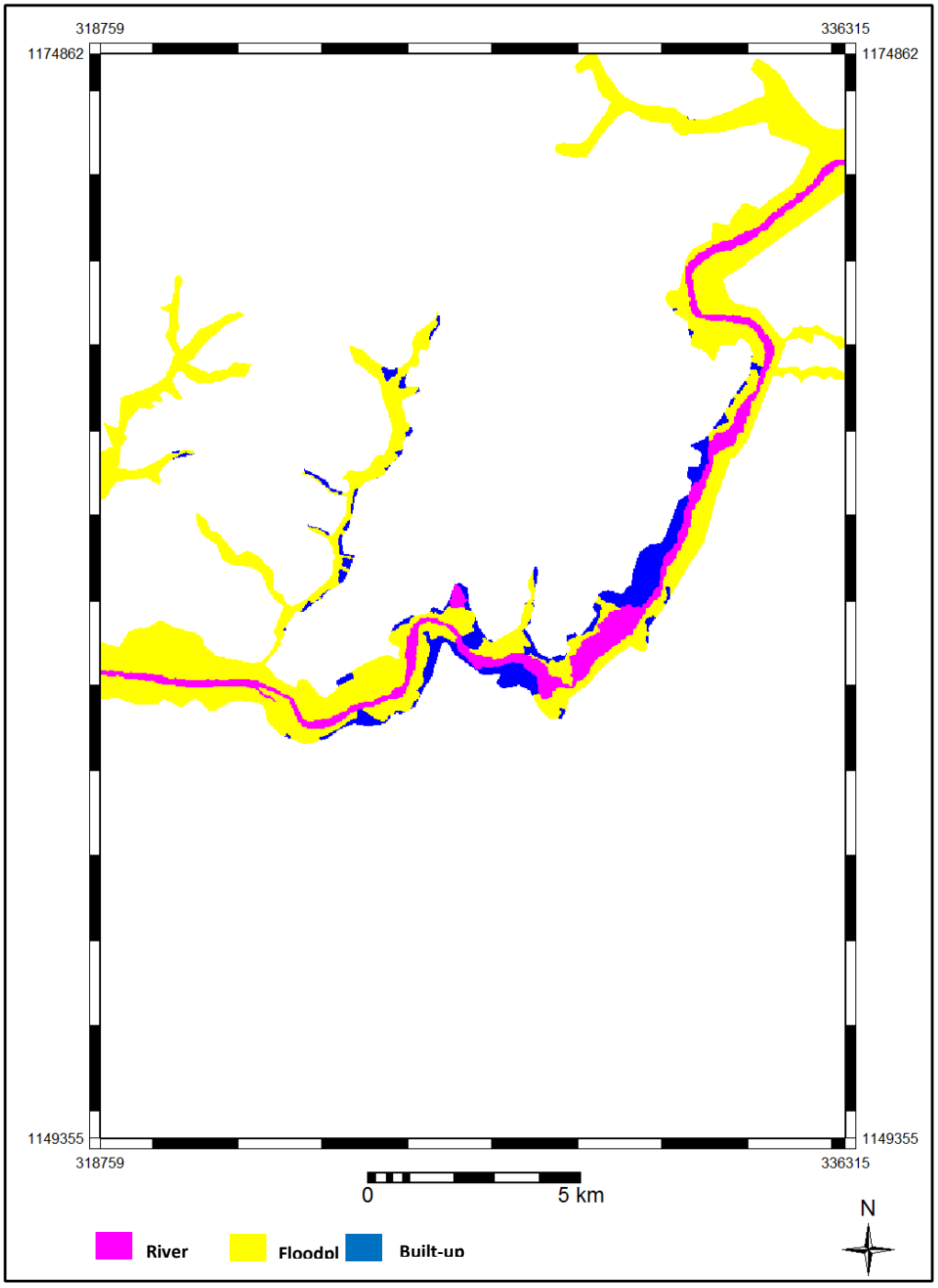
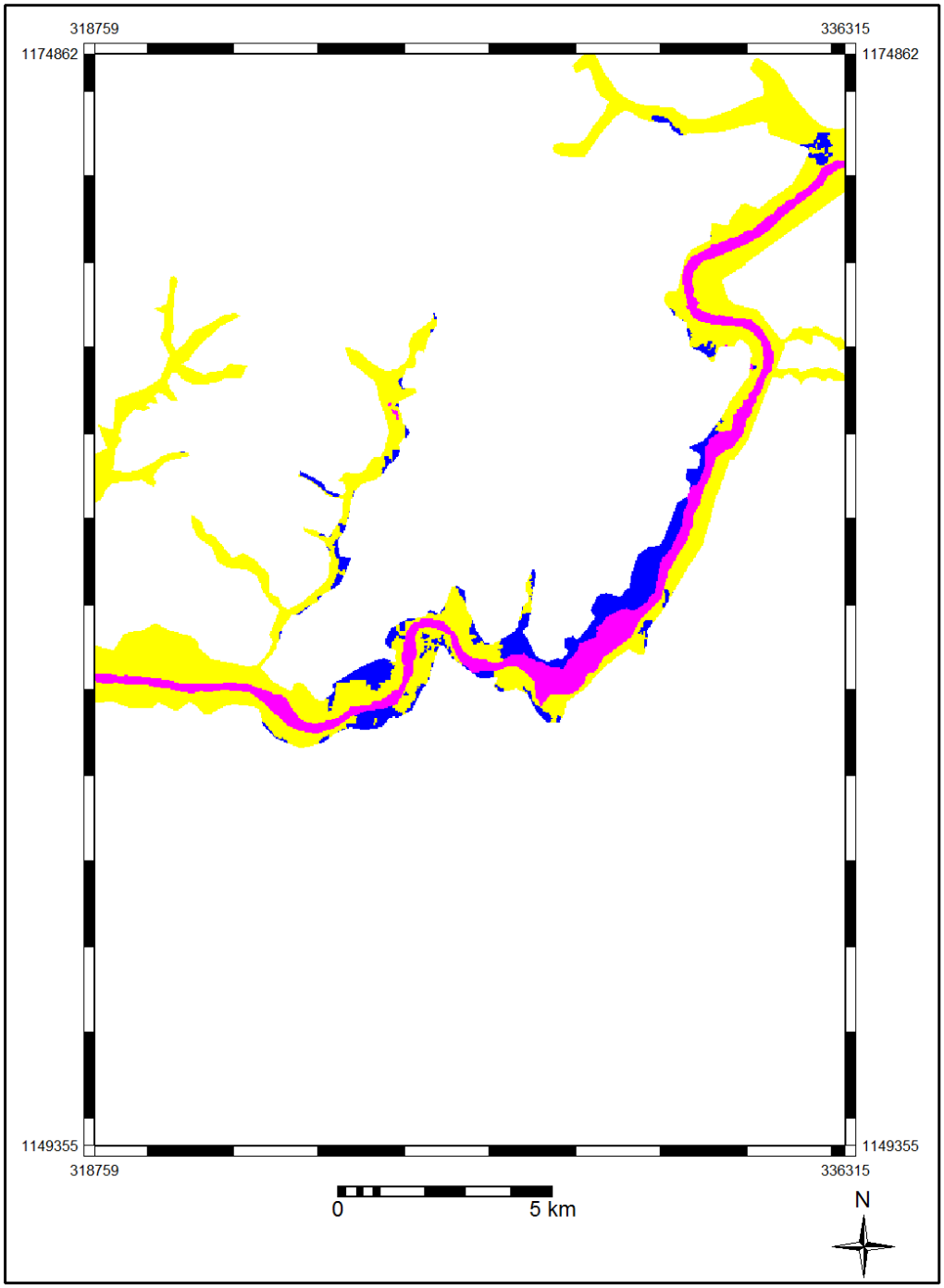


Fig. 2 Built-up Encroachment on Floodplain in 1990
Source: Author's GIS Analysis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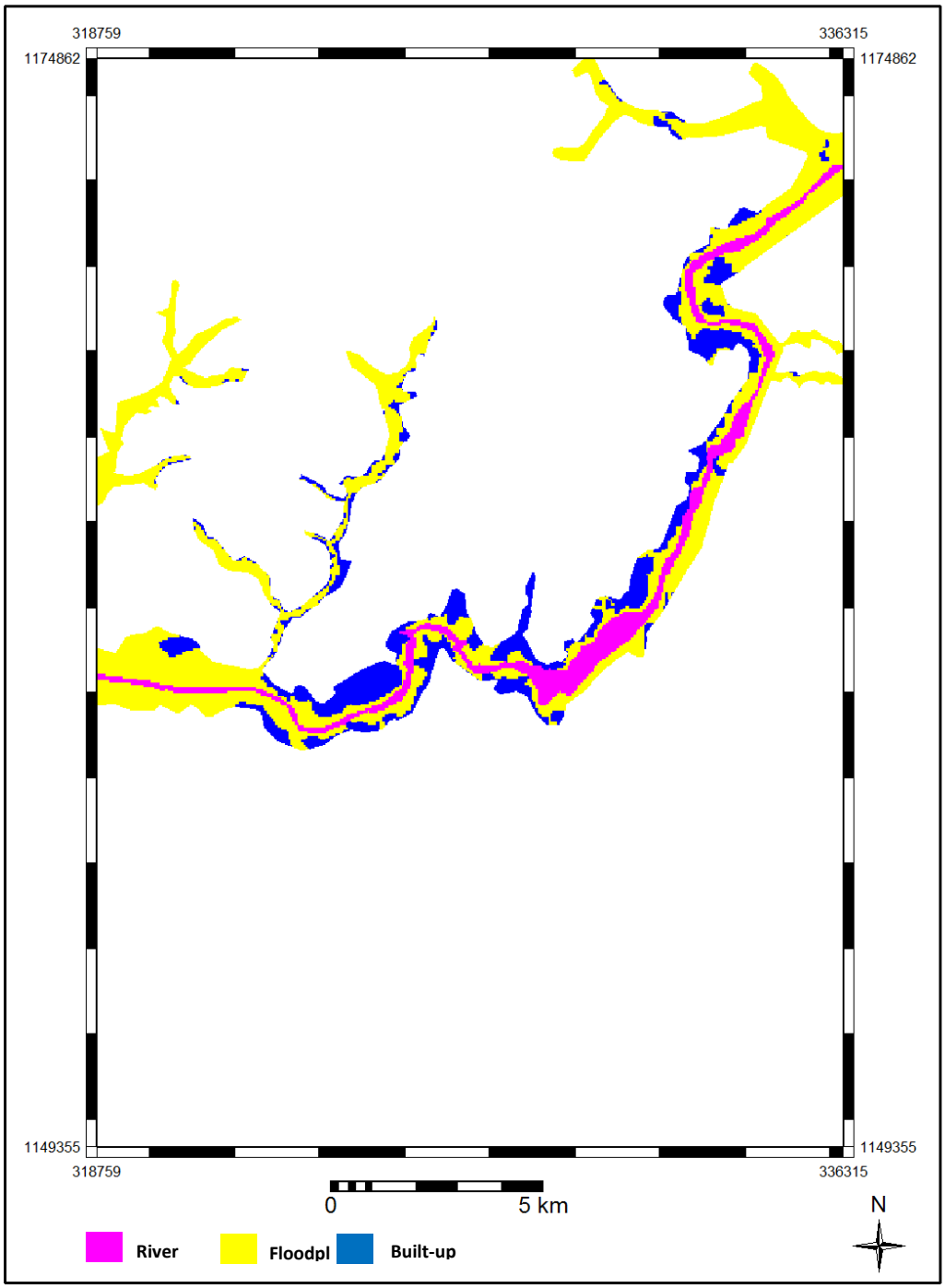

Fig.4 Built-up Encroachment on Floodplain in 2009
Source: Author's GIS Analysis

Plate 1 Building on Flood prone Area in Nassarawa, Kaduna These houses are on a floodplain and are consequently at the mercy of flooding whenever rainfall increases.

Source: Author's Field Survey

Plate 2 Buildings on Flood- Prone Area in Kabala Costain, Kaduna. These buildings are on a floodplain and therefore, experience flooding at the slightest increase in rainfall

Source: Author' s Field Survey

The interview with personnel of KASUPDA revealed that the inability of the government to create new layouts in order to keep pace with the pressure of the high urban expansion has given rise to the development of illegal layouts and encroachment on floodplain. The interview further identified corrupt practices of some of their agency's staff and interference by government officials who have no respect for land use plan as other factors. Lack of properly trained planners and inadequate remuneration of the staff in addition to the various ethno-religious crises experienced in the area were other factors.

5. Conclusion and Recommendations

The inadequate planning and monitoring of the rapid spatial growth of Kaduna has resulted to encroachment of physical development on lands that are liable to flooding which may have serious adverse effects on the environment and the residents. This paper discovered that the extent of built-up encroachment on floodplain increased from 4.96% in 1973 to 22.15% in 2009. In other words, 22.15% of the entire floodplain in the area was already built in the year 2009.

This paper recommends that KASUPDA should engage adequate and well trained personnel in order to improve efficiency in controlling development. In addition, Remote Sensing and Geographic Information System (GIS) techniques have the capability for efficient monitoring of such rapid urban expansion and should therefore, be adopted for the control of urban expansion. The establishment of agencies like Kaduna Geographic Information System (KGIS) is a step in the right direction but these units should be well equipped and adequately funded. The government should partner with the private land owners in order to developed adequate layouts to keep pace with the rapid growth of the city. The government should also integrate and standardize the informal land market since it is the easiest source of land for development accessed by urban dwellers.

References

Akpu, B. (2012) An Analysis of the Spatio-Temporal Growth of Kaduna Metropolis and its Environmental Consequences in Kaduna, Nigeria. Unpublished Ph.D Thesis, Department of Geography Bayero University Kano.

Angel,S, Sheppard, C. S, Civco, L.D, Buckley, R. , Chabaeva, Gitlin, L. A. Kraley,A., Parent,J & Perlin, M. (2005). The Dynamics of Global Urban Expansion. Transport and Urban Development Department, The World Bank Washington D.C

Bello, A.L. (1993). Kaduna State. In Udo R.K. and Mamman A.B. (eds) (1993). *Nigeria Giant in the Tropics- State Surveys Vol. 2.* Lagos: Gabumo Publishers.

Bello, S. & Oyedele, E. (not dated). The City of Kaduna. In Ashiwaju, G., Enem U. & Abalagu U. (not dated) Cities of the Savanna (A history of some towns and cities of the Savanna) (eds): *Nigeria Magazine*

DFO (2003). Flooding On-Going Northern Nigeria and Central Nigeria, Kaduna, Kano, Jigawa and Niger States. http://www.dartmonth-edu/floods/2003232html. 1/12/08.

Floodplains (Not Date). Centre for Earth and Environmental Science, Indiana University - Purdue University, Indianapolis. http://www.cees.iupui.edu/edu. 26/01/2013.

Fundamentals of Remote Sensing (not dated) A Canada Centre for Remote Sensing Tutorial Natural Resources Canada

Ishaya, S. Ifatimehin, O.O. & Okafor, C. (2008). Remote Sensing and GIS Applications in Urban Expansion and Loss of Vegetation Cover in Kaduna Town, Northern Nigeria. *American- Euroasian Journal of Sustainable Agriculture Vol. 2 Number 2. pp 117 – 124.* http://209.85.173.132/search.

Jat, M. K., Garg, P.K & Khare, D (2008) Monitoring and Modelling of Urban Sprawl Using Remote Sensing and GIS Techniques. *International Journal of Applied Earth Observation and Geoinformation Vol. 10 Issue 1 pp26-43*

Liu, J, Zhan, J & Deng, X. (2005). Spatio - Temporal Patterns and Driving Forces of Urban Land Expansion in China during the Economic Reform Era *AMBIO: A Journal of the Human Environment Vol.34 Issue 6 pp 450 – 455.*

Ndabula, C. (2006). Assessment of Landuse/ Landcover Changes in Kaduna Metropolitan Area using Remote Sensing and Geographic Information System.. Unpublished Msc Thesis, Department of Geography, Ahmadu Bello University, Zaria.

NPC (1991) Census 1991 Final Results, Kaduna State

Oyedele, O. E. (1987). Colonial Urbanization in Northern Nigeria: Kaduna 1913-1960. Unpublished Ph.D Thesis, Department of History, Ahmadu Bello University, Zaria.

Primer on Natural Hazard Management in Integrated Regional Development Planning (1991). Department of Regional Development and Environment Executive Secretariat for Economic and Social Affairs Organization of American States, Washington, D.C.