Original Research Article

Geospatial Analysis of Urban Expansion and Its Impact on Vegetation Cover in Kaduna Metropolis, Nigeria

Abstract

Cities world-wide are experiencing rapid spatial growth and cities in the less developed countries are already accounting for more of this growth. If such rapid growth is unplanned and uncontrolled, it would have adverse effect on the environment and in most cases, vegetation is highly endangered. Such removal of vegetation cover causes great harm to the ecosystem and contributes greatly to the global warming effect. The aim of this paper is to analyze urban expansion and its impact on vegetation cover in Kaduna metropolis, Nigeria using geospatial techniques. Landsat MSS imagery of 1973, Landsat TM image obtained in 1990, Landsat ETM+ data of 2001 and Nigerian Sat-1 image (2009) were used. Visual interpretation method was used to sort the various datasets into land use/cover classes. The built-up area and vegetation cover were extracted and the rates of change were ascertained for each of the landcover types. ILWIS 3.3 software was used for the analysis. The results show that the built-up area increased from 14.3% in 1973 to 44.1% in 2009. The city was growing at the rate of 5.72% per annum within the period studied. Within the same period, 81.8% of the vegetation cover was lost at an annual rate of 2.3%. The regression analysis revealed a strong positive correlation between increase in built-up land and vegetation loss at 0.175 significant level. The R value of 0.825 and R^2 of 0.680 suggests that 68.0% of the vegetation loss in the area was accounted for by built-up. At this rate of vegetation loss and urban expansion, the city may be stripped bare of almost all her vegetation cover within the shortest possible time if no adequate control measure is put in place. This paper recommends: i) the application of geospatial techniques for proper planning and development of Kaduna and other cities ii) proper monitoring of the pattern of urban expansion proper decision making on the planning process.

Keywords: Urban; Expansion; Cities; Vegetation; Geospatial

Introduction

The rapid rise in the number and severity of environmental problems has become a threat to all societies. The unrestrained destruction of natural resources for the purpose of development is posing serious threats to the world and has already taken a stern toll on the ecosystem. In particular, the rapid growth of the urban population is putting great pressure on the urban infrastructure and also resulting in uncontrolled growth (Badshah, 1996).

Urban land expansion is commonly referred to as the spreading out of a city and its suburbs toward non built-up areas at the periphery of an urban area. This process involves the conversion of other land use categories into built-up developed land over time. According to Environmentalists, the actual amount of urbanized land is an important overall measure of urban land expansion (Liu, Zhan & Deng, 2005).

Cities in the world are experiencing rapid spatial expansion mainly due to rapid population growth, economic development and infrastructure initiatives (Torrens & Alberti, 2000; Barnes *et al*., 2001; Epstein *et al*., 2002 in Jat,& Khare, 2008). In the year 2000, urban built-up area in the world consumed about 400,000 square kilometers, amounting to about 0.3% of the total land area of the globe (Angel, *et al*, 2005). This is projected to reach 1,100,000 (about 0.85%) by 2030 if the sane growth rate is sustained. The authors pointed out that cities in the less developed countries would account for more of this growth. If such growth is not properly planned and controlled, it would have adverse effect on the environment; destroying natural resources and disrupting the ecosystem and consequently, leading to different forms of hazards with attendant consequences on both human and natural environment. In most cases, vegetation is at greatly endangered. Schlein, De Capua and Kruger (2007) noted that the environmental impact and susceptibility to various forms of environmental hazards increase as urban areas continue to grow in their spatial extent particularly, if the growth is not adequately planned and monitored.

Vegetation refers to the plant cover of the earth; and it displays patterns that reflect a wide variety of environmental characteristics and temporal aspects operating on it (Kumi-Boateng, Boye & Issaka, 2012). The authors noted that this is because it supports critical functions in the biosphere by regulation the flow of numerous biochemical cycles like that of water, carbon and nitrogen; it is also of immense importance in local and global energy balance. Adekeye (2001) as well as David and Mark (2005) pointed out that vegetation also has strong effect on soil characteristics which includes soil fertility, chemistry and texture.

Vegetation in a city sometimes signifies the presence of nature in the predominantly Man- made environment. Urban vegetation is vital for sustainable development, environmental conservation

and urban planning process of a city (Rahman, 2009 in Rahman. Hasan. Islam & Maitra. 2011). However, this is the most endangered component of the ecosystem the world over and Nigeria in particular.

Deforestation rate or loss of vegetation in Nigeria is about 3.5% which implies a loss of 350,000–400,000 hectares per annum (Adesina *et al* 1999; Ladipo,2010). Between 1990 and 2005 alone, Nigeria lost 21% of her forests (Ladipo, 2010). Much of the vegetations have been deliberately removed for infrastructural development, fuelwood, mineral exploration and expansion of settlements (Adesina, 2005). For instance, Akpu (2002) discovered that the rapid growth of Abuja led to encroachment of residential land use (built-up) on areas designated for other uses particularly Green areas, open space, park and recreational land uses. The residential area in Wuse II deviated from the Masterplan by 38.89% while 50.0% of the land allotted to Green Areas had been lost to built-up at 2002. Similarly, Ujoh, Kwabe and Ifatimehin (2011) discovered that while built-up area increased, vegetation cover decreased at an alarming rate in and around Nigeria's Federal Capital City, Abuja. According to them, the Vegetation in the area decreased from 31.02% in 1987 to 12.19% in 2006 whereas, Built-up increased from 8.83% in 1987 to 42.6% in 2006. Akpu and Adamu (2007) unveiled that the unguarded expansion of Zaria has resulted to the loss of Green Areas. Between 1976 and 2006 the Green Area reduced from 55.86 hectares to 46.54 hectares; reducing at the rate of about 0.5hectares per annum.

As the vegetation is removed, so too is the biodiversity. It implies destruction of wildlife habitat, depreciation or outright wiping off of genetic pool, loss of food and medicinal herbs as well as promotion of desertification, pollution, erosion and drought (Adesina, 2005; Ladipo,2010). The long term effects of vegetation depletion on climate, soil conservation and hydrological regimes cannot be over emphasized (Principles of Remote sensing). Deforestation or vegetation loss contributes about 1.6billion metric tons of carbon to the atmosphere per year thereby, increasing atmospheric carbon dioxide (Co_2) which is a major contributor to atmospheric green house effect. These green house gasses tend to absorb and re-emit radiation thereby, warming the atmosphere, or increasing the average global temperature of the atmosphere near the earth surface (Botkin & Keller, 2005).

Kaduna metropolis has got its fair share of rapid unguarded spatial expansion with adverse implications on the ecosystem which includes vegetation loss. For instance, as much as 3,272.3ha of vegetation cover in Kaduna metropolis was lost to urban transformation between 1990 and 2000 at an annual rate of 297.5ha (Ishaya, Ifatimehin & Okafor, 2008).

Despite the great pressures on vegetation resources due to rapid urbanization, there are management issues following the inadequate information on the condition of vegetation cover (Adesina, 2005) particularly in developing countries like Nigeria. Remote Sensing and Geographic Information System are ideal for forest management. Remote sensing brings together a multitude of tools to better analyze the scope and scale of the deforestation. It also provides a unique perspective of how cities evolve; it can be used to classify landuse in an economic and repetitive manner over large areas (Principles of Remote Sensing, not dated). Geographic Information System (GIS) has the unique capabilities to integrate data from different sources, manage, analyze, and output information at will. Hence, these technologies are powerful for effective monitoring and controlling of rapid urban expansion and vegetation loss. Hence the need for this paper to analyze the impact of the spatial growth of Kaduna metropolis on the vegetation cover in the area using geospatial techniques. In the light of this, the specific objectives are to: i) determine the extent and rate of spatial growth of Kaduna city between 1973 and 2009; ii) determine the extent and rate of vegetation loss in Kaduna city between 1973 and 2009; and analyze the extent to which the spatial growth of the city is responsible for vegetation loss.

The Study Area

Kaduna got her name from River Kaduna which was traditionally known as *kogin kadduna* in hausa meaning “river of crocodiles”. This name 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 (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.

Kaduna lies under the Tropical Continental climate and experiences seasonal alternation of moist maritime air mass and dry continental air mass. The rainy season begins in April and lasts till October while the dry season (hamattan) spans from November to March (Bello, 1993). The temperature is high throughout the year attaining its 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).

Kaduna lies under the northern guinea savanna vegetation belt with scattered trees and woody shrubs as well as extensive grass cover. The dominant grass species include *Aristida, pennisetum, Ctenium and Andropogon* while *Isobelina, Terminalia and Acacia* are the dominant tree species (Olomode, 2002). The trees are deciduous, in other words, they shed their leaves during the dry season in order to cope with the long dry season (Bello, 1993). However, the vegetation cover is declining mainly in favor of physical development due to rapid urbanization and expansion of the city.

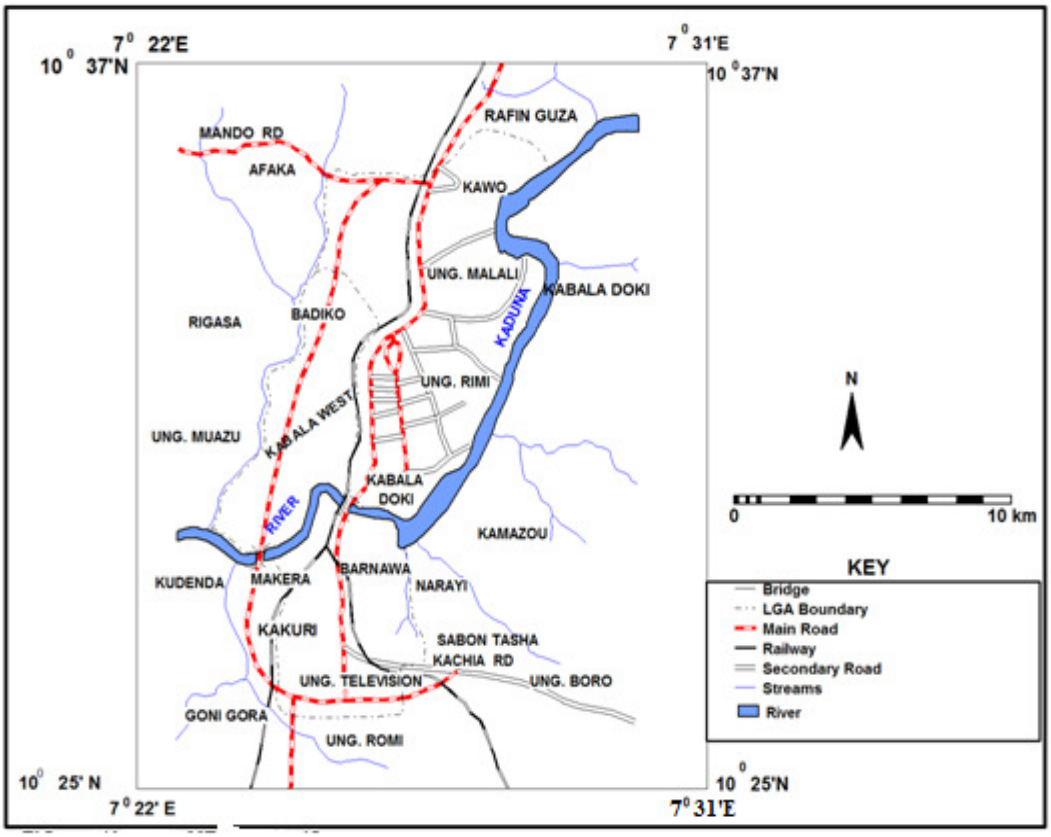


Fig. 1 Kaduna Metropolis

Source: Modified from Kaduna Environmental Protection Agency

The 1991 census puts the human population of Kaduna metropolis at 971,070 which comprised 515,373 males and 455,697 females (NPC, 1991). The population of the city was projected to reach 1,729,142 (917,702 males and 811,440 females) in 2012 (Akpu, 2012). The movement of the West African Frontier Force (WAFF) 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.

Materials and Method

Satellite imageries of four time periods were used for the study thus: Landsat MSS imagery of 1973; Landsat TM captured in 1990; Landsat ETM+ of 2001 and Nigeriasat-1 image of 2009 with spatial resolution of 80m, 30m, 30m and 32m respectively. The imageries were used to generate the built-up and vegetation layers. Subsetting of the area of interest (AOI) (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 corrections. 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 to make it possible for overlay and other GIS operations to be carried out.

Visual or manual image interpretation technique interpretation method was used to identify the targets and sorted them into classes where they most suitably fit with the aid of elements of image interpretation and knowledge of the study area. The landuse/cover 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. The built-up and vegetation classes for the four time periods were extracted from the classified images in order to determine the spatial growth of the city and changes in vegetal cover. The percentage change between 1973 and 1990 was calculated assuming that the landuse in 1973 was 100%. The extent and rate of vegetation change was determined for the period of study using the same procedure. Linear regression was also used to establish the actual relationship between spatial growth and vegetation loss with the built-up value as the independent variable (predictor) while vegetation was the dependent

Results and Discussion

The results of the analysis are presented in tables and maps. The extent and rate of urban

Expansion is shown in table 1 while table 2 presents the extent and rate of vegetation change.

Extent and Rate of Spatial Growth

The analysis of the satellite imageries shows the extent and rate of the spatial growth of Kaduna Metropolis between 1973 and 2009. This is presented in Table 1 .

Table 1
Extent and Rate of Urban Expansion in Kaduna Metropolis

Period	Year	Built-up (Ha)	Growth Increase		Arithmetic Mean (Growth Rate)	
			Ha	%	Ha/Year	%/Year
1973-1990	1973	6,410.4	3,691.0	57.6	217.12	3.4
(17years)	1990	10,101.4				
1990-2001	1990	10,101.4	2,864.0	28.4	260.4	2.6
(11years)	2001	12,965.4				
2001-2009	2001	12,965.4	6,741.8	55.0	842.7	6.9
(8years)	2009	19,707.2				
1973-2009	1973	6,410.4	13,296.8	207.4	369.4	5.8
(36years)	2009	19,707.2				

Source: Author's GIS Analysis, 2012

The results of the analysis as shown in Table 1 reveal that the 36 years period of study (1973-2009), shows that the built-up area increased from 6,410.4ha to 19,707.2ha indicating an increase of 13,296.8ha (207.4%). The annual growth rate within the period of study (1973-2009) was 5.8%. The period 2001-2009 recorded the most remarkable increase in built-up area with an annual growth rate of 6.9%. The high growth rate experienced this period could be attributed to one of the most severe post-crises periods that occurred in the area which was ethno-religious in nature. The crises prompted the mass movement of people to parts of the metropolis where they felt secured. There was also improvement in the wages of civil servants that period and consequently, a lot of people could afford to build their own houses. This mounted pressure on the land and consequently, built-up landuse increased to the detriment of other land cover types especially vegetation. Maps of the urban growth in shown in figure 2.

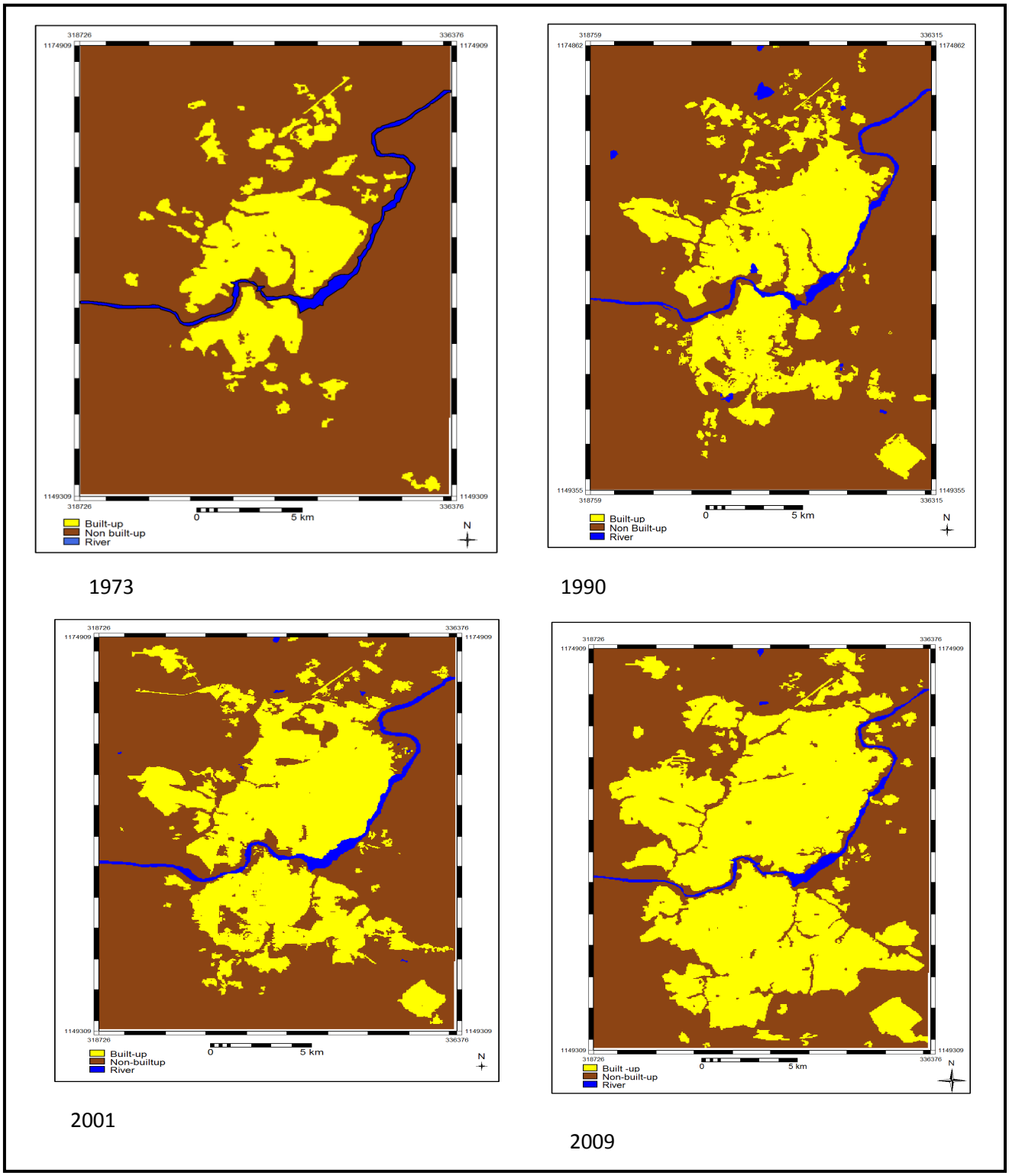


Fig. 2: Urban Extent of Kaduna Metropolis for 1973, 1990, 2001 &2009
Source: Authors' GIS analysis

Extent and Rate of Vegetation Change

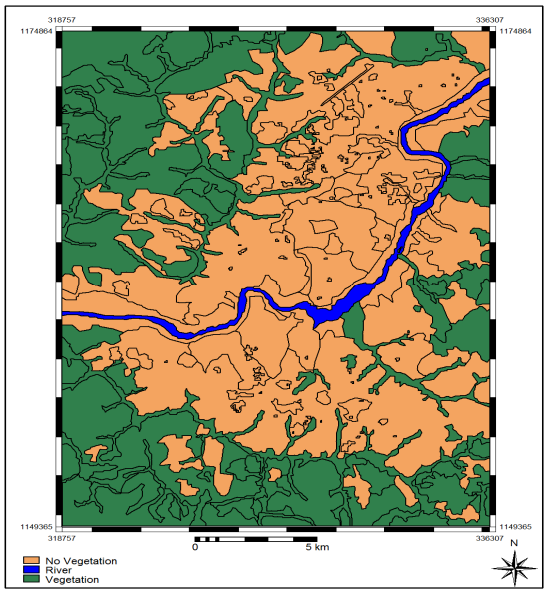
Urban trees perform a vital air-cleaning service by absorbing and filtering out air pollutants as well as removing carbon dioxide from the air through their leaves and storing carbon in their biomass (Yuan, 2008). The vegetation cover in the area had being experiencing decline due to increase in built-up or physical development. For the purpose of this study, vegetation comprises woodland/shrubland and riparian vegetation. Table 2 presents the extent and rate of vegetation change in the area over the period of study. The map of vegetation change is shown in figure 3.

Table 2
Extent and Rate of Vegetation Change

Period	Year	Vegetation Cover (ha)	Extent of Change		Arithmetic Mean (Rate of Change)	
			Ha	%	Ha/Year	%/Year
1973-1990	1973	19,323.9	-11750.4	-60.8	-691.2	-3.6
(17years)	1990	7,573.5				
1990-2001	1990	7,573.5	-314.1	-4.1	-28.6	-0.4
(11years)	2001	7,259.4				
2001-2009	2001	7,259.4	-3737.7	-51.5	-467.2	-6.4
(8years)	2009	3,521.7				
1973-2009	1973	19,323.9	-15802.2	-81.8	-439.0	-2.3
(36years)	2009	3,521.7				

Source: Authors' GIS Analysis,2012

The unplanned growth of the metropolis has resulted to the loss of vegetation cover. The built-up area is increasing mainly due to the conversion of vegetation cover and agricultural land. The high demand for both residential and commercial as well as other developmental structures has mounted great pressure on the land hence, the clearing of vegetation and agricultural land for physical development.



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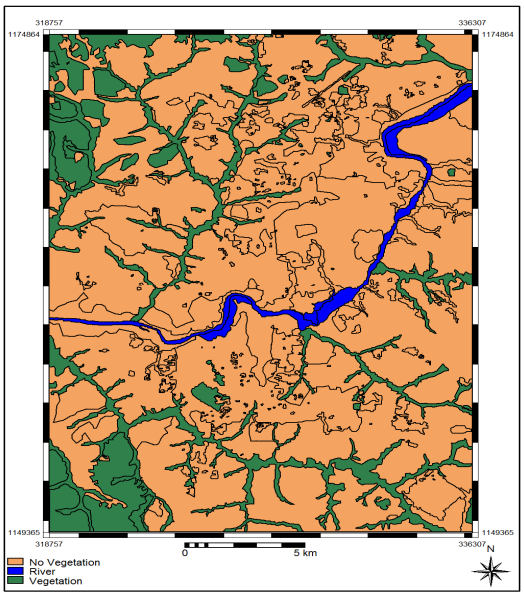

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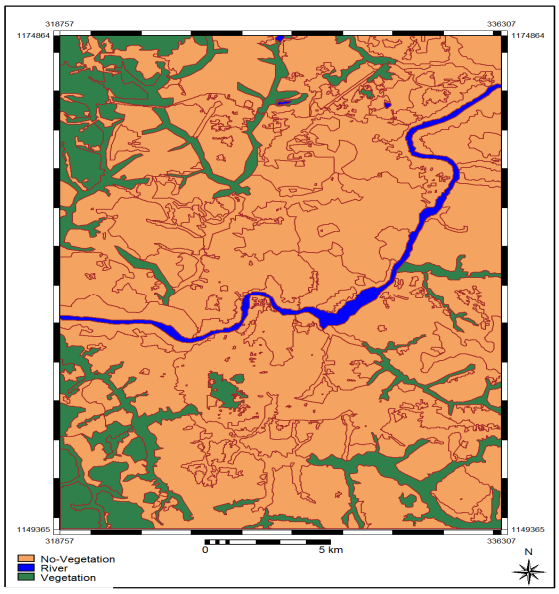

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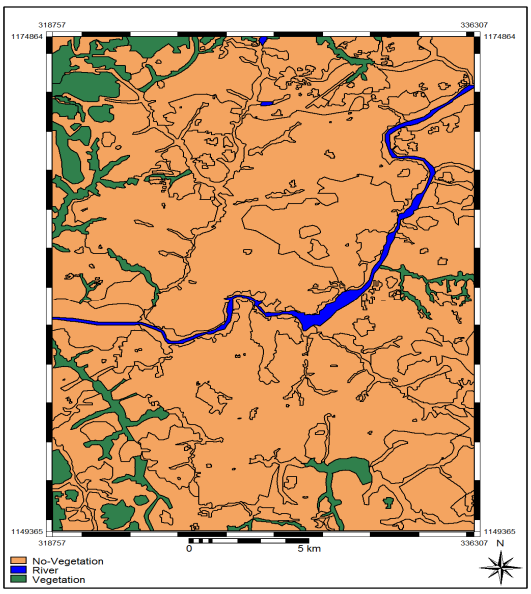

2009

Fig. 3 Vegetation Extent of Kaduna Metropolis for 1973, 1990, 2001 & 2009
Source: Authors' GIS Analysis

The analysis in Table 2 reveals that the period 2001-2009 which recorded the highest rate of spatial growth also shows the highest proportion of vegetation loss (51.5%) indicating an annual

loss rate of 6.4%. It can therefore, be assumed that the built-up is taking up the vegetated land including the agricultural land which is normally fragmented into plots and given out for physical development. Within the study period (1973 -2009), 81.8% of the vegetation cover was lost at an annual rate of 2.3%. If vegetation loss continues at this rate without adequate control measure, the city may be stripped bare of almost all her vegetation cover within the shortest possible. Fig. 4 shows the trend of urban growth and vegetation loss. As the built-up increased sharply between 1973 and 1990 by 57.6%, vegetation declined by 60.8%. Also, as urban growth dropped between 1990 and 2001, vegetation loss reduced as well. The period 2001-2009 saw another rise in both urban growth and vegetation loss.

Vegetation varies between the northern and southern parts of the metropolis as shown in Table 3.

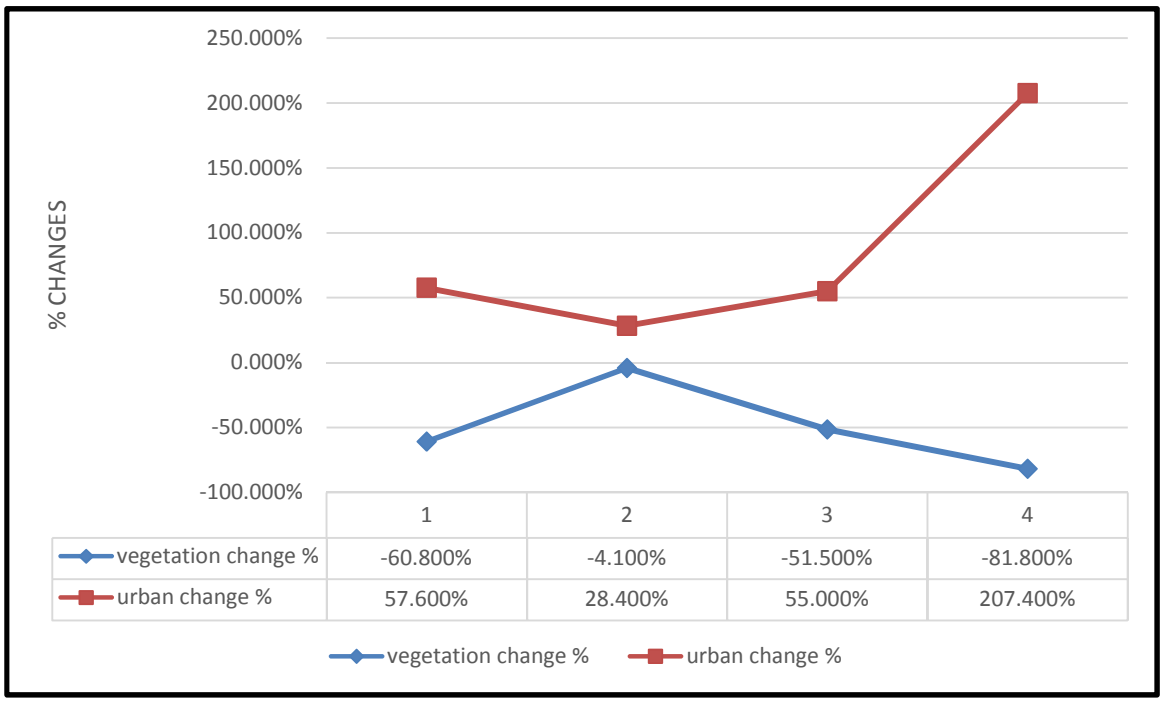

Fig. 4 : Relationship between Urban Expansion and Vegetation Loss in Kaduna
Source: Authors 'analysis, 2012

Table 3

Extent of Vegetation Change in the Northern and Southern parts of the Metropolis

Zones	Period	Year	Vegetation Cover (ha)	Extent of Change		Arithmetic Mean (Rate of Change)	
				Ha	%	Ha/Year	%/Year
North	1973-1990	1973	8951.7				
	(17years)	1990	4006.5	-4945.2	-55.2	-290.9	-3.2
	1990-2001	1990	4006.5				
	(11years)	2001	3393.2	-613.3	-15.3	-55.8	-4.8
	2001-2009	2001	3393.2				
	(8years)	2009	2072.5	-1320.7	-38.9	-165.1	-4.9
	1973-2009	1973	8951.7				
	(36years)	2009	2072.5	-6879.2	-76.8	-191.1	-2.1
South	1973-1990	1973	10372.2				
	(17 years)	1990	3567.0	-6805.2	-65.6	-400.3	-3.9
	1990-2001	1990	3567.0				
	(11years)	2001	3866.2	299.2	8.4	27.2	0.8
	2001-2009	2001	3866.2				
	(8years)	2009	1449.5	-2416.7	-62.5	-302.1	-7.8
	1973-2009	1973	10372.2				
	(36years)	2009	1449.5	-8922.7	-86.0	-247.9	-2.4

Source: Authors' GIS Analysis, 2012

According to the analysis in table 3, vegetation cover greatly declined in both the northern and southern parts of the city. However, the southern part witnessed higher loss in vegetal cover amounting to 8,922.7ha (86.0%) as against 6,879.2ha (76.8%) in the northern part. The period 2001-2009 had the highest annual rate of vegetation loss in both the northern (-4.9%) and southern (-7.4%) parts of the city. This coincided with the period of highest increase in built-up or physical development. The vegetation loss that period was higher in the south than the north. Within the study period, the rate of vegetation loss was slightly higher in the south (-2.4%) than the north (-2.1%). This can be explained partly by the higher physical development in the area partly due to the influx of people into the area that period.

The regression analysis revealed a strong positive correlation between built-up land and vegetation loss at 0.175 significant level. The R value of 0.825 and R^2 of 0.680 suggests that 68.0% of the vegetation loss in the area was accounted for by built-up (Table 4). In other words, as built-up area increases, vegetated surface declines.

Table 4

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.825[a]	.680	.520	10.13169	.680	4.246	1	2	.175

a. Predictors: (Constant), BU

Source: Author's Analysis

Some previous studies show a similar trend. For instance, the study by Lin, Lin, Wang and Hong (2008) discovered that the increase of built-up land in Paochiao watershed in Taiwan led to the decline of vegetation between 1990 and 2000. The increase in built-up land led to about 8% decline in vegetated surface in the SW part of Mexico City between 1973 and 1992; by the year 2000, the vegetation cover and cropland further declined in favor of urban land (Torres-Vera, Prol-Ledesma, & Garcia-Lopez 2009). Also, the study by Akpu (2002) which discovered that the residential area in Wuse II, Abuja deviated from the Masterplan by 38.89% while 50.0% of the land allotted to Green Areas had been lost to built-up at 2002. Ujoh, Kwabe and Ifatimehin (2011) which shows that the Vegetation in and around Nigeria's Federal Capital City, Abuja decreased from 31.02% in 1987 to 12.19% in 2006 whereas, Built-up increased from 8.83% in 1987 to 42.6% in 2006. Again the work by Akpu and Adamu (2007) revealed that the unguarded expansion of Zaria has resulted to the loss of Green Areas. Between 1976 and 2006 the Green Area reduced from 55.86 hectares to 46.54 hectares; reducing at the rate of about 0.5hectares per annum. The consequences of such indiscriminate removal of vegetation cover may include erosion, air pollution and increased carbon in the atmosphere with their adverse effects like global warming.

Conclusion and Recommendation

The study shows that the 36 years period of study (1973-2009), shows that the urban landuse increased by 13,296.8ha (207.4%) with an annual growth rate 5.8%. On the contrary 81.8% of the vegetation cover in the area was lost at an annual rate of 2.3% within the study period. The period 2001-2009 recorded the highest increase in built-up area as well as the most remarkable decline in vegetation cover. The study shows that as the urban landuse increases, the vegetated area declines. About 68.0% of the vegetation loss in the area was accounted for by urban expansion, specifically physical development.

Based on the findings of this paper the following: are recommended

a. The application of geospatial techniques for proper planning and development of Kaduna and other cities. This is because these technologies have the capability to capture data from different spectral bands repeatedly over time, penetrate inaccessible areas, obtain up-to-date data over large area at a relatively low cost. They can also integrate data from different sources, analyze and output results in real time.

b. Proper monitoring of the pattern and rate of urban expansion. This will help to make the right decisions on the urban planning process in order to achieve sustainable development.

c. The environmentalists and other stakeholders should enlighten the people on the dangers of deforestation through campaigns using various media like the mass media. It should also be stressed in the school curriculum beginning from the primary level.

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