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The impact of urbanization on vegetation cover in Nigeria's Federal Capital Territory: A case study

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Since Abuja became Nigeria's Federal Capital Territory in 1976; it has been experiencing rapid expansion, urbanization and significant changes in its physical landscape. This study used Remote sensing and GIS techniques to identify, mark and measure the extent of change in the various land uses from the Landsat imageries of 1987 and 2001, and Nigeriasat-1 imagery of 2006. The study revealed that while built- up area increased, vegetation cover decreased at an alarming rate. Using population figures of the study area for 1987, 2001 and 2006, the Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC) were determined. Increasing population and expansion in the Federal Capital City (FCC) resulted in land degradation including loss of vegetal cover, indiscriminate waste disposal, contamination of surface water, etc. now clearly visible in the FCC. In view of the important role that vegetation plays as a carbon sink, policy-makers are requested to strictly enforce the existing laws on afforestation and parks establishment and other measures, within and around the FCC in order to achieve a sustainable urban growth and development.

Key words: Urbanization, habitat fragmentation, land consumption rate, land absorption coefficient, landuse/cover change.

INTRODUCTION

Since humans have controlled fire and domesticated plants and animals, they have cleared forests to wring higher value from land. Thus, about half of the ice-free land surface has been converted or substantially modified by human activities over the last 10,000 years (Population Reference Bureau, 2001; Mittermeier, 2003). Some studies have shown that there remain only few landscapes on the earth surface that is still in their natural state (Fasal, 2000; FAO, 2003a). This is due to natural processes and disasters, as well as intense pressure from anthropogenic activities such as deforestation, urbanization, intensive agriculture and mineral exploitation (CARPE, 2003; FAO, 2003b; Lambin et al., 2003; Ndjomo, 2008; Sarma et al., 2008). Living conditions deteriorate continually, particularly in cities of

the developing countries. This is due to poorly planned human interference and limited access to adequate information and appropriate technology. Hence, in order to effectively monitor settlement growth, it is not only necessary to have the information on existing land use land cover but also the capability to monitor the dynamics of land use resulting out of both changing demands of increasing population and forces of nature acting to shape the landscape.

Conventional ground methods of land use mapping are labour intensive, time consuming and are done relatively infrequently. Indeed, Olorunfemi (1983) argues that monitoring changes and time series analysis is quite difficult with traditional method of surveying. Therefore, efforts to improve, conserve and protect the environment will include not only the resolution of political policies but also the application of a state-of-the-art scientific approach to planning and implementation. In recent times, viewing the earth from space has become crucial to the understanding of the influence of man's activities

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on his natural resource base over time. In situations of rapid and often unrecorded landuse change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from earth remote sensing satellites have become vital in mapping the earth's features and infrastructures, managing natural resources and studying environmental change (Arimoro et al., 2003). Satellite Imagery, which is acquired through Remote Sensing (RS), and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of earth-system function, patterning, and change at local, regional and global scales over time (Rajeshwari, 2006). Such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and sustainable management of bio-diversity (Wilkie and Finn, 1996).

Urban expansion, LULC change and vegetal cover loss in Nigeria

LULC change studies have become a central component in current strategies for managing natural resources and monitoring environmental changes. Thus, providing an accurate evaluation of the spread and health of the world's forest, grassland, water, and agricultural and land resources has become an important priority (Mengistu and Salami, 2007). Land Use/Land Cover (LULC) changes are products or outcome of prevailing interacting natural and anthropogenic (socio–economic) factors (Fagbeja, 2000; Fashona and Omojona, 2005) and their utilization by man in time and space (Clevers et al., 2004). LULC change is therefore, central to environmental processes, environmental change and environmental management through its influence on biodiversity, water budget, radiation budget, trace gas emissions, carbon cycling, livelihood (Verburg et al., 2000; Verburg et al., 2004), urban expansion and loss of vegetal cover (Ifatimehin and Ufuah, 2006), agricultural land loss (Lambin et al., 2003; Ujoh, 2009), and a wide range of socio- economic and ecological processes (Desanker et al., 1997), which on the aggregate affects global environmental change and the biosphere (Fashona and Omojona, 2005).

Studies on settlement expansion have now become a central component in current strategies for managing land as a resource and in monitoring environmental changes. Settlements represent the most profound human alteration of the natural environment through a spectrum of urban land use activities (Ifatimehin and Ufuah, 2006) which include, but are not restricted to, transportation, commercial, industrial, residential, institutional, and recreational land uses. The expansion that ensues as a result of increase in the demand for

these land uses explains the underlying and fundamental cause of urban expansion which is population increase. Urbanization is the process that refers to the growth both in size and numbers of urban centres. This growth has been phenomenal from the turn of the 20th century (UNCHBP, 1974; Lambin et al., 2003; EEC, 2006; Ifatimehin and Musa, 2006), especially in developing countries such as Nigeria.

In pressured environmentally sensitive and ecologically important regions, there is a continuing need for up-to-date and accurate land cover information that can be utilised in the production of sustainable land use policies. The importance of vegetation in the environment is underscored by the role it plays as a major carbon sink. Therefore, this study would attempt to map the status of LULC of Abuja, Nigeria's Federal Capital City over a 20-year period (1987- 2006) with a view in estimating the rate of vegetal cover that has been lost due to urban expansion, as well as the consequences of this development, an understanding of which would aid in developing policies that would ensure sustainable use of the environment of the study area.

MATERIALS AND METHODS

The study area

Abuja, Nigeria's Federal Capital Territory, is located almost at the centre of the country (Figure 1) on Latitude 8° 25" and 9° 25" North of the equator and Longitude 6° 45" and 7° 45" East of the Greenwich. The Federal Capital City (FCC) is located on the north-eastern part of the FCT. According to Mabogunje (Mabogunje, 1976), the area is considered as the most ideal and conducive for human habitation and settlement development within the FCT. The area is characterized by a hilly, dissected terrain and is the highest part of the FCT with several peaks that are 760 m above sea level (Balogun, 2001). The geology of the area is underlain by basement complex rocks. The annual rainfall is highest within the FCC and its environs which is about 1,631.7 mm. The annual mean temperature ranges between 25.8 and 30.2°C (Balogun, 2001). The soils of the study area are basically alluvial and luvisols. The FCC is rich in infrastructure such as expanding road network, electricity, drainage and sewage systems and piped water as well as facilities such as hospitals, schools, libraries, social and recreational centres, etc. The city is the administrative headquarters of all government parastatals and extra-ministerial agencies, and seat of government.

Data used and source

This would be done through the use of remotely sensed data and Geographic Information System (GIS) tools. Landsat satellite images of the study area were acquired for two epochs (1987 and 2001); and Nigeriasat-1 image of 2006. The 1987 and 2001 images were obtained from Global Land Cover Facility (GLCF), an Earth Science Data Interface, while the Nigeriasat-1 image of 2006 and Nigeria's Administrative map were obtained from the National Space Research and Development Agency, Abuja. The population of the FCC for 1987 was acquired from http://www.nationsencyclopedia.com/Africa/Nigeria/POPULATION.html#ixzz0VXllf89e, while that of 2001 was obtained from estimates of the United Nations. The 2006 population figures were sourced
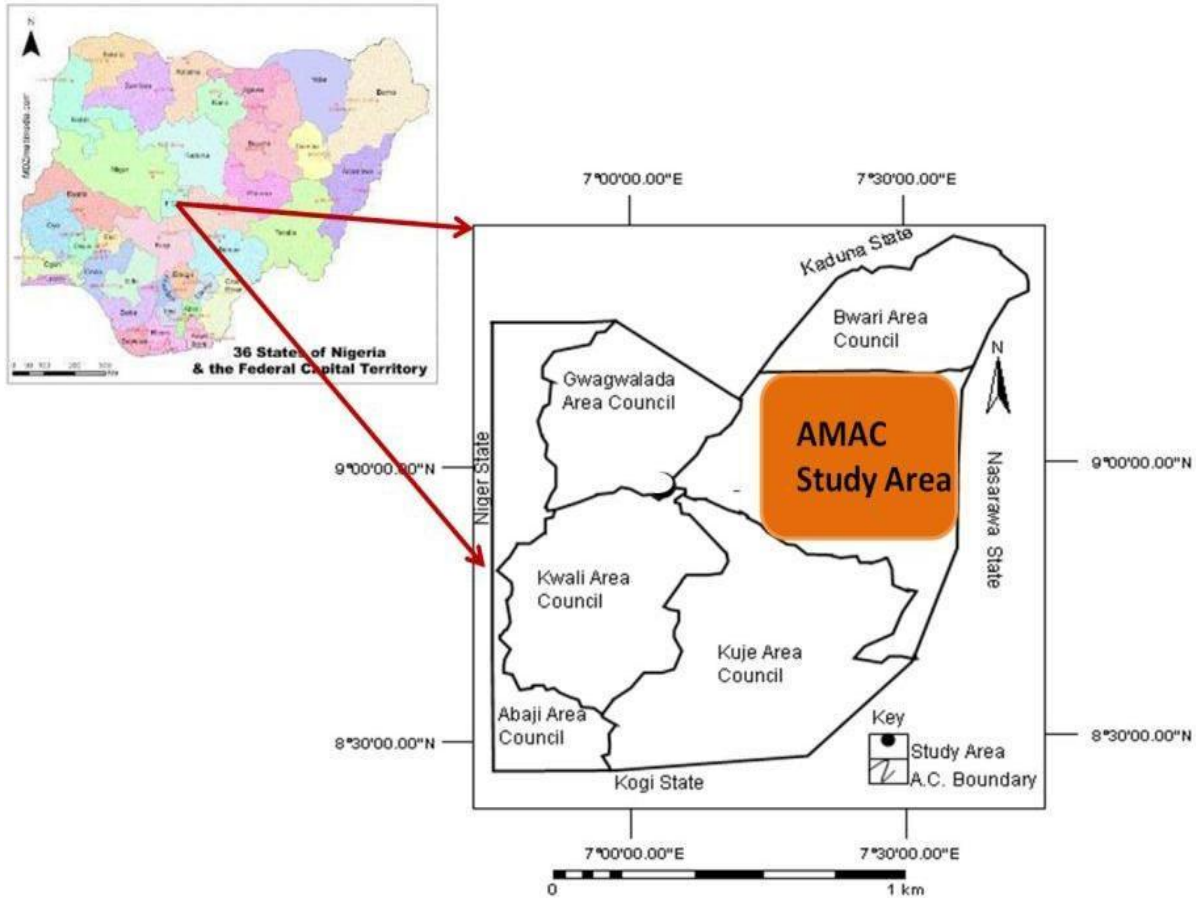
Figure 1. Location of the study area in Nigeria.

from the 2006 National Population Census.

Software used and source

ILWIS 3.2 Academic version image classification software was used in classifying the 3 images of the study area. The software was obtained online free from www.ilwis.com. Microsoft Office package was used for presenting the work.

Methods of data analysis

The algorithm for digital data analysis is shown in Figure 2. Other methods of data analysis adopted in this study include:

(i) Maximum likelihood classifier algorithm,
(ii) Calculation of the area in hectares of the resulting land use/land cover types for each study year and subsequently comparing the results. Thus, the percentage change to determine the trend of change was calculated by the formula given below:

Trend (% change) = (Observed change / Sum of change) × 100

(iii) Construction of a matrix showing the transformation (gains from and losses to other land use categories) between the land use categories of the various study epochs, and

(iv) Calculation of the Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC). The LAC is a measure of change in consumption of new urban land by each unit increase in urban population while the LCR is the measure of compactness which indicates a progressive spatial expansion of a city (Yeates and Garner, 1976).

RESULTS AND DISCUSSION

LULC change in the FCC

An important aspect of change detection is to determine the quantity of change. This information will serve as a vital tool in management decisions. The LULC of the study area had undergone significant changes over time. The classification and quantification of the images of the study area aided the detection of changes in the various LULC that took place over the study period. The static LULC distribution for 1987, 2001 and 2006 is shown on Table 1. The table reveals that as at 1987, vegetation and cultivated land constituted the largest landcover categories in the FCC (258.62 km^2 and 212.43 km^2, respectively), collectively occupying an area of 471.05 km^2 (representing 56.5%) of the total landcover of the
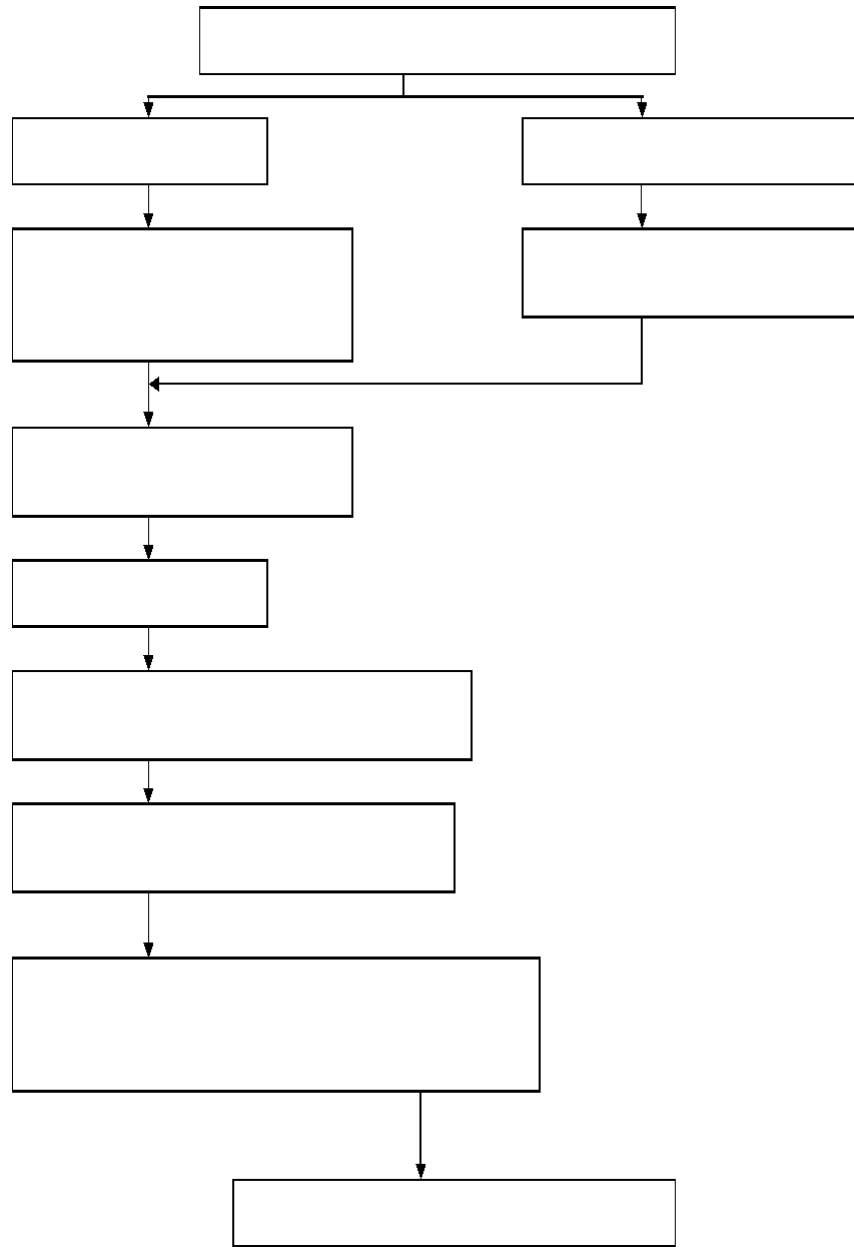
Figure 2. Flow diagram of digital image processing.

study area. Built-up area was the least visible land cover type in the study area with 73.6 km^2 (representing 8.83%). The other landuse categories which include bare surface and wetland vegetation occupied 136.45 km^2 (or 16.37%) and 152.61 km^2 (or 18.3%), respectively.

By 2001, there was a significant shift in the distribution of LULC of the FCC. Built-up area increased while all other landcover types (except for vacant land) experienced significant loss between 1987 and 2001. The least occurring landcover type in 2001 shifted from built-up area to wetland vegetation. Consequently, the annual rate of gain in built-up area between 1987 and 2001 was

12.91 km^2, while the total built-up area gained within the same period (14 years) was 180.8 km^2 (Table 2). This indicates that there was rapid urban growth consequent upon the expansion in built-up area which includes residential and official buildings, shopping malls and plazas, infrastructure and facilities such as schools, hospitals, recreational parks and gardens, etc. Note: Figures in bold (diagonally) represent area under that particular landuse in 1987, while figures in the same column represent the shift in area to other landuses. Similarly, figures in the same row are increase in area captured from the landuses.

Table 1. LULC Distribution of the FCC in 1987, 2001 and 2006.

Code	LULC categories	1987		2001		2006	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area(km^2)	Area (%)
CL	Cultivated land	212.43	25.48	177.08	21.24	104.40	12.52
BUA	Built-up area	73.60	8.83	254.40	30.51	355.04	42.6
BS	Bare surface	136.45	16.37	155.37	18.64	202.50	24.3
VG	Vegetation	258.62	31.02	175.10	21.00	101.61	12.19
WV	Wetland vegetation	152.61	18.3	71.68	8.6	69.29	8.31
	Total	833.71	100	833.71	100	833.71	100

Source: Derived from classified satellite images (1987, 2001 and 2006) study area.

Table 2. Gain in built-up area of the study area between 1987 and 2001.

Year	Built-up area (km^2)	Gain in built-up area (km^2)		Time in years	Arithmetic mean gain (per year)
		km^2	%		
1987	73.60	180.8	245.65	14	12.91
2001	254.4				

Source: Classified Satellite Imagery of FCC for 1987 and 2001.

Table 3. LULC transformation in the FCC between 1987 and 2001.

LULC Categories	1987					2001
	Cultivated land	Built-up area	Bare surface	Vegetation	Wetland vegetation	
Cultivated land	**212.43**	140.07				177.08
Built-up area	143.79	**73.6**	96.23		80.93	254.4
Bare surface	31.63		**136.45**	83.52		155.37
Vegetation				**258.62**		175.1
Wetland vegetation					**152.61**	71.68

Source: Derived from classified satellite images of study area 1987 and 2006.

Table 3 shows the transformation between landuses, that is, changes from one landuse to another. Built-up area gained from cultivated land, bare surface and wetland vegetation. Vegetation lost to bare surface. The expansion in bare surface is due to the fact that vegetation is usually cleared in most situations while awaiting approval from the authorities before development of structures commences. Between 2001 and 2006, the pattern of LULC change shows that built-up area again gained from 254.4 km^2 in 2001 to 355.04 km^2 in 2006. Vegetation and wetland vegetation declined from 175.1 and 71.68 km^2 in 2001 to 101.61 and 69.29 km^2 in 2006, respectively (Table 1). The gain in built-up area of the FCC between 2001 and 2006 is 100.67 km^2 over the 5 year period (2001 - 2006). The annual rate of expansion translates to 20.13 km^2. The transformation of

LULC between 2001 and 2006 shows that built-up area gained 122.08 km^2 from cultivated land, while vegetation and wetland vegetation lost 73.49 and 2.39 km^2, respectively to cultivated land. It then means that as pressure is exerted on the surrounding cultivated land for construction purposes, vegetation and wetland vegetation suffers subsequently. Note: Figures in bold (diagonally) represent area under that particular landuse in 2001, while figures in the same column represent the shift in area to other landuses. Similarly, figures in the same row are increase in area captured from the landuses. Hence, a combination of the data on Tables 1, 2, 3, 4, 5 and 6 reveals that urban expansion between 1987 and 2006 has converted 281.47 km^2 of land from other landuses/cover. The false colour composite from the classified images of the study area for 1987, 2001 and
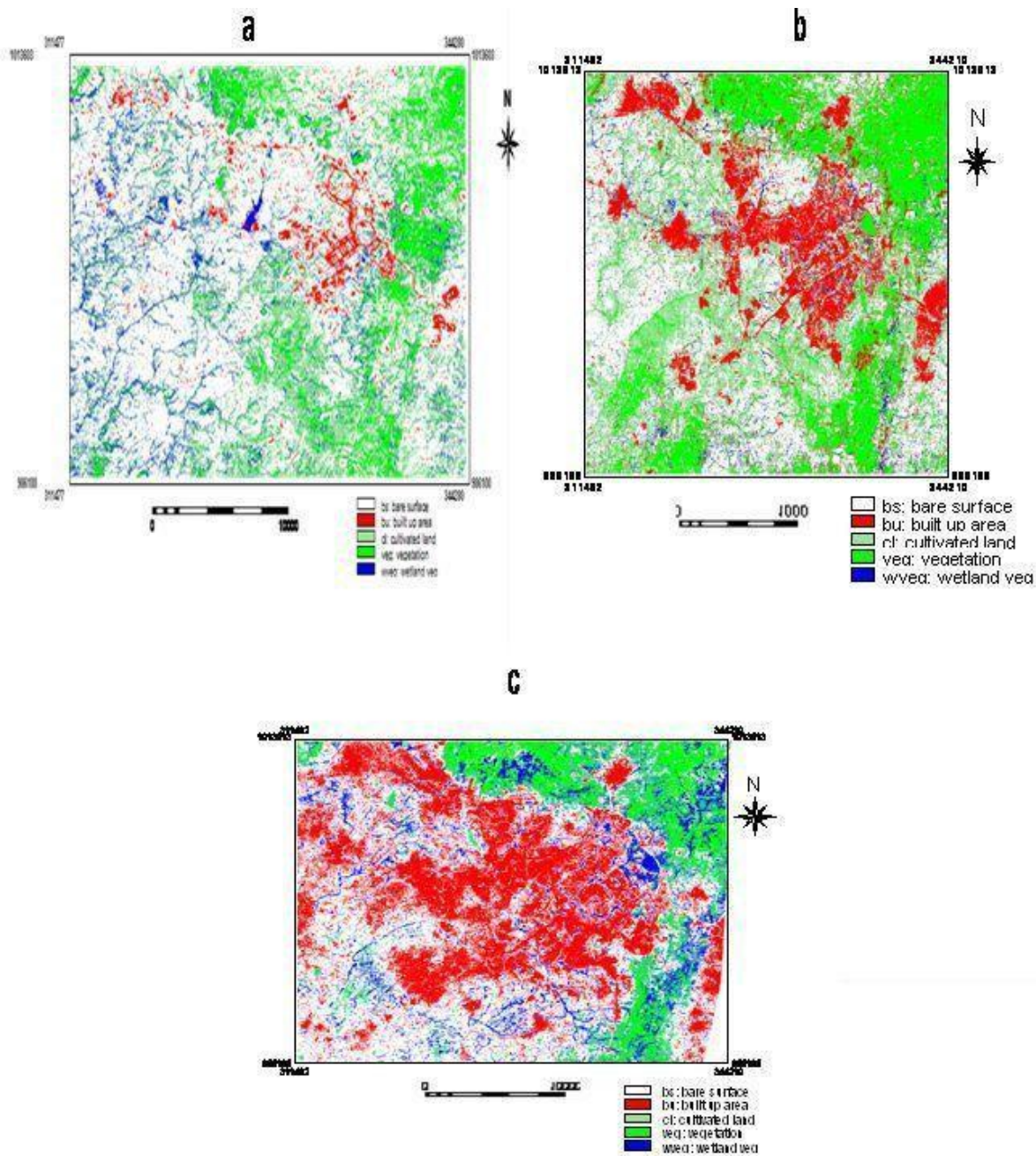
Figure 3. LULC Maps of FCC in: (a) 1987; (b) 2001; and (c) 2006.

2006 (Figure 3) also show the changes that have occurred in the LULC. It reveals that an expansion in the built-up area of the Federal Capital City.

LCR and LAC in the FCC

The LCR and LAC indicate expansion between 1987 and 2001, and decline between 2001 and 2006 (Table 7). The figures are in harmony with the figures of the static LULC

(Table 1). The FCC expanded by 21.68% between 1987 and 2001. However, the rate of expansion of the city between 2001 and 2006 declined to 12.09%. This can be attributed to the strict urban planning policies enforced by the Federal Capital Territory Administration (FCTA) between 2003 and 2007. During this period, the FCTA Minister, Ahmed Nasir el-Rufai embarked on the demolition of structures that were not provided for in the master plan. Also, efforts were intensified towards re-afforestation and greening of the city. Indeed, physical

Table 4. Gain in built-up area of the study area between 1987 and 2001.

| Year | Built-up area (km^2) | Gain in built-up area (km^2) | | Time in years | Arithmetic mean gain (per year) |
		km^2	%		
1987	73.60	180.8	245.65	14	12.91
2001	254.4				

Source: Classified satellite imagery of FCC for 1987 and 2001.

Table 5. Gain in built-up area of the FCC between 2001 and 2006.

| Year | Built-up area (km^2) | Gain in built-up area (km^2) | | Time in years | Arithmetic mean gain (per year) |
		Km^2	%		
2001	254.40	100.67	39.6	5	20.13
2006	355.04				

Source: Classified satellite imagery of FCC for 2001 and 2006.

Table 6. LULC Transformation in the FCC 2001-2006.

| LULC Categories | 2001 | | | | | 2006 |
	Cultivated land	Built-up area	Bare surface	Vegetation	Wetland vegetation	
Cultivated land	177.08			73.49	2.39	104.40
Built-up area	122.08	254.40				355.04
Bare surface	26.48	21.44	155.37			202.50
Vegetation			0.79	175.10		101.61
Wetland vegetation					71.68	69.29

Source: Derived from classified satellite images of study area 2001 and 2006.

Table 7. Population of the Federal Capital City.

Year	Population	Source	*LCR	Year	*LAR	*% Population increase
1987	15.000	NPC, 1991	0.5	1987-2001	0.05	2738.7
2001	410.809	Kwabe, 2010	0.06	2001-2006	0.02	52.7
2006	778.567	NPC, 2007	0.04			

*Source: Author's research analysis.

development of structures within this period was reduced as very stiff urban planning conditions had to be met before the commencement of construction. This saw a lot of people relocating outwards to the neighbouring Nasarawa state on the north eastern fringes of the FCC, and parts of Niger state.

Similarly, the city's population increased tremendously between 1987 and 2001, while the period between 2001 and 2006 witnessed a drastic drop in population expansion (Table 7). Again, the period of rapid population increase coincided with the period of the official movement of the Federal Capital of Nigeria from Lagos to Abuja (12 December, 1991). From 1991, the headquarters of all Federal Government Ministries, Parastatals, and extra-ministerial agencies were instructed to move to Abuja. This development marked

the beginning of an unprecedented influx of people of all walks of life into Abuja, the new Federal Capital. Consequently, the FCC witnessed increase in its population as it was the most habitable area in the entire FCT with suitable favourable weather condition and infrastructure for comfortable human existence at that time.

Implication of the results

Widespread alteration in the LULC of any given area (usually driven by a variety of social causes) result in changes that affect biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect micro-climate and alter the biosphere (Riebsame et al., 1994; Twumasi et al., 2004; Kelarestaghi et al., 2006; Ifatimehin, 2007). The extent and rate of LULC changes revealed by this study poses a significant regional disturbance/threat to the environment. As rightly observed by Pellika et al. (2007), some manifestations of these changes are beginning to be observed in the form of rapid disappearance of vegetation cover leading to significant decline in the amount of forestland, soil erosion, soil degradation, huge biodiversity losses, changes in micro-climatic conditions and unfavourable hydrological changes. Significant progress in the quantification and understanding of urban expansion-driven LULC changes in tropical regions has been achieved in recent times. However, much remains to be learned before we can fully assess and project the future role of LULC change in the functioning of the earth system and identify conditions for sustainable land use. Anthropogenic activities have been identified to cause changes that strongly interact with natural environmental variability, and therefore, result in severe damages to the environment and ecology of regions where urban land use is not well planned. These generally summarize the implication of the pattern observed in Abuja.

Conclusion and recommendation

The analysis above shows that urban expansion has been rapid within the FCC, at the expense of vegetal cover. The expansion has been observed to be radial like those observed in other capital cities such as Beijing and Tokyo (Liu et al., 2000; Sorensen, 2000). As earlier stated, in pressured, environmentally sensitive and ecologically important regions such as the study area, there is a continuing need for up- to-date and accurate land cover information that can be utilised in the production of sustainable land use policies. This study is one of such efforts aimed at providing information that would aid in developing sustainable urban land use policies in Abuja. This is necessary as the natural land cover of Abuja continues to be removed in ecologically

significant amounts for construction and other urban usage. Thus, the study recommends further research toward these synergetic factors driving land use changes in Abuja. In light of the need for more housing in Abuja, the study also recommends a review of the existing urban planning practices to include Strategic Environmental Assessment (SEA) for housing projects in Abuja where the overall impacts of large scale housing projects can be identified and mitigated accordingly. Lastly, high-rise housing units should be encouraged as against the single-unit bungalows that consume large land area with just a few thousand units. This is in addition to efforts towards creating environmental awareness with specific attention to urban land consumption. Buffer zones and parks within the city should be reclaimed, while aggressive re-greening of the city should be pursued with utmost vigour and the seriousness it deserves.

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APPENDIX I

Formula for deriving LCR and LAC

The LCR and LAC are a function of the following formula:

$$L.C.R = A/P$$

Where, A = areal extent of the city in hectares and P = population

$$L.A.C = (A2 - A1) / P2 - P1$$

Where, A1 and A2 = areal extents (in hectares) for the early and later years, P1 and P2 = population figures for the early and later years, respectively (Yeates and Garner, 1976).