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Assessing the Spatio-Temporal Rates and Extent of Land Use Changes in the Fringes of North Central Nigeria

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Abstract
The study analyzed spatial and temporal land use /land cover change in parts of north central Nigeria. This was carried out with the use of land sat images from 1974-2011. A hypothesis was put forward that there is no significant difference in the rate and extent of land use change among the cities under study from 1974 to 2011.The result shows that there is a significant difference in the rate of land use change in the fringes of the three cities under study, between 1974 and 2011,($F=1.481$, $p=0.025$, $p<0.05$). This significant change in land use is obvious from the result, since the F probability ratio is greater than the threshold value at 0.05 significant level. Thus, the change among the three towns in terms of their land use varied significantly. This has serious implication to planning.
Keywords: GIS, land use change; urban dynamics; land use pattern.

INTRODUCTION

According to Brockerhoff (2000) and Aleenjeet et al (2013), Urbanization is now a common feature of all third world countries. Primate cities and mega cities are emerging in developing countries. In Asia, Africa and Latin America, the unprecedented population growth that characterized much of the 20th century has evolved into unparalleled urban growth. The United Nations in 2009, estimates that between 2007 and 2025 the annual urban population increase in developing nations is expected to be over 53million (or 2.27 percent) compared to 3 million (or 0.49 percent) in developed nations. Predictions further show that many new megacities of over 10 million persons will emerge during the next few decades particularly in the developing nations (City alliance, 2009).

Urban land use change is the spatio-temporal reflection of urban growth. Correspondingly a broad range of techniques have attempted to explain these changes, these includes the Markov chain, Cellular automata (CA), multiple regression and logistic regression (Clarke and Gaydos, (1998); Batty et al (1999); Cheng and Masser (2003).

Urban growth has led to changes in the landscape pattern of various cities across the globe. International Geophere-biophere programme (IGBP) and the Global change in the humanities program (IHDP) in 1995 put forward the "Land use and land cover change" (LUCC) research project. This has since been seen as the essence of global change research in which spatio-temporal land use dynamics taps its goals. Literatures have since existed based on the development and methods of investigating geo–spatial information technology to investigate issues of LUCC such as change detection,(Mertens and Lambin (2000);Zhou et al (2002), Li and Zhou(2009), He et al (2000) and Zhang et al (2002) used multi-temporal remote sensing images to analyze LUCC in the metropolitan region of Beijing, where the result shows rapid expansion in the eastern district of Beijing. Zhou et al (2005) analyse land use structure using information entropy and balanced degrees in Shangai down town area in the past 50 years and modeled the urban spatial morphology of the fractal structure theory.

Remote sensing and GIS technologies have been widely used in land use change and urbanization studies. Using multi-temporal satellite image to detect land use/cover change and its spatio-temporal pattern has been proven an efficient approach (e.g Masek et al (2000); Maktar and Erbek(2005); Dietzel et al (2005). In spite of the varying levels of success demonstrated by these techniques, they are also limited since land use data always violate most assumptions. Example in the use of multiple regressions, such as normal distribution, appropriated error structure of the variables, independence of variables and model linearity (Olden and Jackson, 2001). However logistic regression and sometimes ANOVA have been found to be more effective tool to analyse and interpret land use change. These methods have been found capable of establishing functional relationships between the probability of land use change and the drivers of change represented by asset of explanatory variables (Munroe et al 2004, Paez and Suzuki, 2001).

Another major issue of concern is the abrupt changes in land use at the fringe area of cities, often without recourse to existing statutes, policies and standards, in most cases leading to slum development. Nigeria as elsewhere in developing countries has experienced profound urban growth and changes in land use over the years. The increasing attractiveness of the city for migrants from surrounding smaller towns and villages to itself without corresponding resources for management has resulted to indecent housing and slum formation, illegal structures and building conversions, incongruous mixed uses, encroachment on open spaces and parks among other problems

(Gana, 1996; Okeke, 2000; Aluko, 2004).

Some towns in the North Central Nigeria have been selected for this research, because they represent a microcosm of Nigerian cities, cosmopolitan with heterogeneous population, with people from all over the country. Specifically Minna, Lokoja and Kaduna, appear to be in the forefront of this unplanned and unsolicited trend in growth at the fringes. Gana (1996) earlier described this city fringe as being characterized by imbalance in land use distribution with uses that are complementary to and incompatible with residential areas lumped together with loss in open space.

Albeit almost everyone has witnessed urban expansion and anticipated its positive and negative impacts in their local environment, a research gap exist in a proper understanding of the spatial and temporal processes of land use change at the urban –rural interface. There is the need to develop geographic understanding of the rate and extent of these change to help direct city growth in order to formulate policies for effective planning. This paper reports case studies in Central Northern parts of Nigeria. Land sat images has been utilized as the main data source to explore the spatio-temporal dynamics and conversion of land use by integral remote sensing and GIS. The overall objective is to improve the understanding of the effects of urbanization of land use change in the regions.

2.0 Study area

The study area is located at the middle belt of Nigeria, geographically described as the North Central. The North Central of Nigeria is located at the central point of Nigeria characterized with guinea savannah and marked by crystalline rock out croppings and gently rolling hills, such as the Adamawa hill, Biu Mountain and Jos plateau. The selected cities are Kaduna, Minna and Lokoja (figure 1).

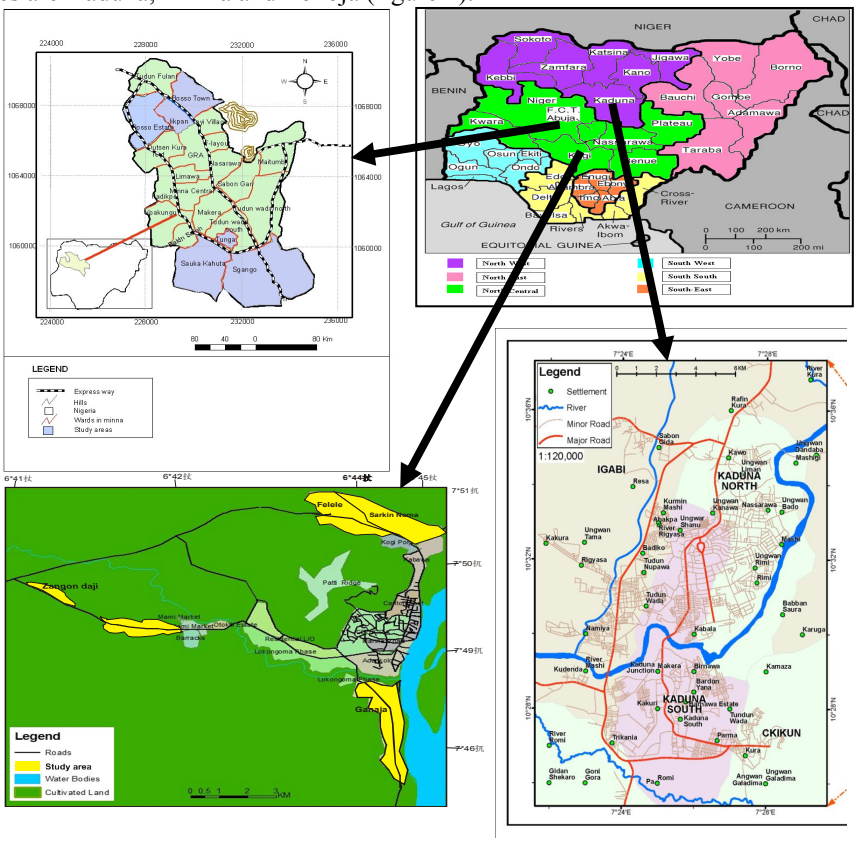

Figure -1 Study area

3.0 Data sources

The 1974 and 1982 land use imagery were acquired on 11th December for Minna. The land use imagery of Kaduna in 1987 was acquired 10th November, while the land use imagery of 2006 was also acquired 15th November and an ASTER VNIR Satellite Imagery 2011 for land use was acquired 21th January, 2011 (Advanced Space Borne Thermal Emissions and Reflections Radiometer – Visible and Near Infrared). Land use map of 1974-1984 in conjunction with satellite imagery of Lokoja for 1985-1996, 1996-2006 and 2006 – 2011 were also acquired.

Satellite images acquired were then keyed into the GIS software of Arc view 9.3. A supervised digital image classification technique was employed and complemented with field surveys that provided on-the-ground information about the types of land use and land-cover classes. The false color composite image was classified using maximum likelihood classification algorithm. The selected training sites collected during the field survey

provided the major classes in which the various pixels were grouped into various land uses/land cover land use data from the images were then classified into, open spaces, built up areas, farmlands, natural vegetation and water body. Land use maps obtained were also rasterised at resolutions of 30m by 30m and 100m by 100m using the arc view 9.3 spatial analyst. The rastering of the maps at different pixel sizes is to examine the effects of spatial resolution on spatial pattern of analysis. Observations of set of land use condition found at each cell in each time period, and then the factors influencing land use change process was then identified. Analysis was then performed at varying time periods to provide an analysis of land use change over time and space. The sets of satellite images were each divided into 500m by 500m cells, with each cell coded for already mentioned land uses as well as for the existence of factors hypothesized.

Hypothesis- that there is no significant difference in the rate and extent of land use change among the cities under study from 1974 to 2011.

4.0 Data presentation and analysis

The table 1 shows variance in land use for Lokoja from the year 1974 to 2011. It reveals that the built-up area in 1974 covered 4.8% of the total land of this area, which constitutes the residential, commercial and the institutional areas covering 3.16%, 0.87% and 0.77% respectively. Farmland areas covered 31.6%, natural vegetation 57.15 and water body 3.75%. The satellite images in this period show that virtually areas designated as fringes today were still areas of natural vegetation and virgin land .By 1991, the trend took a different pattern where population increased astronomically, economic development also increased, hence increased in built-up size to about 10.93% of the total area. Residential area increased to about 8.2%, while the commercial and institutional areas increased to 2.8% and 1.25% respectively. By the year 2011 the built-up area had increased to 33.97%, where the residential area covered 22.36 %, commercial area covered 8.59% and the institutional area covered 3.02%. Natural vegetation had reduced to 8.7% due to gradual take over by buildings (figure 2).

5.1 Extent of built –up expansion in study area.

Table 2 shows the changes in built-up area specific to the neighborhoods sampled for the study. In the city of Minna, the Bosso area was found to have increased in size from 2.03 km^2 in 1984 to 4.69 km^2, Jikpan area increased to 0.94 km^2; Sango area increased to 10.36 km^2;Sauka-kahuta also increased to 7.94 km^2 and Tunga area increased to 0.84 km^2 .

Table 1 also shows the extent of built–up expansion in the neighborhoods covered by this study. In Lokoja, it was found that the built-up area of Sarkin–Noma increased from 0.35 km^2 in 1984 to 2.79 km^2 in 2011. Felele area increased from 0.35 km^2 to 2.87 km^2. Ganaja area increased from 0.5 km^2 to 3.43 km^2, while Zangon–daji area increased from 0.1 km^2 to 2.11 km^2

Table 1. The extent of built –up expansion in study area.

City	Neighborhood	Built-up **1974-1984 Km^2**	Built-up **1985-1996 Km^2**	Built-up **1996-2006 Km^2**	Built-up **2006-2011 Km^2**
MINNA					
	Bosso	2.03	2.33	2.71	4.69
	Jikpan	0.21	0.56	0.80	0.94
	Sango	0.60	7.54	8.79	10.36
	Sauka kahuta	0.64	5.14	6.00	7.94
	Tunga	0.25	0.50	0.70	0.84
LOKOJA					
	Sarkin Noma	0.35	1.40	2.60	2.79
	Felele	0.30	0.90	2.20	2.87
	Ganaja	0.50	2.00	2.50	3.42
	Zagon -dagi	0.10	0.40	1.93	2.11
KADUNA					
	Kawo	2.8	3.2	4.41	5.20
	Mando	1.9	2.3	4.78	5.1
	Gonin-gora	-	1.4	3.14	4.2
	Sabon tasha	-	1.2	3.3	4.5

Source: Field survey, 2012

Figure 2 illustrate the rate of land use change for the area under study. Lokoja shows an open space reduction at the rate of 2.6% within ten years (1974-1984), while Kaduna shows a reduction in open space at the rate of 0.66% and Minna shows also a loss of open space at the rate of 8.34% (figure 3).

Table 2. Rate of land use change

Land use types		**Rate of change (%) 1974-1984**			**Rate of change 1996-2011(%)**		
		Lokoja	Kaduna	Minna	Lokoja	Kaduna	Minna
Open spaces		-2.6	-0.66	-8.34	0	2.34	-3.55
Built-up	**Residential**	4.1	-6.65	10.18	6.6	2.92	4.12
	Commercial	-1.1	13.45	15.83	16.7	3.75	6.73
	Institutional	4.6	5.85	8.09	9.7	1.82	0.36
	Industrial		16.16			8.56	
Farm land		7.7	14.94	8.50	-0.77	1.25	9.15
Natural vegetation		3.25	-4.98	-4.97	-17.9	-6.402	-0.065
Water body		-0.73	0	31.2	9.1	0	-0.0338

Source: Field work, 2012

5.2 TEST OF HYPOTHESES

Ho: There is no significant difference in the rate of land use change in the fringes of the three cities under study between 1974 and 2011as measured by absolute marginal change.

Results

Table 3 Summary of the hypothesis results

	Sum of squares	df	Mean square	F	Sig.
Between groups	8980.294	2	4490.147	1.481	0.025
Within groups	57610.341	19	3032.123		
Total	66590.635	21			

Source: Field survey, 2012

This result shows that there is a significant difference in the rate of land use change in the fringes of the three cities under study, between 1974 and 2011. The null hypothesis is therefore rejected ($F=1.481$, $p=0.025$, $p<0.05$). This significant change in land use is obvious from the result, since the F probability ratio is greater than the threshold value at 0.05 significant level. Thus, the change among the three towns in terms of their land use varies significantly. Again, the value of the test of homogeneity of variances which was derived from Levene test shows a significant value of 0.093(see appendix).

6.0 Discussions

The result of the test of hypothesis showed that there is a significant rate of change **and variation** in land use, between 1974 and 2011 in the three cities under study. This is buttressed by the satellite image observation which shows that the land use changes occurred gradually in succession with farm and forest lands gradually colonized and converted to built-up areas. These fit the ecological theories of urban land use pioneered by Harris and Ullman (1957) and Hoyt (1934). Land use dynamics in the study area tend to follow certain pattern depending on the increasing development pressure and high ways. The satellite images show the presence of urban sprawl and leap frog style urban development and some fragmentation with increasing compactness of the built up area (figure-2;3).

The changes in land use in Lokoja area can be observed to have occurred over the years, where the dominant land use between 1974 and 1984 was the residential; the industrial use was not too significant at this period. This could be attributed to the construction and reconstruction going on in the country after the civil war. This, however, continued to the next two decades, that by 2011 the built-up area had tremendously increased. This could also be attributed to the influx of people who migrated to the town from other states after it became a state capital in 1991.Commercial activities was boosted to increase areal coverage to 8.59% by 2011, which seemed to have coincided with the importance of Lokoja as a transport node from the South to Abuja Federal Capital Territory

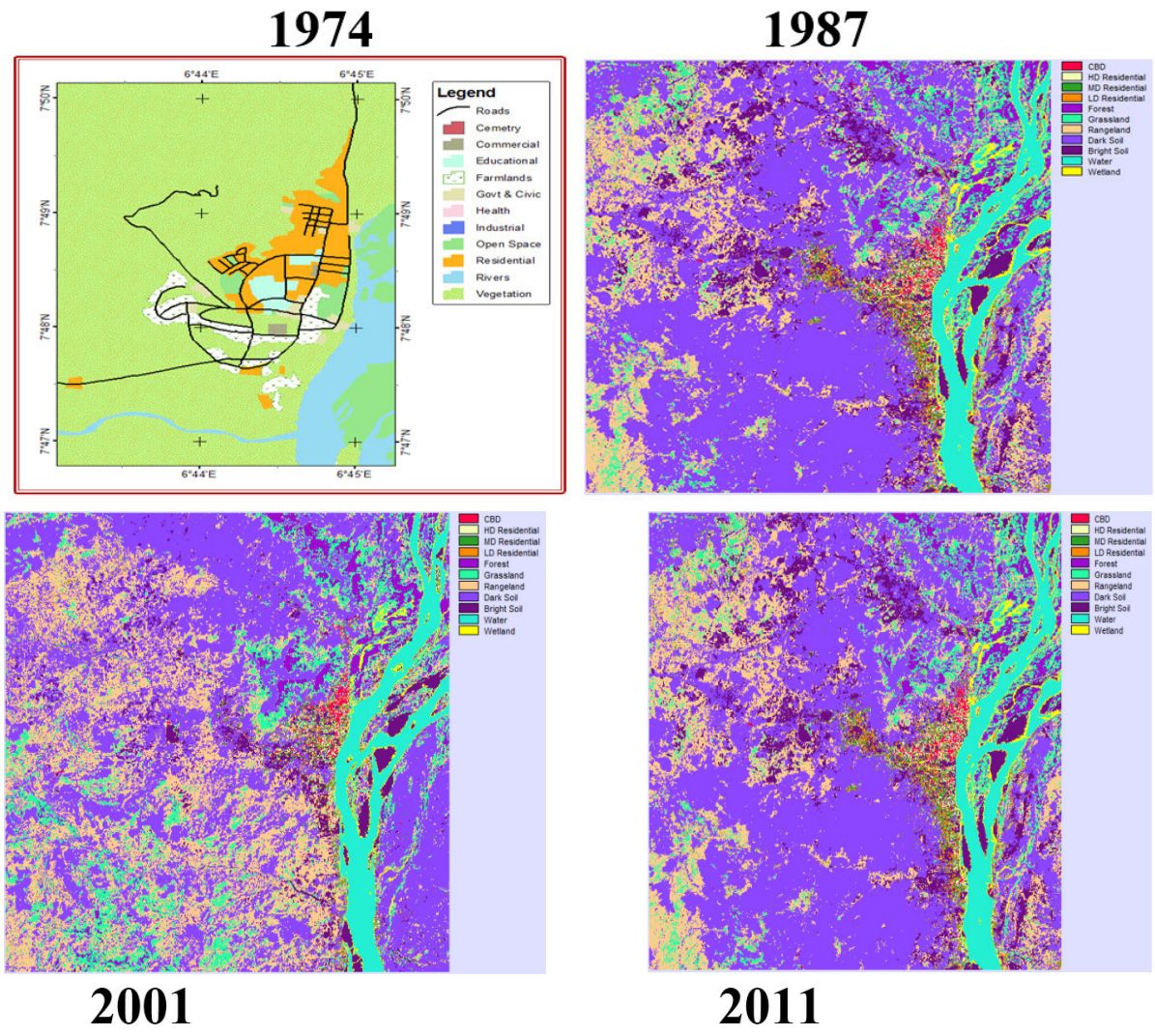

Figure 2 Extent of built-up area in Lokoja, 2001-2011

The axis of Abuja-Lokoja express road around Sarkin –noma have developed into areas of slum and make shift stores of different forms in the name of eateries and vehicle parks. This area is in the state of anomie without proper drainage and improper waste management.

It is, however, pertinent to note that the portion covered by industrial activities today was not insignificant at this period. After its conversion to a state capital, about sixteen kilometers radius of the town was declared a planning area which contributed as a government policy to direct growth. However, the proposed pattern in the master plan was not adhered to by developers who tend to move towards the fringe areas, avoiding the congestion at the core and taking advantage of space and cheap lands at the fringe areas. Area that were Gazetted as forest reserves have now been subsequently taken over by buildings in the Zangon-daji area. The flood plains at the River Niger side of Ganaja area have also been virtually taken over by residential buildings and hotels. The absence of serious industrial activity at the planning area might be attributed to the issue of space, plot size and land cost. The industrial areas of the town have shifted to the fringes where only light industries could be found but the heavy industries were sited at the nieghbouring settlements at the outskirts, such as the Obajana cement industries, Ajaokuta steel rolling mills and Itakpe steel company. These industries form the nucleus of land development at the fringes. This, however, agrees with Browder et al (1995) position that the poor or informal fringes of the cities are the product of the interaction of state intervention and policies (programmed action, specific projects or "laisser faire") and the action and practices of the inhabitants seen as everybody and appropriation of spaces, land and housing strategies and self –building practices. It also agrees with the concept of multi nuclei theory of land use dynamics by Harris and Ullman, 1945, where urban land uses concentrate around several nuclei, rather than one. This is contrary to the assumption of a single monocentric city of Burgess' in the concentric city theory. It is also in contrast to the findings of Adindu et al (1988) where the nature of growth of Owerri town was found to develop in circular form at the fringes. It is also in line with Onokerhoraye and Omuta (1986) that land values bring a competition for central sites, but push the industries to urban fringe.

Kaduna had the residential areas occupying 29.84% of its built-up area from 1974 to 1984. The commercial area covers 2.6% and the institutional 56.82%. However in contrast to the other areas, the industries covered significant area to the level that by 1985, this trend took a new turn, where the industrial area increased to 10.12%. This was concentrated at the Kaduna south, precisely the Makera and the Kudenda industrial area at the southern fringe which was as a result of government policy and the need for space. This area has a close proximity to Sabon –Tasha and Gonin- gora, which now serve as area of residence for most of the industrial workers. The institutional areas also increased around this period also due to government policy of locating most military installations at the Kawo and Mando area at the northern fringe of the city. By 2011 the residential area coverage had increased to 53.43%. This is not surprising, since increase in population calls for demand for more accommodation. Surprisingly, however, there is the continuous increase in commercial area and a corresponding reduction in institutional area coverage. This may probably be due to the creation of Abuja as the Federal Capital where most national and international head offices of establishments where moved. However, this trend in the move to the peri urban which witnessed a surge in growth of urban land use and activities could be attributed to the influence of violence, as people try to escape from the inner city areas that are prone to violence, which have tremendous effect on the people during crises.

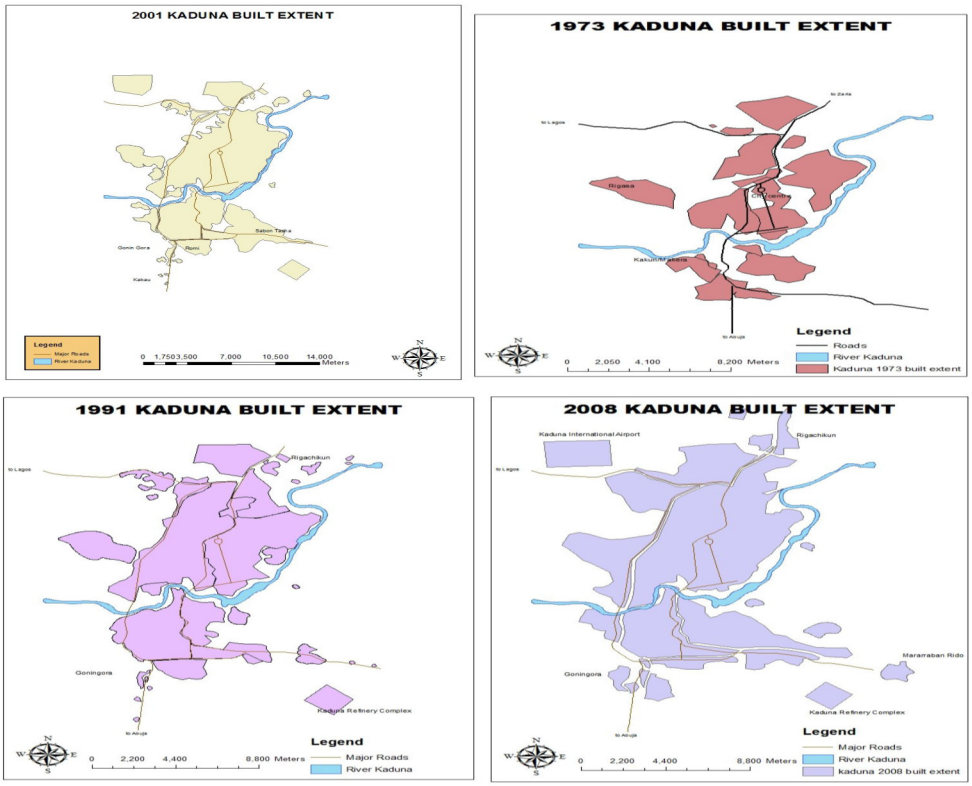

Figure 3 Extent of built -up area in Kaduna, 2001-2008

These have initiated massive movement of Christians from the inner city to Sabon- Tasha and Gonin-gora and on the other hand Moslems move to the northern fringes of Kawo and Mando. This influx of people have brought in increased sale of properties, fragmentation of plots, conversion of residential dwellings to commercial use (shops), especially along the major roads and vertical extension of buildings by developers to acquire more rent. This trend comes in agreement with the findings of Lambin, Geist and Lepers (2003) that institutional factors, security and demographic factors tend to interlink with other factors to increase land use dynamics.

Minna, between 1974 and 1984 had 4.10% of its landscape covered by residential use, while the commercial land use occupies 2.02% and a negligible area for industries. By 1996, the residential area had increased to 48.6%. This could be attributed to the influx of people that came into the town after it became a state capital in 1991 and a major transport route to Abuja. This also caused the increase in commercial land use which took 12.33% of the land use. The institutional land use also increased to 9.27%, which could be attributed the building of schools, hospitals, government offices and other public establishments. By 2011 the residential land use had increased much more than the commercial area while the institutional area was on the decline.

The findings identified the major cause of these as lack of development control. This is in agreement with the findings of Jiboye (2005) that lack of adherence to development control measures is the bane of development in Nigerian cities, particularly the fringes.

Conclusion

The study found that there is a significant change in the rate and nature of land use change over the last 37 years. Traditional agricultural land use which dominated the rural land and forest has been transformed to urban land use at the rural-urban fringe. When viewed in time order, the land use structure has undertaken a shift from the simple pattern of traditional rural land use structure to the complex one of the rural-urban land use and later to the simplified urban land use. It was found that the pattern of land use in the study tends towards sprawling. The existing major roads have helped in shaping urban sprawl being on major transport nodes. It implies a state of haphazard development, loss of biodiversity, increase urban heat island, reduction in wetlands and threat to food security. The foregoing no doubt contributes to knowledge by the applied methodology and findings. This research has shown how the use of Geographical Information System (GIS) and remote system is enabled to integrate with quantitative data to shed light on issues in land use dynamics.

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Appendix

ANOVA test of Hypothesis

Descriptive Oneway

Descriptives

perchange

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
lokoja	7	15.9857	14.78890	5.58968	2.3083	29.6632	1.50	43.50
minna	7	36.3571	38.71558	14.63311	.5512	72.1631	1.10	105.00
kaduna	8	64.6250	82.20592	29.06418	-4.1009	133.3509	1.40	203.00
Total	22	40.1545	56.31148	12.00565	15.1874	65.1217	1.10	203.00

Test of Homogeneity of Variances

perchange

Levene Statistic	df1	df2	Sig.
6.044	2	19	.009

ANOVA

perchange

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8980.294	2	4490.147	1.481	.253
Within Groups	57610.341	19	3032.123		
Total	66590.635	21			

Robust Tests of Equality of Means

perchange

	Statistic[a]	df1	df2	Sig.
Brown-Forsythe	1.641	2	10.617	.239

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: perchange

	(I) state	(J) state	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	lokoja	minna	-20.37143	29.43333	.771	-95.1453	54.4025
		kaduna	-48.63929	28.49870	.229	-121.0388	23.7602
	minna	lokoja	20.37143	29.43333	.771	-54.4025	95.1453
		kaduna	-28.26786	28.49870	.591	-100.6674	44.1317
	kaduna	lokoja	48.63929	28.49870	.229	-23.7602	121.0388
		minna	28.26786	28.49870	.591	-44.1317	100.6674
Scheffe	lokoja	minna	-20.37143	29.43333	.789	-98.4879	57.7450
		kaduna	-48.63929	28.49870	.258	-124.2752	26.9966
	minna	lokoja	20.37143	29.43333	.789	-57.7450	98.4879
		kaduna	-28.26786	28.49870	.619	-103.9038	47.3681
	kaduna	lokoja	48.63929	28.49870	.258	-26.9966	124.2752
		minna	28.26786	28.49870	.619	-47.3681	103.9038

perchange

	state	N	Subset for alpha = .05
			1
Tukey HSD[a,b]	lokoja	7	15.9857
	minna	7	36.3571
	kaduna	8	64.6250
	Sig.		.235
Tukey B[a,b]	lokoja	7	15.9857
	minna	7	36.3571
	kaduna	8	64.6250
Scheffe[a,b]	lokoja	7	15.9857
	minna	7	36.3571
	kaduna	8	64.6250
	Sig.		.265

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 7.304.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.