ASSESSMENT OF SPATIO-TEMPORAL DYNAMICS OF URBAN SPRAWL IN KADUNA METROPOLIS, NIGERIA

By

Yakubu, B.M.[1*], Usman. A.K.[2] and Jacob, R.J.[2]

[1]Department of Geography, Kaduna State University, Kaduna, Nigeria.
[2]Department of Geography and Environmental Management, Ahmadu Bello University, Zaria.
*Corresponding Author's Email: yakubumakarfi@gmail.com

ABSTRACT

The study assessed urban sprawl in Kaduna metropolis. Remote sensing and GIS in conjunction with Shannon entropy were used to compute the intensity of urban sprawl in the metropolis. Landsat data for 1990, 2002 and 2014 was acquired for land use land cover classification using maximum likelihood algorithm. Findings from the land use land cover classification revealed that built up areas in Kaduna metropolis have increased drastically from 6073.9 hectares in 1990 to 12423.6 hectares in 2014. Findings from Shannon entropy analysis of the metropolis indicated that the sprawling has increased from 3.234 in 1990 to 3.361 in 2014. This research can assist Local Government authorities in monitoring the growth of built up areas and in drafting measures and policies to address the effects of urban sprawl.

Key words: Urban sprawl, Image classification, Shannon's entropy, Land use-Land cover.

INTRODUCTION

Urban sprawl is the process in which the spread of development across the landscape far outpaces population growth (Ewing, 1994). But urban sprawl is not just growth; it is a specific and dysfunctional style of growth regarded as a by-product of suburbanization by human geographers (Feng, 2009). In addition, (Peiser, 2001) conceives it as "the gluttonous use of land, uninterrupted monotonous development, leapfrog discontinuous development and inefficient use of land" which Nelson (1995) describe as unplanned, uncontrolled, and uncoordinated single use development that does not provide for a functional mix of land use and/or is not functionally related to surrounding land uses and which variously appears as low density, ribbon or strip, scattered, leapfrog, or isolated development.

In view of the implications of the increasing urban population for sustainable development in low and middle income countries, the 2002 Johannesburg world Summit on Sustainable Development (WSSD) called on all the governments to address the overwhelming challenge of provision of urban basic services especially decent house, water and sanitation for the teeming population in slums, where the quality of life is appalling. While continents like Europe and the America have stabilized their population growth and economy to a large extent, most countries in Africa, Asia and Latin America have in the last decades not been able to deliver on their promise of alleviating the precarious state of living environment of their citizens (UNHabitat, 2003).

Urban sprawl is one of the foremost threat facing agricultural lands in Nigeria (Nwafor, 2006). Sprawl has been criticized for eliminating agricultural lands, spoiling water quality, and causing air pollution. Other frequently mentioned consequences are: green space consumption, high cost of infrastructure and energy, an increasing social segregation and land use functional division. Furthermore, the need to travel, dependence on private car and consequently increased traffic congestion, energy consumption and polluting emissions are associated with sprawl (Allen and Lu, 2003).

One of the prerequisites for understanding urban sprawl is successful land use change detection (Jain, 2009). Urban sprawl, as a type of urban growth, varies in terms of pattern, density, and rate at which built-up land develops. This is however dependent on the way in which development occurs (Allen and Lu, 2003). Zhang (2001) stated that urban sprawl results from poorly planned, large scale new residential, commercial and industrial developments in areas previously not used for urban purposes. Sprawl often occurs faster than the development of the infrastructure (e.g. schools, roads, sewer systems, and water lines) needed for support (Pohanka, 2004).

One of the methods commonly used to measure urban sprawl is Shannon’s entropy (Yeh and Li, 2001). Shannon’s entropy is an index that determines the distribution of built up as a function of the area of built up within a defined spatial unit (Jat, Garg and Khare, 2007). It characterizes the pattern – dispersed or concentrated – of built-up over time that can help officials to identify which area is being used inefficiently (Yeh and Li, 2001).

Many researchers in Nigeria have used Shannon’s entropy to study urban sprawl. Micheal (2009) used Shannon’s entropy to measure and examined urban sprawl pattern in Lokoja, Nigeria. The Study shows that Lokoja is experiencing growth along the major highways traversing the city. In Kaduna metropolis, Bununu and Ahmed (2013) demonstrated the application of a unified frame of sprawl analysis based on the integration of GIS, remote sensing and the Shannon's entropy method. The analysis of the entropy values revealed sprawling in the different quadrants of the metropolis. Ndabula et al. (2014) used quantitative indices as an improved approach to characterize, analyse and explain urban sprawl. Results revealed that Built-up Change Intensity Index (Ti) has a gradual increasing trend from 7.8% between 1967 and 1987 to 11.88% between 2001 and 2009. On the other hand both Built-up Dynamic Index (Ki) and Rate of Growth (L) showed declining trend from 24.89 and 1.01% to 18.04 and 0.53% respectively between 1967/1987 and 2001/2009.

Bununu and Ahmed (2013) calculated the entropy values by dividing the study area into 4 quadrants. They did not use residential neighbourhood shape file. This research analysed urban sprawl in every residential neighbourhood in Kaduna metropolis. This research will provide urban planners, GIS Analyst and Managers with an accurate, precise, flexible and cost effective means of undertaking a time-series analysis of urban sprawl and its resultant implications in every residential neighbourhood in the metropolis. This is very important because the metropolis is experiencing change in land use as a result of urban development in every residential neighbourhood, which is leading to loss of vegetation, cultivated land, loss of biodiversity and also the rate of erosion. So, there is a need to conduct a research in order to analyse the rate and pattern of the urban sprawl resulting from the development.

The main objective of this study is to use Shannon’s entropy in conjunction with Remote Sensing and GIS techniques to analyse urban sprawl in Kaduna metropolis.

THE STUDY AREA

The study area is Kaduna Metropolis and its environs located between latitudes 10^0 23′ N to 10^0 38′ N of the Equator and longitudes 7^0 21′ E to 70^0 31′ E of the Greenwich Meridian. The metropolis cuts across four local government areas including Kaduna North, Kaduna South, part of Chikun and Igabi LGAs. Its natural sphere of influence covers approximately 122km east to west and 80-96 km north to south (Mamman, 1992). See Figure 1. For this research the study area is divided into 39 residential neighbourhood as shown in Figure 2.

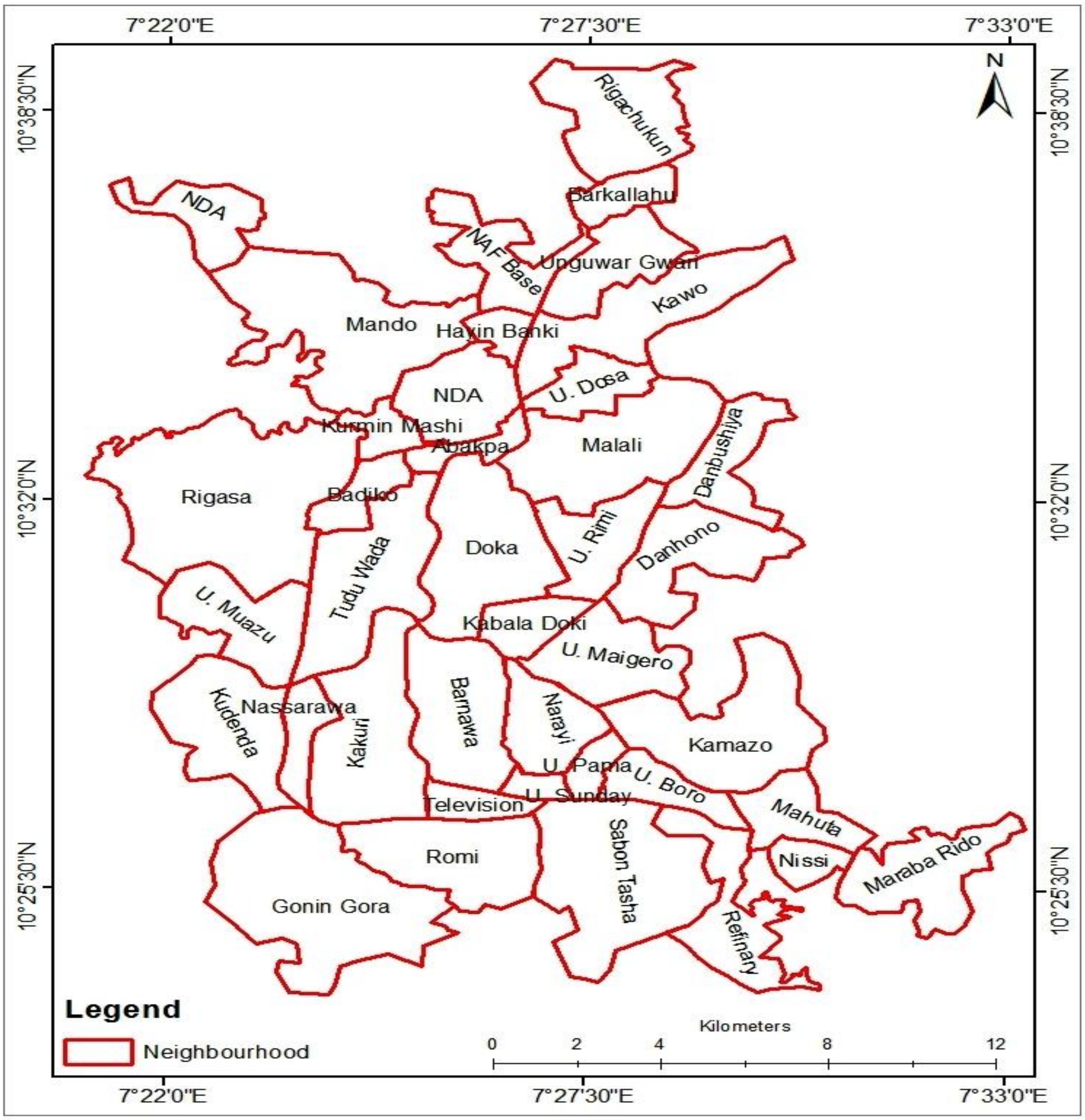

Fig 1: Residential Neighbourhoods in Kaduna Metropolis
Source: Adapted from the Google map of Kaduna Metropolis

MATERIALS AND METHODS

Types of Data

Reconnaissance survey was embarked upon in order to have good understanding of the study area. This knowledge was very useful during visual image interpretation process before and after image classification and during creation of neighbourhood shape file. In order to achieve the aim and objectives of this study, the types of data used were satellite imageries and the residential neighbourhood shape file of the metropolis. All the three satellite imageries were downloaded from the United States Geological Survey (USGS) website, www.glovis.usgs.gov and these include the following:

i. Landsat Thematic Mapper (TM) of 27th November, 1990 with a spatial resolution of 30meters.
ii. Landsat Enhanced Thematic Mapper Plus (ETM+) of 19th October, 2002 with a spatial resolution of 30meters.
iii. Landsat 8 Operational Land Imager (OLI) of 27th December, 2014 with a spatial resolution of 30 meters.

Image Classification

For the purpose of land use/land cover classification and image analysis, it was necessary to produce a colour composite image of the study area. This was done by stacking all the spectral bands of each year together in ArcGIS 10.1

The composite images were imported into Erdas imagine 9.2 environment after which a subset covering the area of interest was extracted from the larger scene of Landsat TM, Landsat ETM+ and Landsat 8 OLI.

Supervised classification technique was performed using maximum likelihood algorithm in classifying the images into various classes (themes).This method is preferable due to its high level of accuracy and reliability in handling spatial data. This technique gives room for the researcher to generate training classes based on the land use/land cover themes present in the area and helps in curtailing ambiguity that is associated with the unsupervised techniques in image classification. The sample sites (training pixels) were selected based on spectral signatures of the features on the images. The various land use land cover types within the area were classified into four viz: built up, vegetation, bare land, and water.

Computation of Shannon's Entropy

To perform the Shannon's entropy analysis, the study area was divided into 39 residential neighbourhoods. The built up land use was extracted from the three classified maps and converted to a polygon shape file. The residential neighbourhood layer was superimposed on built up polygon layer using the ArcGIS 10.1 Intersection tool to obtain the quantity of built up in each residential neighbourhood in the study area. The density of urban development in each neighbourhood was calculated and the entropy values were calculated for each year by using the formula (Hekmatnia and Mousavi, 2006):

$$E_n = -\sum_{i}^{n} PiLogPi$$

Where $Pi = \frac{xi}{\sum_i^n xi}$ is the density of land development, which equals the amount of the built up land divided by the total amount of land in the zone and total zones. Zero value represent physical compressed (zipped) development of the metropolis. The Login (natural log of n) represents the scattered development of the metropolis.

RESULTS AND DISCUSSION

Land use Land Cover Classification

The land use land cover classification maps for the study area in 1990, 2002 and 2014 were generated and presented in Figure 2. Table 1 shows the summary of the total land area for each land use land cover and the corresponding percentage of the total.

Table 1: Areal Extents and Proportions of Land Use Land Cover

	1990		**2002**		**2014**	
	Area(Ha)	Area(%)	Area(Ha)	Area(%)	Area(Ha)	Area(%)
Built up	6059.2	19.4	8297.4	26.5	11854.7	37.9
Vegetation	10250.6	32.8	9394.9	30.0	4430.9	14.2
Water	346.5	1.1	291.9	0.9	348.3	1.1
Bareland	14619.8	46.7	13291.9	42.5	14642.2	46.8
Total	31276.1	100.0	31276.1	100.0	31276.1	100.0

Source: Authors' GIS Analysis (2016)

Table 1 shows that in 1990, bare land dominated the landscape with a proportion of 46.7% of the total land area. This is followed by vegetation which occupied 32.8%. Built up and water accounted for 19.4% and 1.1% of the total area respectively. In 2002 bare land has decreased to 42.5% but was still the largest land use land cover in the study area. Vegetation and water reduced to 30.0% and 0.9% respectively while built up area increased to 26.5%. The year 2014 recorded an increase in the proportion of bare land (46.8%) and built up (37.9%). Vegetation reduced drastically to 14.20% while water accounted for only 1.1%. The increase in built up land use in Kaduna metropolis is basically as a result of population growth. For instance, the population of Kaduna metropolis was 337,639 in 1991 but based on projection, the population of the metropolis was expected to reach 1,827,571 in 2014 (Akpu and Tanko, 2012).

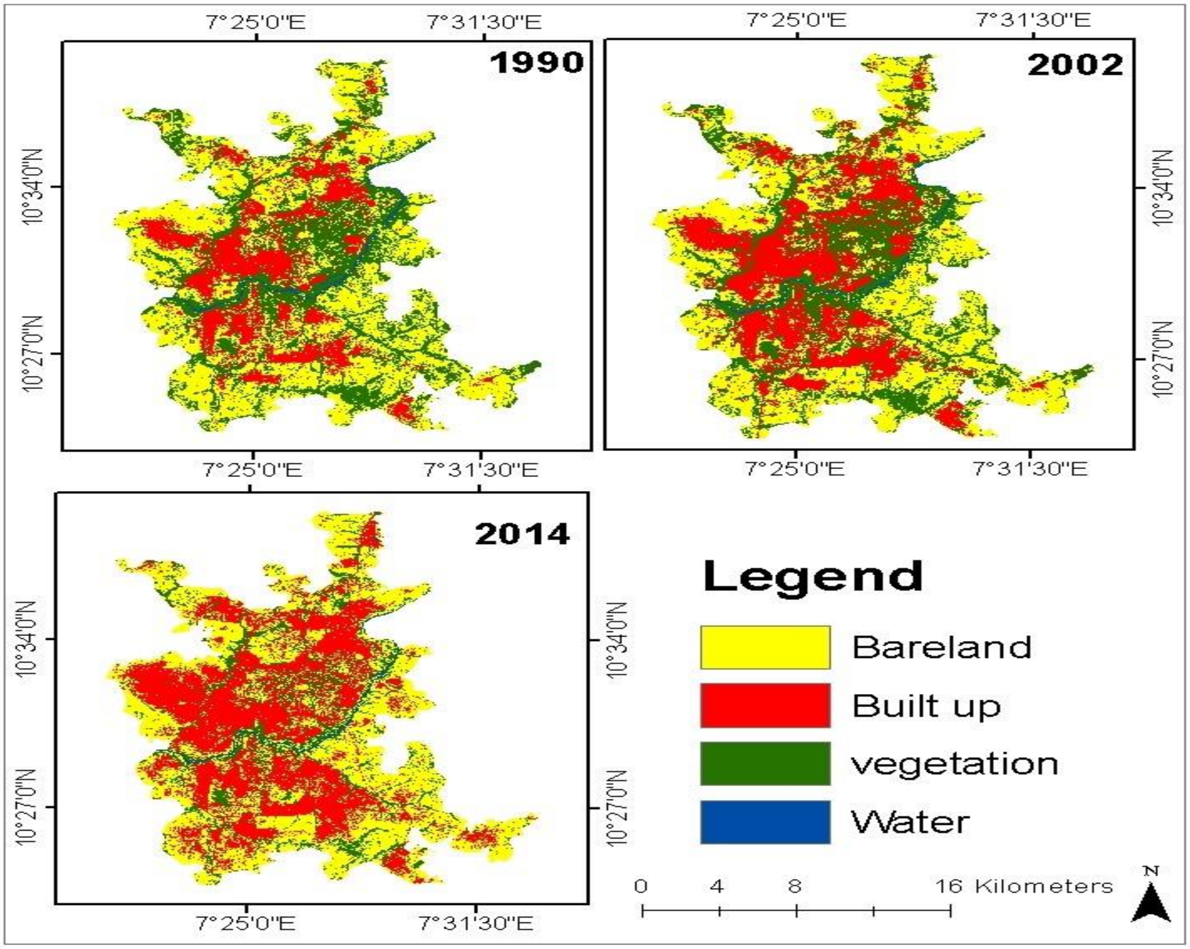

Fig 2: Land use land covers Classification
Source: Authors' GIS Analysis (2016)

This is not surprising because increase in human population fosters urban development. Other human activities such as farming, grazing, and land excavation especially for road construction might be responsible for the increase in bare land and reduction in vegetation. The characterization of sprawling in Kaduna metropolitan area by Ndabula et al. (2014) supports the findings of this research that the metropolis has been experiencing accelerated urban expansion since 1967.

Urban Sprawl Analysis

Entropy value ranges from 0 to log (n). In the present case, log (n) is 3.664. Entropy value closer to zero represents compact distribution of urban growth, while values closer to 'log n' represent dispersed distribution of sprawl. Values of entropy near to 'log n' reveal the dispersion of built up area, which indicates the occurrence of urban growth and heterogeneity of land uses (Punia and Singh, 2012).

The entropy values in the study area for 1990, 2002 and 2014 were calculated from the built up area for each residential neighbourhood and the results are presented in Table 2.

Table 2: Calculation of Shannon's Entropy for Neighbourhoods in the Study Area

Name	Urban Area (Ha)			-PxLog(P)		
	1990	2002	2014	1990	2002	2014
Doka	438.3	586.8	709.3	0.001	0.006	0.014
Kurmin Mashi	116.6	131.8	148.5	0.007	0.012	0.026
Nassarawa	251.5	271.3	272.7	0.014	0.017	0.028
Romi	181.6	244.6	308.1	0.004	0.009	0.036
Ung Pama	88.9	106.7	143.3	0.004	0.005	0.036
Ung Boro	70.4	106.8	229.4	0.043	0.055	0.043
Badiko	194.2	223.2	245.3	0.005	0.009	0.044
Kabala Doki	86.7	106.9	129.0	0.068	0.057	0.044
Refinary	172.3	249.5	243.0	0.044	0.053	0.048
Kamazo	0.0	4.1	130.6	0.068	0.060	0.048
Hayin Banki	99.7	116.8	124.4	0.061	0.056	0.049
Mahuta	5.9	15.3	57.0	0.000	0.004	0.050
Malali	191.0	341.4	559.9	0.062	0.056	0.053
Tudu Wada	611.6	719.9	825.1	0.076	0.066	0.055
Ung Gwari	56.6	100.3	123.4	0.059	0.088	0.059
Ung Sunday	99.6	109.7	112.6	0.088	0.077	0.060
Barkallahu	13.7	23.7	64.5	0.045	0.050	0.062
Rigasa	572.5	797.8	1448.1	0.024	0.031	0.062
Kawo	217.7	282.6	504.0	0.111	0.095	0.074
Mando	212.0	322.9	504.5	0.052	0.056	0.076
Maraba Rido	26.3	50.6	175.5	0.101	0.105	0.080
Television	195.2	215.2	219.7	0.110	0.097	0.080
Rigachukun	58.7	92.2	174.0	0.132	0.112	0.087
Nissi	1.0	6.9	26.8	0.056	0.072	0.088
Ung Muazu	214.0	257.1	312.3	0.078	0.079	0.089
Kakuri	520.6	681.1	611.9	0.105	0.104	0.095
Barnawa	200.1	348.7	439.8	0.118	0.108	0.096
Ung Rimi	119.9	167.3	284.1	0.142	0.122	0.102
NAF Base	55.7	103.7	109.3	0.097	0.108	0.117
Kudenda	78.3	147.5	280.4	0.098	0.101	0.119
Ung Dosa	279.9	307.4	340.3	0.113	0.133	0.122
Danhono	4.5	10.8	111.3	0.120	0.115	0.134
Danbushiya	3.5	6.2	87.3	0.117	0.126	0.134
Narayi	162.8	259.3	413.7	0.049	0.082	0.142
NDA	83.9	195.0	163.9	0.109	0.131	0.144
Ung Maigero	3.1	10.7	87.2	0.211	0.205	0.153
Abakpa	141.4	162.3	165.2	0.190	0.187	0.169
Gonin Gora	65.5	177.0	546.1	0.231	0.212	0.185
Sabon Tasha	163.7	236.1	423.2	0.223	0.225	0.257
Total	6059.2	8297.4	11854.7	3.234	3.287	3.361

Source: Authors' GIS analysis (2016)

The analysis reveals that 2014 has the highest entropy value of 3.361, followed by 2002 which has the entropy value of 3.287. The lowest value of entropy was recorded in 1990 (3.234). Increasing entropy values from 1990 to 2014 shows the tendency of urban sprawl as we move towards the outskirt of the metropolis. The highest values of entropy are found in Sabon Tasha, Gonin Gora and Unguwan Maigero. Such high entropy values are mainly because such districts are more recently urbanized and contains abundant agricultural and vacant lands. This increase in value of entropy indicates increase in dispersion of built-up area, which is an indication of urban sprawl.

The closer to the upper limit of log (n) *i.e.* 3.664 the more dispersion is the built-up area in the region. Higher value of overall entropy for the whole urban area represents higher dispersion of built up area which is a sign of urban sprawl. Increase in dispersion is due to new areas being added. The higher values of entropy in outer areas indicate more urban sprawl compared to Doka residential neighbourhood which is the Central Business District (CBD) of Kaduna metropolis. Distribution is predominantly dispersed in outer areas, whereas it is more compact in areas surrounding the centre of the metropolis. It is obvious that the growth of the metropolis has mainly been characterized by increase in unplanned/informal residential settlements which has emerged from the increase in the population of the metropolis due to rural urban migration which has increased demand on it for residential housing. This result confirmed the report of Bununu and Ahmed (2013) that there is urban sprawl in Kaduna metropolis.

CONCLUSION

The study analysed the spatio-temporal dynamics of urban sprawl in Kaduna metropolis. Remote sensing and GIS in conjunction with Shannon entropy were used to compute the intensity of urban sprawl in the metropolis. This study has proven that remote sensing and GIS in conjunction with Shannon entropy can be used to analyse urban sprawl and its implication to other land use land cover. The research has revealed that urban development in Kaduna metropolis is uneven and scattered. Hence it can be concluded that Shannon's entropy is a useful and effective tool for identifying the urban sprawl phenomenon in terms of dispersion of the built up area.

As a result of rapid urban development which has resulted in urban sprawl from 1990 to 2014 in the study area, the Kaduna State Urban planning and Development Agency should adequately plan and monitor the rapid urban growth being experienced in the metropolis.

REFERENCES

Allen, J. and Lu, K. (2003). Modelling and Prediction of Future Urban Growth in the Charleston Region of South Carolina: a GIS-based Integrated Approach. *Conservation Ecology*, 8(2).

Akpu, B. and Tanko, A.I. (2012). Determining the Rate and Pattern of the Spatio-Temporal Growth of Kaduna Metropolis, Kaduna State, Nigeria.54th National Conference of the Association of Nigerian Geographers, Kano State University, Wudil, Kano State, Nigeria.

Bununu, Y.A. and Ahmed, A. (2013). Extending the Frontier of GIS Applications: Towards Evolving a Hybrid Tool for Sprawl Analysis. *ATBU Journal of Environmental Technology*, 6(1).

Ewing, R.H. (1994). Characteristics, Causes and Effects of Sprawl: A Literature Review, *Environmental and Urban Issues*, Winter, 1994.

Feng, L. (2009). Applying remote sensing and GIS on monitoring and measuring urban sprawl. A case study of China, Institute of Regional Development Planning University of Stuttgart, Stuttgart.

Hekmania, H. and Mousavi, M.N. (2006). *Use of Models in Geography with an emphasis on Urban and Regional Planning*, Modern science publications, Yazd.

Ifeoluwa, A.B., Debo, Z.A, Ahmed, B. and Tobi, E.M. (2011). Analysis of Urban expansion and land use changes in Akure, Nigeria, Using Remote Sensing and GIS techniques. *Journal of Geography and Regional Planning*, 4(9), 533-541.

Jain**,** M. and Dimri, A.P. (2009). Urban Sprawl Patterns and Processes in Delhi from 1977 to 2014 Based on Remote Sensing and Spatial Metrics Approaches, 2(12), 49-57.

Jat, M.K., Garg, P.K. and Khare, D. (2007). Monitoring and modeling urban sprawl using remote sensing and GIS techniques. *Int. J. Appl. Earth Observ. Geoinform,* 10(1), 26-43.

Mamman, M. (1992). *Analysis of fertility differentials in Kaduna metropolis*. An unpublished PhD thesis submitted to the Postgraduate School, Ahmadu Bello University, Zaria.

Ndabula, C., Jidauna, G.G., Averick, P.D., Ayotayo, T.K. Abaje, I.B. and Ali, A.Y (2014).Characterization of sprawling in Kaduna metropolitan area. *American Journal of Environmental Protection*, 3(3), 131-137.

Nelson, M. (1995). Urban Sprawl: A developing country approach, e-journal of *The World Student Community for Sustainable Development.*

Nwafor, J.C. (2006). *Environmental Impact Assessment for Sustainable Development: The Nigerian Perspective* (1st ed.). EDPCA Publishers

Peiser, R. (2001).The Impacts of Urban Built-Up Area Expansion on the Livelihood of Farm Households, in the Peri-Urban Areas of Mekelle City: The Capital of Tigray Regional State.

Pohanka, M. and Fitzgerald, S. (2004). Urban sprawl and you: How sprawl adversely affects worker health. *Journal of the American Association of Occupational Health Nurses*, 52(6), 242-246.

Punia, M. and Singh, L. (2012).Entropy Approach for Assessment of Urban Growth: A Case Study of Jaipur, India. *Indian Society of Remote Sensing*, 40(2): 231-244.

UNHabitat (2003). The Challenge of slums: Global reports on human settlements, pp 24-27.

Yeh, A.G.O. and Li, X. (2001). Measurement and monitoring of urban sprawl in a rapidly growing region using entropy. *Photogr. Eng. Remote Sens.*, 67(1), 83-90.

Zhang, L., Wu, J. and Zhen, Y. (2001). A GIS-based gradient analysis of the urban landscape pattern of Shanghai Metropolitan Region. *Acta Phytoecologica Sinica*, 28(1), 78-85.