Landscape metrics analysis of land use patterns and changes in suburban local government areas of Ibadan, Nigeria

Adewale Mukhtar Olayiwola[1], Olayinka Fakayode[2]

[1]Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria, olaadewale1@gmail.com; amolayiwola@oauife.edu.ng
[2]Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria, fakayodeolayinka@gmail.com

DOI: http://dx.doi.org/10.4314/sajg.v8i2.7

Abstract

This study examined the spatiotemporal pattern of urban growth and magnitude of changes in selected Local Government Areas (LGAs) in the suburban area of Ibadan using remote sensing cum spatial metrics. Data for the study were obtained from administrative maps of the study area, population data and satellite imageries. All of these were complemented with ground validations using Global Positioning System (GPS) receiver. Periods of change analysis were divided into two epochs; 1986 to 2002 and 2002 to 2017. The imageries were classified into four landuse/cover classes based on Anderson's modified version of supervised classification scheme. Accuracy assessment of the imageries was carried out using 100 randomly sampled ground truth points. Ten spatial metrics were selected for analysis using Fragstats program. Results show a significant loss in vegetation due to conversion (Land Consumption Rate, LCR = 0.025, 0.019 and 0.027; Land Absorption Coefficient, LAC = 0.012 and 0.048). Moreover, there was a persistent increase in Number of Patches (NP) indicating a scattered and fragmented but continuous development. However, dwindling values of Patch Density (PD = 90.94, 27.07 and 30.30) indicate expansion through conversion of other landuses at varying rates. Results also indicate an incidence of fragmented low density development in the fringe areas (Area Weighted Mean Patch Fractal Dimension, AWMPFD = 1.37 and 1.39). The study highlights the chaotic land development and unrestrained urban expansion in the study area.

Key Words: *Remote sensing; landscape metrics; landuse patterns; landuse changes; suburban; Local Government Areas; Ibadan*

1. Introduction

Settlements provide a spatial emphasis for most of human activities (Ahmed and Ahmed 2012). Investigating the spatial forms of settlements can contribute to greater understanding of land use changes, ecological processes, cultures and lifestyles. Examination of the growth pattern of settlements at different time-scales can be used for effective planning of landuse for maximum use of land resources (Abolade 2007; Olayiwola *et al.* 2014). Hence, the spatial arrangement and the underlying forces of settlement growth and development are important topics of analysis in urban studies (Aguilera *et al*. 2011). Moreover, there is a revived attention of scholars on the expansion of cities into the neighbouring settlements (Ferreira *et al*. 2018; Karg *et al*. 2019).

A suburban area is a transition zone between the urban cores and the neighbouring rural areas (Lawanson *et al*. 2012; Adedire 2018). In many of the developing countries, this zone is usually characterised by sporadic built-up areas and lower population density. Therefore, they are generally described as newly urbanised zones (Adedire 2018). Suburban development is caused by population and spatial expansion of the metropolitan city, decline in urban environmental quality and easy access to land for building and commercial purposes (Dutta 2012; Appiah *et al*. 2014). The pull factors at the suburb include improved infrastructure and socio-economic activities and quest for affordable housing (Lawanson *et al*. 2012; Acheampong and Anokye 2013; Appiah *et al*. 2014). On the whole, there are changes in both the physical processes and human activities in the suburban areas (Appiah *et al*. 2014; Karg *et al*. 2019).

The advent of land-change technology, including progresses in GIS and remote sensing, has provided a platform to scrutinise landscape alterations through space and time (Guindon and Zhang 2009; Estoque and Murayama 2015). For instance, there is an increased awareness in the use of spatial metrics for characterizing the landscape structure and spatio-temporal pattern of landscape transformations (Pham *et al.* 2011; Fan and Myint 2014; Estoque and Murayama 2015). Shyamantha *et al.* (2016) reiterated that spatial metrics are developed based on information theory measures and fractal geometry. They noted that the ability to quantitatively describe the landscape structure is a prerequisite for studying landscape functions and transformations.

Spatial metrics is a quantitative way of representing spatial structures and patterns (Chen *et al*. 2016). In landscape analysis, spatial metrics are usually employed to detect landscape pattern and fragmentation (Dezhkam *et* al. 2017). Therefore, they are used to analyse the structure or patches of an area with homogeneous thematic entities (Ferreira *et al*. 2018). Also, they can be employed to quantify the spatial heterogeneity of patches of a common class (Kumar *et al*. 2018). In settlement studies, spatial metrics are adopted to assess the spatial characteristics and structures of settlements (Ayila *et al.* 2014; Wondrade *et al*. 2014; Rastandeh and Zari 2018). The metrics can be calculated as patch-based indices (such as size, shape, edge length, patch density, fractal dimension) or as pixel-based indices (such as contagion and lacunarity) computed for all pixels in a patch (Singh *et al.* 2017; Inkoom *et al*. 2018).

Previous studies on Ibadan and its environs have revealed series of settlement expansion patterns (Fabiyi 2006; Toyobo *et al.* 2011; Agbor *et al.* 2012; Adegboyega and Aguda 2016). These studies relied on just simple change detection techniques which yielded a single estimate of spatial growth between two dates. Also, the previous studies combined remote sensing with descriptive statistics to analyse growth pattern of the study area. Furthermore, the studies concentrated on either a Local Government Area (LGA) or one settlement in Ibadan suburb; none of them incorporated all or, at least, combined a few of these LGAs or settlements. In effect of these defects, the present study examined the spatiotemporal pattern of urban growth and magnitude of changes in the suburban areas in the North-eastern part of Ibadan using remote sensing cum spatial metrics.

2. The Study area

The study was conducted in the Northeast suburban areas of Ibadan, Nigeria. Ibadan, the capital city of Oyo State, consists of eleven LGAs; while five constitute the municipal, the remaining six LGAs form the suburb. The area selected for the study consists of three LGAs, these are: Akinyele, Lagelu and Egbeda LGAs. The study area is located between Latitudes 7º 21'N and 7º 41'N; and Longitudes 3º 47'E and 4º 09'E (Figure 1). The National Population Commission (NPC 2006) revealed that the study area contained 643,587 people spread over a total land area of about 969.08km² (Table 1). The major and aboriginal indigenes of study area are the Yorubas, though there are other tribes from different parts of the country (Fabiyi 2006).

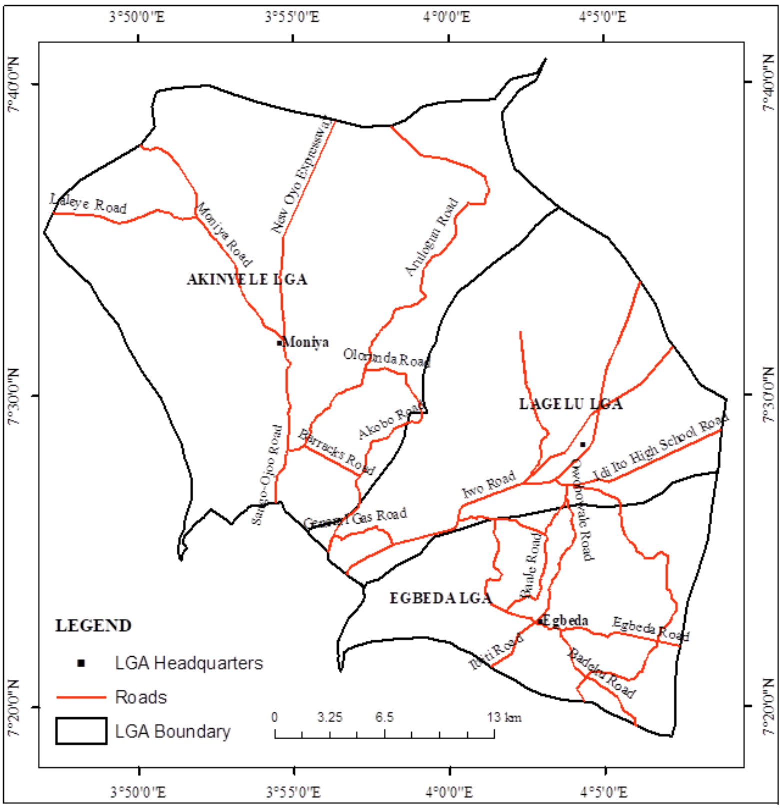

Figure 1. The Study Area
Source: Oyo State Ministry of Lands

Table 1. Size of the Study Area

S/N	L G A	Land Area (Ha)*	Population 1991**	2006**	2017***
1.	Akinyele	51,405	140,118	211,811	294,622
2.	Egbeda	18,833	129,461	283,643	394,538
3.	Lagelu	26,670	68,901	148,133	206,048
	Total	**96,908**	**338,480**	**643,587**	**895,208**

Sources: * Town Planning Departments of Akinyele, Egbeda and Lagelu LGAs
** National population Commission of Nigeria (NPC 1991; 2006)
*** Projection at 3% annual growth rate (National Bureau of Statistics 2012)

The study area falls within the tropical climate characterised by a long wet season which lasts for about eight months between March and October and a dry season of about four months between November and February. The mean annual temperature is 26.6ºC with seasonal variation. While the mean annual rainfall is about 1,260mm, the relative humidity could be as high as 76% (Ogolo and Adeyemi 2009; Egbinola and Amobichukwu 2013). The natural vegetation is derived forest consisting of such trees as *Iroko*, Mahogany, *Obeche*, and other similar varieties of hard wood (Toyobo *et al.* 2011). Whereas the northern part of the study area consists of the pre-Cambrian igneous rocks composed mainly of the medium grained gneiss, the southern section is dominated by sedimentary rocks. The major soil type in the study area varies from savannah soils in the northern part and forest soils with deep well drained sandy loamy and sandy clay loamy soil in the eastern and western parts (Oladele and Bakare 2011).

As a result of these geographical accounts, agriculture is the major human occupation in the area. Among the cash crops cultivated in the area are oil palm, cocoa and kolanut (Adelekan *et al.* 2014). Other economic activities include trading, public service employment and transport. Also, there are many local craft industries in the area that are using local materials to produce highly sophisticated farming tools and other items. However, there are few modern manufacturing industries in the area (Fabiyi 2006; Oladele and Bakare 2011; Adelekan *et al.* 2014).

3. Methodology

3.1. Data Sources and Acquisition

Data for this study were obtained from both primary and secondary sources. Primary data were sourced through fieldwork using Global Positioning System (GPS) receiver to obtain the geographic coordinates of relevant features for ground validations. Secondary data used for this study include administrative maps of the study area obtained from the Town Planning Departments of the respective Local Government Secretariats; population data obtained from the records of the National Population Commission, Ibadan; and satellite imageries (Table 2). In view of the available data, the period of change analysis was divided into two epochs; while the first epoch covered a period of sixteen years (1986-2002), the second epoch spanned over fifteen years (2002-2017).

Table 2. Satellite Imageries

Satellite Sensor	Spatial Resolution	Acquisition Years	Path	Row	Source
Landsat 5 MSS/TM	30m	1986	191	55	http;//glcf.umiacs.umd.edu
Landsat 7 ETM+	28.5m	2002	191	55	http;//glcf.umiacs.umd.edu
Landsat 8 OLI/TIRS	28.5m	2017	191	55	GLOVIS

3.2. Data Preparation

Hardcopies of the administrative maps of the three selected Local Government Areas in the suburban area of Ibadan were scanned, georeferenced and digitized for further analysis within GIS environment. Also, population data were used in calculating consumption rate and urban landuse coefficients of the study area. All the imageries used have been geometrically corrected and geo-referenced by the providers, therefore no geometric correction was carried out again; they were just projected. The digitized boundary was used to clip each of the imageries so as to extract only those portions that is within the study area. Imagery enhancement, contrast stretching and false colour composites were created to improve the visual interpretability of the imagery by increasing the apparent distinctions between the features. Furthermore, the imageries were classified into four landuse/cover classes using Anderson's modified version of supervised classification scheme to produce land-cover maps of the study area (Anderson 1971). In addition, accuracy assessment of the imageries was carried out using 100 randomly sampled ground truth points (Foody 2002).

3.3. Data Analysis

All analyses in this study are based on the contiguous suburban areas in the North-eastern part of Ibadan; all the three LGAs are treated at the whole landscape level. Therefore, the Landsat imageries used in this study were classified into four feature classes, namely: built-up area, vegetation, exposed surfaces and water bodies using maximum likelihood classification algorithm as a supervised classification technique (Table 3).

Table 3. Classification of Landuse/cover in the suburban Area

S/N	Classes	Land use/cover
1.	Built-up Area	Residential, industrial, commercial, paved surfaces and mixed pixels having built-up area.
2.	Vegetation	Farmlands, plantation, arable lands, natural vegetation, all other green spaces
3.	Exposed surfaces	Sandy areas, bare/exposed rocks, roads (earth surfaced), transitional areas, all other non-green open spaces.
4.	Water bodies	Rivers, streams, lakes, dams, reservoirs and all other surface water areas.

Source: Adapted after Anderson (1971).

In the attempt to quantify the spatio-temporal extent and rate of growth in the study area, results of landuse/cover classification were combined with class area spatial metrics (Cushman *et al*. 2008; Alphan *et al*. 2009; Deng *et al*. 2009; Yeh and Huang 2009; Buyantuyev *et al*. 2010; Kumar *et al*. 2018). In this study, ten spatial metrics were selected for analysis based on the potential of each to best describe the landscape pattern in the study area (Table 4). All the metrics were calculated using Fragstats program (McGarigal *et al.* 2002).

Table 4. Characteristics of landscape metrics used in Fragstats

Metric	Description	Units	Range
CA (Class Area)	Sum of the areas (Ha) of all urban patches.	Hectare (Ha)	CA > 0, no limit
NP (Number of Urban Patches)	Number of urban patches in the landscape.	None	NP ≥ 1, no limit
ED (Edge Density)	Sum of length (m) of all edge segment involving the urban patch type, divided by the total landscape area (Ha).	Metres per Ha	ED ≥ 0, no limit
PD (Patch Density)	Number of patches/total landscape area	Numbers per 100	PD ≥ 1, no limit
LPI (Largest Patch Index)	LPI equals the area (m²) of the largest patch of the corresponding patch type divided by total area covered by urban land type (m²), multiplied by 100 (to convert to percentage).	Percent	0 < LPI ≤ 100
AWMPFD (Area Weighted Mean Patch Fractal Dimension)	AWMPFD equals values of all urban patches, the fractal dimension of a patch equals two times the logarithm of patch perimeter (m) divided by the logarithm of patch area (m²).	None	1 ≤ AWMPFD ≤ 2
CONTAG (Contagion Index)	Sum of patches of all classes (i,j), of two probabilities of patch (class i) being adjacent to patch (class j).	Percent	0<CONTAG≤100
SHEI (Shannon Evenness Index)	SHEI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion, divided by the logarithm of the number of patch types.	None	0 ≤ SHEI ≤ 1
SHDI (Shannon Diversity Index)	SHDI equals minus the sum, across all patch types, of the proportional abundance of each patch type multiplied by that proportion.	Information	SHDI ≥ 0, no limit
ENNMN (Euclidian Mean Nearest Neighbour Distance)	ENNMN equals mean value of the distance (m) over all patches to the nearest neighbouring urban patch, based on shortest edge-to-edge distance from cell centre to cell centre.	Meters	ENNMN > 0, no limit

Source: Adopted after McGarigal *et al.* (2002)

4. Results and Discussion

4.1. Imagery Classification and Accuracy Assessment

Table 5 shows that the overall accuracies of the classification were 99.98% (1986), 99.62% (2002) and 99.21% (2017). These values indicate that there were high significant agreements between reference points and the extracted classes (Foody 2002; Herold *et al*. 2005). Figure 2 shows the results of the classification and the landuse/landcover maps of the study area.

Table 5. Imagery Classification and Accuracy Assessment

Class Name	1986 $Pa, Ua.$	2002 $Pa, Ua.$	2017 $Pa, Ua.$
Built-up	100.00, 100.00	100.00, 95.36	99.80, 99.49
Vegetation	100.00, 100.00	99.71, 99.96	98.93, 100.00
Exposed Surfaces	99.30, 98.87	97.35, 94.99	100.00, 48.96
Water body	96.58, 97.50	94.01, 100.00	100.00, 100.00
Kappa Statistics (k)	0.9972	0.9748	0.9829
Overall Accuracy	99.98%	99.62%	99.21%

Sources: Landsat TM 1986; ETM+ 2002 and OLI/TIRS 2017 (Path 191 Row 55)

Note: Pa = producer's accuracy, Ua = user's accuracy

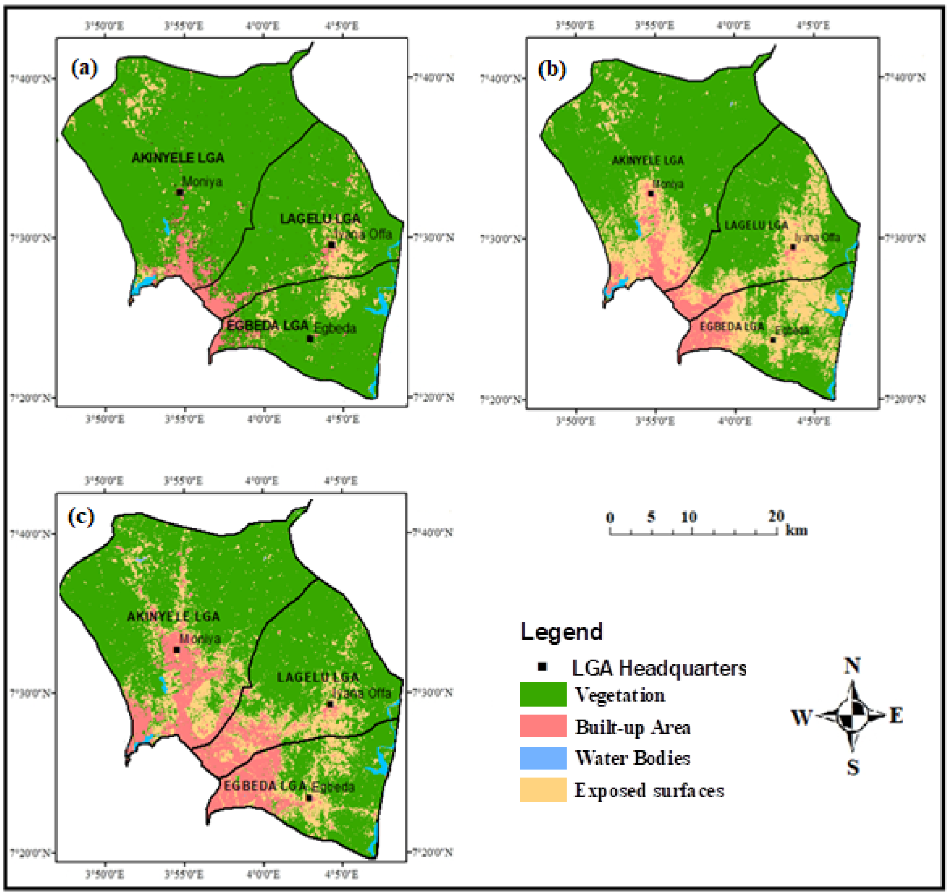

Figure 2. Land use land cover of the Study Area: (a) 1986 (b) 2002 (c) 2017
Sources: Landsat Imageries (Path 191 Row 55): TM 1986; ETM+ 2002; OLI/TRI 2017

4.2. Physical Changes in the Suburban Areas of Ibadan

Table 6 shows that vegetation covered the greatest proportion of the land at 78.89%, 74.84% and 49.63% in 1986, 2002 and 2017, respectively. Exposed surfaces occupied 12.16% in 1986, 12.28% in 2002 and 24.87% in 2017. The built-up area occupied 8.82% in 1986, 12.71% in 2002 and 25.30% in 2017. Water body occupied the least part of the landcover at 0.13% in 1986, 0.17 in 2002 and 0.20% in 2017. Increase in the proportion of exposed surfaces is an indication of intense human activities that might have encouraged opening up of the land thereby resulting in significant conversion of vegetated areas. However, a visit to the study area during the field survey revealed that most of the cleared portions (exposed surfaces) towards the eastern part of the area in 2002 have been covered by cultivated crops in 2017. Also, there was an increase in the area occupied by water body between 2002 and 2017 which might be as a result of the dredging and expansion of water channels embarked upon by the Oyo State Government of Nigeria in 2016 (Oyo State Government 2016).

Furthermore, Table 6 shows that there was a decrease in LCR from 0.025 in 1986 to 0.019 in 2002 which later increased to 0.027 in 2017. This shows that as the population increases over the years, the level of compactness increased between 1986 and 2017. This is an indication that there is a significant level of fragmentation and an outward spread of the built up class. Also, there was an increase in LAC from 0.012 to 0.048 between the two epochs indicating that as the population increases, rate of conversion of other classes of landuse to built-up also increases (Table 6).

Table 6. Summary of Landuse/Landcover Statistics

Landuse/Landcover		Built-up	Vegetation	Exposed Surfaces	Water Body
Landuse	**Year**				
(area covered in Ha, % in parenthesis)	1986	8,548 (8.82)	76,449 (78.89)	11,782 (12.16)	130 (0.13)
	2002	12,317 (12.71)	72,521 (74.84)	11,909 (12.28)	161 (0.17)
	2017	24,510 (25.30)	48,091 (49.63)	24,110 (24.87)	197 (0.20)
Growth Indicator	1986 to 2002	3,768.9 (44)			
(area covered in Ha, % change in parenthesis)	2002 to 2017	12,192.7 (99)			
Land Consumption Rate	1986	0.025			
(built-up class only)	2002	0.019			
	2017	0.027			
Land Absorption Coefficient	1986 to 2002	0.012			
(built-up class only)	2002 to 2017	0.048			

Sources: Landsat TM 1986; ETM+ 2002; OLI 2017

4.3. Growth Pattern / Overall Landscape Pattern of the Study Area

Table 7 shows that the total built-up area (CA) increased from 8,548.38ha in 1986 to 12,317.31ha in 2002 and later increased to 24,509.97ha in 2017. The highest rate of urban growth was observed during the second period of urbanization (2002 to 2017) in which the built-up area increased more than twice the previous size within 15 years (Table 7). Moreover, NP of the built-up class increased slightly in year 2002 which is an indication of more fragmentation and less of infilling development. The same scenario occurred in 2017 as proportionate increase in NP was recorded in 2017 indicating the continuing development of scattered and fragmented urban patches. The situation can be attributed to the emergence of built-up patches which occurred as the built-up expands outward. Increase in the NP between 1986 and 2002 (from 94 to 809) shows increased fragmentation of the built-up area during the study period (Table 7). This suggests that the period between 2002 and 2017 experienced tremendous expansion rate through the conversion of other landuse classes.

Table 7. Spatial Metrics of Built-up Class at the Entire Landscape Level

Year	CA	NP	PD	LPI	ED	AWMPFD
1986	8548.38	94	90.94	4.6695	2.41	1.37
2002	12317.31	455	27.07	5.7981	5.83	1.39
2017	24509.97	809	30.30	11.122	10.84	1.39

Sources**:** Landsat TM, 1986; ETM+, 2002; OLI, 2017

Table 7 shows further that PD decreased from 90.94 in 1986 to 27.07 in 2002 and, later increased to 30.30 in 2017. Therefore, it can be summed that some patches were merging to form a homogeneous landscape. This is further manifested in the increasing NP and a much faster increase in the CA. The cumulative effect is revealed by the gradual increase in LPI for the built-up land; this is a sign of agreement between the metrics Furthermore, AWMPFD was 1.37 in 1986 and 1.39 in 2017. These results imply that for a unit increase of patch area, the perimeter increased by 37% and by 39% in 2017. The higher value obtained in 2017 shows that the geometry of urban patches is getting more complex over time. This could be an indication of the prevalence of fragmented low density development in the fringe areas.

Results reveal that development pattern was not uniform in all directions and varies with the availability of space for expansion. Several studies have analysed the land use and land cover in the study area using GIS and remote sensing techniques, though at individual settlement or Local Government level (Fabiyi 2006; Toyobo *et al.* 2011; Agbor *et al.* 2012; Adegboyega and Aguda 2016). This study has combined spatial metrics analysis with the previous techniques, which helps in understanding the direction of growth and the nature of the landscape in the study area. For instance, the continuous rise of NP indicates that heterogeneous and fragmented growth process was taking place in the study area. However, a comparison of CA and NP metrics reveals that there was rapid urban growth resulting from increase in and expansion of the built-up area. Also, the increasing intensity of buildings in the area increased the LPI of the built-up area leading to a tremendous urbanization pressure over the other land uses. The increase of PD in built-up areas is a result of the urbanization process that occurred rapidly between 2002 and 2017. Increase in population necessarily aggravated the demand for more houses, subsequently creating new built-up areas at the fringe areas. Furthermore, a visual comparison of the classified imageries indicates an infill form of development between 1986 and 2002 and more of edge expansion during the second epoch.

5. Conclusion

This study investigated the growth patterns of selected LGAs in the suburban areas of Ibadan using remote sensing and spatial metrics techniques. Four major landuse/landcover classes were identified for the study: vegetation, built-up, exposed surfaces and water bodies. The study revealed a significant reduction in vegetation within the study period (1986 to 2017), and a corresponding increase in exposed surfaces and built-up landuse/landcover classes. While the increase in built-up class can be attributed to increase in population, the increase in exposed surfaces could be as a result of shifting cultivation farming systems and opening-up of more lands for road and other construction works. Moreover, this study found that the dominant growth process of settlements in the study area could be attributed to a creation process whereby patches representing settlements areas are increasing. The spatiotemporal analyses showed that a large proportion of vegetation was transformed to built-up areas. A proportional transition of other land uses to the built-up areas was also found to be consistently increasing.

6. Implications of the Study

The urbanization process in the area has caused fragmentation of the landscape and heterogeneous land use development. The result of landscape analysis showed that the trend of growth is to some extent influenced by haphazard land development practices and uncontrolled urban expansion. However, the heterogeneous landscape development will most likely continue into the next few decades as the built-up areas in the southern part have already started to agglomerate. Furthermore, the decreasing trend of nearest neighbourhood distance is an indication that homogeneity will increase by refill type of development after sometimes.

In view of the foregoing, the study recommends the need to incorporate the capabilities of Remote Sensing and GIS in landuse policy and decision making processes. This will greatly help in mitigating haphazard growth of the study area and also check the implications of dynamism and complexity associated with urban landuse problems like urban food crisis, poor accessibility, sprawl development at the fringe and other environmental problems that may be imminent.

7. References

Abolade, O, 2007, 'The Pattern, Direction and Factors Responsible for Urban Growth in a Developing African City', *Journal of Human Ecology*, vol. 22, no. 3, pp. 221-226.

Acheampong, RA, & Anokye, PA, 2013, 'Understanding households' residential location choice in Kumasi's peri-urban settlements and the implications for sustainable urban growth', *Research on Humanities and Social Sciences*, vol. 3, no. 9, pp. 60–70.

Adedire, FM, 2018, 'Peri-urban Expansion in Ikorodu, Lagos: Extent, Causes, Effects, and Policy Response', *Urban Forum*, vol. 29, no. 3, pp. 259-275.

Adegboyega, SA and Aguda, AS, 2016, 'Spatio-temporal analysis of urban sprawl in a fringe area around Ibadan, Southwestern Nigeria', *Ife Research Publications in Geography*, vol. 9, no. 1, pp. 132-154.

Adelekan, I, Olajide-Taiwo, L, Ayorinde, A, Ajayi, D & Babajide, S, 2014, 'Assessing Urban and Peri urban Agriculture in Ibadan, Nigeria', in J Padgham, and J Jabbour (eds.), *Building Urban resilience*. United Nations Environment Programme, Nairobi, Kenya.

Agbor, CF, Aigbokhan, OJ, Osudiala, CS & Malizu, L, 2012, 'Land use land cover change prediction of Ibadan metropolis', *Journal of Forestry and Environment*, vol. 9, pp. 1-13

Aguilera, F, Valenzuela, LM & Botequilha-Leitao, A, 2011, 'Landscape metrics in the analysis of urban land use patterns: A case study in a Spanish metropolitan area', *Urban Planning*, vol. 99, pp. 226–238.

Ahmed, B & Ahmed, R, 2012, 'Modelling urban land cover growth dynamics using multi-temporal satellite images: A case study of Dhaka, Bangladesh', *Int. J. of Geographic Information*, vol. 1, pp. 3–31.

Alphan, H, Doygun, H, & Unlukaplan, Y, 2009, 'Post-classification comparison of land covers using multitemporal Landsat and ASTER imagery: the case of Kahramanmaraş, Turkey'. *Environmental Monitoring and Assessment*, vol. 151, issues 1-4, pp. 327-336.

Anderson, JR, 1971, 'Land use classification schemes used in selected recent geographic applications of remote sensing', *Photogramm. Eng*., vol. 37, no. 4, pp. 379-387.

Appiah, D. O., Bugri, J. T., Forkuo, E. K., & Boateng, P. K. (2014). Determinants of peri-urbanization and land use change patterns in peri-urban Ghana. Journal of Sustainable Development, 7(6), 96–106.

Ayila, AE, Oluseyi, FO, & Anas, BY, 2014, 'Statistical Analysis of Urban Growth in Kano Metropolis, Nigeria', *International Journal of Environmental Monitoring and Analysis*, vol. 2, no. 1, pp. 50-56.

Buyantuyev, A, Wu, J & Gries, C, 2010, ‘Multiscale analysis of the urbanization pattern of the Phoenix metropolitan landscape of USA: Time, space and thematic resolution’, *Landscape and Urban Planning*, vol. 94, issues 3–4, pp. 206-217.

Chen, A, Zhao, X, Yao, L & Chen, L, 2016, ‘Application of a new integrated landscape index to predict potential urban heat islands’, *Ecological Indicators*, vol. 69, pp. 828-835.

Cushman, SA, McGarigal, K & Neel, MC, 2008, ‘Parsimony in landscape metrics: strength, universality and consistency’. *Ecol. Ind.*, vol. 8, pp. 691–703.

Deng, JS, Wang, K, Hong, Y, & Qi, JG, 2009, ‘Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization’, *Landscape and Urban Planning*, vol. 92, issues 3–4, pp. 187-198.

Dezhkam, S, Jabbarian Amiri, B, Darvishsefat, AA & Sakieh, Y, 2017, ‘Performance evaluation of land change simulation models using landscape metrics’, *Geocarto international*, vol. 32, no. 6, pp. 655-677.

Dutta, V, 2012, ‘Land use dynamics and peri-urban growth characteristics: reflections on master plan and urban suitability from a sprawling north Indian city’, *Environment and Urbanization ASIA*, vol. 3, no. 2, pp. 277–301.

Egbinola, CN & Amobichukwu, AC, 2013, ‘Climate Variation Assessment Based on Rainfall and Temperature in Ibadan, South-Western, Nigeria’, *Journal of Environment and Earth Science*, vol. 3, no. 11, pp. 32-45.

Estoque, RC & Murayama, Y, 2015, ‘Intensity and spatial pattern of urban land changes in the megacities of Southeast Asia’, *Land Use Policy*, vol. 48, pp. 213–222.

Fabiyi, O, 2006, ‘Urban Land Use Change Analysis of a Traditional City from Remote Sensing Data: The Case of Ibadan Metropolitan Area, Nigeria’, *Humanity & Social Sciences Journal*, vol. 1, no. 1, pp. 42-64.

Fan, C & Myint, SA, 2014, ‘Comparison of spatial autocorrelation indices and landscape metrics in measuring urban landscape fragmentation’, *Lands. Urban Plan.*, vol. 121, pp. 117–128.

Ferreira, IJM, Ferreira, JHD, Bueno, PAA, Vieira, LM, de Oliveira Bueno, R & do Couto, EV, 2018, ‘Spatial dimension landscape metrics of Atlantic Forest remnants in Paraná State, Brazil’, *Acta Scientiarum. Technology*, vol. 40, issue 1, pp. 1-8.

Foody, GM, 2002, ‘Status of land cover classification accuracy assessment’, *Remote Sensing of Environment*, vol. 80, no. 1, pp. 185-201.

Guindon, B, & Zhang, Y, 2009, ‘Automated Urban Delineation from Landsat Imagery Based on Spatial Information Processing’, *Photogrammetric Engineering & Remote Sensing*, vol. 75, no. 7, pp. 845-858.

Herold, M, Couclelis, H, & Clarke, K, 2005, ‘The role of spatial metrics in the analysis and modeling of urban land use change’, *Computers, Environment and Urban Systems*, vol. 29, no. 4, pp. 369–399.

Inkoom, JN, Frank, S, Greve, K, Walz, U & Furst, C, 2018, ‘Suitability of different landscape metrics for the assessments of patchy landscapes in West Africa’, *Ecological Indicators*, vol. 85, pp. 117-127.

Karg, H, Hologa, R, Schlesinger, J, Drescher, A, Kranjac-Berisavljevic, G, & Glaser, R, 2019, ‘Classifying and Mapping Periurban Areas of Rapidly Growing Medium-Sized Sub-Saharan African Cities: A Multi-Method Approach Applied to Tamale, Ghana’, *Land*, vol. 8, no. 3, pp. 40.

Kumar, M, Denis, DM, Singh, SK, Szabo, S and Suryavanshi, S, 2018, ‘Landscape metrics for assessment of land cover change and fragmentation of a heterogeneous watershed’, *Remote Sensing Applications: Society and Environment*, vol. 10, pp. 224-233.

Lawanson, T, Yadua, O, & Salako, I, 2012, ‘An investigation of rural-urban linkages of the Lagos megacity, Nigeria’, *Journal of Construction Project Management and Innovation*, vol. 2, no. 2, pp. 464–581.

Liu, X, Li, X, Chen, Y, Tan, Z, Li, S & Ai, B, 2010, ‘A new landscape index for quantifying urban expansion using multi-temporal remotely sensed data’, *Landscape Ecology*, vol. 25, no. 5, pp. 671-682.

McGarigal, K, Cushman, SA, Neel, MC & Ene, E, 2002, FRAGSTATS: spatial pattern analysis program for categorical maps, Computer Software Program, University of Massachusetts, Amherst, viewed 29 April 2019. http://www.umass.edu/landeco/research/fragstats/fragstats.html

National Bureau of Statistics, 2012, *Demographic Statistics Bulletin 2012*, Federal Government Press, Abuja.

National Population Commission, 1991, *1991 Census Report*, National Population Commission, Lagos.

National Population Commission, 2006, *Census 2006: National Summary*. National Population Commission, Lagos.

Ogolo, EO & Adeyemi, B, 2009, 'Variations and Trends of Some Meteorological Parameters at Ibadan, Nigeria', *The Pacific Journal of Science and Technology*, vol. 10, no. 2, pp. 981-987.

Oladele, BM & Bakare, HO, 2011, 'Dynamics of urban land use changes with remote sensing: Case of Ibadan, Nigeria', *J. of Geography and Regional Planning*, vol. 4, no. 11, pp. 632-643.

Olayiwola, AM, Ajala, OA & Sangodipe, JA, 2014, 'Physical Growth Pattern of Settlements in a Traditional Region, Southwest Nigeria', *International Journal of Geosciences*, vol. 5, pp. 1345-1360.

Oyo State Government, 2016, *The Pacesetter State*, The Official Website of Oyo State, viewed 22 August 2018. http://www.oyostate.gov.ng/ about-oyo-state/.

Pham, HM, Yamaguchi, Y & Bui, TQ, 2011, 'A Case Study on the Relation between City Planning and Urban Growth using Remote Sensing and Spatial Metrics'. *Landscape and Urban Planning*, vol. 100, pp. 223–230.

Rastandeh, A & Zari, MP, 2018, 'A spatial analysis of land cover patterns and its implications for urban avifauna persistence under climate change', *Landscape Ecology*, vol. 33, no. 3, pp. 455-474.

Singh, SK, Srivastava, PK, Szabo, S, Petropoulos, GP, Gupta, M & Islam, T, 2017, 'Landscape transform and spatial metrics for mapping spatiotemporal land cover dynamics using Earth Observation data-sets', *Geocarto international*, vol. 32, no. 2, pp. 113-127.

Shyamantha, S, Ronald, CE & Yuji, M, 2016, 'Spatiotemporal Analysis of Urban Growth Using GIS and Remote Sensing: A Case Study of the Colombo Metropolitan Area, Sri Lanka', *International Journal of Geo-Information*, vol. 5, no. 11, pp. 1-19.

Toyobo, AE, Muili, AB & Adetunji, MA, 2011, 'The Relevance of Infrastructural Facilities to Rural Housing Development in Lagelu Local Government, Oyo State, Nigeria'. *International NGO Journal*, vol. 9, no. 3, pp. 29-34.

Wondrade, N, Dick, OB, & Tveite, H, 2014, 'Landscape mapping to quantify degree-of-freedom, degree-of-sprawl, and degree-of-goodness of urban growth in Hawassa, Ethiopia', *Environment and Natural Resources Research*, vol. 4, no. 4, pp. 223-237.

Yeh, CT & Huang, SL, 2009, 'Investigating spatiotemporal patterns of landscape diversity in response to urbanization', *Landscape and Urban Planning*, vol. 93, issues 3/4, pp. 151-162.