NIGHTINGALE PUBLICATIONS AND RESEARCH INTERNATIONAL]

ASSESSING URBAN SPATIAL GROWTH OF KADUNA TOWN, NIGERIA, USING GIS/REMOTE SENSING AND LANDSAT IMAGES

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Abstract

This paper seeks to assess urban spatial growth of Kaduna town using GIS/remote sensing and Landsat images.Multi-temporal Land satellite raw imagery of Kaduna for 1999, 2009 and 2019 were acquired and used in the analyses and each of the imageries at 30-meter Resolution. Cloud-free Landsat ETM and satellite images downloaded from the USGS Earth Explorer website. ArcGIS 10.5 and ERDAS imagine 2015 software's were used to overlay two or more independently produced classified images to ascertain or examine the change detection that had occurred between the 20-year period of study from 1999-2019. The remotely sensed data were georeferenced and cropped to the study areas. The data were projected to the

Introduction

Urbanization is a global socio-economic phenomenon that has led to noteworthy land use changes in both developed and developing countries (Lin, 1994; Deng, Wang, Hong, & Qi, 2009; Magidi and Ahmed, 2019). All over the world, land cover is being progressively lost to anthropogenic activities with profound impacts on various environmental components such as land and water (Lambin, Helmut, & Lepers, 2003; Dewan & Yamaguchi, 2009; Tolessa, Senbeta, & Kidane, 2017; Liu, 2018). UN Habitat annual statistics reveal that more than half of the world's population is living in urban areas (Moore, Gould, & Keary,

NIGHTINGALE PUBLICATIONS AND RESEARCH INTERNATIONAL

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Minna UTM (Universal Transverse Mercator) zone 32N. ERDAS Imagine 2015 was employed to classify all the Landsat imagery into four main classes, which are built-up areas, water, natural vegetation and bare land. Results show that from 1999 to 2019, there was a notable change in urban areas as it increased from 4498.0 ha (1999) to 10805.1 ha (2019) (Table 2). From 1999 to 2019, urban areas increased by 6307.1 ha and within that same period the population more than doubled. The loss in vegetation can be seen with the steady decline in the percentage coverage from 88.1% to 83.6% and 70% in 1999,2009 and 2019 respectively, while water bodies and bare land seems to be on the increase. Bare-land land-use has shown an increase occupying 12.6% of the total area in 2019 as against 4.5% in 1999. Further projection of the Built-up to 2029 shows an increase of up to 21.81%, signifying future loss of vegetation and peri-urban agricultural land in the projected year from 70.1% (46,099.6 Ha) to 56.54% (37,210.9 Ha). It is recommended that policy makers make use of this method in establishing urban development and the impacts of this development on landuses. This is important for ensuring sustainable urban development in the study area.

Keywords: *Urban Spatial Growth, GIS/remote sensing, Landsat images*

2003; Cohen, 2006; Patel & Thomas, 2009; UN Habitat, 2014; Zhang, 2016). This development is certainly not without negative externality on the environment especially on land uses and land cover. The sensational dimension of this phenomenon is the reality that this rapid urbanisation is domiciled in cities of developing countries. What makes this sensational is that, developing countries are least resilient and have least ability to cope with vagaries of urbanisation, and paradoxically, they are the most rapidly urbanizing (Brennan, 1999; Brennan, 2002). The highest urban population growth rate of 5% between 1995 and 2015 was in Africa (Brennan, 1999; Brennan, 2002;Cohen, 2006; Fotso, 2007; UN-HABITAT, 2016).This phenomenon leads to conversion of large tracts of peri-urban land and largely agricultural land to urban land use (Mohammed and Worku, 2019). Seto, Fragkias, and Gu (2011) also pointed out that globally the rate of urban land expansion is twofold greater than that of the rate of population growth. This is evident with the failure by the authorities to provide adequate infrastructure and basic services such as water and sanitation (UN-HABITAT,

2016). As at 2018, an estimated 55.3% of world's population lived in cities, and this is estimated to rise to 60% globally in 2030 (United Nations, 2018). Urbanization in sub-Saharan Africa paints a grim picture of rapid urban expansion without the provision of commensurate infrastructure. According to UN-HABITAT, 2016, 90% of urbanization in this region takes place in informal settlements and is mostly accompanied by poverty, unemployment, environmental degradation, decaying of infrastructure and uncontrolled growth. With these startling facts, it is clear that urban spatial growth is an inevitable part of the human development process and there is a need for the spatial extent of this growth to be thoroughly assessed.

Recent years has witnessed an astronomical rise in the use of Geographical information system and remote sensing to monitoring urban growth, growth pattern and trends. Patterns of urban growth can be detected, mapped, and analyzed integrating Geographic Information Systems and spatial statistics approaches, such as the percentage of built-up areas (Sudhira, Ramachandra and Jagadish, 2004) dispersion, which quantifies the spatial distribution of built-up areas (Hayek, Jaeger, Schwick, Jarne and Schuler,2011) urban permeation, which measures how far the built-up areas have extended through a given territory (Hayek, Jaeger, Schwick, Jarne and Schuler,2011) or the proximity index, which quantifies the degree of isolation and fragmentation of the urban areas (Torrens, 2000 and Bhatta, Saraswati and Bandyopadhyay, 2010).Remote observation of urban areas are now a major application of GIS and remote sensing. GIS and remote sensing techniques provide a decision support system that enables researchers, urban planners and resource managers to have a historical perspective of the earth, detect and quantify urban land use changes which will inform their decision making process (Sudhira et al., 2003; Sudhira and Ramachandra, 2007)

This paper examines the urban spatial growth in Kaduna using GIS and Land Sat Image to assess the extent of growth that has occurred between 1999 to 2019. Geographical Information System (GIS) and remote sensing technologies was used for the detection of maps, monitoring urban spatial growth and also the provision of multi-temporal geospatial information concerning total land use categories of Kaduna metropolis planning area, growth rate, pattern through time series analysis of remotely sensed imageries from (1999 to 2019) at the interval of ten (10) years each. Result

from this study will, in the future, form the basis for efficient and effective planning models to be adopted in town and cities world over.

Study Area

The study area is Kaduna town, the administrative capital of Kaduna state. Kaduna metropolis as it is popularly known is located between Latitudes 10° 20' N and 10°37'N of the Equator and Longitudes 7° 22' E and 7°31'E of the Greenwich meridian. The metropolis consists of Kaduna North, Kaduna South, as well as parts of Igabi and Chikun Local Government Areas of Kaduna State. Kaduna got her name from River Kaduna known as "*Kogin Kadduna"* in Hausa which means "*river of crocodiles*". The name Kaduna was derived from the plural form of the Hausa word for crocodiles - Kadduna which was abundant in the Kaduna. The estimated population figure of the four local government areas making up Kaduna town was 1,550,087 as at 2006 (See table 1) and it is projected that the annual growth rate of Kaduna will rise from 1.1% between (2000-2018) to 2.7 % between (2018-2030) (United nations, 2018). The land coverage of all the four local governments is 8,503Km$^{2.}$

Table 1: Break down of Local Governments and their population (2006 Census)

S/No	*Local Government*	*Land Area Coverage Km²*	*Population*
1	*Kaduna North*	*72 km²*	*357,694*
2	*Kaduna South*	*59 km²*	*402,390*
3	*Igabi*	*3,727km2*	*430,753*
4	*Chickun*	*4,645km2*	*368,250*
		8,503 Km²	***1,550,087***

Source: Author's analysis 2019

Kaduna is situated in Northern Guinea savanna vegetation region characterised by dispersed trees and shrubs with vegetal cover (Akpu, Tanko, Jeb, & Dogo, 2017). Aristida, Pennisetum, Ctenium and Andropogon are the dominant grass species while Isobelina, Terminalia and Acacia are the dominant tree species. The trees are deciduous, in other words, they shed their leaves during the dry season so as to cope with the long dry season. However, the vegetation cover is declining due the effect of climate change mainly in favor of physical development due to rapid expansion of the city. The study area is mainly drained by River Kaduna which tends to divide the city into two unequal parts (see Fig 3).

Fig 1: Location of Kaduna State in the Context of the Map of Nigeria

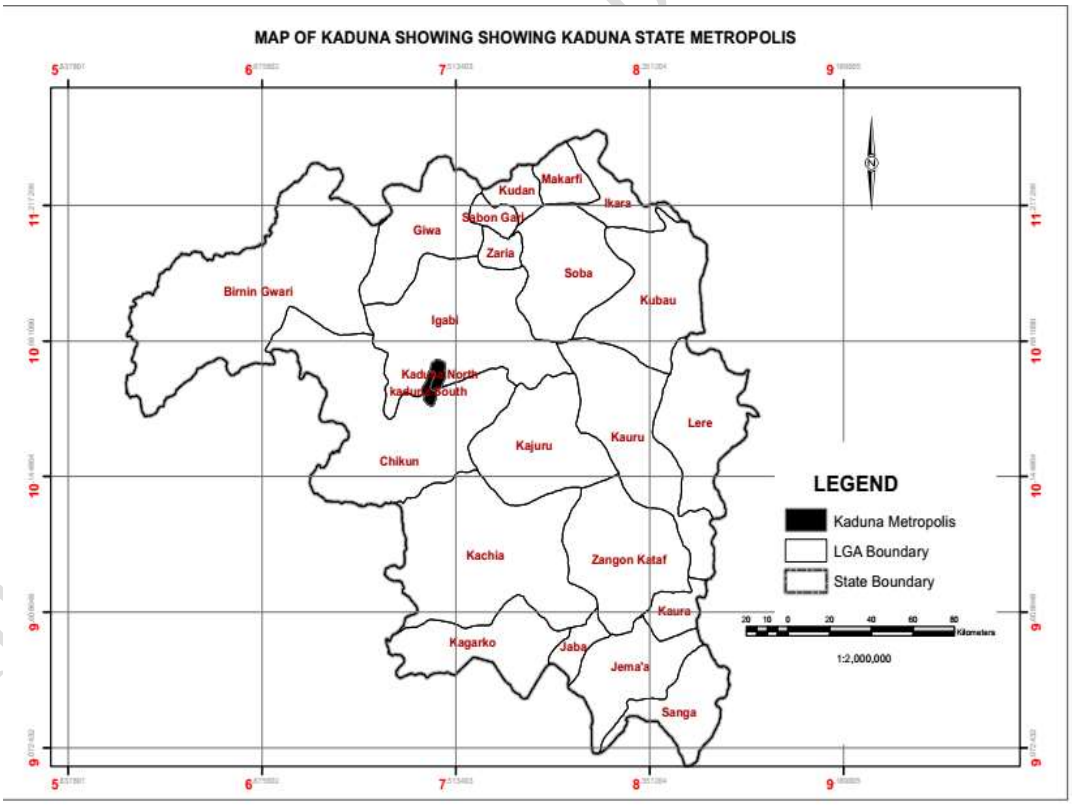

Fig 2: Map of Study area (Kaduna State)

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

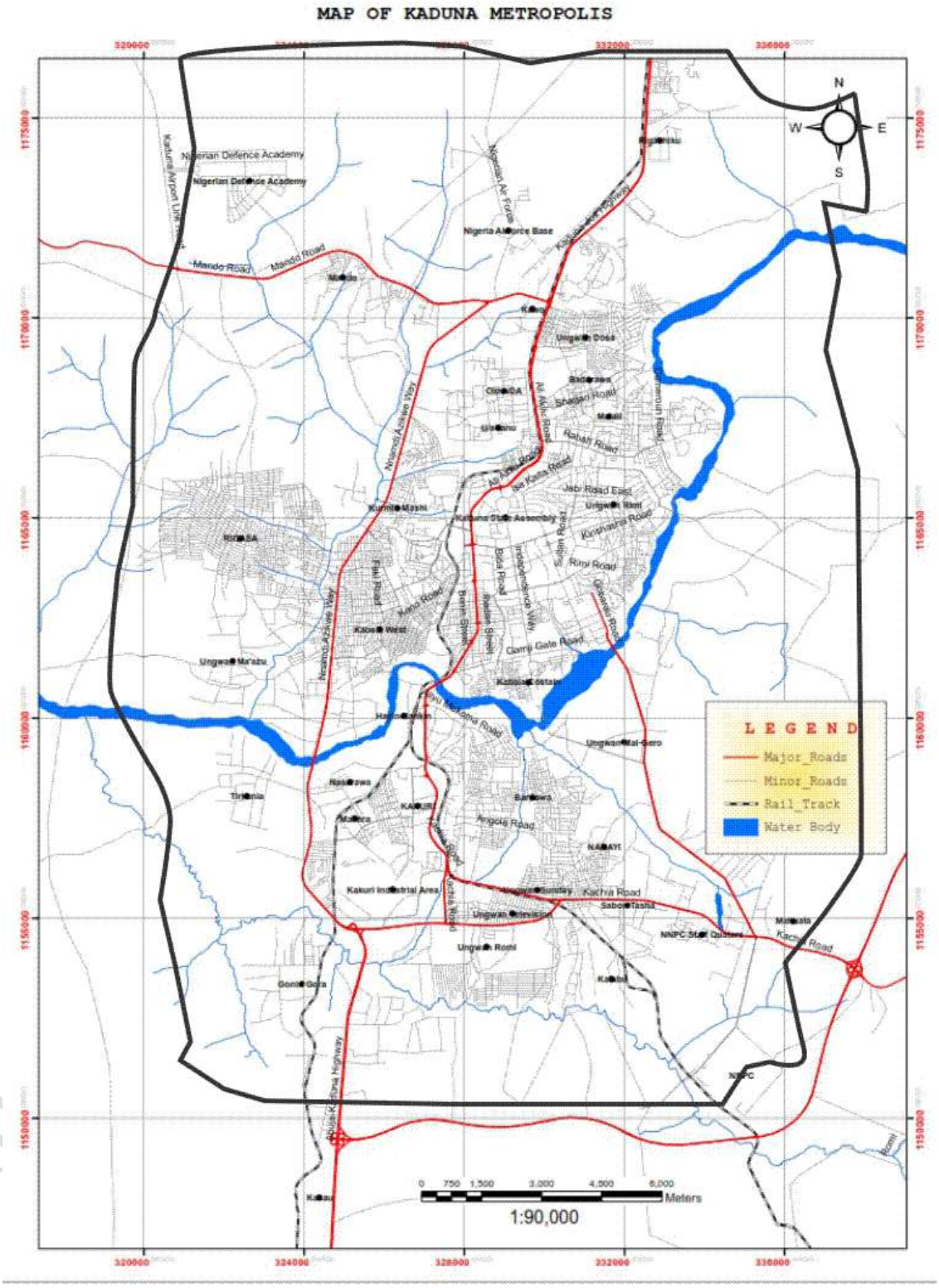

Fig 3:Map of Study area (Kaduna Metropolis)

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

Data and Methods

This study employed the use of both primary and secondary data. This includes both spatial and non-spatial data. Multi-temporal Land sat Satellite Imageries (MSS of 1998 ETM to 2018) and Google satellite imagery .Multi-temporal land sat satellite raw imagery of Kaduna for 1999, 2009 and 2019 were acquired and used in the analyses and each of the imageries at 30-meter Resolution. Cloud-free Landsat ETM andsatellite images downloaded from the USGS Earth Explorer website. These datasets were available free of charge which makes them cost-effective, and proficient for multi-temporal monitoring and quantification of change in the earth surface (Magidi and Ahmed, 2019). The images were downloaded downloaded on the 2nd of January 1999, 2009 and 2019 respectively so as to maintain sequence and uniformity in the images and interval with which the study was carried out.
ArcGIS 10.5 and ERDAS imagine 2015 software's were used to overlay two or more independently produced classified images to ascertain or examine the change detectionthat had occurred between the 20-year period of study from 1999-2019. The remotely sensed data were georeferenced and cropped to the study areas. The data were projected to the Minna UTM (Universal Transverse Mercator) zone 32N. ERDAS Imagine 2015 was employed to classify all the Landsat imagery into four main classes, which are built-up areas, water, natural vegetation and bareland.

Result and Discussion

The land cover maps of 1999 (Fig. 3), 2009 (Fig. 4), 2019 (Fig. 5), based on precise ordering and graphics crutiny shows alterations in urban areas flanked by the years. Upsurge in urban areas revealed with the increase in the impervious surfaces (built-up areas), which was apparent on the land cover maps (Figs. 3-5). These land cover maps (Figs. 3-5) visually exposes urban sprawl in the Kaduna and it's clear that built-up areas were expanding outwards into non-built-up bare land environments. Based on the results from 1999 to 2019, there was a notable change in urban areas as it increased from 4498.0 ha (1999) to 10805.1 ha (2019) (Table 2). From 1999 to 2019, urban areas increased by 6307.1 ha and within that same period the population more than doubled.

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

Table 2: Built-up Area, vegetation bare land and water bodies in hectare between 1999-2019

Year	1999	2009	2019
Built up Area	4498.0	7253.2	10805.1
Vegetation	57944.5	54988.3	46099.6
Bare land	2954.1	3046.8	8302.2
Water Body	409.2	517.5	598.9
Population	1413861	1994391	2813285

Source: Author's analysis 2019

The land use in the study area in 1999 can be visually seen from the map (Fig 3) which depict a greater proportion of vegetation which has 88.1%, followed by bare land with 4.5%, built-up 6.8% and water body with 0.6% of the total land cover as shown in table 3. Also the figure for 2009 satellite image show significant growth in built-up area and loss of vegetation in Kaduna metropolis, build up area grew from 4498.0 ha in 1999 to 7253.2 ha in 2009 thus between that 10-year period 2.755.2 ha was added to the built up area.

Table 3: land use change Percentage coverage in hectares between 1999-2019

Year	1999	% of area coverage	2009	% of area coverage	2019	% of areacoverage
Build-up area	4498.0 ha	6.8	7253.2 ha	11.0	10805.1 ha	16.4
Vegetation	57944.5ha	88.1	54988.3 ha	83.6	46099.6 ha	70.1
Bare land	2954.1 ha	4.5	3046.8 ha	4.6	8302.2 ha	12.6
Water body	409.2 ha	0.6	517.5 ha	0.8	598.9 ha	0.9
Total	65805.8 ha	100	65805.8ha	100	65805.8ha	100

Source: Author's analysis 2019

With this growth, built-up area will expand to be greater than vegetation, if measures for control are not taken to deliberately manage the spatial growth of the town.The changes in the land use occurred due to growing human demands such as residential, commercial and office complex constructions and recreation.

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

The loss in vegetation can be seen with the steady decline in the percentage coverage from 88.1% to 83.6% and 70% in 1999, 2009 and 2019 respectively, while water bodies and bare land seems to be on the increase. Bare-land land-use has shown an increase occupying 12.6% of the total area in 2019 as against 4.5% in 1999, (see Table 3) although it is not clear why bare land is increasing, it can be deduced that a lot of communities are abandoning their farm land as a result of security issues in the state. The remaining land-use categories, the water body (0.9%) shows a further increase due to over flooding which is most probably a result of increased human population and activities in the study area. This is seasonal as the size is influenced by seasonal variation.

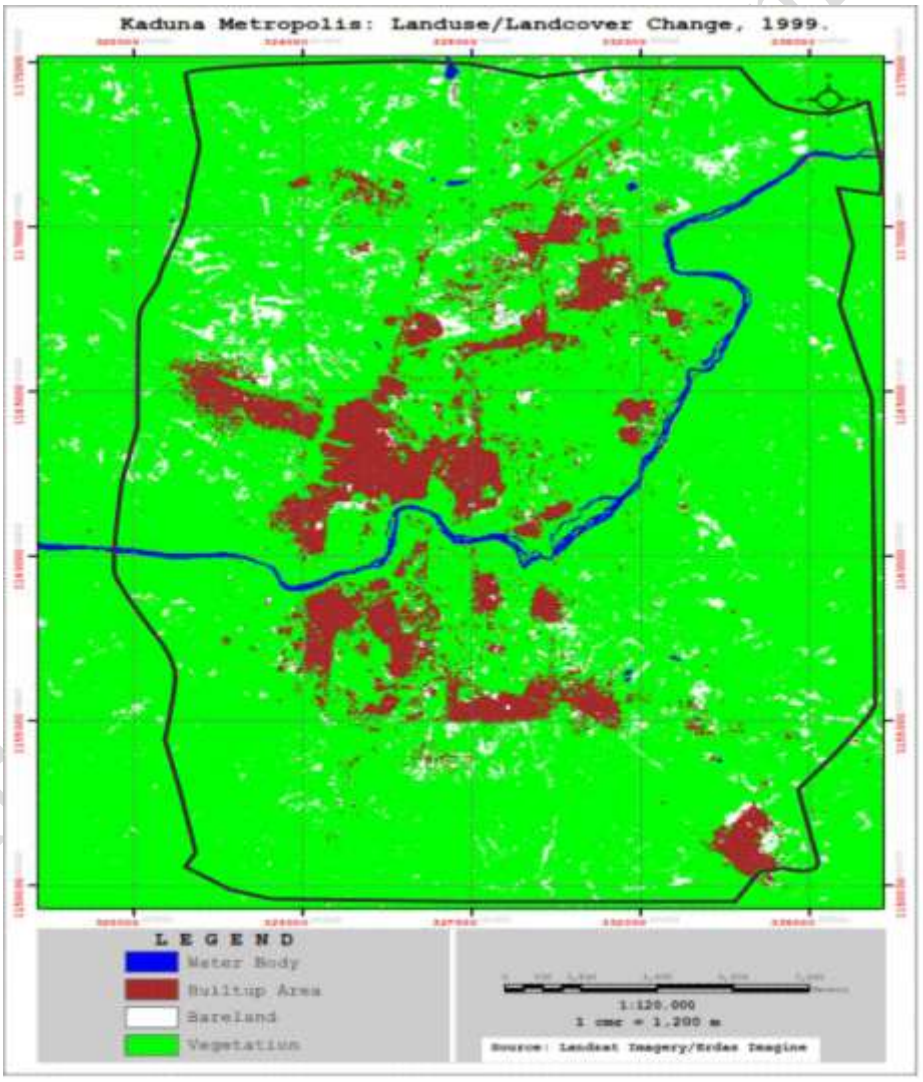

Fig 3: Land use/ land cover change of Kaduna metropolis (1999)

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
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Vol. 11, NO. 4]

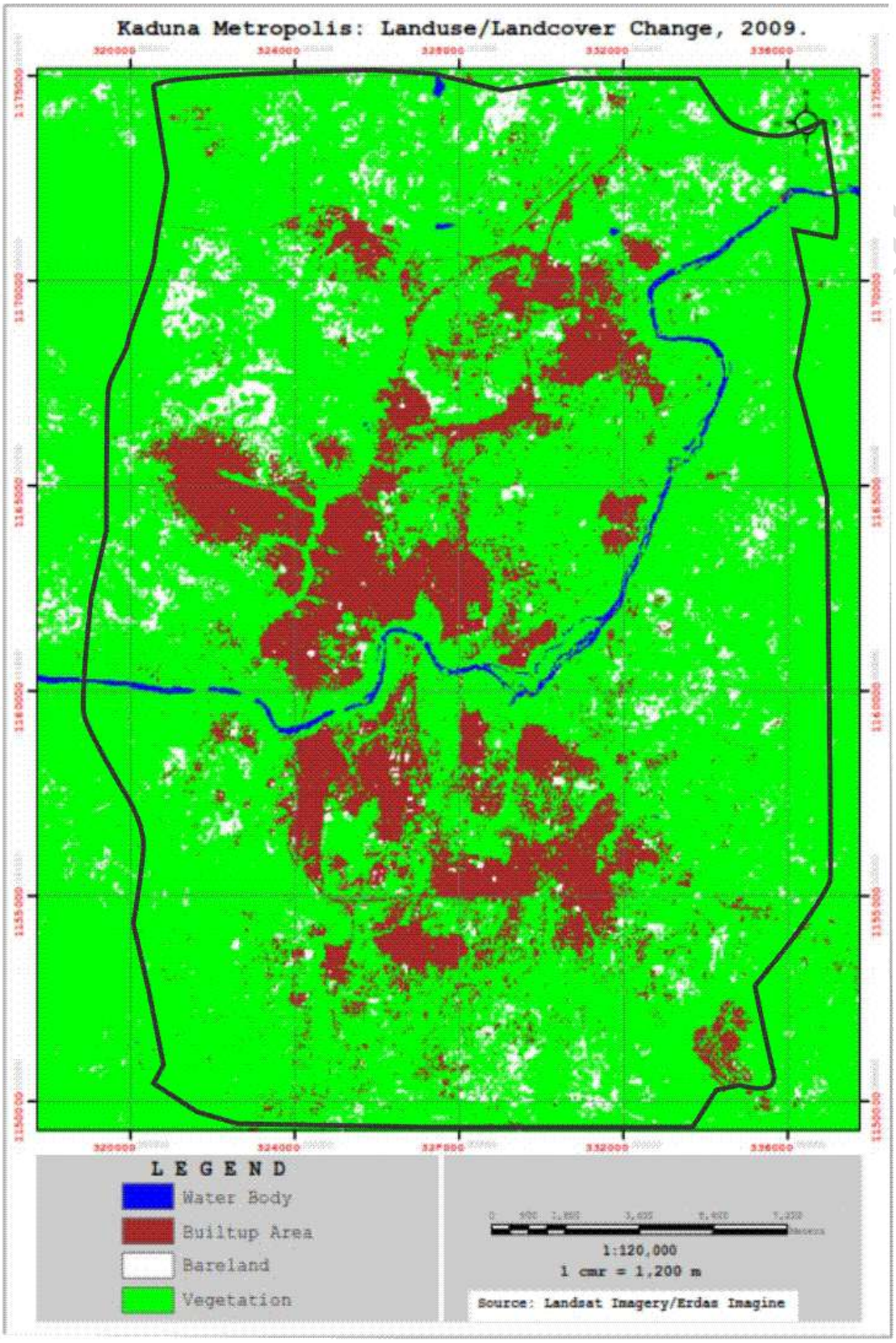

Fig 4: Land use/ land cover change of Kaduna metropolis (2009)

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

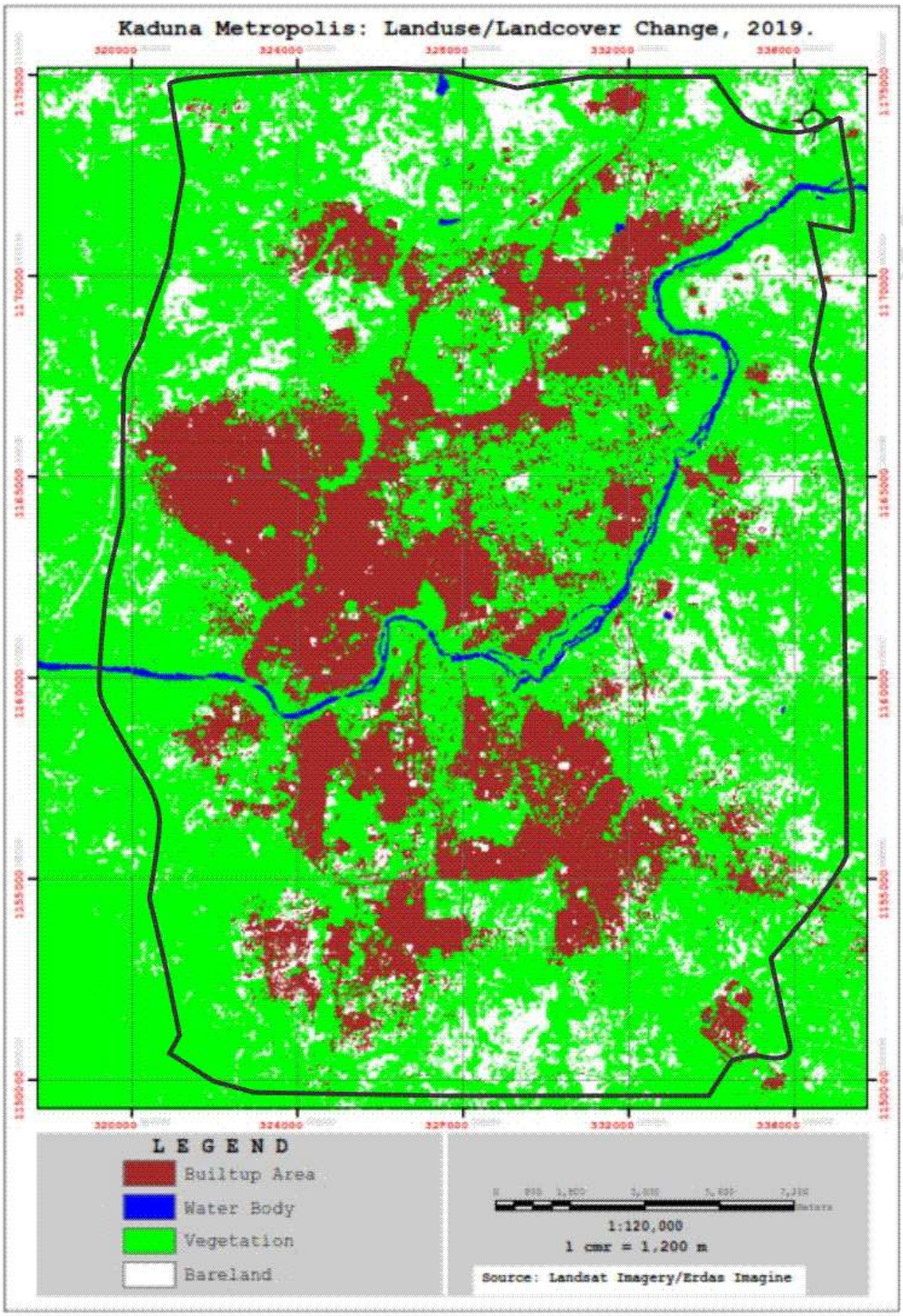

Fig 5: Land use/ land cover change of Kaduna metropolis (2019)

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

Composite Analysis of Land Cover Change in The Study Area (1999-2019)

The commonly known Vector Overlay and Statistical techniques were used in calculating the proportion of land use change for the period between 1999 and 2019. In order to have a clear understanding and a vivid visualization of the land cover of the study area, overlay analysis was used and the overlay analysis was done for the built-up land use only, since the built-up land use expands and takes over part of the other land uses, especially the bare land and vegetation land use. The proportions of the land use change for the years were found considerably significant. High proportions of the built-up, vegetation, bare land and water body between the years were observed and the changes that occurred. The built-up land use shows an increase in area from about 4498.0ha to 10805.1ha while the vegetation land cover shows a decrease from about 57944.5ha to 46099.6ha, while bare land shows an increase from about 2954.1ha to 8302.2haand the other land use which is the water body shows a slight increase which is cause by expansion of river bank as a result of over flooding over time from 409ha 1999 to 598.9ha in 2019. This may pose a threat to sustainable development goal of eradicating hunger as agricultural land is progressively being converted to urban land due to pressure arising from rapid urbanisation.

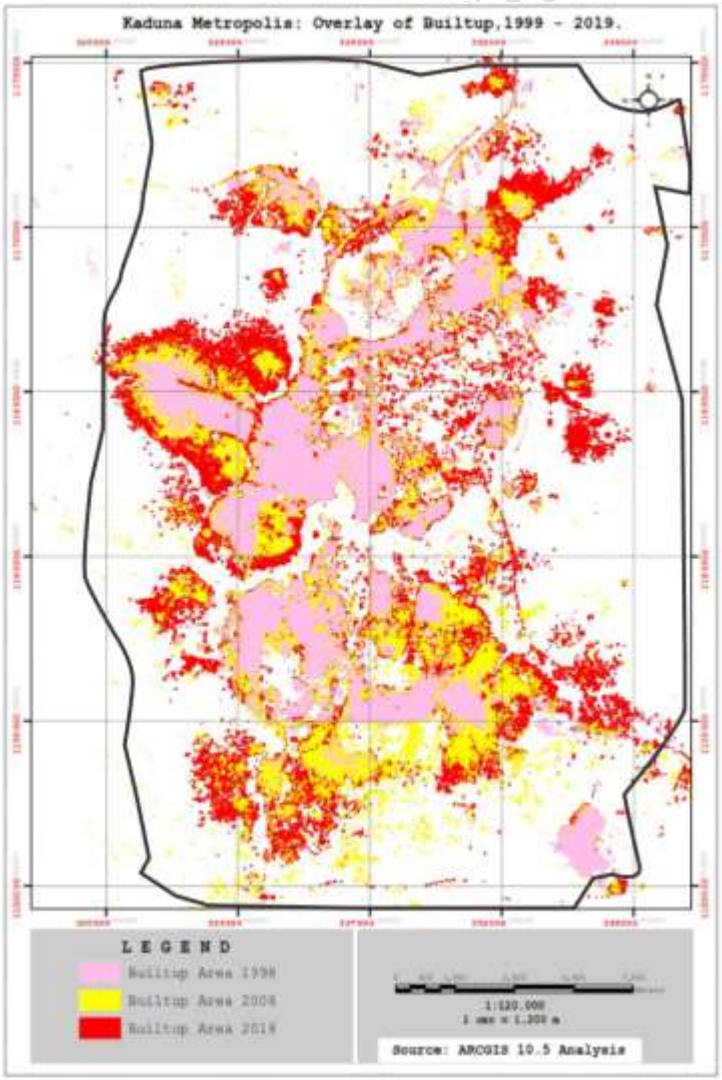

Fig 6:Kaduna metropolis overlay map of build-up land use.

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
IJECM ISSBN: 2167-4774
Vol. 11, NO. 4]

Future projection and modelled urban growth

A simulation analysis of future growth projection was also carried out in the course of this study and it reveals an inevitable occurrence of urban sprawl. The projection was done to cover a period of 10 years into the future. Simulation image generated indicates that pockets of urban sprawling areas are expected in Kaduna given it location as an administrative center and its proximity to the Abuja FCT by both road and railway routes. Further projection of the Built-up to 2029 shows an increase up to 21.81%, signifying future loss of vegetation and agricultural land in the projected year from 70.1% (46,099.6 Ha) to 56.54% (37,210.9 Ha) (see Table 4). Consequently, actions ought to be taken to address the consequence of urbanization problems such as over-crowding, congestion, pollution, building congestion, over stretching of facilities/ utilities, crime and juvenile delinquency. The upsurge in population demands for more land for housing construction to accommodate rising population growth. The most worrisome of the likely consequence is the possibility of food shortage due to cut down in agriculture arising from conversion of agricultural land to urban land use. this may jeopardize the efforts of government in meeting sustainable development goal of eradicating hunger.

Table 4: Projection of Built-up Area, vegetation bare land and water bodies in hectare and population between 1999-2029

Year	*1999*	*2009*	*2019*	*2029*
Built up Area	*4498.0*	*7253.2*	*10805.1*	*14,357*
Vegetation	*57944.5*	*54988.3*	*46099.6*	*37,210.9*
Bare land	*2954.1*	*3046.8*	*8302.2*	*13,202.2*
Water Body	*409.2*	*517.5*	*598.9*	*1,035*
Population	*1,413,861*	*1,994,391*	*2,813,285*	*3,531,588*

Source: Author's analysis 2019

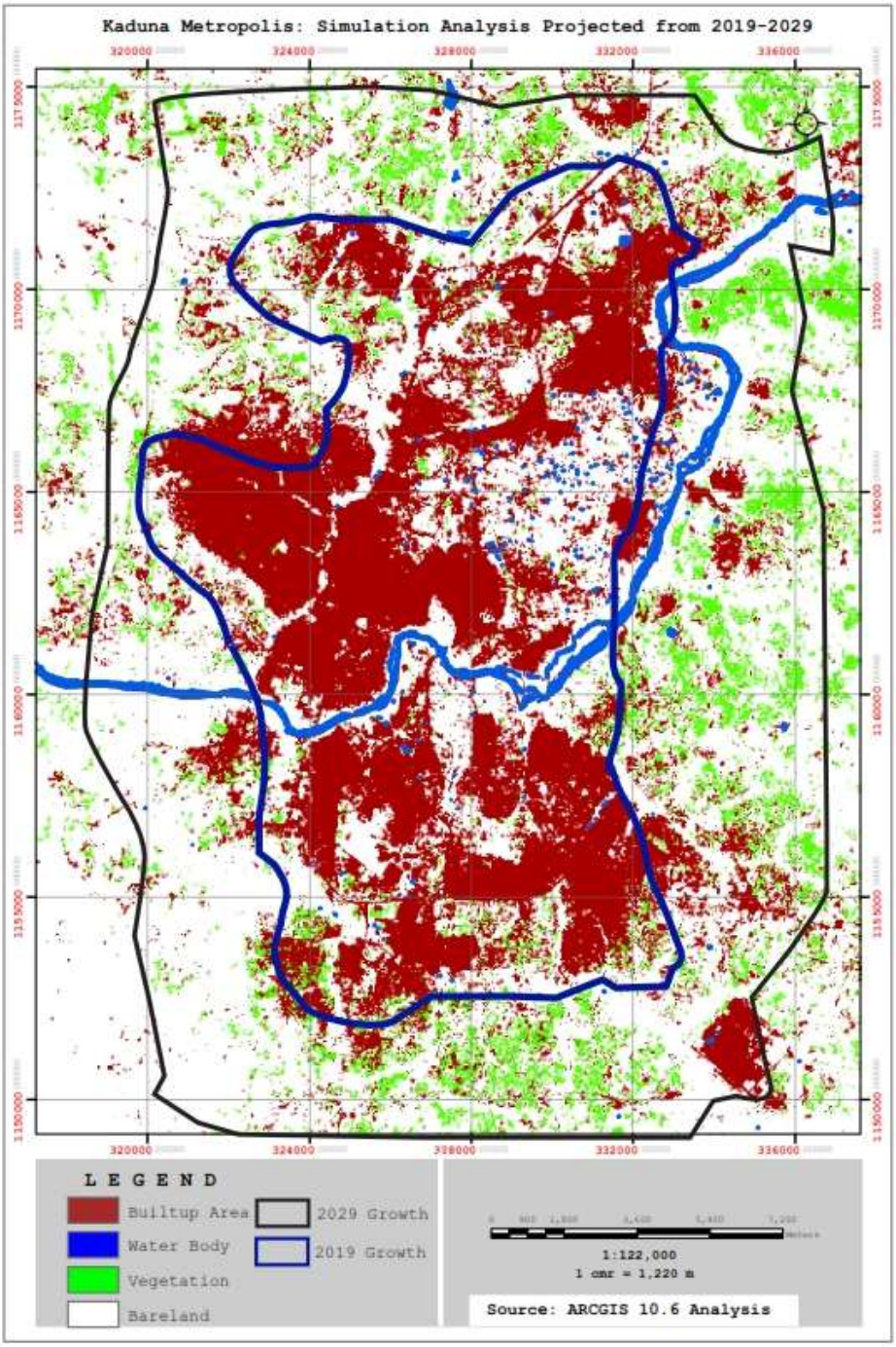

Fig 7: Simulation analysis projection from 2019-2029.

Conclusion and Recommendation

The study, using the techniques of Remote Sensing(RS) and Geographic Information System(GIS) attempted to provide an understanding of the urban

NIGHTINGALE
PUBLICATIONS AND RESEARCH INTERNATIONAL
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Vol. 11, NO. 4]

growth Kaduna metropolis from1999 to 2019, which is a period of 20 years. The study was carried out with the aid of Land Sat Imagery of 1999, 2009, 2019 and Google earth of 2019, ArcGIS 10.3.1 and Erdas imagine. The study also established that Kaduna metropolis has been increasing like most median cities of the world with built-up area showing an increase in coverage from about 4498.0ha to 10805.1ha while the vegetation land cover showing a decrease from about 57944.5ha to 46099.6ha.These changes in urban areas were also evident on the land use and land cover maps of 1999, 2009 and 2019.

The rate of the city growth calls for policy intervention in building sound, reliable and big data aided repository, that will provide the platform for effective monitoring and development control. This is to be accompanied by innovative urban development policy and zoning ordinance that will ensure strict vertical growth at the city centre in order to curb and minimize the prospects of gentrifying to the suburbs. Secondly, as development sprawls to the peripheries of the city, chances are that, weak development control around the fringes may pave way for the emergence of informal and squatter settlements. This may pose a threat to actualization of sustainable development goals of creating sustainable cities and reducing inequalities. It is imperative that the corporate limit of the city is redefined and development control activities extended to such limit. Thirdly, as the metropolis is situated within the river Kaduna tributaries, efforts must be contrived and ossified to prevent further push of urban growth to the vulnerable and environmentally sensitive zones liable to flooding. This is necessary to prevent loss of life's and properties to flooding. This drive conforms with the sustainable development goal of advancing life on land. In view of all these implications, it is imperative to have a synergy between the residents and the urban regulators on the need for implementing and monitoring measures that will ensure sustainable urban development in Kaduna metropolis. Increased urban renewal efforts of Kaduna State government must be sustained and site and serviced schemes must be introduced to curb informal development especially at the fringes.

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