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SPATIO-TEMPORAL TRENDS AND PATTERNS OF URBAN EXPANSION IN KADUNA METROPOLIS

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ABSTRACT

The aim of the study is to determine the spatio-temporal trends and patterns of urban growth in Kaduna metropolis. Specifically, the study determined the major factors of urban growth in Kaduna metropolis. Overtime, the drivers of urban expansion in Kaduna metropolis include rural-urban migration, urban migration, population increase, commerce, transportation, technology and industrialization, Institutions and demand for living space, etc. This paper evaluated and discussed the spatio-temporal trends and patterns of urban expansion in Kaduna metropolis from 1998 to 2013 and suggested physical planning solutions for improvement. The remote sensing, GIS and spatial metrics techniques to evaluate spatial-temporal urban growth trends and patterns were used to provide information on the extent and rate of urban growth. The spatial metrics was computed based on the remote sensing image classification results to quantify the trends and patterns of growth. The integration of both techniques provided better understanding of urban growth processes and patterns. The results of the findings revealed that the spatial development change in Kaduna metropolis is drastically at a rise from 1998, 2003, 2008, and 2013. Water bodies experience insignificant increase from 1.52161%, 1.38209%, 1.65265%, and 4.23816% respectively as a result of development encroaching wetland within the year under review (1998, 2003, 2008, and 2013). The built up area on the other hand increased significantly from 3.57834% to 16.57835%. There was a tremendous decrease on non- built up area causing disparity as a result of rapid urbanization and other

influencing activities in the study area. Non -built up area decreased from 94.90004% in 1998, 88.46415 % in 2003, 85.89385% in 2008, and 79.18350% in 2013 respectively. It was concluded that there is a rapid rise in growth and development in Kaduna Metropolis. Based on the results of the findings of the study it was recommended that the state government should muster the land supply monitoring for the dynamic aspects of urban growth by estimating the current and future supply of developable land to determine which lands are potentially developable according to physical constraints, governmental policies so that the location of current infrastructure could be made.

Keywords: *Evaluation, Urban expansion, Spatio-temporal growth, Trends and Patterns*

INTRODUCTION

In line with the New Urban Agenda's commitment to promote integrated urban and territorial planning, including planned urban extensions based on the principles of equitable, efficient and sustainable use of land and natural resources and prevents urban sprawl it is important for decision makers and urban managers to have readily at their disposal information concerning changes in land use patterns and structures occasioned by the phenomenon of urban expansion. This study seeks to provide that information. From the experiences of developed countries around the globe, uncontrolled residential expansion brings about some problems during the process of residential suburbanization such as fast urban sprawl without control, severe residential segregation of different estates and races, hollow urban centre and environmental cost of these problems in the decline of city centre and loss of farm land and open spaces (Ewing, 1997; Freilich and peshoff, 1997; Hylton, 1995; Rusk, 1993; Katz and Bernstem, 1998).

The population growth brings much pressure on both residential and farm land creating the need for measures to monitor rational residential expansion to make a good balance between the need to maintain the amount of arable land and the need to accommodate the demand of urban households. It is necessary for the government to take some strategies to monitor the residential expansion process for sustainable urban development. The Nigeria's urban government has long traditions to monitoring and controlling the residential expansion by means of urban master plan. Rapid urban growth of Kaduna is accompanied by high

population growth, dramatic land use/cover change and social transformation. Such rapid demographic and environmental changes in the past decades have resulted in environmental degradation, haphazard physical developments on wetlands and poor land use planning practices (Mabasi, 2009). Influence by topography, most of those growths are taking place in close proximity to wetland which are prone to flooding, this has aggravated the vulnerability of many inhabitants to natural disasters such as flooding and diseases (Stephen, 2009). Basically, planning and management of urban space requires a comprehensive knowledge of the development process and physical dimensions of cities (Klosterman, 1999). Evaluation of urban expansion will provide a clear insight of planning and management processes of urban patterns and growth in Nigeria. Therefore, the study on evaluation of urban expansion in Kaduna metropolis is timely and very relevant towards achieving a sustainable urban growth.

Over the last thirty years many urban areas in Nigeria have experienced dramatic growth as a result of rapid urbanization and population growth. While cities in Nigeria as well as other parts of the world command a dominant role as both centres of production and consumption, rapid urban growth of Nigerian cities has seriously outstripped the capacity of most cities to provide adequate basic services to their citizens. The causes that force growth in urban areas and the causes that are responsible for undesirable pattern or process of urban growth are essentially important for the analysis of urban growth. The consequences or the impacts of urban growth, whether ill or good, are also necessary to be understood and evaluated towards achieving a sustainable urban growth. Therefore, whether a pattern is good or bad it should be analyzed from the perspective of its consequences. Causes are also similarly important to know the factors that are responsible to bring such pattern. Indeed, remote sensing data is not enough to analyze the causes or consequences in many instances; one should have clear understanding of causes and consequences of urban growth and sprawl to encounter the associated problems. However, it is important to realize that urban growth may be observed without the occurrence of sprawl, but sprawl must induce growth in urban area. Some of the causes, for example population growth, may result in coordinated compact growth or uncoordinated sprawled growth. A tool such as GIS, Spatial metrics, and other techniques need to be implored in data generation to evaluate urban expansion. Therefore, this study was an evaluation of urban expansion in Kaduna metropolis to identify the factors determining spatio-temporal growth.

URBAN PATTERNS AND SPATIAL METRICS

Spatial primitives such as location, distance, direction, orientation, linkage, and pattern have been discussed as general spatial concepts in geography. In geography these concepts have been implemented in a variety of different ways. Under the name of landscape metrics, spatial metrics are already commonly used to quantify the shape and pattern of vegetation in natural landscapes (Gustafson, 1998; McGarigal, et al., 2002; Kadiogullari and Baskent, 2008). Landscape metrics were developed in the late 1980s and incorporated measures from both information theory and fractal geometry based on a categorical, a patch-based representation of a landscape (Mandelbrot, 1983). Patches are defined as homogenous regions for a specific landscape property of interest, such as 'industrial land', 'park' or 'high density residential zone' and so on.

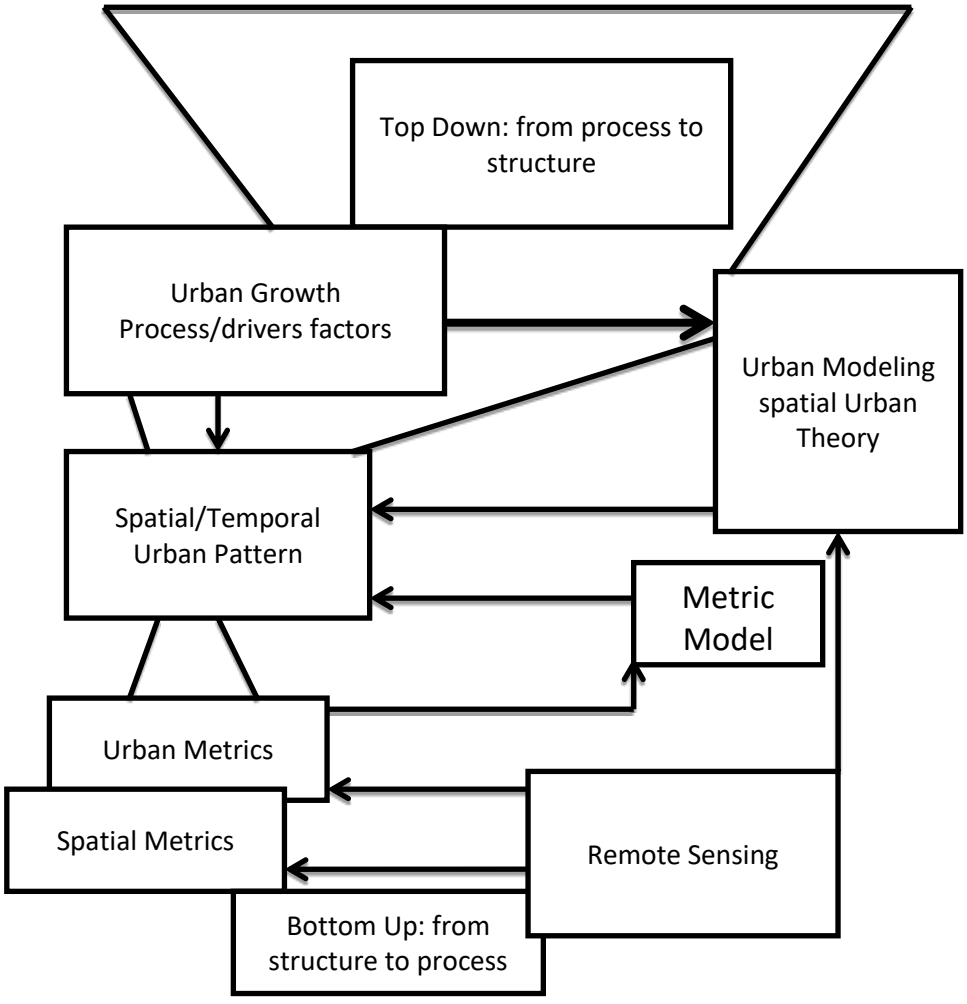

Chart Source: Conceptual approach for studying spatio-temporal urban dynamics (adapted from Herold, et al., 2005).

The landscape perspective usually assumes abrupt transitions between individual patches that result in distinct polygons as opposed to the continuous 'field' perspective. In analyzing environmental dynamics of forest or urban areas, landscape metrics are used to quantify the spatial heterogeneity of individual patches, of all patches belonging to a common class and of the landscape as a collection of patches. The metrics can be spatially non-explicit aggregate measures but still reflect important spatial properties. Spatially explicit metrics can be computed as patch-based indices (e.g., size, shape, edge density, patch density, fractal dimension) or as pixel-based indices (e.g., contagion) computed for all pixel in a patch (Gustafson, 1998). Herold, et al, (2005) applied spatial metrics to fields of research outside landscape ecology and across different kinds of environments (in particular, urban areas). In general, spatial metrics can be defined as measurements derived from the digital analysis of thematic-categorical maps exhibiting spatial heterogeneity at a specific scale and resolution. This definition emphasized the quantitative and aggregate nature of the metrics, since they provide global summary descriptors of individual measured or mapped features of the landscape (patches, patch classes, or the whole map). Furthermore, the metrics always represent spatial heterogeneity at a specific spatial scale, determined by the spatial resolution, the extent of the spatial domain and the thematic definition of the map categories at a given point in time. When applied to multi-scale or multi-temporal datasets, spatial metrics can be used to analyze and describe change in the degree of spatial heterogeneity (Wu, et al., 2002; Herold, 2003). Spatial metrics can be used to interpret the localized implications of different model scenarios. Similarly, spatial metrics can also be used to define rather than just interpret growth scenarios, as they can help represent locally detailed alternative spatial configurations. The calculated metrics allow having an overview of heterogeneity and spatial differentiations of patches in a landscape and a dynamic environment.

METHODOLOGY

This study focused on the evaluation of spatio-temporal trends and patterns of urban expansion in Kaduna metropolis to identify the factors determining spatio-temporal growth. The planning as delineated by the state government (40 Kilometers radius) was used for the study. Kaduna metropolis is a fast growing town whose population census shows that it has an estimate of 711, 115, it increased to 960,000 while in 2006, it rises to 1,642,537National Population Commission (2014). Projecting the population in 2013, it will rise to **2,703,983** The study determined the changes of spatial development in Kaduna metropolis using the Integration of Remote Sensing, GIS, and Spatial metrics technique.

The study was limited to spatial development that has significant planning implications within Kaduna metropolis.

- Landsat image of the study area at different multi-temporal time series were obtained from United State Geological Survey (USGS) website//hptt.www.earthexplorer.com as standard product. The images are of the same spatial resolution of 30m which made the comparison of changes and patterns that occurred during the time under consideration easier.
- Quick bird satellite imagery of the study area with 50m resolution was obtained from Ministry of Lands and Surveys, Kaduna State. The 2013 Google image of 60m resolution was derived from google earth 6.2 to assist in the field observation data in training the images during classification. It helped in identifying factors such as location of towns and places. The built up areas were derived from VHR Google earth image geodatabase. All data set used in the study were geometrically referenced to the ARC-1960-UTM-Zone-32 north projected coordinate systems.
- Coordinate of different locations in the study area was obtained by the use of GPS Garmin 78s. Informal interview was conducted by the researcher to determine the factors that are responsible for spatio-temporal growth in different locations of the study area. The source of additional information and the features found on the map and image verified on the ground (ground truthing) was gathered during the interview. The Tables 3.1 and 3.2 below show the summary of all the images used during the study respectively:

FINDINGS

The results and discussions of the generated land cover maps from classification of Landsat images include spatial temporal assessment of the maps, analysis of the nature, extent and rate of land cover change maps and statistics. The spatial analysis of change detection and patterns, using spatial metrics were also presented.

Table1: Summary of the spatial development change analysis in Kaduna metropolis

Land Cover Type	Year	Area (Ha)	Area (%)
Built Up Area	1998	5699.34	3.57834
	2003	16172.19	10.15375
	2008	19835.1	12.45351
	2013	26404.85	16.57835
Non Built Up Area	1998	151150.23	94.90004

	2003	140899.59	88.46415
	2008	136805.76	85.89385
	2013	126118.01	79.18350
Water Bodies	1998	2423.52	1.52161
	2003	2201.31	1.38209
	2008	2632.23	1.65265
	2013	6750.23	4.23816

The Table1 above reveals that the spatial development changes in Kaduna metropolis is drastically at a rise from 1998, 2003, 2008, and 2013. Water bodies experience insignificant increase from 1.52161%, 1.38209%, 1.65265%, and 4.23816% respectively as a result of development encroaching wetland within the year under review (1998, 2003, 2008, and 2013). The built up area on the other hand increased significantly from 3.57834% to 16.57835%. There was a tremendous decrease on non- built up area causing disparity as a result of rapid urbanization and other influencing activities in the study area. Non -built up area decreased from 94.90004% in 1998, 88.46415 % in 2003, 85.89385% in 2008, and 79.18350% in 2013 respectively.

Figure1 shows the summary of spatial development change in Kaduna metropolis (1998, 2003, 2008 and 2013) respectively.

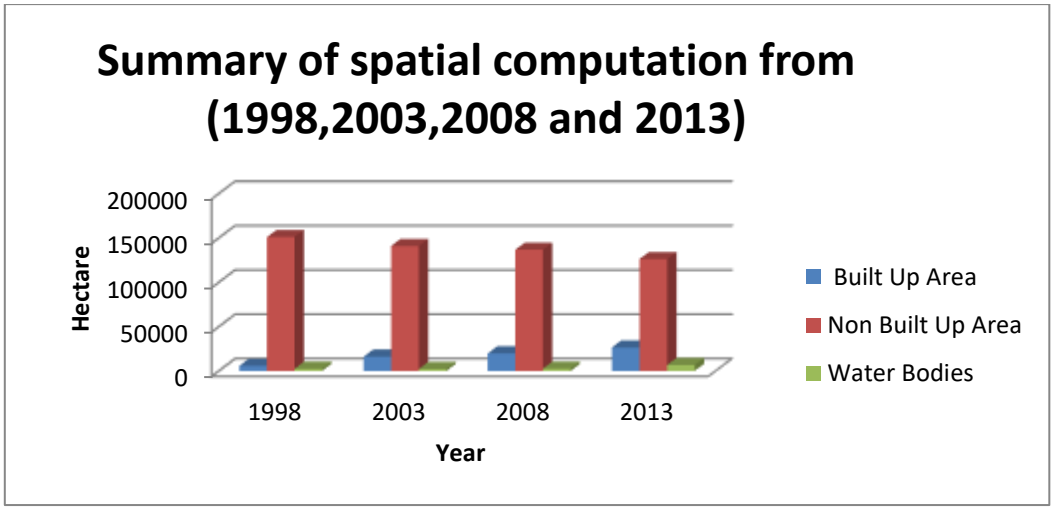

Figure1: Summary of Spatial Computation

Table2: Summary of the overall amount, extent and rate of change statistics of the classified landsat imagery from 1998-2013

Land Cover Type	1998-2003			2003-2008			2008-2013			1998-2013			
	Change area(Δ/ha)	Change	Rate of %	Change	Change	Rate of %	Change	Change	Rate of %	Change	Change	Rate of %	

		extent (%)	/ yr	area(ha)	extent (%)	/ yr	area(ha)	extent (%)	/ yr	area(ha)	extent (%)	/ yr
Built Up Area	+10472	+18	+3	+3662	+22	+1	+6569	+33	+1.2	+20705	+36	+1.8
Non Built Up Area	-10250	-6	-1	-4093	-2	-1	-10687	-7	-1	-25032	-16	-1
Water Body	-222	-9	0	-430	-1	-2	+4118	+1	-2	+4326	+1	-1

Table2 above shows the summary of the overall amount; extent and rate of change statistics of the classified landsat imagery from 1998-2013.In the study periods covered, the major land cover classes identified included built up area, non-built up area, and water bodies. The land cover types identified, i.e., built up area and non -built up area constituted the predominant type of land cover with an approximate area of 95% in their spatial extent in the study area and water bodies accounted for approximately 5% of the total area of the study area representing the small proportion of the land cover. During the investigation periods, distinct changes reflected in the Table above occurred on the major land use/land cover types.

The figure2 shows the Summary of the overall amount, extent and rate of change statistics of the classified landsat imagery from 1998-2013

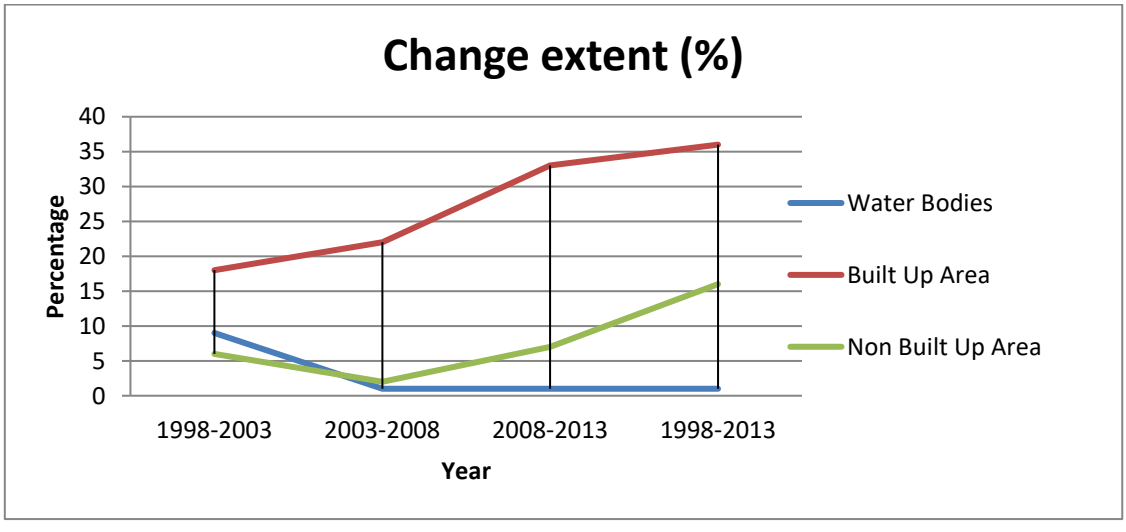

Figure 2: Change extent

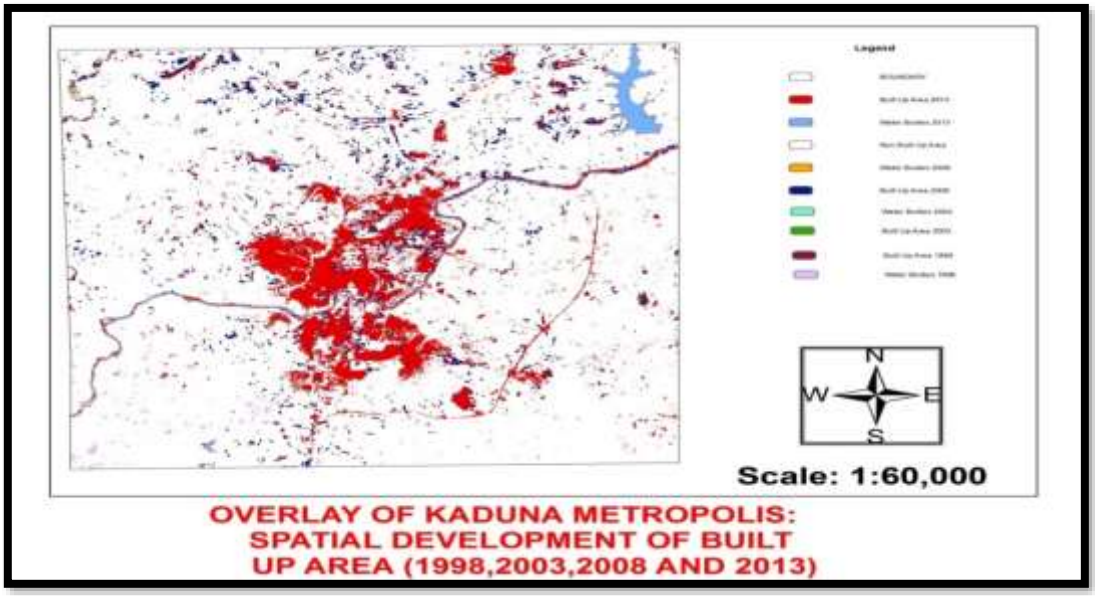

Figure 3 Overlay of Kaduna Metropolis: Spatial Development of Built Up Area 1998, 2003, 2008, and 2013

Discussions and Conclusion

The results of the findings of the study showed that the factors responsible for growth in the study area include: increase in urban land features, residential development, roads, and extension of motor parks (Kawo park, Tipper garage, Mando park, UgwanDosa park, Television Garage, Bakin Ruwa park, Abuja garage, etc.,). The results of the informal interview revealed that commercial areas as well as urban commercial services such as petrol stations, banking and government special land/institutional policies (NDA, Air-Force Base, Army Barracks, and Airport).

In 2003 an element of urbanization showed significant increase in expansion ranging from 5699.34 hectares to16172.19 hectares for built up area. Other factors included economic activities, and non- built up into urban uses. Example are the Kawo new extension, the legislative layout around Kawo area, the extension of Barakanlahu village and numerous farm lands that now form the urban periphery along Zaria road which enhanced expansion around Ungwan Sarki to Kawo. Transportation activities along NDA junction, construction works of new Kawo fly-over, Rigasa Bridge, Hayin Danmani Bridge, eastern bye pass, creation of new Kaduna millennium city attracted expansion of activities. Other militating factors against normal growth included natural occurrences such as the increasing incidental flooding in several parts of Kaduna metropolis, cultural and religious upheaval of February, 2000 and May, 2003 respectively.

In Kaduna, urban growth has historically been strongly related to transport technology. In fact, in urbanization process accessibility has played a key role especially in eastern and western parts of Kaduna metropolis. The available road network linking the northern and eastern part of the metropolis has led to urban expansion process from traditional base city models. These urban expansion factors are complicated due to the corresponding changes they greatly depict. The development of industries serves as the dominant factor toward the southern area of the metropolis (areas such as Makera district and Chikun district). Before the reform and opening up policy in 2003, basis condition and transport construction is a direct factor, while population and residential growth diffusion are main factors. For instance, the Kawo axis, construction of new eastern bye pass, new Kaduna millennium city layout among others. The reform and opening up policy in 2003 implementation in Kaduna paved way to city expansion and new towns suddenly emerged. Since institutional factor is said to be one of the determinants of the pattern of the whole development in Kaduna metropolis, therefore policies are important in guiding expansion in the study area. If this growth is not checkmated, urbanization would cover the whole metropolis. The Table3 below shows the summary of the drivers of urban expansion terminals in the study area.

Table 3 Summary of the Drivers of Urban Expansion Terminals of the study area

1998-2003	2003-2008	2008-2013
Rural-Urban Migration	Rural-Urban Migration	Urban Migration
International Trade Fair Complex in (1998)	Kaduna State University in (2004)	Petroleum Training Institute in (2009)
Return of civilian rule in (1999)	Population increase (2006) census	Rehabilitation of Murtala Square Sports complex in (2009)
Initiation of eastern bypass and 3rd (Kamazou)and 4th (Gobarau u/Rimi) bridge project in (2003)	Rehabilitation of Ahmadu Bello Stadium in (2006)	Development of Millennium city initiative in (2009)
		Northern noodles LTD (indomie) in (2013)

Growth in any urban area has a particular direction and pattern. Urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy

and society (Luck and Wu, 2002). Land use/land cover classifications and relative changes from 1998 to 2013 in Kaduna metropolis were shown in Figure 3. Furthermore, in a close visual look at Figure 2 & 3 spatial patterns of land cover revealed that urban built up area expansion followed certain directions depending on the new plan for land type for management, developing highways and relatively population growth. Built-up areas showed dramatic increase while the non -built-up area substantially decreased. Expansion of built up area has exhibited a consistent response since 1998 to 2013 in its areal extent Figure 2 & 3. There had been a continuous conversion of non-built up surface to built-up environments especially in areas adjacent to the existing urban boundaries in temporal dynamics. Kaduna town has recorded a significant increase in the built-up area and in the peripheral of the town mainly due to population growth and development in its formal and informal sector of the economy.

From the prospective of typology, Forman (1995) divided urban growth into three types: infilling, edge-expansion, and outlying. During infilling, a "hole" within an existing urban patch is filled with a newly developed urban patches (Liu, Li, et al., 2010). An edge expansion refers to newly developed urban patches spreading out from the edge of existing urban patches (Forman, 1995; Xu et al., 2007). New urban patches isolated from existing urban patches characterize outlying growth (Liu, Li, et al., 2010; Xu et al., 2007). Infilling growth types can be confused with edge-expansion or outlying growth type. Clearly, the confusion is caused by whether the existing urban patch approximates annulus. The infilling and edge-expansion are the predominant growth type pattern in Kaduna metropolis. Kukumaki Trade Fair Village Layout, Falalu Bello Layout behind Turkish International School, RafinGuza, Barakanlau village, Afaka layout, etc., to the north and to the east is Hayin Dan Bushiya layout, to the south Ungwan Mua'zu, Kudenda, Gonin Gora, Kamazo are some of the neighbourhoods that emerged through edge- expansion and were formally agricultural lands. The infilling pattern results as packets of land or parcels of land in the existing built-up areas or developed urban patches are gradually developed or filled. Old neighbourhoods like Sabon Gari, Tudun - Wada, Badarawa, Gabasawa, Hayin Banki, Doka, Kawo, Kurmin Mashi, Ungwar Sanusi and Badiko, etc., are experiencing an infilling growth pattern. The socio-economic status of land owners, land speculation and poor government intervention in housing and urban development is in one way or the other responsible for the infilling pattern. A new layout to the east known as new Kaduna millennium city is an example of an outlaying growth type pattern because it is a new urban patch isolated from existing urban patches. Based on urban growth phase theory, spatial urban evolution can be a general temporal oscillation between phases of diffusion and coalescence (Dietzel, Oguz,

Hemphill, Clarke, and Gazulis, 2005b; Duncan, Sabagh, & Van Arsdol, 1962; Yu & Ng, 2007; Winsborough, 1962). Diffusion is defined as the dispersion of patches, while coalescence is the fusion of patches into one patch (Dietzel, Oguz, et al., 2005). Outlaying growth corresponds with diffusion, and edge expansion and infilling represent coalescence (Xu et al., 2007). An overlay analysis of built-up areas of Kaduna metropolis in (figure 3) revealed that Growth is mostly outward from the edge of existing urban patches. In Kawo, Badarawa, Gabasawa, Rigasa, Rigachikun district, and Makera district growth is towards northeast and southwest direction. In Mando/Afaka district growth is mainly in the Northwest direction. Tudun Wada district is witnessing growth more predominantly towards the east and west. Growth in Chikun district is mainly linear in nature because of the linear pattern of the district defined majorly by the Kachia road. The expansion however occurred in Chikun district covering Gonin Gora up towards Kakau along the Abuja road around the refinery complex axis and particularly in Romi and Sabon Tasha, Kamazo along Kachia road. Kaduna town is expanding in every direction but with more concentration in the south and the general growth pattern of Kaduna metropolis is radial as it spread out ward virtually in all directions.

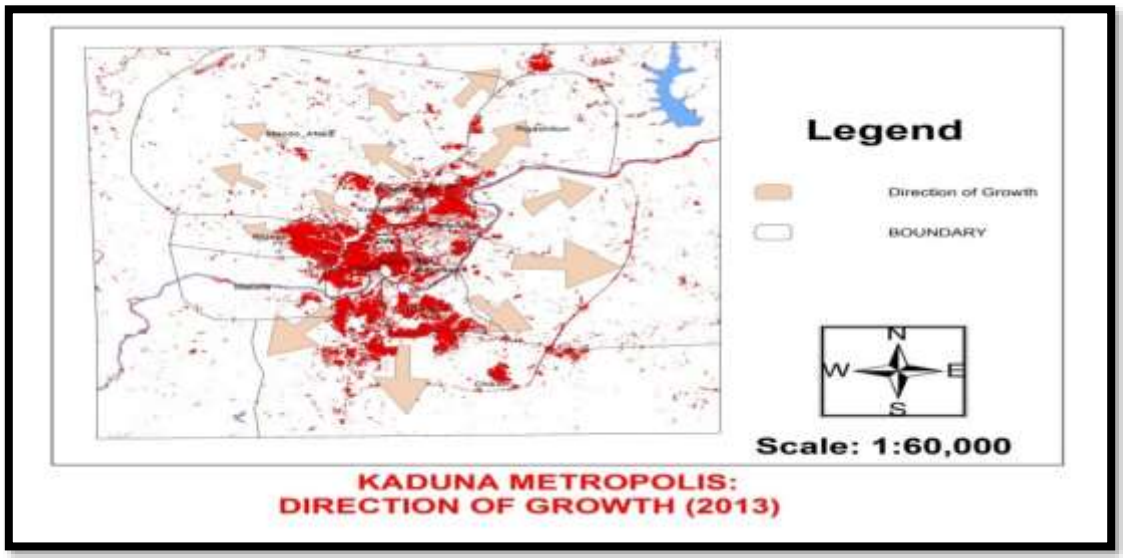

Figure 4 Kaduna Metropolis: Direction of Growth 2013

CONCLUSION AND RECOMMENDATIONS

Based on the results of the findings of the study, it was concluded that there is a rapid rise in growth and development in Kaduna Metropolis and the following physical planning solutions to urban growth were proffered:

1. Based on the results of the findings of the study it was recommended that the state government should muster the land supply monitoring annually for the dynamic aspects of urban growth by estimating the current and future supply of developable land to determine which lands are potentially developable according to physical constraints, governmental policies so that the location of current infrastructure could be made.

2. The steps involved in conducting Land inventory should include identifying vacant land and those lands that cannot be developed due to environmental constraints. Subtracting land needed for urban public services, adding land that can be redeveloped or developed at greater intensity through infill by identifying serviced land and estimating development capacity.
3. Through a systematic land assessment planning can create and assess alternative land use scenarios. These types of scenarios can be helpful for both master planning and for "envisioning exercises". Using geographic information systems (G.I.S.) modeling would help illuminate the possible effects of several land policies which may include, but are not limited to: increases in the permitted density of existing residential land and in intensity of existing commercial and industrial lands in a zoning ordinance; financial incentives for higher density housing; reduction of on-site parking requirements in a zoning ordinance; reduction of space requirements in a zoning ordinance; provisions permitting additional density or intensity beyond that generally allowed in the particular zoning district(s) in exchange for amenities and features provided by the developer; minimum density or intensity requirements in a zoning ordinance; redevelopment, infill, or brownfields strategies; authorization of housing types or site planning techniques in a zoning ordinance that were not previously allowed by the local comprehensive plan or zoning ordinance authorization of changes in the zoning use classification, including the employment of mixed use zones; and changes in standards for public and community facilities or services, including transportation, that require the use of less land. Sophisticated land use analysis can help policy-makers identify broad spatial trends, which can underpin planning strategies as this usually entails the development and application of planning support systems.
4. The use of Urban Service Boundaries to delineate the area beyond which certain urban services such as sewer and water will not be provided should be discouraged. They are often linked with adequate public facilities ordinances that prohibit development in areas not served by specific public services and facilities. Some metropolitan areas using USB adopts tiering

systems that attempt to direct public infrastructure into new areas in a particular sequence.

5. There is the need for inclusive and locally rooted visions of 21st century cities for all, there is no one top-down solution to urban sustainability but a wealth of bottom-up approaches instead. One of the strengths of cities in both poor and rich cities all over the world needs inclusive pro-poor strategies and guidelines enabling innovative local Mechanism. If this recommendation is given utmost priority, it would go a long way to help actualize the vision and mission for cities and human settlements of the New Urban Agenda which includes fulfillment of their social, participatory and fulfill their territorial functions amongst others.

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