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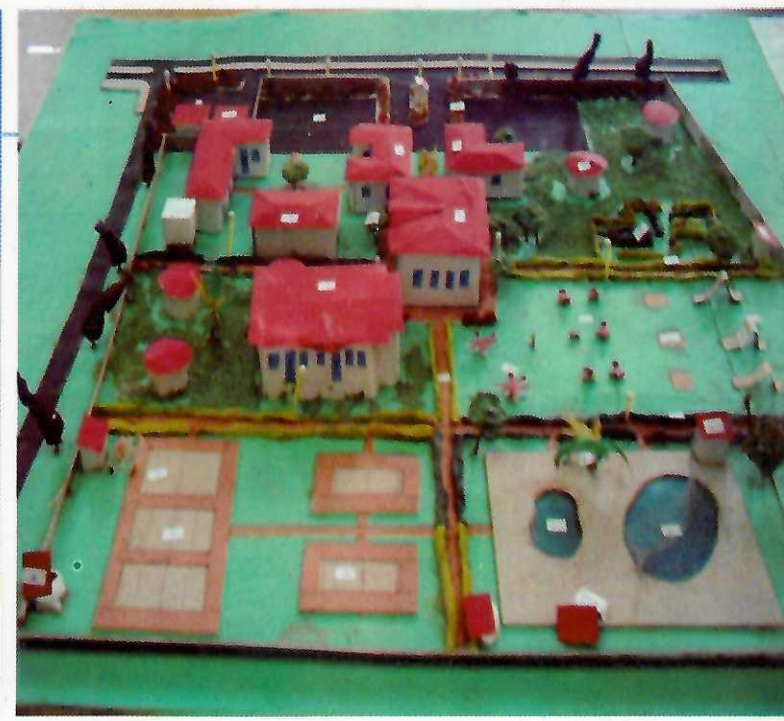

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Urban Sprawl Pattern Recognition and Modeling of Kaduna Metropolis Using Geographic Information System

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Abstract

Urban sprawl has been recognized as a problem that faces the developed world. Most developing countries follow their erstwhile colonial master's pattern of development; hence the problem of urban sprawl is not restricted to the developed world as it exists also in the developing of the world. However, the indicators are different as are the causes for sprawl. Developing country sprawl is largely a result of necessity people move to the city in search of better employment and opportunity Population dynamics are often cited as a driving force behind urban sprawl. This paper used Geographic Information Systems (GIS) mapping and land cover change analysis and neighborhood statistics, to measure urban sprawl in Kaduna metropolitan area. Analyzes of time series satellite images of urban land cover of Kaduna metropolis from 1973 to 2001(Landsat MSS of 1973, Landsat TM of 1990 and Landsat ETM of 2001). The data were reclassified to show only those classes that represent urbanized land. The two period's data were compared, to show the extent of urban growth over the last twenty eight years. Patterns analyses of urban expansion using mapping capabilities within the GIS and neighborhood statistics were carried out in order to show the density and connectivity of patches of new growth. The quantitative results from GIS data collection and analysis, and visual detection of sprawl patterns shown that urban sprawl is a part of urbanization processes in Kaduna metropolis. There is a 53.27 % increase in the level of urban land from 1973 to 2001. The increase in built-up land use was visible and result shows increase in the percentage of urban land in 1973 - 1990 constituted for approximately 46.73% of the study area. From 1990 to 2001, urban land accounted for approximately 53.27% of the study area. The result of the time series analysis revealed that urban land has increased over the twenty eight years time period by 145.52sq.metre.

Keywords: landuse conversion, urban sprawl, cluster development, growth management

1.0 Introduction

Urban sprawl is perhaps one of the most development challenges facing urban and rural communities today. It is generally recognized that sprawl has to do with individual choices regarding land use and location, our collective understanding of the factors influencing these decisions and how these decisions "aggregate up" over time and space to create sprawl is inadequate. This is due to limitations on both the theoretical and empirical fronts Sudhira et al, 2004).

From a theoretical viewpoint, theories that explain the link between individual choices and urban spatial structure are for the most part too simplistic in their representation of space to explain sprawl as the aggregate result of individual choices and behaviors. Because

sprawl is hypothesized to result partially from interactions among neighboring agents (e.g. via land use externalities), as well as spatially heterogeneous exogenous features (e.g. commuting costs, as well as topography and other natural features) and spatially varying policies (e.g. zoning, provision of public services), a theory of sprawl must treat space as multidimensional to account for the relative distance among agents as well as the spatial distribution of key sources of landscape heterogeneity. In contrast, most models of urban spatial structure simplify space to a one-dimensional measure of distance. For example, the traditional urban bid-rent model defines space in terms of distance to a central business district and ignores the remaining heterogeneity by imposing the assumption of a featureless plain (Strazheim, 1987).

More recent models of endogenous urban structure formation treat space as a measure of relative distance among agents, but ignore other sources of spatial heterogeneity (Anas and Kim, 1996). While these more recent models allow for a partial explanation of sprawl in terms of interactions among spatially distributed agents, they do not allow for a full treatment because they are unable to consider jointly the role of endogenous interactions and exogenous sources of spatial heterogeneity, including spatially varying policy, in creating or mitigating sprawl patterns of development.

From an empirical viewpoint, the lack of understanding of how individual actions translate into sprawl is due mainly to data limitations that have prohibited extensive explorations of how exogenous and endogenous factors influence individual land use decisions and how these decisions then relate to neighborhood and regional patterns of land use change. Because of lack of spatial data on individual-level land use and location choices over time, most empirical studies of sprawl are limited to aggregate values of population, employment, and urban development as measures of sprawl (Dennis,1989). At this more aggregate scale of analysis, causal explanations of sprawl that link underlying individual behaviors to observed patterns are difficult to come by and separate identification of endogenous vs. exogenous effects is impossible. As a result, the analyses are limited to identifying characteristics that are associated with, but do not necessarily cause, sprawl.

Nigeria, as one of the important countries in the less developed region of the world (United Nation World Urbanization Projects 1990) shares similar urban development challenges as other countries in the region, arising from high rate of urbanization. The rate of growth

of Nigerian towns and cities is unprecedented. A study by the World Bank (1995) estimated that the population of Nigeria would have doubled by the 21st Century. This is reinforced by the fact that whereas the national population growth rate is estimated by the Bank as being around 2.9%, that of urban population is 5.5% between 1980 and 1993.

In recent years Kaduna's metropolitan area has witnessed significant growth in peripheral urban development, or urban sprawl, with progressively increased land consumption, matched by a decrease in population at the core. Regardless of the differences between the planning areas and the unplanned areas, it is clear that the town is experiencing "urban sprawl".

Urban sprawl is often difficult to gauge because it can occur slowly over time. As Wilson et. al (2003) rightly indicate, no such universally accepted definition of urban sprawl exists and indeed the phenomenon it seeks to describe, i.e. the land-consumptive pattern of urban development, can be interpreted both positively and negatively. The authors develop an urban "growth", rather than "sprawl" model, to quantify the amount of land converted to urban uses, leaving it open to subjective interpretation whether or not it constitutes "sprawl". They wisely suggest that "the challenge is to quantify and categorise urban growth in a way that is useful and meaningful to land use decision-makers at the municipal, regional and state levels" (p. 276).

Urban sprawl is characterized by leapfrog land use patterns, strip commercial development along highways, and very low-density single-use developments, all of which occur over a relatively short period of time (Ewing 1997). It has also been defined in terms of associated causes: urban sprawl is generally believed to result from poorly planned, large-scale new residential, commercial and industrial developments in areas not previously used for urban purposes (Zhang 2001). However, there is one overriding theme in the recognition of urban sprawl: a spatial-temporal signature unique to the phenomenon. Over the past 50 years the process of urbanization, suburbanization, counter-urbanization, and re-urbanization, has allowed for urban expansion into rural areas taking the form of low-density development, predominantly single family residential subdivisions and strip commercial development (Lee et al 1998). "Sprawl is urbanization that takes place in either a radial direction around a well-established city or linearly along the highways over a given period of time (Sudhira et al 2004). Clearly, radial and linear are just two types of map

patterns that sprawl can take. Sudhira et al. (2004) state that to understand the complexity of urban sprawl, land use change analyses and urban growth pattern recognition must be determined.

1.1 Statement of Problem

The unprecedented population growth in Nigeria coupled with unplanned developmental activities has led to many planning problem such as over-urbanization, dispersed development, e.t.c. This dispersed unplanned development along highways or surrounding the city and in rural countryside is often referred to as sprawl (Theobald, 2001).

Patterns of sprawl and analysis of spatial and temporal changes could be done cost effectively and efficiently with the help of spatial and temporal technologies such as Geographical Information System (GIS) and Remote Sensing. These are land related technologies that are very useful in the formulation and implementation of land-related component of sustainable development. The spatial patterns of urban sprawl over different periods can be systematically mapped, monitored and accurately assessed from satellite data (remotely sensed data) along with conventional ground data (Leta et al 2001).

This paper therefore, explores the patterns and extent of urban sprawl in Kaduna metropolitan area using multi-temporal satellite data with a view to providing adequate information and measures towards mitigating physical development problems and effective urban management.

1.2 Research Questions

Two research questions guide this study.

1) Has urban sprawl taken place in the study area based on characteristics of new urban growth? or
2) Has urban sprawl taken place within the study area based on an increase in the amount of urban or built-up land from 1973 to 2001?

1.3 Objectives of the Study

To measure urban sprawl within the study area based on urban land use change between 1973 and 2001 and assess patterns and directions of new urban growth thereby classifying those patterns as urban sprawl: linear or strip along highways, expansion or cluster, and leapfrog or relocation as the case might be.

1.4 Description of the Study Area

Kaduna occupies almost the entire central part of the north and shares common border with Sokoto, Katsina, Niger, Kano, Bauchi and Plateau states. The states also shares as border with the new federal capital territory, Abuja.

The global location of the state is between longitude $06^0 00'$ $09^0 00'$ east of the Greenwich meridian and also latitude $09^0 00'$ and $11^0 30'$ North of the Equator, while the state capital Kaduna roughly lies on longitude $10^0 35'$ north of the equator(fig.1). The state occupies an area about 48,372 square meters.

Kaduna metropolis stands in rolling pack land above sea level; the soil is good with average rainfall (Bryant 1969:1)., The climate is equable and invigorating and compares favourably with that of any town in Nigeria. The area has no dominant native associations large enough to build large cities. Thus Kaduna as a settlement was concerned as a new colonial township of a second class status (Maxlock, 1967:84). Essentially, Kaduna was selected as a site for the capital of the Northern region of Nigeria. It is expected that the character of the city would bear resemblance to the conceptual vies of the ruler of the time and socio-economic realities of the time Kaduna was conceived.

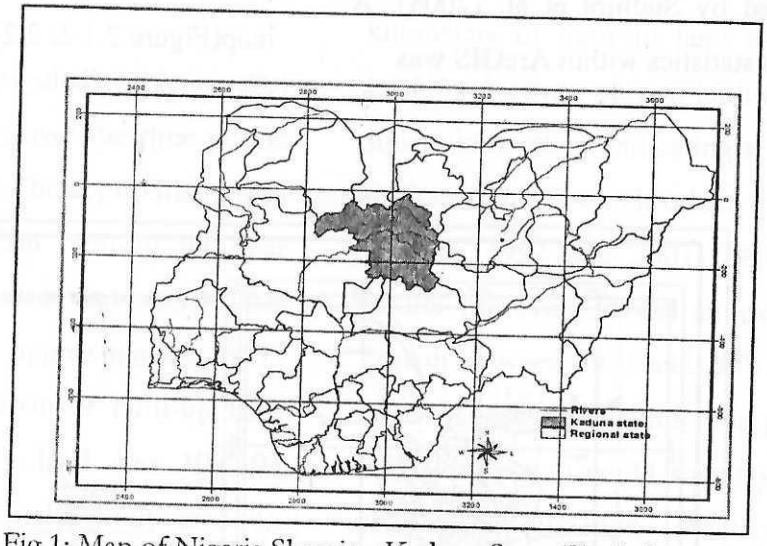

Fig.1: Map of Nigeria Showing Kaduna State (Shaded)

Research Methodology

Quantitative approach was adopted in this study. Quantitative methods involved the use of Geographic Information Systems data to produce maps of urbanization within the study area. Neighborhood statistic measurements were also used to quantify and display the density and connectivity of

patches of new built-up land. The Geographic Information System allowed for reclassification of land cover data into categories appropriate for the purposes of this study: built-up (urban) and non-built-up (non - urban) areas.

This study analyzes time series satellite images of urban land cover of Kaduna metropolitan area from 1973 to 2001 using LandSat MSS acquired in 25th December 1973, LandSat TM acquired in 27th November 1990 and LandSat ETM acquired in 24th October 2001.

Urban sprawl was assessed based on the urban growth patterns by performing a land use change analysis from non-built to built-up areas as stated by Sudhira et al. (2004). A neighborhood statistics within ArcGIS was used to calculate patch density, based on the spatial distribution and pattern of that density, the new growth areas were classified as one of three types of sprawl: cluster, leapfrog, and linear.

2.1 Data Set Presentation

The quantitative data for the study area and all necessary spatial data layers were collected and analyzed accordingly. The spatial data include time series satellite images to map urban landuse in the study area between 1973 to 2001.The satellite data include LandSat MSS acquired in 1973, LandSat TM acquired in 1990, and LandSat ETM acquired in 2001.Other data layers include boundary files for the entire study area, and cadastral map(Figure 2.1 & 2.2)

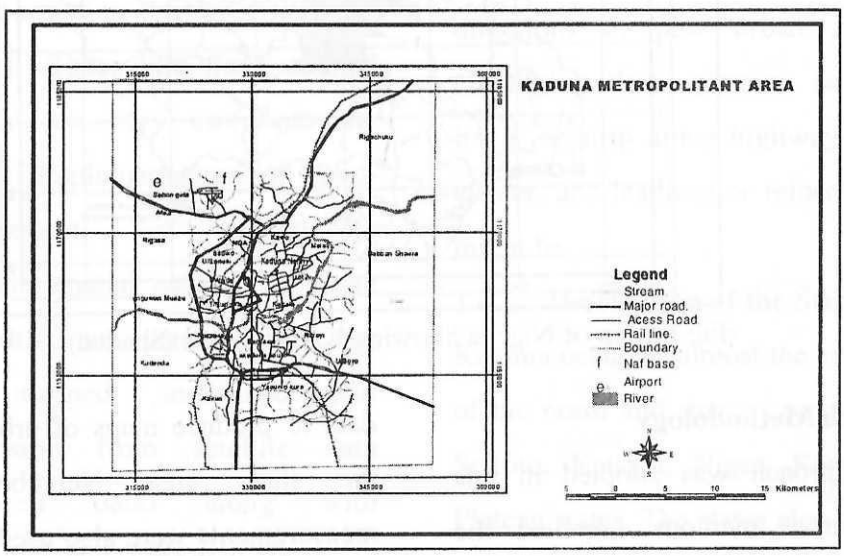

Figure 2.1: The map of the physical features of the Study Area

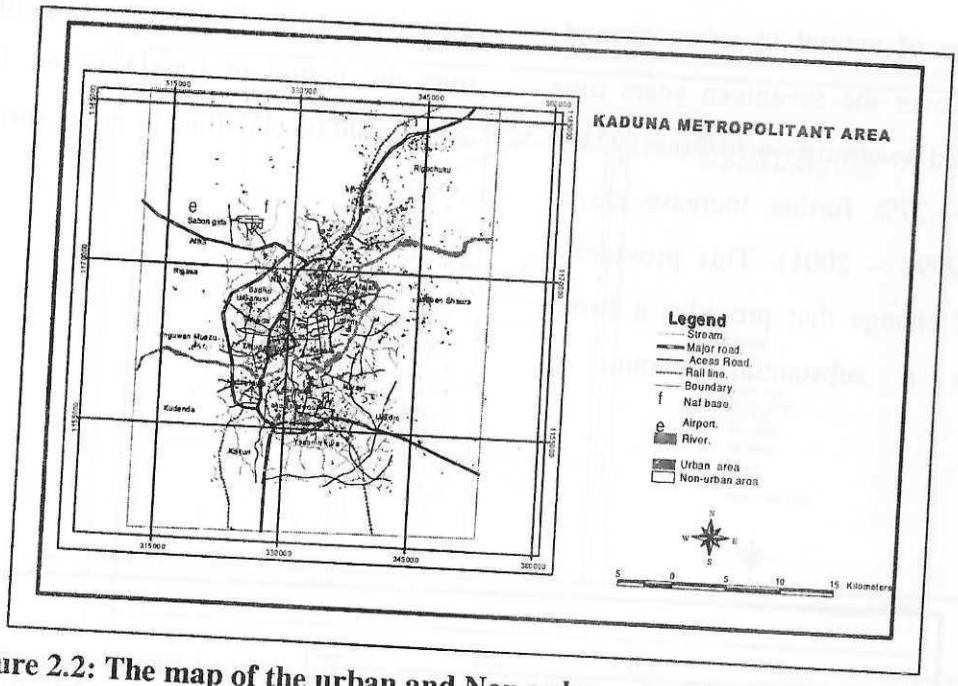

Figure 2.2: The map of the urban and Non-urban areas in Kaduna Metropolis

3.0 Result and Interpretation

3.1 GIS Mapping of Growth Distribution

The data analysis revealed basic spatial patterns of urbanization over the time period between 1973 and 2001.The approximate area (in square Km) of urban built-up for year 1973 and 2001 are shown in figures 3.1a, b& c. In 1973 there was approximately 59.55 square kilometers of urban or built-up land while the non- built-up land was 1072.03 square kilometers within the study area. In 1990 that number increased by 47.12% to 98.86 square kilometers of urban or built-up land and decrease in non-built-up land to 1032.72 square kilometers of land indicating large increase in the extent to which urban sprawl occurred between 1973 and 1990 (Figure 3.2). By the year 2001 that number increased by 53.27% to 145.52 square kilometers of built-up land and decrease in total land cover of non-built-up to 986.058 square kilometers, indicating a larger increase in the extent to which urban sprawl occurred between 1992 and 2001 (Figure 3.3). The results however, reveal an extensive urban growth between 1973 and 2001 inspite of the crisis experienced within this period (figure 3.4).This growth could strongly attributed to commercial function of the town and infrastructural development.

The built-up area generated has shown that new urban growth has occurred within the study area. Without urban growth, there would be nothing to classify as urban sprawl.

The percentage of natural to urban ground-cover change over the seventeen years time period increased by almost 46.73%(i.e.1973 to 1990), and 53.27% further increase eleven years after(19990 – 2001). This provides a great deal of change that provides a strong chance that a substantial amount of urbanization in Kaduna metropolitan area over the period of time between 1973 and 2001 could be classified as urban sprawl..

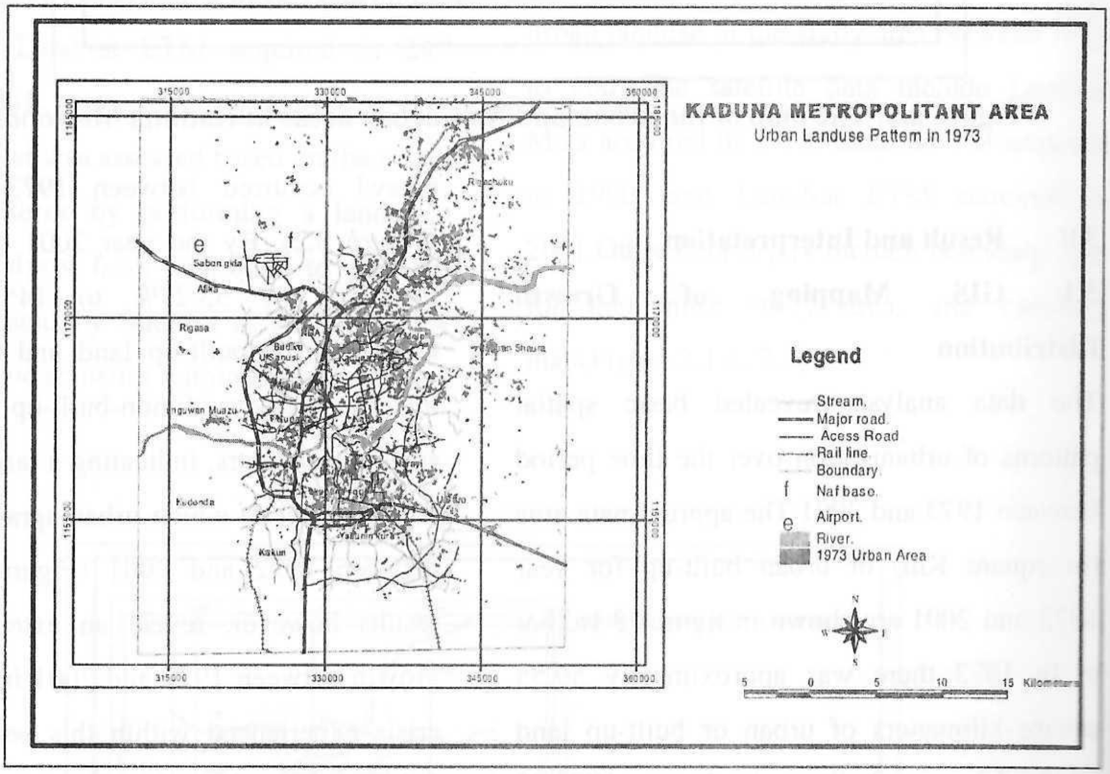

Figure 3.1a: Extent of Urban Growth in Kaduna Metropolitan Area in 1973

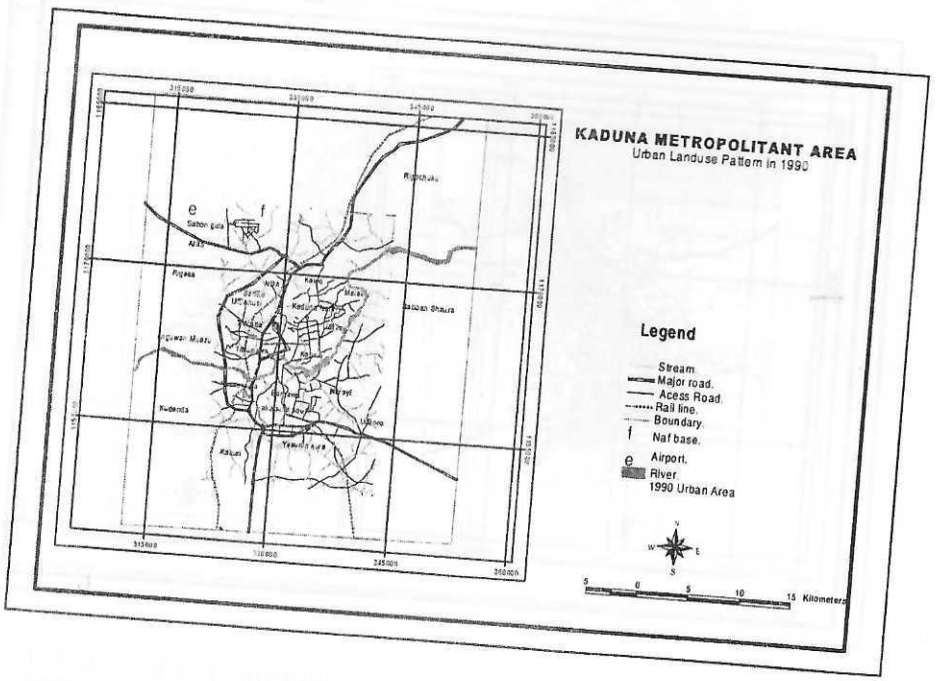

Figure 3.1b: Extent of Urban Growth in Kaduna Metropolitan Area in 1990

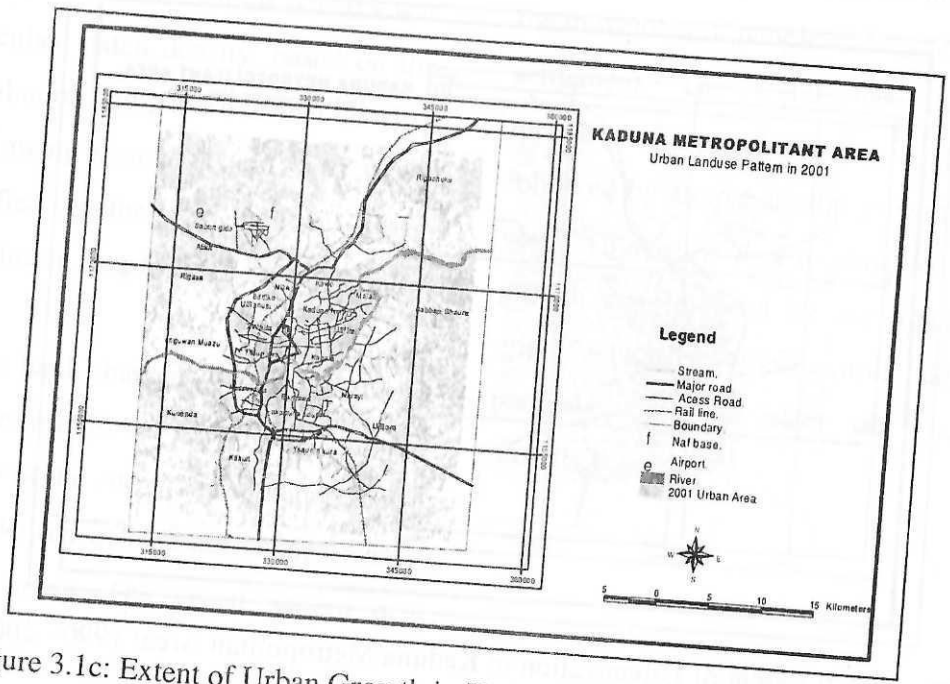

Figure 3.1c: Extent of Urban Growth in Kaduna Metropolitan Area in 2001

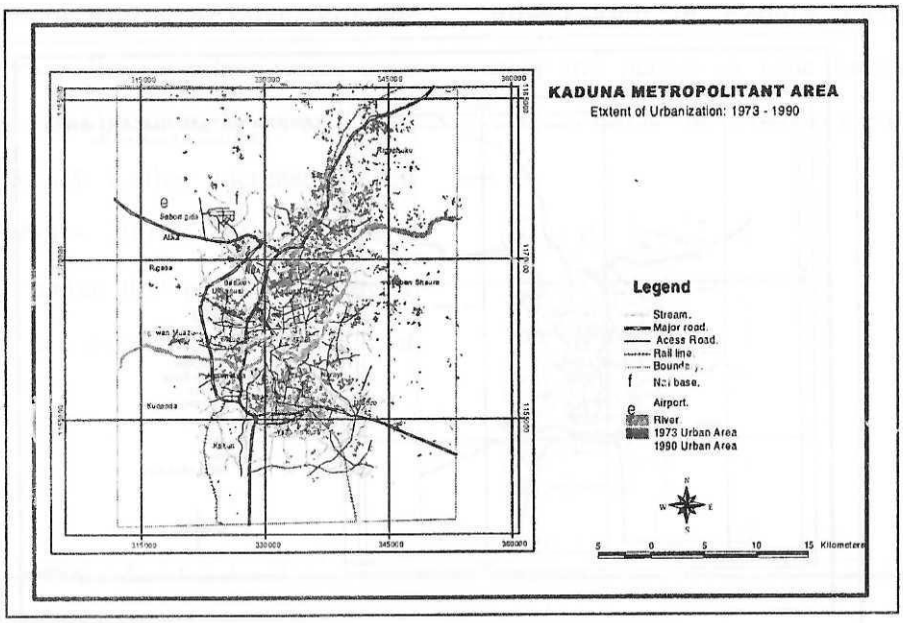

Figure 3.2: Extent of Urbanization in Kaduna Metropolitan Area: 1973 – 1990

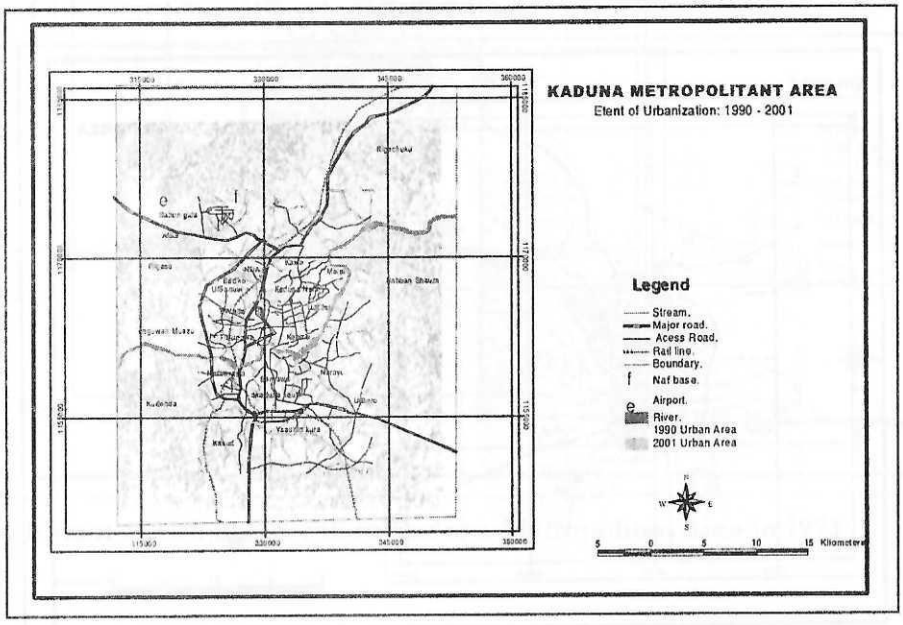

Figure 3.3: Extent of Urbanization in Kaduna Metropolitan Area: 1990 - 2001

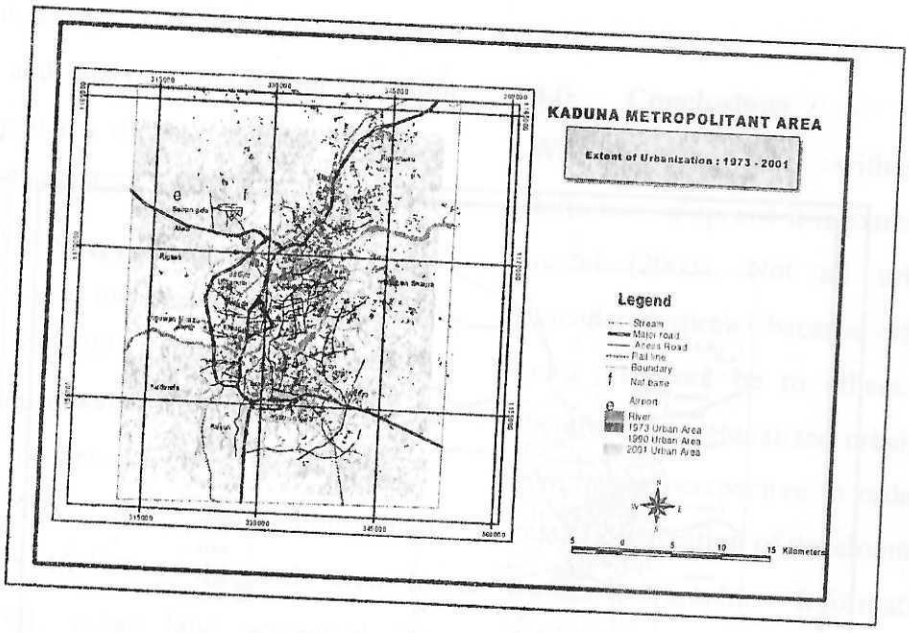

Figure 3.4: Extent of Urbanization in Kaduna Metropolitan Area: 1973 – 2001

3.2 Patterns of Urban Sprawl and Type

A neighborhood statistics within ArcGIS was used to calculate patch density, based on the spatial distribution and pattern of that density, and the following sprawl pattern and types were identified in the new built-up areas that's the: cluster, leapfrog, and linear(figure 3.5).

Based on the land changed in 2001 from a given land use to built-up. Direction of urban sprawl outside of the city limits was identified based on the density of land use change from non-urban to urban. The visual pattern of cluster of urban sprawl around the city shows the movement of people and choice of area for settlement. The result has shown gross increase of sprawl in the Kaduna north, followed by almost similar growth in Kaduna south (figure 3.6). The direction of urban growth is influenced by the timely Kaduna crisis which in most cases defined the people's choice of place of residence for security reasons.

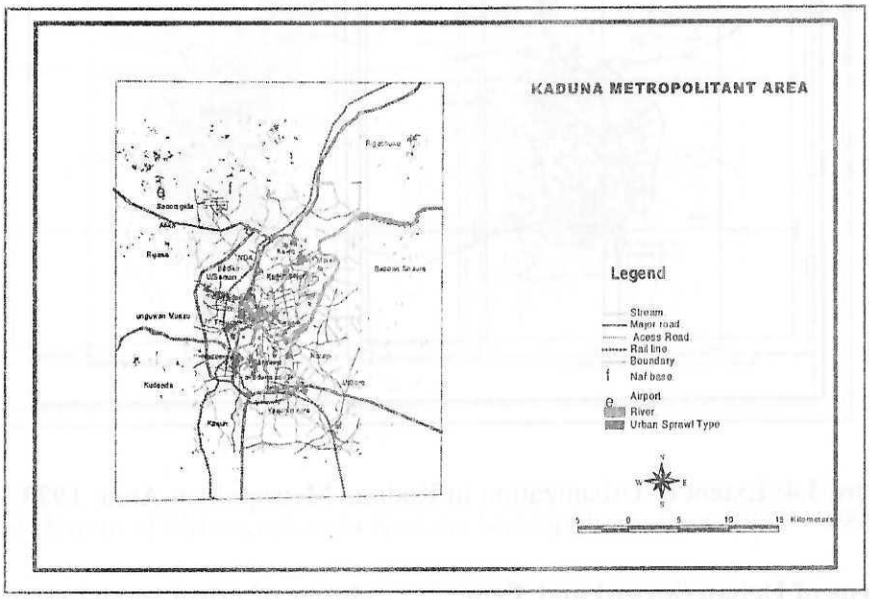

Figure 3.5: Map of Sprawl Type in Kaduna Metropolis

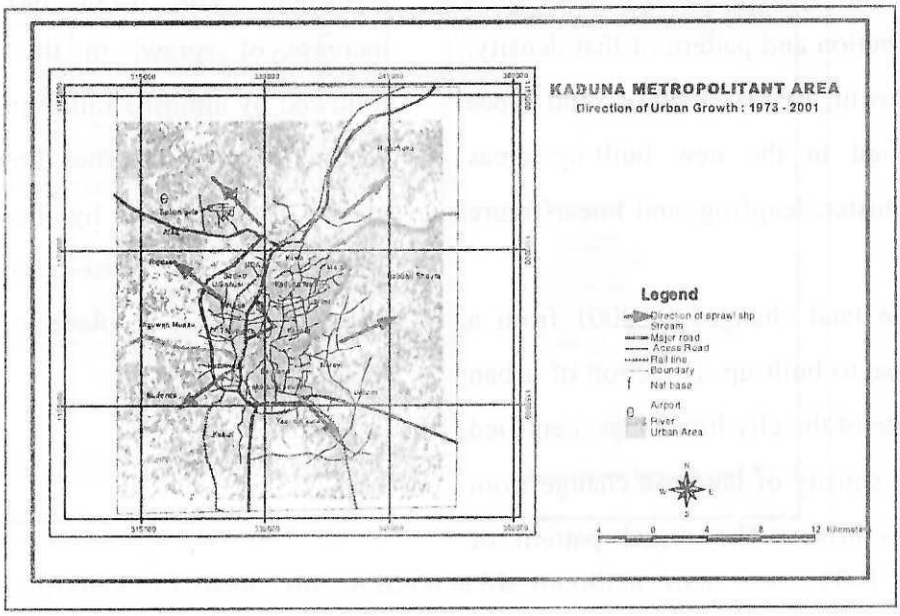

Figure3.6: Map of the Direction of Sprawl in Kaduna Metropolitan Area

3.3 Summary of Findings

The quantitative result through GIS data collection and analysis, and visual detection of sprawl patterns shows that urban sprawl is part of urbanization processes in Kaduna metropolitan area.

There is a clear increase in the amount of urban land from 1973 to 2001. The increase in built-up landuse was visible and result shows increase in the percentage of urban land. In 1973 - 1990 urban land constituted approximately 46.73% of the study area. In 1990 to 2001, urban land accounted for approximately 53.27% of the study area. This result revealed a gross increase in urban land over the last twenty eight years.

Based on the land changed in 2001 from a given land use to urban or built-up, many possible patterns of urban sprawl were detected outside of the city limits based on land use change from non-urban to urban. This seems to be because there is so much urban or built-up land in the Kaduna City that it was difficult to detect any landuse change there. Hence most of the patterns within the city would be characteristic of urban growth. However, as the city grows, it often takes the shape of what some would classify as a cluster pattern of urban sprawl. The visually pattern we could find in cause of the study are the cluster and leapfrog patterns of urban sprawl.

4.0 Conclusions

Wilson argues that without a universal definition of sprawl it is extremely difficult to model (2003). Not all urban growth is considered sprawl because what is sprawl to some may not be to others. This research therefore, conceptualized urban sprawl from a geographic perspective in order to assess the spatial distribution of development patterns by using Geographic Information Systems. Development patterns that exhibited characteristics of sprawl were classified as such. And the result revealed that urban sprawl did take place in Kaduna over the last 28 years.

This research also, demonstrates the importance of Information Technology in urban environmental monitoring, planning and management. Therefore, an understanding of how urban environment can be enhanced and sustained is a fundamental issue in successful urban management and planning. Since urban environment involve multi-faceted components of natural/cultural resources and a multiplicity of man-made resources, a systematic GIS database and analysis provides a framework for effective visualization, monitoring and decision making in urban management.

4.1 Recommendations

Inview of the above findings, the following recommendations were made for the improvement of urban sprawl and management in Kaduna and Nigeria as a whole.

1 Provision for a systematic GIS database should be encouraged in decision making process involving urban environmental monitoring, planning and management analysis in all concerned planning agencies.

2 Effective development control mechanism should be put in place to check non-conform and non-harmonized developments resulting from rapid urbanisation.

3 Finance and microfinance: to support house or plot purchase, small business enterprise and livelihood development, and home improvement loans;

4 Community training and capacity building programs: to empower and promote greater self-reliance, and to support training for improved community organization, estate management, and small business/livelihood activities;

5 Education and awareness-raising campaigns on deteriorating environment: including those directed to the private sector to encourage investment in pro-poor programs, and encouragement of community savings and loan programs.

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