SPATIO – TEMPORAL ANALYSIS OF URBAN EXPANSION IN KADUNA METROPOLIS, NIGERIA

BY

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DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA NIGERIAIN PARTIAL FULFILMENT OF THE REQUIRMENT FOR THE AWARD OF MASTERS OF SCIENCE DEGREE IN REMOTE SENSING AND GIS

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DECLARATION

I hereby declare that the content in this dissertation titled "**Spatio Temporal Analysis of Urban Expansion in Kaduna Metropolis, Nigeria**" was carried out by me **Mukhtar ABDULKARIM** under the supervision of Prof. I.J Musa and Dr. A.K. Usman. All information obtained from literature has been acknowledged in the text as well as the list of all references.

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CERTIFICATION

This dissertation titled " **Spatio- Temporal Analysis of Urban Expansion in Kaduna Metropolis, Nigeria"** by **Mukhtar ABDULKARIM** meets the regulations governing the award of degree of Masters of Science in Remote Sensing and Geographical Information System of the Ahmadu Bello University, Zaria, and is also approved for its input to knowledge and literary presentation.

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DEDICATION

I dedicate this work to God Almighty, my beloved parents, brothers and sisters.

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My foremost appreciation is to Almighty Allah (S.W.T) for the privilege given to me to run this programme from the start to finish. The wisdom, strength and health as well as mercies cannot be overemphasised.

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ABSTRACT

Several factors contribute to the challenges of spatial planning and urban policy in megacities including rapid population shifts, less organized urban areas and limited data with which to monitor urban growth and land use change. This study was carried out to analyzethe spatio - temporal variations of Urban Expansion in Kaduna metropolis, Nigeria from 1986 to 2016. The study also determined the extent, rate, pattern and predicted the pattern change through to 2045 in the area. Landsat imageries of 1986, 2000 and 2016 were used to monitor the expansion of urban built-up land in the study area. The extent and rate was determined by total land density of area, the pattern of urban expansion was determine using the Shannon's entropy while projection was carried out using Cellular Automaton (CA) and Markov Model. The results showed that farmland accounted for 193.10Km² (61.63%) in 1986 but decreased to 66.47Km^2 (21.22%) in 2016. The reverse effect was recorded for built up area which increased from 77.84Km^2 (24.84%) in 1986 to 194km^2 (62.01%) in 2016. The result shows that Kaduna metropolis has a relative entropy value of 0.1334 in 1986, which increased to 0.1597 in 2000 indicating a difference of 0.026 from 1986 to 2000 which means that the city has expanded by 19.84% within the period. In 2016, the relative entropy reduced to 0.156 indicating a difference of -0.00030. For the entire period of study i.e. between 1986 and 2016, the difference in the relative entropy was found to increase by 14.95%.The result revealed that farmlands have (0.801) and built-up (0.61) high probabilities remain as built-up areas in 2045. The probability of vegetation to change to urban built-up was 0.0221 (2.21%). The result also shows that the urban built-up land will increase from 194.27Km^2 in 2016 to 213.31Km^2 in 2045. The study recommends effective projection for adequate provision of urban municipal services to Kaduna residents by the Kaduna State Urban Development Authority and mapping updates by KADGIS to track future trends in urban spatial change in the study area.

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CHAPTER ONE
1NTRODUCTION

1.1 BACKGROUND OF THE STUDY

Tobler's first law of Geography states that ''everything is related to everything else, but near things are more related than distant things" (Tobler, 1970:1). This implies that the surroundings of a location are related to the land use at that location, but close surroundings have a stronger influence than more remote surroundings. Land uses are spatially related and that nearby land uses have a stronger relation than land use at a greater distance

Urbanization the gradual increase in the proportion of people living in urban areas, and the ways in which each society adapts to the change. It is also a process by which towns and cities are formed and become larger as people shift to live or work in clustered locations(Davidson, Franka and Adams 2011). The United Nations had projected that half of the global population would live in urban areas by the end of 2008 and predicted that by 2050 64% of developing countriesand 86% of developed countriesrespectively would be urbanized. Thisprojection stands at approximately 3 billion urban dwellers by 2050, most of whom would be in Africa and Asia. Notably, the United Nations has also recently projected that nearly all global population growth from 2016 to 2030 will be absorbed by cities, about 1.1 billion new urbanites over the next 14 years.

Kumar, Garg and Khare (2008) definedurban growthas a process where settlements and communities rapidly increase in population, become industrialized with complex service institutions drawn up by governments of the affected locations.In essence, a factor in urban growth is the trigger of people's movement from rural settlements to bigger cities. Thereafter, the cities increase in size and space due to advanced land use activities. Myers,(2011) summarized urban growth as theexpansion of a metropolitan or suburban area into a surrounding environment**,** often controlled by an urban growth boundary (UGB), and defined by legally enforced zoning tools. However, Kumar,Garg and Khare (2008) argued that the extent and

manifestations of an Urban Growth Process (UGP)are derivatives of changes in land use-land cover patterns accelerated by human settlements.

World Population Data Sheet (2013) reported that Africa will have the largest population growth from 2013 to 2050, with a projection growth of 1.3 billion billion between 2013 and 2050Africa will add more population than any world region, virtually all the growth will be in the 51 countries of sub-Saharan Africa. It is expected to increase from 1.1 billion in 2013 to 2.4 billion in 2050. Additional reports by the United Nations Centre for Human Settlement, (UNCH, 2002) and (World Bank Regional Report, 2005), indicated that Africa has the highest rate of urbanization complicated by ineffective and unsustainable urban planning and land management strategies, limited social services and bad institutional governance.Statistics of World population highlights from world population data sheet (2013) also included Nigeria among the most populous countries on earth and projected a population rise from 173 million in 2013 to 440 million in 2050.Other reports byNigeria's Federal Ministry of Environment, Housing and Urban Development, (2008a and b; Vision 2020:20 2009) revealed that Nigerian urban centres have increasedfrom 56 in 1953 to 450 in 2000 and an exponential trend in the rise may persist beyond 2050. Consequently, this trend could be accompanied with the evolution of urban sprawls. Nigerian cities have sprawled into suburban areas and along major transport networks withincreased total land areas occupied built up surfaces(Ogunbodede and Balogun, 2013).

The genesis of Kaduna metropolisas a rapidly growing urban settlement in Kaduna State,dates back to its being a regional capital of Northern Nigeria from 1900-1967 and the administrative capital of Kaduna State from 1967 to date (2017). In addition are the pull-push factors of migration, population increase of the settled communities. This demand for space has transformed the River Kaduna floodplains into built-up areas and the constriction of agriculturallandscape and green zones(Ogunbodede and Balogun, 2013)

The combined use of Geographic Information System, (GIS) with Remote Sensing techniques has enabled scholars observe land use changes, visualise, monitor and forecast them. Their application gives the ability to acquire data through the space/air borne sensors, resulting in multispectral, multi-temporal data, which is used for the creation of land use maps (Herold, Scepan& Clarke, 2002).

Entropy method is perhaps the most widely used technique in analysing the pattern of urban expansion (Yeh and Xia, 2001; Sudhira, Karthir and Raj, 2004). Shannon's entropy is used to analyse the degree of spatial concentration or dispersion of geographical variables among zones (Thomas 1981). The value of entropy ranges from 0 to $\log_e(n)$. A value of 0 indicates that the distribution of built-up areas is very compact, while a value closer to $\log_e(n)$which is the maximum limit of entropy signifies a dispersed distribution. Higher entropy values indicate the occurrence of sprawl or its potential. Half-way mark of $\log_e(n)$ is generally considered as threshold. If the entropy value crosses this threshold, the city is considered to have expanded. Relative entropy can be used to scale the entropy value into values that ranges from 0 to 1. Because entropy can be used to measure the distribution of a geographical phenomenon, the measurement of the difference of entropy between time *t*1 and *t*2 can be used to indicate the magnitude of change of urban expansion (Yeh and Xia, 2001). The change in entropy can be used to identify whether land development is toward a more dispersed or compact pattern.

A Markov-Cellular Automata (Markov-CA) model is capable of simulating temporal and spatial dynamics of Land use-Land cover change by integrating remote sensing and GIS based data. (Myint and Wang, 2006). In the Markov-CA model, markov chain analyzes temporal change among the LULC classes based on transition probabilities matrices (Takada *et al.,* 2010); while the Cellular Automata geographically evaluates the spatial contiguity and land cover suitability (Houet and Hubert-Moy, 2006). The Markov chain technique in combination with CA is capable of generating a better spatiotemporal pattern of the LULC change.

1.2. STATEMENT OF THE RESEARCH PROBLEM

Urban centres over a half century ago in most developing countries have continued to witness unprecedented expansion in spatial growth. This expansion is premised on the perceived improvement

in living conditions of the urban environment (Kombe and Kreibich, 2000). Thus, as settlements grow in size they become more complex with passage of time.

Cities in most developing countries like Nigeria have been undergoing unprecedented changes both in population and spatial extent (Adeboyejo and Abolade, 2006) and as a result are faced with a variety of problems such as uncoordinated land development, conflicting land uses, high densities in certain parts of the urban areas and the absence of adequate road network which could ensure efficient intra-urban mobility within the city. One of the most important features of all of these urban centres is their increasing territorial extent and attendant poor spatial pattern of land use developments which are largely uncontrolled and unmonitored due to paucity of data and non-application of modern technology of information acquisition (Ikhuoria, 1995).

The influx of people into Kaduna metropolis was due to several factors amongst which wereemployment opportunities and infrastructure development,good roads network, access to medical facilities, institutions of learning, military establishment and business opportunities among others. The increasing urbanization and sprawling pattern of development in Kaduna Town have culminated into the quick disappearance or total transformation of fertile agricultural sites to peri-urban development and expansion (KEPA, 2016).

Many relevant researcheson urban expansion have been carried out. Sunday and Abubakar (2013) examined the challenges of rapid urbanization on sustainable development of Nyanya in FCT Abuja. They used two Landsat ETM+ (30m resolution) satellite data images covering Nyanya settlement for year 2001 and 2010. The researchersobserved that the primary factor responsible for rapid urbanization ofNyanya within a short period was migration. Consequently, infrastructural services such as water supply, electricity power supply, good quality housing, good healthcare services were grossly inadequate. Urgent need for the FCT Administration to embark on urban renewal of Nyanyaand mechanisms for periodic review and upgrading that would ensure qualitative built-urban environment were recommended.

Waheed and Chukwuemeka (2010) studied the impact of urbanization on geomorphic parameters of the Kaduna River along the City of Kaduna. The study focused on hydrological analysis alongside flood frequency analysis. The results obtained indicated that increasing urbanization along the Kaduna River floodplain is responsible for the problem of flooding experienced in recent times along the river floodplain

Akpu and Tanko (2012) examined the rate and pattern of the spatio-temporal Growth of Kaduna Metropolis, Kaduna State Nigeria, using GIS and Remote Sensing techniques. Visual interpretation method was used to sort the various datasets into land use land cover classes. The result of the study showed that the built-up area increased from 6,410.4ha in 1973 to 19,611.5ha in 2009. The city was growing at a rate of 5.72% annually and the areas towards the southern part of the River Kaduna were growing at a higher rate of 11.24% while the growth rate of the northern part was 3.71%.

Opatoyinbo, Adepetu, and Abdullahi (2015) worked on population growth in relation to urban land use changes along River Kaduna floodplain in Kaduna North-Western Nigeria. The study employed projected population data, Remote Sensing Technology and Geographic Information System to determine the trend of population growth and urban land use changes with reference to urban land use types along the river floodplain in Kaduna for the period of 1976 to 2010. The result revealed that population growth was not the only factor that caused changes on urban land use along River Kaduna floodplain in Kaduna metropolis. Other factors include; urbanization, security, employment opportunity, closeness to working environment, government acquisition for public interest, private acquisition for building houses and commercial centers.

Bununu (2017) simulated urban expansion using Kaduna in North-West Nigeria as a case study. Hybrid model that integrates the similarity-weighted instance-based machine learning algorithm for transition potential modelling and the Markov chain model to quantify and allocate land-use change was used to overcome the identified weaknesses of known modelling techniques such as the cellular automata, Markov chain and standard logistic regression models. Environmental and urban physical variables that act as constraints and/or incentives to urban expansion were operationalized to create

transition potentials for spatiotemporal states of built-up land use for the year 1990 and 2001. Model evaluation and validation was carried out using the relative operating characteristic and kappa index of agreement statistics.

Several methods and techniques have been developed and applied to quantify and characterise urban expansion processes and patterns. Traditionally, visual interpretation of high resolution aerial photographs were used to acquire comprehensive information for mapping urban areas. However, advancement in Remote Sensing techniques, and the availability of high resolution spatial data, possibilities of monitoring the urban expansion of settled communities with precision have become popular (Nefra, Tommy and Benth, 2006).

Therefore, since rapid and unplanned urbanization process has negative socio-economic and environmental consequences, a research of this nature is of paramount significance in providing predictive data on the best practices in coping with rapid urbanization and minimizing its effects on the environment for sustainability and wellbeing of urban communities.

To the best of this work's knowledge, there is no study that tried to predict urban expansion in Kaduna metropolis from 2016-2045 using markov cellular automata using predictive scenarios as different drivers to urban expansion and using Shanonn's entropy in Python 3.2 programming language to see the pattern of expansion. This is therefore the gap in knowledge which this work filled.

In view of the above, the research was addressed from the following guiding questions

1) What is the extent and rate of urban expansion in the study area? (1986 – 2016)
2) What is the pattern of urban expansion in the study area? (1986-2016)
3) What would be the possible extent of urban expansion in the study area in the next 30 year period (2016 – 2045)?

1.3 AIM AND OBJECTIVES

The aim of the research is toanalyzespatio-temporal pattern ofurban expansion in the study area with a view to predict possible extent of urban expansion in the next 30 years that may provide data

that may assist effective urban management. This was achieved through the following specific objectives to;

i. determine the extent and rate of urban expansion in the study area (1986-2016)
ii. examine the pattern of urban expansion in the study area (1986-2016)
iii. forecast possible urban expansion for 2045 in the study area

1.4 SCOPE OF THE STUDY

The study determined the extent, rate, pattern and forecast the change for 30 years (2016-2045). The studycovered both Kaduna North and South LGAsbetween Latitudes 10° 26' 00'' to 10°38' 00'' N of the Equator and between Longitudes 7° 22' 00'' to 7° 33' 00'' E of the Greenwich Meridian.The temporal scope covers a period of 30 years (2016-2045)

1.5. JUSTIFICATION OF THE STUDY

Following the increasing demand for empirical data and systematic analysis of urban growth processes and patterns, there is an increasing curiosity on the development of quantitative methods of urban analysis. It is significant to provide valuable information to help regional land use planners to better understand the urban growth processes and make informed decisions (Ogunleye, 2005).

Urban growth is an inescapable process, efforts can be made to protect natural resources, reduce natural hazards such as flooding and improve the livelihoods of urban dwellers through proper way of urban planning and management (Soffianian, Ahmadi, Yaghmaei and Falahatkar, 2010). The outcome of this study will facilitate city planners, policy makers and resource managers use up- to- date techniques to acquire reliable quantitative information on urban growth processes and patterns.

It will also facilitate the establishment of management mechanisms and relevant policy interventions for proper allocation of resources and urban infrastructure based on empirical evidences. However, the available information on city growth and evolution is insufficient and outdated. This makes decision process complex and less transparent. Therefore, quantifying urban growth processes is crucial to developing and implementing urban management policies and regulations. Scholars can also use outcome of the this study as a bench mark for further researches

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses some of the concepts as understood and applied in the study. In addition, several studies related to the objectives of this project conducted by previous authors were reviewed to give credence to the methodologies utilized in this thesis. These previous works were a great aid in designing the present project and were also good reference for interpreting and discussing the findings.

2.2 CONCEPTUAL ISSUES

2.2.1 Urban Area

There is no any universally agreed definition or criteria of classifying settlement into rural and urban or country side. Different threshold or parameters are used in defining settlement which varies from one country to another; and also varies over time within a county. The parameters used in classifying settlements into urban are; administrative and political functions, population size or density, economic function and presence of urban characteristics. The classification of settlement into urban and rural area depends on countries level of development, population size and density. Another problem associated with settlement classification is defining extent of urban area; as most of the developing countries urban fringe exhibit characteristics of rural settlement as well as the rural areas engulfment into urban development process, this leads to a shift away from the assumption of the mainstream paradigms to a new conceptual landscapes where rural-urban links are being redefined (Geiman, 1999).

The variation in criteria of urban/rural area classification, among different region of the world, makes generalization very problematic if not impossible. In most of the sub-Saharan African countries, the classifications are largely on administrative, demographic and infrastructural basis, as a result several small settlements were classified as urban (Gado and Guitart, 1996). In Benin Republic, the National Institute of Statistics and Economic Analysis, classified any settlement with a population of 10,000 or more and with at least four (4) of the following: post office, tax office, public, treasury, bank,

running water and electricity supply, health centre and secondary school as urban (Tingbe-Azalou, 1997) while in Nigeria any settlement with a population of 20,000 inhabitants can be regarded as an urban (Adeleke*et al,* 2002).

2.2.2 Urban Expansion

The concept of urban growth entails either relative or absolute increase in the number of people who live in town and cities, which leads to structural and functional changes. The urban population growth can be as a result of natural increase and net migration or reclassification of rural settlements into towns and cities.

Urban planners and decision makers have widely accepted the fact that urban system is highly complex. Cheng and Masser (2002), argue that if urban growth can be considered as a complex system, then there is a need for finding the universal and unique characteristics that can distinguish it from other complex systems, and this can only be done by answering four (4) relevant questions;

i. Where is urban growth occurring from system perspectives?
ii. What is the complexity of urban growth?
iii. What should be understood in supporting urban development?
iv. How can urban growth complexity be modelled?

Urban development consists of physical expansion and functional changes. Specifically, change in space and major land use activities. Therefore, space and activity should be considered as basic units (elements) of urban growth system.

Cheng and Masser (2002) defined urban growth as a system resulting from complex dynamic interactions between, the spatial, conceptual, socio-economic and physical/ecological system. The interaction between these three systems resulted in urban growth, the spatial/conceptual system provides planning control requirement for urban growth, while socio-economic and physical/ecological systems contributes activities/stimulant factors for development respectively.

2.2.3 Urban Sprawl

Urban Sprawl is an uncontrolled disproportionate expansion of urban area into the surrounding country side forming land density, poorly planned patterns of development. Urban sprawl can be said to be continuous disperse development to low density residential units and isolated tracts, separated from other areas by vacant land, forming ribbon or leap frog pattern along highways or other driving agents, or forming spatial patch within undeveloped land (Torren, 2000).

The concept of ''Urban Sprawl'' means increase in spatial or peripheral area of towns or cities. Therefore urban sprawl can lead to the following drawbacks;

i. Affect the infrastructural planning;
ii. Affect traffic by increasing travelling distance within the cities;
iii. Affect the distribution of services;
iv. Making Administration of city extremely difficult;

2.2.4 Forms of Urban Growth

Wilson *et al*. (2003) identified three categories of urban growth namely: Infill, Expansion, and Outlying. Outlying form of urban growth is further separated into isolated, linear branch, and clustered branch growth (Figure 2.3). The relation (or distance) to existing developed areas is important when determining what kind of urban growth has occurred. Indeed all types of urban growth are not considered as sprawl; one development that can be considered as sprawl by someone may not be considered by others (Roca *et. al.* 2004).

Furthermore, urban sprawl has a negative connotation, and not all urban growth is necessarily unhealthy. In fact, some types of urban growth (e.g., infill growth) are generally considered as remedies to sprawl. Therefore, sprawl cannot be characterized by the simple quantification of 'the amount of land that has changed to urban uses.' Sprawl phenomenon should be treated separately from the general urban growth. Ewing (1994) reviewed several patterns of urban sprawl, and argued that the pattern of sprawl is 'like obscenity', the experts may know sprawl when they see it.

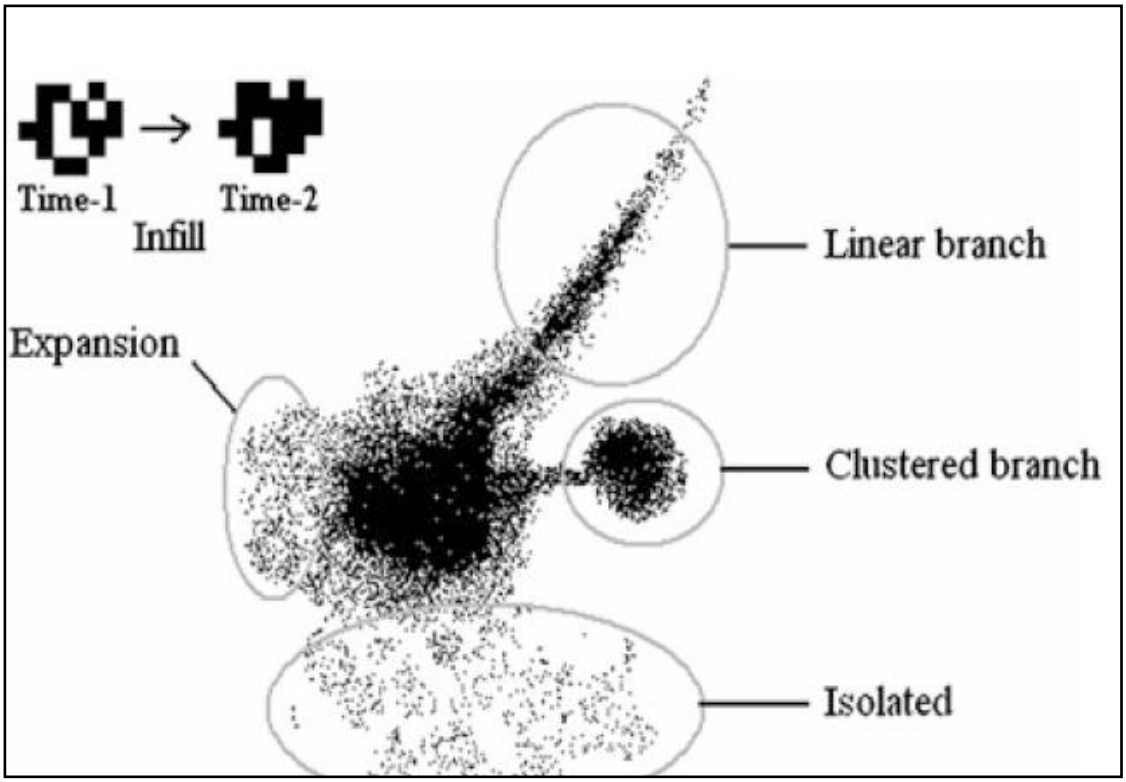


Fig. 2.1: Schematic Diagram of Urban Growth Pattern
Source: **Bhatta, (2010:12)**

2.2.5 Change Detection

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest.

Macleod and Congation (1998) listed four aspects of change detection which are important when monitoring natural resources:

i Detecting the changes that have occurred

ii Identifying the nature of the change

iii Measuring the area extent of the change

iv Assessing the spatial pattern of the change

The basis of using remote sensing data for change detection is that changes in land cover result in changes in radiance values which can be remotely sensed. Techniques to perform change

detection with satellite imagery have become numerous as a result of increasing versatility in manipulating digital data and increasing computer power.

Change detection according to Singh (1989) and Mejabi (2008) is the concept of identifying contrasts or discrepancies in the state of an object or phenomenon by observing it at different times. This involves the ability to quantify temporal alteration and transformation using multi-temporal data sets. In general, change detection involves the application of multi-temporal data sets to quantitatively analyse the temporal effects of the phenomenon.

2.2.6 GIS and Remote Sensing

One of the most important paradigms in Geography and related disciplines that manage or use spatial data, associated with methodological changes is the advancement in Remote Sensing and Geographical Information System and the availability of satellite imageries. Remote sensing technology has been the subject of research in a variety of contexts and situations and has been successfully introduced as sole, complementary or corroborative source of data for many applications (Batty, 2000)

Remote Sensing technology has great potential for acquisition of detailed and accurate land use information for management and planning of urban regions. However, the determination of land use data with high geometric and thematic accuracy is generally limited by the availability of adequate Remote Sensing data in terms of spatial and temporal resolution and digital image analysis techniques (Herold*et. al.,* 2002). The technique of Remote Sensing provides a powerful tool for studying urban issues, like land use/cover changes, urban growth modelling, urban sprawl etc. Remote Sensing image classification is one of the important application aspects for Remote Sensing technique, through computer processing with specific software, like ERDAS, the results of the classification of landuse can be auto-patted (Li Feng, 2009).

For decades the visual interpretation of aerial photography of urban area has been based on the hierarchical relationships of basic image elements. The spatial arrangement and configuration of the basic elements (tone and color) combine to give higher order interpretation features of quarters complexity such as size, shape and texture or pattern and association, that are significant and

characteristics for urban areas and urban land use (Bowden 1975). Much of the expert knowledge of the human image interpretations was lost in the transition from air photo interpretation to digital analysis of satellite imagery. The great strength of Remote Sensing is that it can provide spatially consistent data sets that cover large areas with both high detail and high temporal frequency, including historical time series. Mapping of urban areas has been accomplished at different spatial scales e.g. with different spatial resolutions, varying coverage or extent of mapping area and varying definitions of thematic mapping objects (Herold*et. al.,* 2005). Global and regional scale studies are often focused on mapping just the extent of urban areas (Schneider *et. al.,* 2001). One of the basic difficulties of mapping urban area from remotely sensed data is that of indistinct demarcation between urban and rural areas on the edge of the city. Remote Sensing provides additional information that more closely respects the actual physical extent of a city extent, but still remains problematic and individual studies must determine its own rules for differentiating urban from rural land (Clarke *et. al.,*, 1998).

2.2.7 Shannon's Entropy

Entropy is a measure of unpredictability of the state, or equivalently, of its average information content. To get an intuitive understanding of these terms, consider the example of a political poll. Usually, such polls happen because the outcome of the poll is not already known. In other words, the outcome of the poll is relatively unpredictable, and actually performing the poll and learning the results gives some new information (Cover and Thomas, 2006).

The Shannon entropy model is an indicator of spatial concentration or dispersion and can be applied to any geographical variable. Shannon's entropy (H,) can be used to measure the degree of spatial concentration or dispersion of a geographical variable (xi) among zones (Theil, 1967; Thomas, 1981).It is calculated by

$$H_n = \sum_i^n p_i \log(1/p_i) \quad \text{---------- (1)}$$

Where pi is the probability or proportion of a phenomenon (variable) occurring in the ithzone ($p_i = x_i / \sum_i^n x_i$), xi is the observed value of the phenomenon in the ith zone, and n is the total

number of zones. The value of entropy ranges from zero to log (n1.If the distribution is maximally concentrated in one zone, the lowest value, zero, will be obtained. Conversely, an evenly dispersed distribution among the zones will give a maximum value of log (n).Relative entropy can be used to scale the entropy value into a value that ranges from 0 to 1. If the distribution is maximally concentrated in one region, the lowest value, zero, will be obtained.

2.2.8 Land Use /Cover Change (LUCC) Models

Hundreds of models of LUCC have been described in literature on landscape ecology, geography, urban planning, economics, regional science, computer science, statistics, geographic information science, and other fields. Because of differing disciplinary perspectives, as well as differing methodological approaches, data availability, and modelling goals, attempts to categorize models are complicated by a relatively large number of dimensions on which the models vary (Munthali and Murayama, 2011). A number of reviews of LUCC models have been produced in recent years, each from their own perspective and producing a number of different typologies.

Early reviews published by Baker (1989) in the context of landscape ecology were focussed on land-cover changes. Whole landscape models seek to model change in some aggregate attribute or state of the landscape over time. Distributional models describe changes in the proportion of landscape in each of a number of land-cover classes. Spatial landscape models describe the location and configuration of changes in land cover (Baker, 1989).

A pair of publications in late 1990s reviewed significant amount of work that had gone into modelling tropical deforestation (Lambin, 1997) availabilities and modelling goals. Attempts to categorize models are complicated by a relatively large number of dimensions on which the models vary.

Agarwal, Green, Grove, Evans and Schweik (2002) described nineteen (19) models that were arrayed on dimensions of space, time, and human decision-making. Models were characterized on these three dimensions according to both the scale at which they operated and degree of complexity in the representation. Parker, Manson, Janssen, Hoffmann andDeadman, (2003) focused on agent-based

models as tools for representing human decision making and simulating the aggregate outcomes that result from decisions made by many individuals. Agent-based models represent a qualitatively different approach to the mathematical and statistical approaches that pervaded earlier reviews, and offer potential for new LUCC models, similar to the approach of ecological modelling offered by individual-based models (DeAngelis and Gross 1992). Parker *et al.,* (2003) argued that combining agent-based models, to represent human level decision-making, with cellular models, to represent biophysical landscape change, offers a promising approach for future model development in LUCC.

The review by Parker *et al.,* (2003) appears to be the first to address both land-use and landcover change, though it has a specific focus on agent-based models. The distinction is important because it affects both the data requirements for calibration and validation and the process representations required. There is not always a one-to-one relationship between the two and while human activity defines land-use, land-cover change can proceed with or without a proximal human driver (e.g., through climate change). If we are to bridge human activity and ecological structure and function, representations of both processes are required, adding greater dimensionality to considerations of models in this field (Cihlar and Jansen, 2001).

According to whether the modelling approach is oriented primarily toward (a) fitting data or (b) simulating processes, the first category of models includes a broad range of models that employ social science theory and represent decision-making and biophysical processes to varying degrees.

2.2.8.1 Empirically Fitted Models

They are based on statistically matching the temporal trends (in the case of longitudinal data) and/or spatial patterns (in the case of cross-sectional data) with some set of predictor variables. The variables to be predicted may represent land use, land cover, change in either of these or some combination and may be measured over pixels, derived from remotely sensed data, parcels (i.e., irregularly shaped spatial units defining legal ownership) or aggregated over some jurisdictional unit. Predictor variables are factors thought to influence land-use, including proximity to roads, proximity to

cities and towns, mix of economic activity, demography, income and wealth, and biophysical factors like slope and soils (Cihlar and Jansen, 2001).

Some of the earliest empirically fitted models represented LULC as Markov random processes, in which the state of land at some time in the future was a function only of its present state, represented by a transition probability (Muller and Middleton, 1994). Though these simple models have appeal for their minimal data requirements and analytical properties, their assumptions are restrictive and they have little utility for analysing policy.

This approach has been used for modelling development in urban areas (Landis, 1994; Landis & Zhang, 1998a; 1998b), along urban-rural gradients (Wear andBolstad, 1998) and in tropical forests (Mertens andLambin, 1997).

2.2.8.2 Dynamic Process Models

In contrast to empirically fitted models, dynamic process models of LUCC seek to represent the most important interactions between agents, organisms, and their environment as computer code. Though fitted models can be used to generate simulations (Brown, Goovaerts, Burnicki and Li, 2002), simulation is clearly more central to the use of process models. Although these models need to be calibrated and validated, they deemphasize the fitting of data and emphasize the fidelity of model elements and processes to what is known about the processes. Three types of dynamic process models that have been used for LUCC: process flow models, cellular automata (CA), and agent-based models.

Models that track material and energy flows through a landscape and how they are transformed and/or transmitted at each location work well for some natural processes and to represent stable, stylized socioeconomic systems (Fitz, et al., 1996).

Models of this sort have been used in a variety of settings, including the Everglades (Wu *et al.,* 1996) and the Patuxent Watershed (Voinov, *et al.,* 1999). These modelling approaches often include enough stochasticity that they become simple simulation platforms to evaluate empirical models as described above. Their primary limitation for modelling LUCC, however, is an inability to represent complex ecological or social interactions, including competition and cooperation, the role of

institutions, interest groups, and limits to rational behaviour, that give rise to behaviours and decisions that affect land-use and cover (Fitz, et al., 1996).

2.3 THEORETICAL FRAMEWORK

2.3.1 Urban growth models

The study of urban land use generally draws from three different descriptive models. These models were developed to generalize about the patterns of urban land use found in early industrial cities of the U.S. Because the shape and form of American cities changed over time, new models of urban land were developed to describe an urban landscape that was becoming increasingly complex and differentiated. Further, because these are general models devised to understand the overall patterns of land use, none of them can accurately describe patterns of urban land use in all cities. In fact, all of these models have been criticized for being more applicable to cities in the U.S. than to cities of other nations. Other criticisms have focused on the fact that the models are static; they describe patterns of urban land use in a generic city, but do not describe the process by which land use changes. Despite these criticisms, these models continue to be useful generalizations of the way in which land is devoted to different uses within the city. Below, we will examine the Concentric Zone Model, Sector Model and Multiple Nuclei Model of urban land use.

2.3.1.1 Concentric Zone Model

The concentric zone model was among the early descriptions of urban form. Originated by Earnest Burgess in the 1920s, the concentric zone model depicts the use of urban land as a set of concentric rings with each ring devoted to a different land use (see Figure 2.5). The model was based on Burgess's observations of Chicago during the early years of the 20th century. Major routes of transportation emanated from the city's core, making the CBD the most accessible location in the city. Burgess identified five rings of land use that would form around the CBD. These rings were originally defined as the (1) central business district, (2) zone of transition, (3) zone of independent workers' homes, (4) zone of better residences and (5) zone of commuters. An important feature of this model is

the positive correlation of socio-economic status of households with distance from the CBD -- more affluent households were observed to live at greater distances from the central city. Burgess described the changing spatial patterns of residential areas as a process of "invasion" and "succession". As the city grew and developed over time, the CBD would exert pressure on the zone immediately surrounding it (the zone of transition). Outward expansion of the CBD would invade nearby residential neighbourhoods causing them to expand outward. The process was thought to continue with each successive neighbourhood moving further from the CBD. He suggested that inner-city housing was largely occupied by immigrants and households with low socio-economic status. As the city grew and the CBD expanded outward, lower status residents moved to adjacent neighbourhoods, and more affluent residents moved further from the CBD.

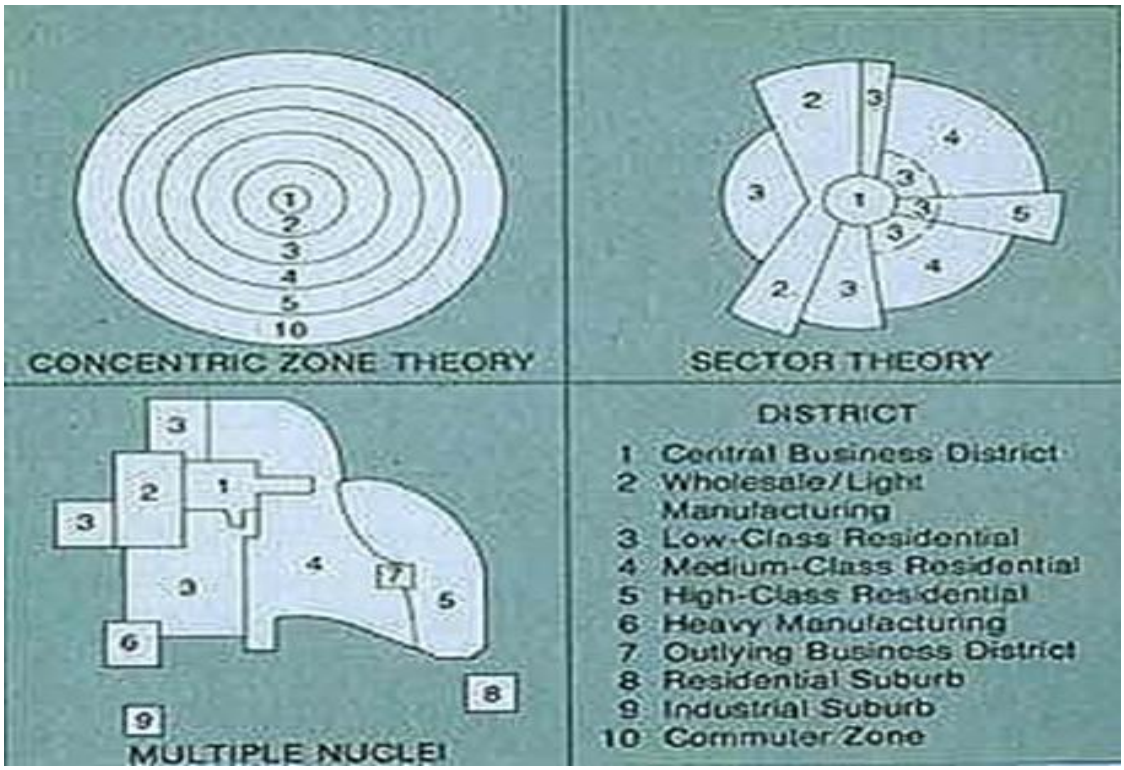


Figure 2.2: Three Generalizations of Urban Structure
Source: Liu, (2001)

2.3.1.2 Sector Model

Soon after Burgess generalized about the concentric zone form of the city, Homer Hoyt re-cast the concentric ring model. While recognizing the value of the concentric ring model, Hoyt also observed

some consistent patterns in many American cities. He observed, for example, that it was common for low-income households to be found in close proximity to railroad lines, and commercial establishments to be found along business thoroughfares. In 1939, Hoyt modified the concentric zone model to account for major transportation routes. Recall that most major cities evolved around the nexus of several important transport facilities such as railroads, sea ports, and trolly lines that emanated from the city's center. Recognizing that these routes (and later metropolitan expressways and interstate highways) represented lines of greater access, Hoyt theorized that cities would tend to grow in wedge-shaped patterns, or sectors, emanating from the CBD and centered on major transportation routes. Higher levels of access translate to higher land values. Thus, many commercial functions would remain in the CBD, but manufacturing activity would develop in a wedge surrounding transport routes. Residential land use patterns also would grow in wedge-shaped patterns with a sector of lower-income households bordering the manufacturing/ warehousing sector (traffic, noise and pollution making these less desirable locations to live) and sectors of middle- and higher-income households located away from industrial sites. In many respects, Hoyt's sector model is simply a concentric zone model modified to account for the impact of transportation systems on accessibility.

2.3.1.3 Multiple Nuclei Model

By 1945, it was clear to Chauncy Harris and Edward Ullman that many cities did not fit the traditional concentric zone or sector model. Cities of greater size were developing substantial suburban areas and some suburbs, having reached significant size, were functioning like smaller business districts. These smaller business districts acted as satellite nodes, or nuclei, of activity around which land use patterns formed. While Harris and Ullman still saw the CBD as the major centre of commerce, they suggested that specialized cells of activity would develop according to specific requirements of certain activities, different rent paying abilities, and the tendency for some kinds of economic activity to cluster together. At the centre of their model is the CBD, with light manufacturing and wholesaling located along transport routes. Heavy industry was thought to locate near the outer edge of city, perhaps

surrounded by lower-income households, and suburbs of commuters and smaller service centres would occupy the urban periphery.

2.4 LITERATURE REVIEW

2.4.1 Measurement and Analysis of Urban Expansion

Arvind and Nathawat (2006) carried out a study on land use land cover mapping of Panchkula, Ambala and Yamunanger districts, Hangana State in India. They observed that the heterogeneous climate and physiographic conditions in these districts have resulted in the development of different land use land cover in these districts. Digital analysis of satellite data indicates that majority of areas in these districts are used for agricultural purpose. The hilly regions exhibited fair development of reserved forests. It is inferred that land use land cover pattern in the area are generally controlled by agro – climatic conditions, ground water potential and a host of other factors.

Chigbu, *et al.,* (2011) analyzed Landuse and Landcover changes in Aba urban area between 1991, 2000 and 2005 using medium resolution satellite imageries (Landsat ETM+, of 2000 and Nigeria Sat-1, of 2005). The results reveal that from 1991, to 2005, the water increased from 15.1% to 22.1% and to 22.4% due partly to increasing activities within and around the waterways, built-up area increased from 21.7% to 26.8% and to 36.5%. Unlike river and built-up area, there is a significant disparity and trend in vegetation landcover due to rapid urbanization and socio economic activities. Thus, vegetation cover decreased from 63.2% in 1991 to 51.1% in 2000 and in 2005 it further decreased to 41.1%.

Oluseyi, (2006) performed urban land use change analysis of metropolitan city of Ibadan within the periods between 1972 and 2003 and discovered that the land use types that are subject to major changes are vegetal covers and sprawl development. Developments in Ibadan are similitude of the building types in the tradition core and the transition zones. It was also obvious that the city was growing at such an alarming rate using up all the green and other forms of soft landscape in the city.

Dami, *et al.*, (2011) used remote sensing and GIS techniques to examine the trends in landuse changes in Maiduguri urban area between 1961 and 2002 and the implications of these in

environmental management. The study revealed among others that trend in land use changes trend in the city showed that Maiduguri grew at a fast rate.

Zubair, (2006) analyzed Landuse/Landcover change in Ilorin between 1972 and 2001, the result of the work shows a rapid growth in built-up land between 1972 and 1986 while the periods between 1986 and 2001 witnessed a reduction in this class. It was also observed that change by 2015 may likely follow the trend in 1986/2001. Many projects were embarked upon after creation of the state and falls within the oil boom era of 1970s. But reduction between 1986 and 2001 attributed of what the researcher called austerity measures known as SAP introduced into the country at the period to restore the country economy.

Bisong (2007) examined the process of land use conversion and rate in common and public lands in South-Eastern Nigeria between 1972 and 2001, the result showed that deforestation was higher in publicly controlled lands than in communal lands. Agricultural land use characteristics, such as farm types and the nature of croplands/fallows, correlated strongly and significantly with deforestation rates. Similarly, Idoko, Bisong, Bisong and Okon (2008) analyzed satellite imageries of 1987 and 2004 for the Federal Capital Territory, Abuja for land use change. The imageries were characterized into five classes using maximum likelihood algorithm. The classes were vegetation, built-up, rock outcrop, water body and farm land. The two classified imageries were compared to identify any changes. Also, a spatio-temporal change in land use type was obtained in quantitative terms. The analysis revealed that vegetation cover reduced by 85.22 per cent between 1987 and 2004. Again, the built-up area increased by 21.99 per cent and farm land increased by 0.14 per cent.

Ade and Afolabi, (2013) monitored urban sprawl in the Federal Capital Territory of Nigeria Using Remote Sensing and GIS Techniques. Multi-date Satellite images of 1987, 1999 and 2007 (Landsat TM, Landsat ETM and Nigeria sat 1 were acquired and used in analyzing the physical expansion of the city overtime. Using supervised classification algorithm, the images were classified into built up, rock-outcrop, vegetation and water bodies and used to carry out change detection or time series analysis. The result showed that the built-up area increased from 8% in 1987 to 22% in 2007, rock-outcrop decreased from 74% to 37%, vegetation decreased from 40% to 17%, while the

area occupied by water body has remained constant overtime. Also projection was done for population in the next nine years and 1,925,464.089 figures which are about 37% is expected. To support this increase in population and physical growth rate observed, constant monitoring of the urban growth is required to be sustained by anthropogenic activities.

2.4.2 Pattern of Urban Expansion from Shannon's Entropy

Sim and Mesev (2009) measured urban sprawl and compactness in Orlando, USA. The study explores a set of quantitative variables to characterize urban forms at the metropolitan level and, in particular, to distinguish compactness from sprawl using a GIS, remote sensing and Shannon's entropy methodology. Six dimensions of sprawl indicators (size, density, continuity, scattering, shape and loss of green space) were selected and evaluated for the Orlando metropolitan region. Results show that spatial characteristics of sprawl can be routinely and quantified using appropriate tools and technologies for monitoring macro-scale long-term changes to urban environments.

Deka, Tripathi, and Khan (2012) integrated remote sensing (RS), Geographic Information and Shannon entropy for urban growth trend analysis in North-East India in order to maintain a systematic urban growth pattern at regional or global level. The study was carried out to quantify the urban growth in Jorhat district of Assam using Shannon's Entropy Approach. The entropy values obtained in the study were 2.32 in 1996 and 2.49 in the year 2010 which are closer to the upper limit of log (n), i.e. 2.63, indicating a dispersed development.

Singh (2014) analysed Urban Growth Using Shannon's Entropy in Rohtak City. The study makes use of Shannon's Entropy with the help of Geographic Information System (GIS) and Remote Sensing technique. The study was carried out over a period 38 years. On the basis of Survey of India Toposheet and satellite images, built up cover of Rohtak was classified for different time periods and Census of India was also used. The result revealed that the growth rate of built-up area was around three times more than population growth rate during 1989-2002. The growth rate in built-up area was 24.14% and population growth rate was 14.47% during 2002-2005.

Al Mashagbah, (2016) quantified the urban growth and trend in Zarqa city during between period 1990 and 2014 using GIS and Remote sensing techniques with Shannon's Entropy statistical method. Three Landsat images for 1990, 2005 and 2014 were used for land use classification by using supervised maximum likelihood classification techniques to extract and assess the changes of urban lands. The results indicated that the urban areas in Zarqa city increased by 22.15% in the period from 1990 to 2005 and 14.86% from 2005 to 2014, with a rate of expansion of 0.96 and by 1.31 km2/ year for the two time periods respectively. The entropy value increased from 1.20 in the first period to 1.38 in the second, while the entropy value for the NE, NW, SE and SW zones showed high values, which confirmed that urban expansion and sprawling had existed in the past twenty four years in the study area.

2.4.3 Transition Probability Matrix

Markov chain model was used to forecast expansion in Kaduna metropolis, markov model is one of the most widely used models for predicting forest depletion as confirmed by the literature. Its outputs include, transition probability matrix, transition area and condition probability images.

Transition area matrix gives the probability that a particular land use class will change to every other land use in the predicted map. Transition area matrix records the total number of pixels that are expected to change to every other one.

2.4.4 Application of Markov Chain Model

Mubea, Ngigi and Mudia (2010) applied Markov chain analysis in predicting land cover change in Nakuru Municipality, Kenya. The projected land use/land cover for 2015 showed a substantial increase in urban and agricultural land use. Islam and Ahmed (2011) predicted land use change in Dhaka city, Bangladesh, using GIS aided Cellular Automata- markov. They modelled the land use change based on the past trend (1991-2008) to generate the future land use map of Dhaka city for the year 2020 and 2050. The result showed that urban built-up areas will increase significantly.

Rimal (2011), studied urban growth and land use/land cover change in Birantnagar Sub-Metropolitan city of Nepal. The study focused on historical urban growth phenomenon and prediction

of land use and land cover change of Birantnagar over four decades by utilizing remote sensing and markov chain model. The result revealed a growing tendency in urban land use, which might threaten the areas that are currently reserved for forest and agricultural purpose. In 1976, urban land cover was 4.8% but increased to 38% in 2009, while cultivated land decreased from 79% in 1976 to 55.8% in 2009.

Ahmed (2011) analysed and predicted future urban growth of Khulna city for 2019 using Multi-layer Perception Markov (MLP-Markov) model. Satellite images of 1989, 1999 and 2009 were used. The result revealed that 33.33% of total study area will be converted into built up area in 2019.

Jeganathan, Roy and Jha (2010), studied change dynamics of forest cover (between 1972 and 1999) in Shimla district, India, using remote sensing and GIS based techniques. Based on their findings, a non spatio-temporal Markov prediction was made for the year 2009. The predicted forest area in 2009 increased from 52.32% in 1999 to 55.49% with 55 errors under Markovian assumption of stationarity. Markov chain analysis can project future change in land use based on the changes from one period to another and spatial characters can be modelled using Cellular Automata (Eastman, 2003).

Datong (2011) carried out a study to determine the market share of mobile communications industry in Yola, North Eastern Nigeria Using first order Markov chain to find out the equilibrium market share of products in 2011 as a basis for predicting future market shares. The result revealed that optimum market mix among the various service providers were as follows: MTN 52.5%, Globacom 27.5%, Zain 15.4% and Etisalat 4.7%.

2.4.5 Application of Cellular Automata Model

Currently, CA-based models are among the most popular ways to simulate land-use changes (Caruso, Peters, Cavailhes andRounsevell, 2007; Long, Shen, and Mao, 2012). A key advantage of CA is their simplicity; they can generate spatio-temporal patterns of great complexity through a limited set of relatively simple rules

In addition, these models can be linked to Geographic Information Systems (GIS) to utilize their functionality and directly use raster-based spatial data derived from remote sensing platforms, revealing CA-markov model as the optimum predictive model for urban growth in 2010 and 2018, using

CA-Markov model based on land use types of 1994 and 2002, it was revealed that the urban and built-up area in 2010 was about 226.98sqkm. While for 2018, based on 2002 and predicted urban and built-up area in 2018 was about 261.53sqkm

Revestity (2011) assessed and predicted human impacts on land use changes of urban area of Zanjan (Iran), using Multi- temporal satellite imageries and GIS for 2020. A combined cellular automata with markov was employed. The result indicated that built up areas will increase from 4662 hectares in 2011 to 5550.4 hectares in 2020 which may endanger other land uses. Ongsomwang and Saravisutra (2011) modelled urban growth in NakhonRatchasma province of Thailand. They compared results of CA-markov and logistic regression model 2002 using overall accuracy and kappa *hat* coefficient of agreement for urban and built-up areas basis. Results revealed that CA-markov model had overall accuracy of 93.41% and kappa hat coefficient of Agreement of 0.84; while logistic the regression had 89.41% and 0.71%.

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter presents the location and examines theClimate, Geology and relief, Vegetation, drainage and socio-economic activities which all have significance to urban expansion of the study area. It also describes the data sources, method of data collection and the techniques used for data analysis.

3.2 THE STUDY AREA

3.2.1 Location

The study areas lies between Latitudes 10° 26' 00'' to 10°38' 00'' N of the Equator and between Longitudes 7° 22' 00'' to 7° 33' 00'' E of the Greenwich Meridian (see Figure 3.1). The area comprises of Kaduna north Local Government, Kaduna south Local Government, part of Igabi Local Government, and part of Chikun Local Government.

3.2.2 Climate

According to Abdulkarim*et al* (2015), Kaduna State has a tropical continental climate type characterized by wet and dry season. The tropical continental is more pronounced in the dry season particularly in December and January. The dry season is dominated by the north-east trade wind called Hamattan which prevails between November-February. The dry season is also rainless from October to April. The wet season is dominated by the tropical maritime trade wind which starts around May to October.

The area has an average monthly temperature of 25.7°C showing a major peak in April with about 37.2°C. As such, temperatures are hot all year round except for the dry cool and dusty months of hamattan in November to February.

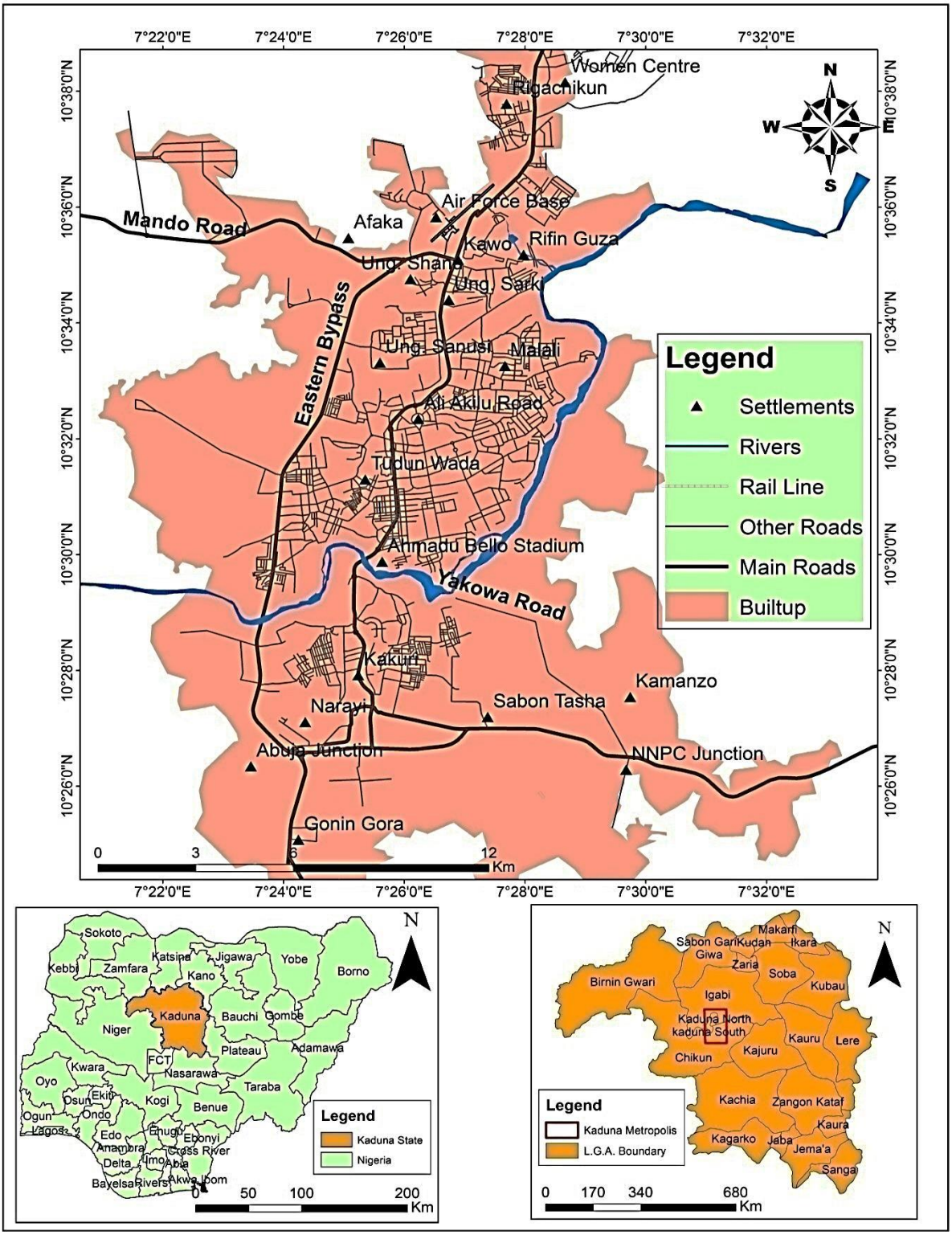


Figure 3.1: Kaduna Metropolis

Source: Earth explorer, 2016.

The maximum temperature seldom falls from about 36°C as in April to about 27°C in the heart of rain season (August-October). The annual rainfall is about 1000mm (Ayoade, 1988).

These seasons are controlled by the apparent movement of an imaginary line known as the inter-tropical discontinuity (ITD), which is in turn dictated by two dominated trade winds; are the tropical continental and the tropical maritime. While according to Thornwaites moisture index the climate of Kaduna falls under the dry sub-humid type.

3.2.3 Vegetation

The natural vegetation of the study area is that of the Northern Guinea Savannah with grass dominating and scattered trees hardly higher than 15ft with broad leaves. Meanwhile, the seasonal character of rainfall in the study area has influenced the vegetation which turns evergreen during the wet season and pale brown in the dry season respectively. Thus, the dominant true species are *IsoberlinaDoka, Dodoneaspp,* and grass communities consist of Hyperhenia and Andropgon species. In the city proper the vegetation is characterized by Silk cotton, Baobab and other protected trees. However, man have greatly affected the vegetation formation in the area, through his activities like; bush burning, cultivation of crops, grazing, lumbering, urbanization and industrial activities among others. The vegetation formation varies and associated with distinct ecological site with particular regard to the nature of the soil

3.2.4 Soils

The soils in the study area have been classified according to Hoores classification scheme for Africa as tropical ferruginous soil. They are zonal soils developed under climatic regimes with appreciable but seasonal rainfall of 500-1200mm and cover nearly half of Northern

Nigeria (Oguntoyinbo, 1983). The soil material consists of several feet of deposited silt sand overlaying sedimentary decomposed rock. The soil is poorly drained because of the high percentage of fine textured materials in the upper layers, which results to water logging especially during the rainy season and tends to dry out and cracks during dry season. Alluvial soil is formed a long riversides (fadama). It is made up of several feet of grey white loamy coarse sand with layers of grey heavy molten occurring at varying depths within the profile. The alluvial soils are usually under intense cultivation of sugarcane and vegetables year-in year-out and as a result in farmers resort to using fertilizers to improve soil fertility

3.2.5 Geology and Relief

The geology of the study area is part of the basement complex geology of central Nigeria. It is composed of older high grade-metamorphosed gneiss interspersed by belt of young meta-sediment of mainly quartzite and schist. The region is underlain by older granitic crystalline, metamorphic rocks of Precambrian to low Paleozoic age (Oguntoyinbo, 1983). It also consists of gneisses which has suffered intense weathering and have remained stable for millions of years. The prolonged weathering under tropical bioclimatic condition has produced rolling plains dotted with residuals of different origin.

The study area lies on the high plains of Hausa land, of height ranging from 550 to 750meters showing a general regional slope to the south and a relative relief of 30 to 45 meters. The plains on which area is situated are parts of the vast, gently undulating plains scenery; which extends almost unbroken from Sokoto to Lake Chad and beyond, from South of Kaduna to the Tidueddi Scarp near Agades. At first sight, they seem remarkable only for their usual monotony and apparent geomorphic simplicity. However, a closer field examination reveals considerable variation in both surface form and composition (Oguntoyinbo, 1983). Sedimentary rocks occur as loose sediments or superficial deposits of clay, laterite and alluvion restricted within flood plains and stream courses. These units of formation which are widespread within Kaduna

Metropolis are found to be useful for agricultural purposes (Ali, 2004).

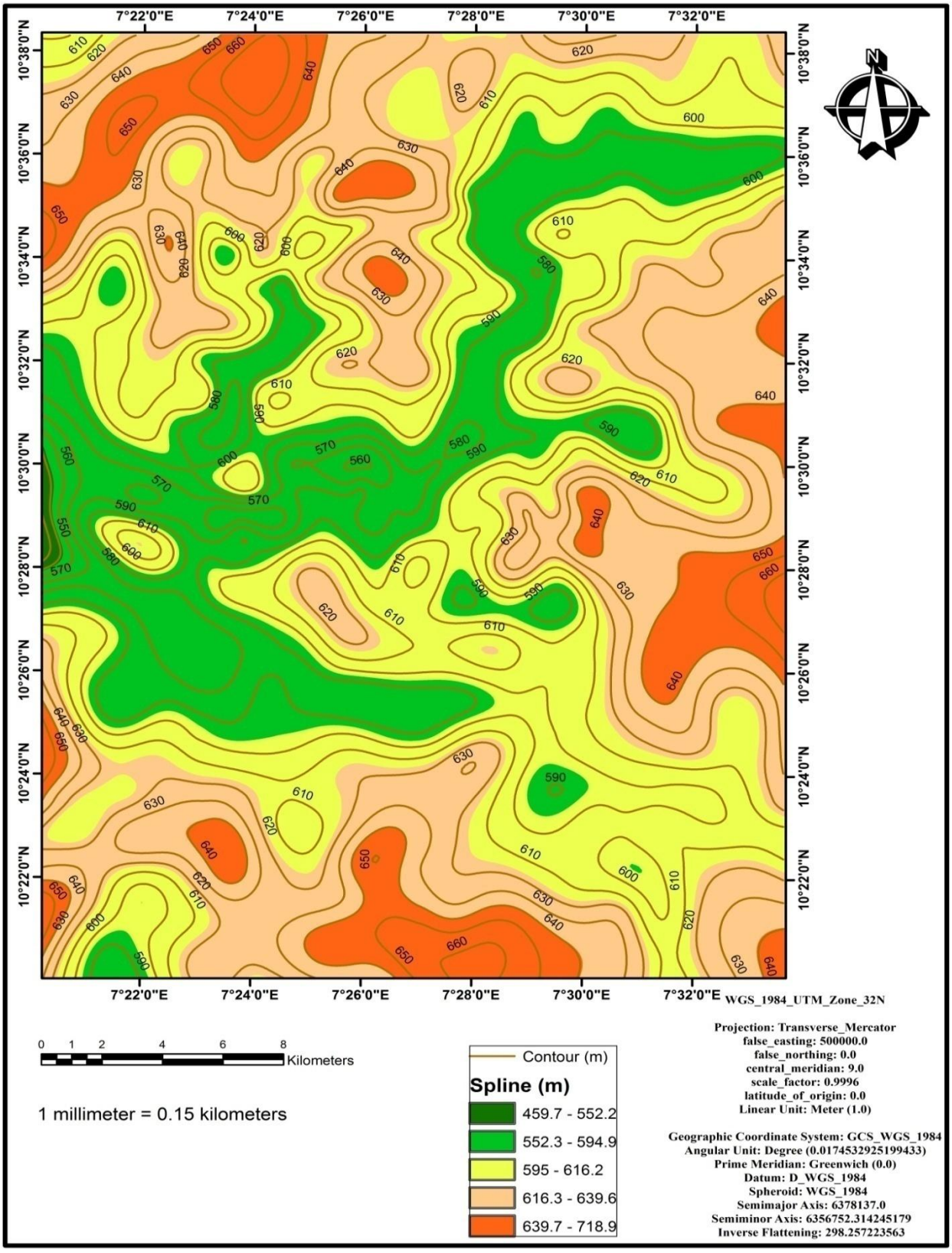


Fig 3.2: Digital Elevation Model
Source: Developed by the researcher (December 2017)

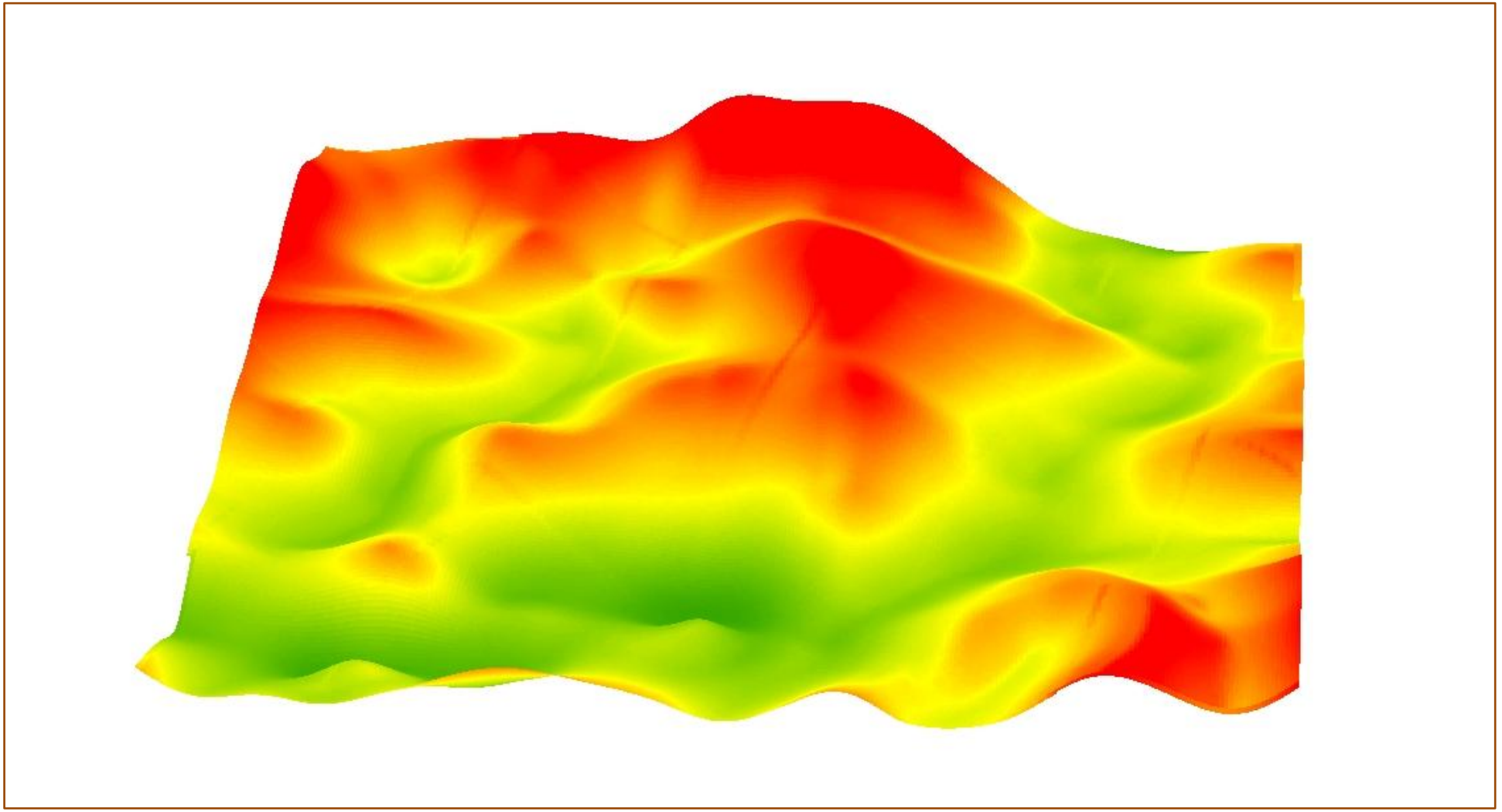


Fig 3.3: Sketch 3D Digital Elevation Model
Source: Developed by the researcher (December 2017)

3.2.6 Drainage

The studyarea is drained by river Kaduna and characterized by high stream frequencies and drainage density. The river drains mostly during the raininy season, and characterized by seasonal and ephemeral attributes. It takes its source from the highland of Jos. It is a great resource for various water usage (Oguntoyinbo, 1983) see figure 3.4 and 3.5 for river Kaduna drainage pattern.

3.2.7 Socio-Economic Activities

Kaduna is a trade Centre and a major transportation hub for the surrounding agricultural areas with its rail and road junction. The symbol of Kaduna State is the crocodile, called *kada*in the native Hausa language. Available evidence shows that, the town is inhabited by over 200 different ethnic groups, with Hausa and English as the most general languages used as means of communication. Kaduna is an industrial center of Northern Nigeria up until early 2000, which has attracted population from most states in the north, Nigeria at large (Kaduna State Government, 2012).

The activities in the study area reflect the commercial, services, administrative, industrial, transport and professional needs of the state and northern Nigeria. The 1956 capital territory law created the limits of the present day Kaduna and set in motion, the rapid and dynamic physical, economic and social transformation of the town. This resulted to the establishment of modern infrastructural facilities such as electric power supply, pipe borne water, good roads, banks, telephone services and international airport.These modem infrastructures were the backbone of the establishment of industries like; textile mills, breweries, bottling companies, flour mills, motor assembly plants, to mention a few. These have attracted many, especially the youths, to seek for employment and share in the economic development of the city in the study area. These industrial growth and high rate of urbanization has attracted both national and international business men, and has made Kaduna one of the strongest commercial center in northern Nigeria and the country at large (Ali, 2004).

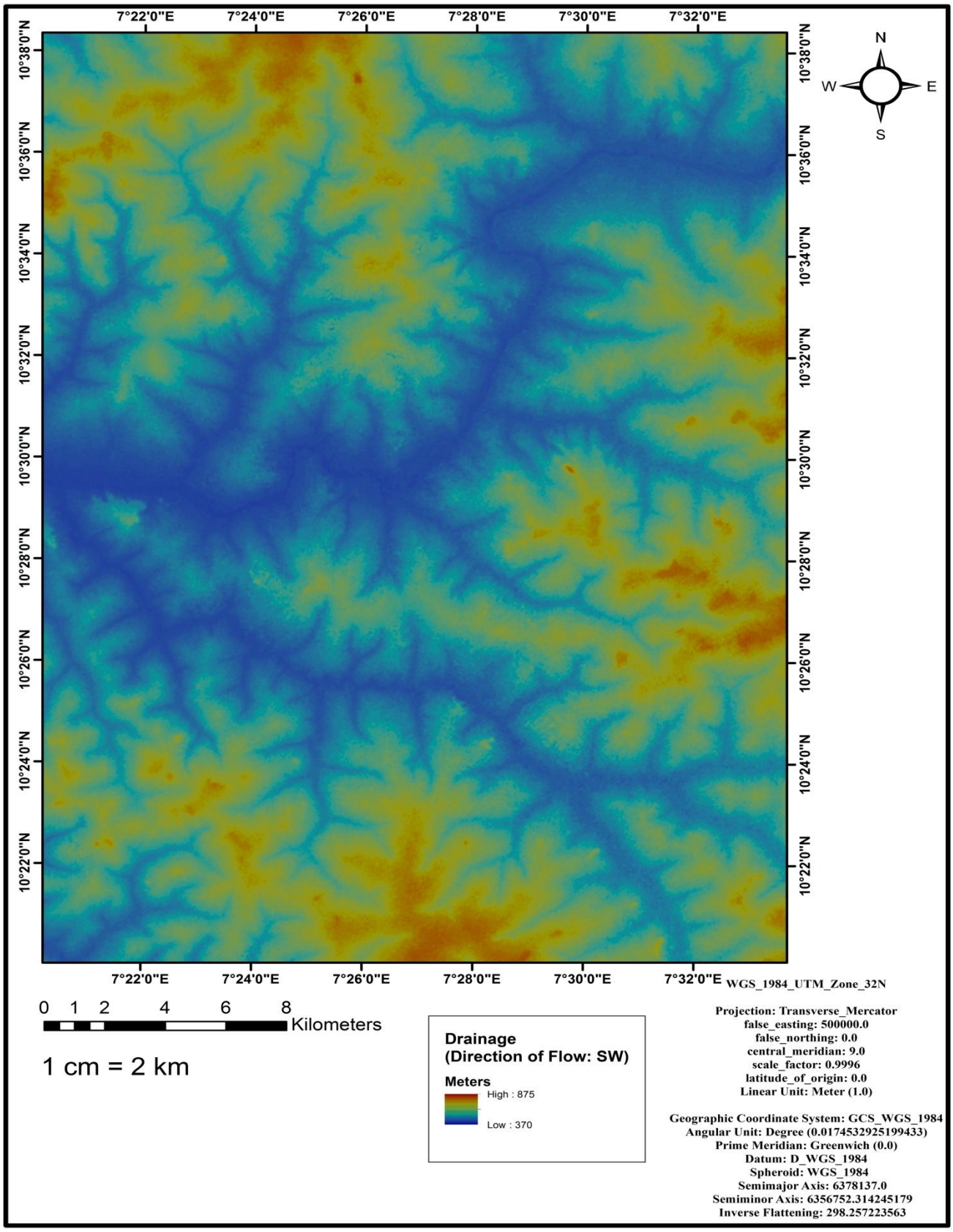


Fig. 3.4: Drainage Pattern
Source: Developed by the researcher (December 2017)

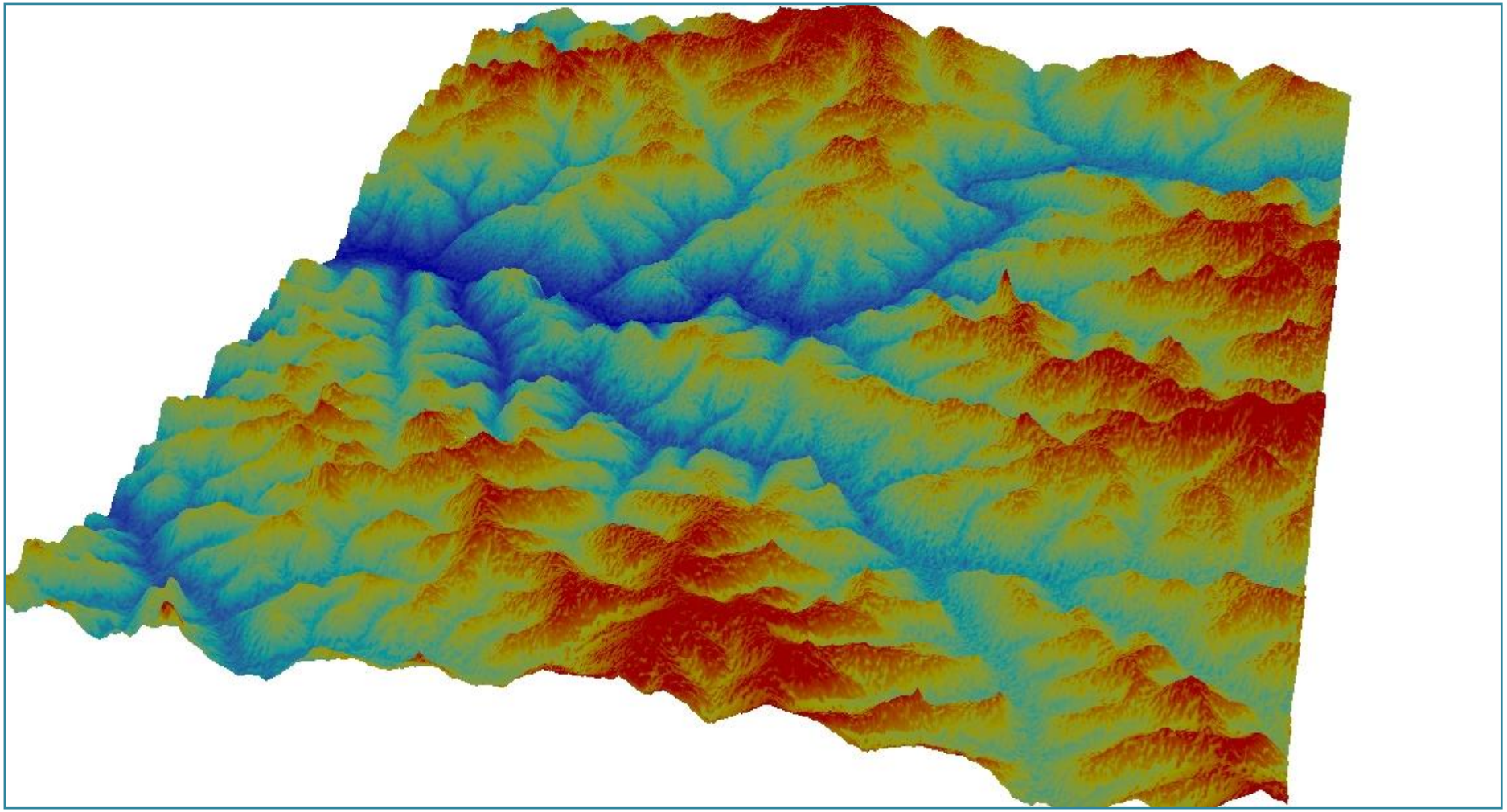


Fig.3.5: Sketch 3D Model of Drainage Pattern

Source: Developed by the researcher (December 2017)

3.2.8 Existing Land Use Pattern

Residential land uses occupy the largest area in Kaduna city. This consists of low, medium and high residential neighborhoods that fall into different Local Climatic Zones (LCZ).The major residential areas include; Kawo, Rigachikun, MandoUngwanRimi, Malali, Kakuri, Tudun Wada, Makera, Rigasa, Barnawa, Sabon Tasha,UngwanDosa, Kamazo, UngwanSarki among others. These neighborhoods are a combination of modem and traditional categories (Ali, 2004).The road and Agricultural land uses cut across all categories of slope. However, agricultural land uses are found along their major route (Kaduna State Government, 2012).

3.3 METHODOLOGY

This section presents the overall methods, techniques, approaches and materials used in achieving the research objectives. It basically explains the data sources and types, methods of field data collection and analysis.

3.3.1 Reconnaissance Survey

A reconnaissance survey of the study areawas carried out from 20th to 22nd June 2016 in order to have more adequate knowledge of the study area. Ten (10) coordinate's locations were taking each for the different land cover class for selection of training sites and also acquiring several more coordinates for computing classification accuracy. This is important as it served as a guide during remote sensing image interpretation and post classification.

3.3.2 Types of Data Used and their Sources

The types of data used for this study were both primary and secondary, namely:

3.3.2.1 The primary data

i. Landsat 5 Thematic Mapper (TM) of 1986 with spatial resolution of 30 metres and acquisition date of 17th/November/1986 was obtained from United State Geological Survey website.(https://earthexplorer.usgs.gov)

ii. Landsat 7 EnhancedThematic Mapper Plus (ETM+) of 2000 with spatial resolution of 30 metres and acquisition date of 2nd/February/2000 was also obtained from United State Geological Survey website.(https://earthexplorer.usgs.gov)

iii. Landsat(8) Operational Land Imager of 2016 with spatial Resolution of 30 metres and acquisition date of 12th/August/2016 was also obtained from United State Geological Survey website.(https://earthexplorer.usgs.gov)

iv. Handheld GPS was used for acquiring coordinates. (model: Garmin GPSMAP 64s)

3.3.2.2 The secondary data

Topographic Map Sheet, obtained from the Kaduna State Ministry of Land and Survey. Literature materials were sourced textbooks, journals, past unpublished theses/projects, world reports among others for information in the reviewed literature

3.3.3 Techniques of Data Processing

3.3.3.1 Image Geo-referencing

The topographic map wasgeoreferenced (registration) to a commonProjected Coordinate System unit (Universal Traverse Mercator), in Erdas Imagine 9.2 user interface. According to Wilford (1977), the UTM isreliable since its measurements are cited in linear, decimal units, rather than in angular, non-decimal units. This was done to translate the images real world coordinate to digital format so that it matched other relevant and related maps that was used in this study.

3.3.3.2 Image Sub-setting

Landsat TM imageries of 1986 and 2000 with 30m spatial resolution; Landsat (ETM +) imagery of 2016 with spatial resolution of 30m was used for the study. The portion of interest (Kaduna Metropolis) was subset from each of the larger scenes using Erdas Imagine 9.2 software since the satellite images comes in bands and cover large area.

3.3.3.3 Image Classification

In classifying the images into various classes, supervised classification technique was performed using maximum likelihood classification (MLC) algorithm. This techniqueenabled the work to

generate training classes based on the actual land-use/land-cover themes present within the study area. It also facilitated reducing ambiguities often associated with the unsupervised technique of image classification according to Liu, Skidmore and Oosten (2002). The MLC was adapted because it is the most widely and commonly used when manipulating remotely sensed data and it has proven to yield the best classification result according to Jensen, (1996). The attribute and statistics from the classification result was generated and used for post-classification comparison between the years (1986 -2000 and 2000 -2016).

Based on the prior knowledge of the area and reconnaissance survey, a classification scheme afterAnderson, Hardey, Roach and Witmer, (1976) was adapted for this study. The classification scheme utilised six (6) classesof landuse – land cover to includeaspects ofUrban/Built-up, non-forested, vegetation, marsh land, barren land and water body. In this study however, the classification scheme was modified to present five (5) classes Built-up land, vegetation land, agriculture land, water and barren ground as shown in Table below:

Table 3.1 Land use classification scheme

CODE	LANDUSE/LAND COVER CLASSES	DESCRIPTION
1	Build-up land	Land use for settlement and building of urban infrastructures such as schools, roads, etc.
2	Vegetated land	Land covered with natural vegetation such as grasses, shrubs, grass like-plants and natural forest.
3	Agricultural land	Land used as cropland, agricultural farmland etc.
4	Water body	Rivers, streams, ponds and dams.
5	Barren Ground	Land devoid of vegetation cover and exposed soils.

Source: Modified from Anderson, Hardey, Roach and Witmer, (1976).

3.3.4. Data Analysis

3.3.4.1 Objective 1: to determine the extent and rate of urban expansion

The extent of the urban expansion was determined by subtracting the developed land extent/areafrom the reference year of 2016 from that of the base year of 1986.

It is represented mathematically as:

E_T = B-A

A = the base year (1986)

B = the reference year (2016)

E_T = the total extent of urban expansion between 1986 and 2016.

In order to determine the rate of the urban expansion, resulting values generated from the extent of urban expansion to compare the data set for1986, 2000 and 2016 to get the expansion in hectares, the total expansion in hectares was divided by the number of the years between the two time periods and subsequently converted to percentage to obtain the rate of expansion between the spatio-temporal periods of 1986-2016.It is mathematically represented as:

$$R = \frac{E_T}{\text{number of years}}$$

Where R =Rate of urban expansion

E_T =Total extent of urban expansion

To get the percentage = $\mathcal{R} = (R)/\ 100\%$

3.3.4.2 Analysis of the pattern of expansion in the study area.

Python 3.2 programming language was usedin computing the entropy valuesto analyze the pattern of urban growth to see if the growth is divergent or compact. The Shannon entropy model is an indicator of spatial concentration or dispersion and can be applied to any geographical variable (Mahdi*et al*, 2001). The entropy computed in python 3.2 language was calculated thus:

$$H_i = -\sum_{j=1}^{m} p_j \log_e(p_j)$$

where

i =temporal span (i.e 1986-2000, 2000-2016)

J =target zone (Neighbourhoods),

p_j=probability or proportion of the variable in the j-th target zonecalculated

m=number of zones=20

log_n=maximum limit of entropy, for the study area.

P_j= is the probability of the variable occurring in zone I and is given as

$$P_j = \left(\frac{Xi}{\sum_k^n Xk} \right)$$

Where;

X_i = the density of land development, which equals the amount of built-up land divided by the total amount of land in the i^{th} zone;

n = the total number of zones

The value of entropy is always between 0 and 1. An entropy value of zero (0) indicates a totally concentrated distribution, and (1) for a totally dispersed distribution.

3.3.4.3 Forecasting possible urban expansion for 2045 using the Markov-Cellular Automata.

To achieve this objective, Cellular Automata -Markov Chain analysis, embedded in IDRISIKilimanjaro software from Clarks Labs was used toforecast the expansion for 2045.A Markov Chain CA used integrated two techniques:

a) MarkovChain analysis described the probability of land cover changefrom one period to another by developing a transition probability matrix between t1 and t2. Theprobabilities were assumed be accurate on a per category basis and there was no knowledge of the spatialdistribution of occurrences within each land cover class, which leads to the second technique.

b) ***Cellular Automata*** was integrated into the Markov approach. The CA component of the CA-Markov model enabled the transition probabilities of one pixel to be a function of otherneighbouring pixels. CA-Markovmodelled the change of several classes of cells by using a Markov transition matrix,cellular automatafor theneighbourhood cell.

Figure 3.6 below shows the flow chart of Markov Cellular Automata for the research

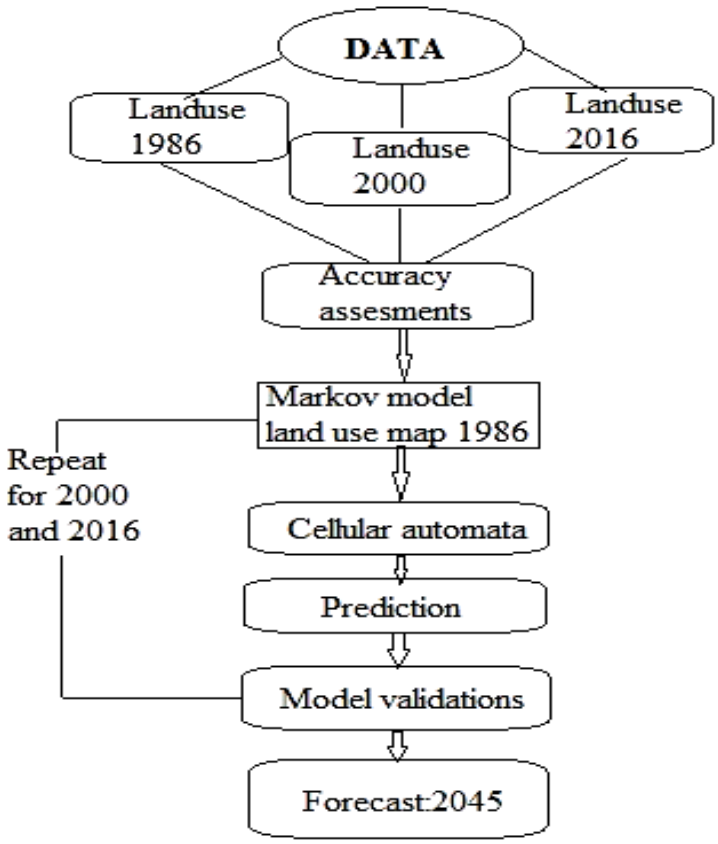
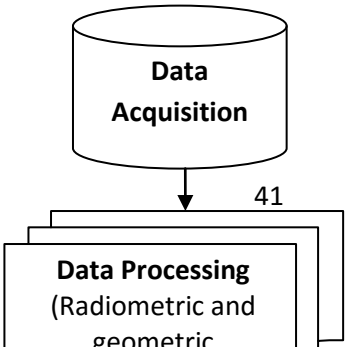


Fig 3.6: Flow chart of Markov Chain – Cellular Automata Model



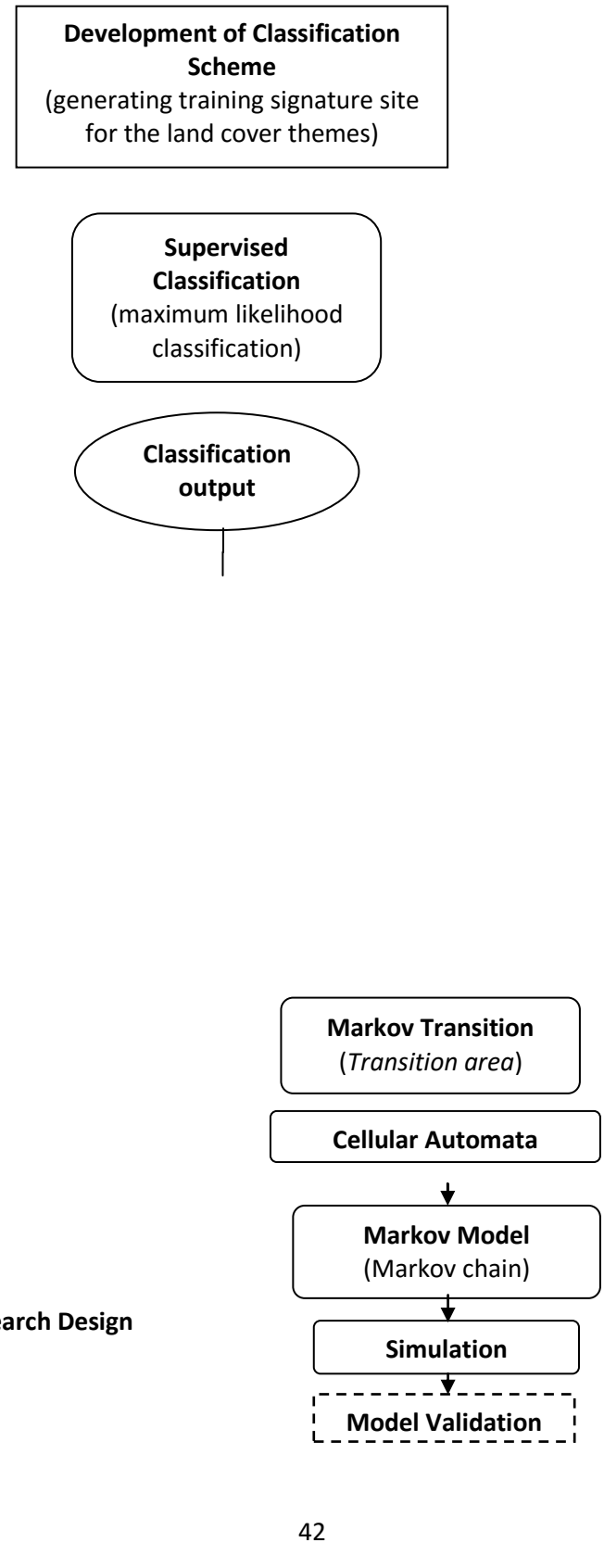


Fig 3.7: Flow chart of Research Design

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents and discusses the findings obtained from the data processing. Also, the forecast of the urban/Built-up area was made and discussed subsequently.

4.2 Accuracy Assessment of Landuse - Landcover Classification

The accuracy assessment of the land use and land cover classification results was obtained by computing error matrix. Thus, the overall accuracy result of the error matrix and the Kappa coefficient for 1986, 2000 and 2016 imageries are presented in Table 4.1.

Table 4.1: Classification accuracy Assessment using Error Matrix

Sensor	Classified map	Pixel to Pixel Accuracy	Kappa Index
Landsat TM	Built up 1986	91.44%	0.89
LandsatETM+	Built up 2000	92.22%	0.90
Landsat 8	Built up 2016	89.97%	0.87

Source: Author's Analysis, 2017

Table 4.1 shows an overall accuracy of 91.44% for the year 1986, 92.22% for the year 2000 and 89.97% for year 2016 respectively. Anderson *et al.,* (1976) suggested a minimum accuracy value for reliable land cover classification as 85%. Hence, the classification accuracy for this study can be acceptable. None of the Kappa coefficients for the three imageries obtained was less than 0.87 and this signifies that the classification accuracy was good enough which agrees with the research of Anthony, Viera and Joanne, (2005).

4.3 Extent of Landuse And Landcover of The Study Area

The land use / land cover of Kaduna Metropolis was determined based on modified classification scheme of Anderson, Hardey, Roach and Witmer, (1976). The land cover facetsused

were urban/built-up areas, farmland, vegetation, bare land and water body only. The statistics of the classified images for the various years are shown in table 4.2, 4.3 and 4.4 below.

Table 4.2: Variations in Land Use/Land Cover in Kaduna Metropolis: 1986

Types of LULC	Area in Km^2	%
Farmland	193.10	61.63
River/Waterbody	17.28	5.52
Bare Land	11.87	3.79
Urban/Built-up Areas	77.84	24.84
Vegetation	13.22	4.22
Total	**313.31**	**100**

Source: Researcher's Analysis, 2017

Table 4.2 shows the five land cover classes for resulting classified image of the study area for1986.The results showed that farmland class had the highest area coverage of 193.10Km² (61.63%) but it decreased steadily over the study years, while the urban/built-up area covered 24.84% of the land, only 3.79 % was bare.

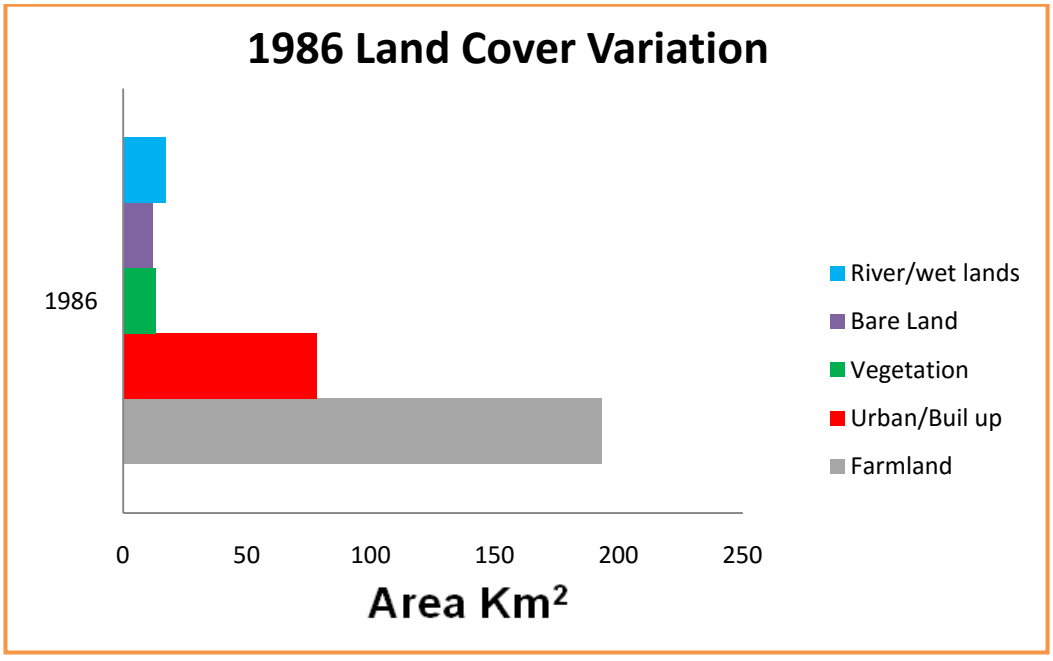


Fig 4.1: Variations in Land Use/ Land Covers in Kaduna Metropolis: 1986

Source: Researcher's Analysis, 2017

The imagery of the study area with its varied LULUs in 1986 is shown in Figure 4.2

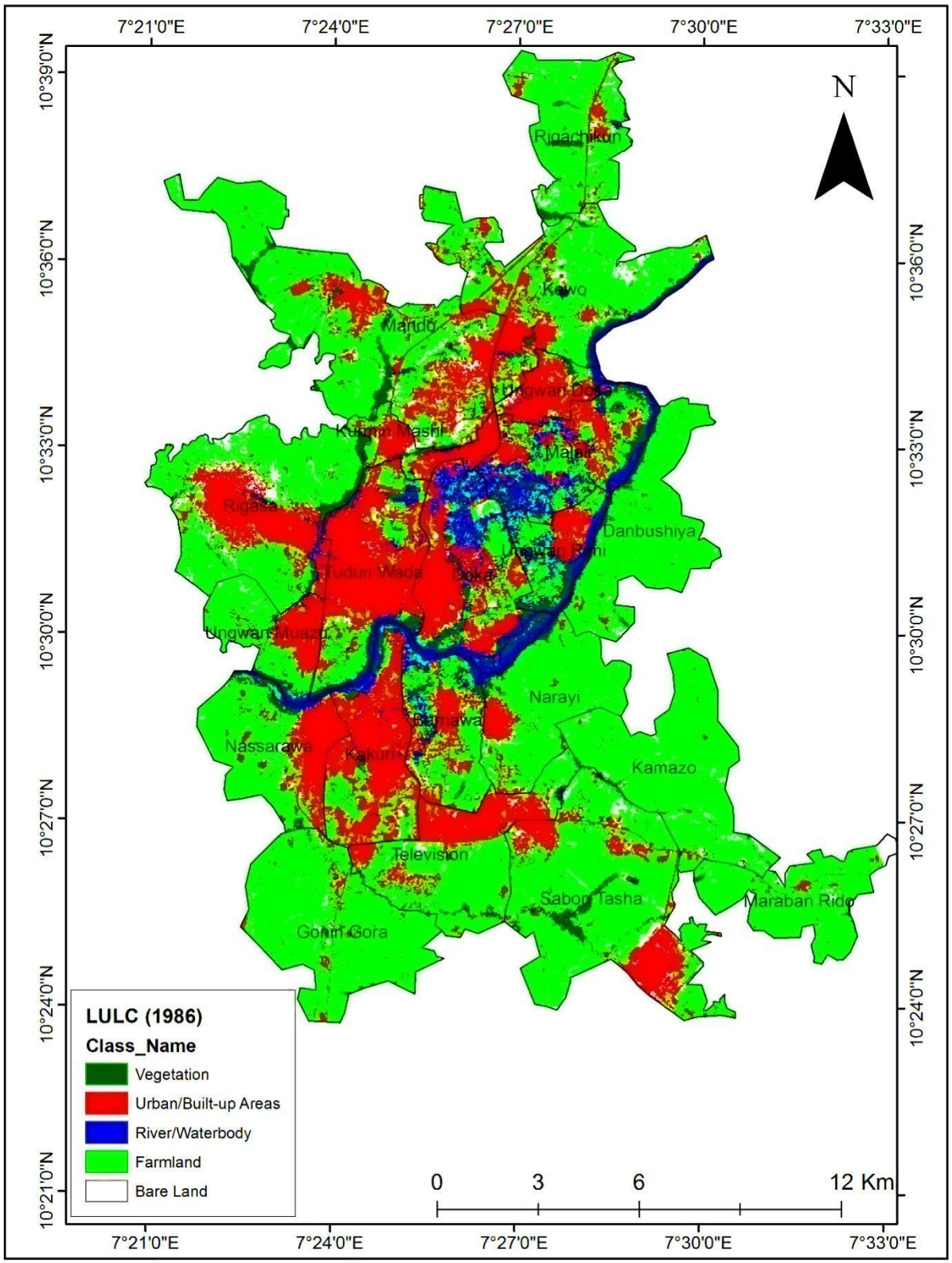


Figure 4.2: Variation inLanduse and Landcover of Kaduna Metropolis: 1986
Source: Researcher's Analysis, 2017

Changes of the LULC of the study area for 2000 was also compiled and presented in table 4.3

Table 4.3: Variation in Land Use/ Land Cover in Kaduna Metropolis:2000

Types of LULC	Area in Km^2	%
Farmland	69.70	22.25
River/Waterbody	4.55	1.45
Bare Land	28.72	9.17
Urban/Built-up Areas	166.62	53.18
Vegetation	43.72	13.95
Total	**313.31**	**100**

Source: Researcher's Analysis, 2017

Statistics in Table 4.3 shows urban/built-up areas in 2000 within the Kaduna metropolis account for the highest (53.18%) of the land coverage. Farmland areas dropped from 61.63 in 1986 to 22.25% in 2000. Bare land has shrunken to just 9.17 % of the total area in focus. The observed reduction in the farmland could be attributed to the increase in the urban built-up. The graphic presentation of the variations in shown in Figure 4.3

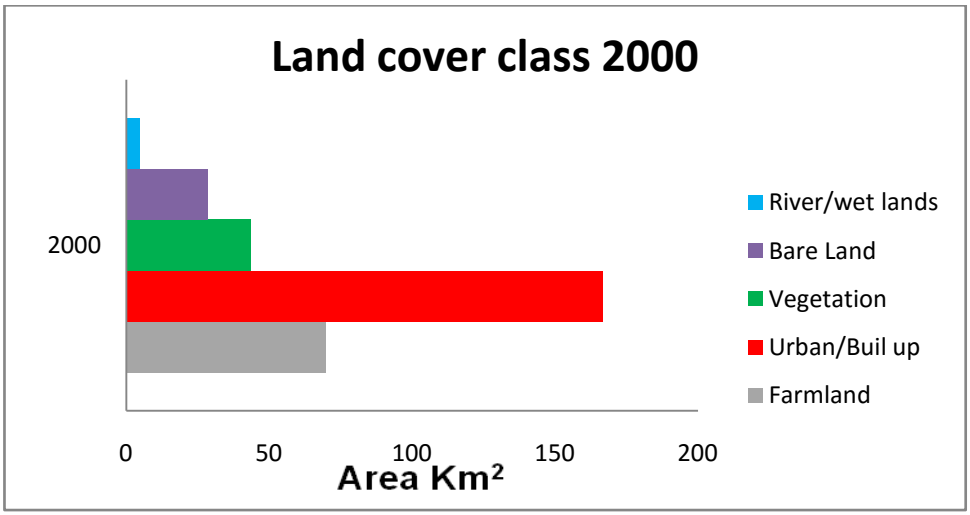


Fig 4.3: Variation in Land Use/ Land Cover in Kaduna Metropolis: 2000
Source: Researchers Analysis, 2017

An imagery of changes in the LULC of the study area for 2000 is shown in Figure 4.4

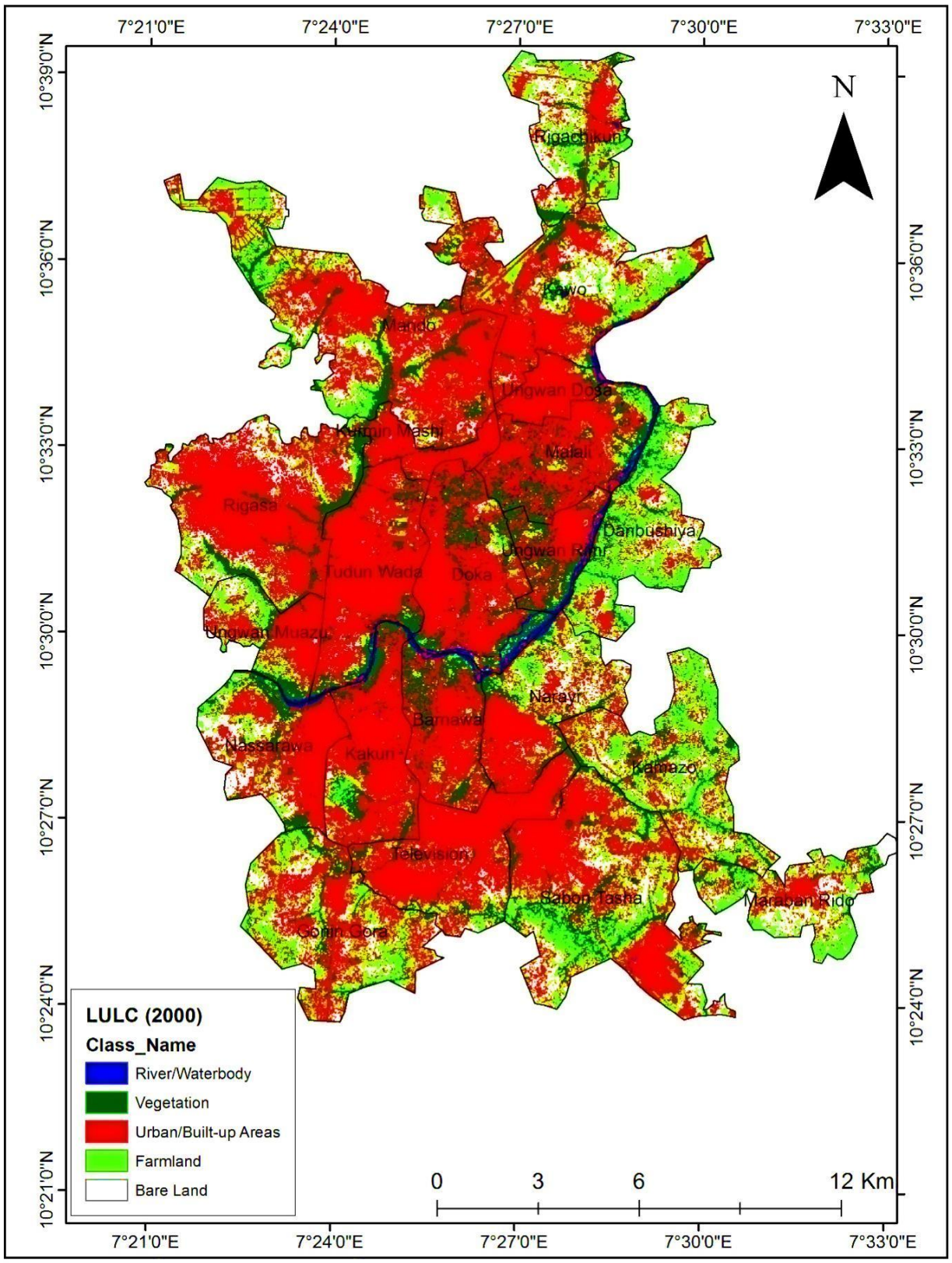


Figure 4.4: Landuse and Landcover Variation in Kaduna Metropolis:2000
Source: Researchers Analysis, 2017

Changes for 2016 was also summarised and presented in Table 4.4

Table 4.4: Variation in Land Use/ Land Cover; Kaduna Metropolis: 2016

Types of LULC	Area in Km^2	%
Farmland	66.47	21.22
River/Water body	5.58	1.78
Bare Land	14.80	4.72
Urban/Built-up Areas	194.27	62.01
Vegetation	32.19	10.27
Total	**313.31**	**100**

Source: Researchers Analysis

Results in Table 4.4 shows similar oscillatory changes in the area extent covered by build-up surfaces (62.01%) of the total land within the study area and a further reduction of farmlands (21.2.%) Bare land and water bodies have consistently remained the least in extent for the 30 years period of the study

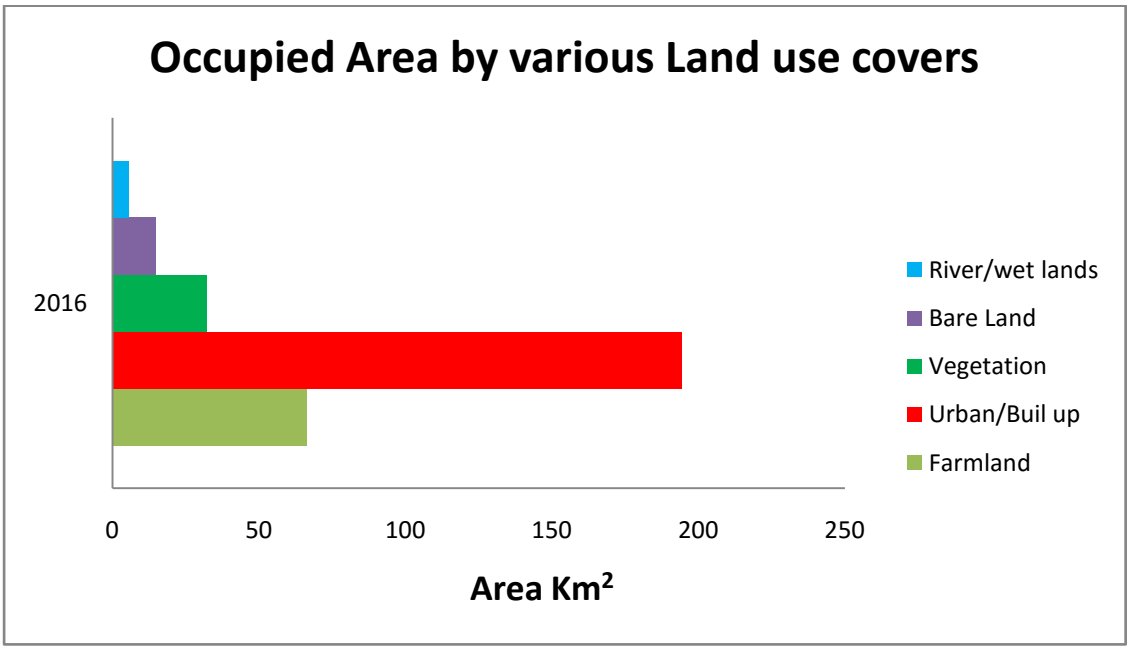


Fig 4.5: Land Use Land Cover Variations in Kaduna Metropolis: 2016
Source: Researchers Analysis, 2017

LULC imagery of the study area for 2016 is also compiled and presented in figure 4.6

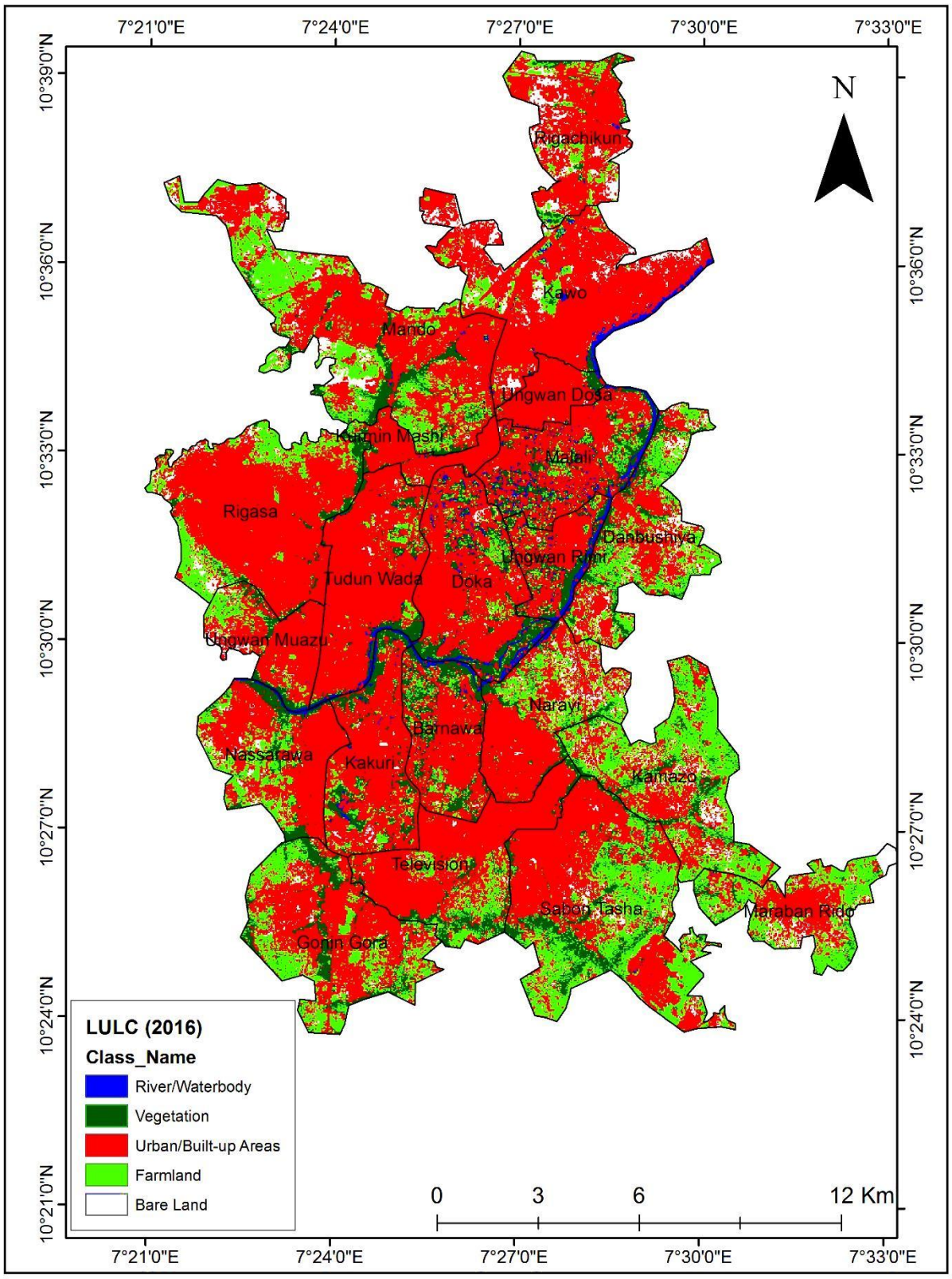


Figure 4.6: Landuse and LandcoverVariation of Kaduna Metropolis, 2016
Source: Researcher's Analysis, 2017

This result affirms the study of Akpu and Tanko (2012) whose findings indicated increase in built-up land use in Kaduna metropolis and as an indicator ofurbanization due topopulation growth and the demand

for urban land. This also implies that increase in human population fosters urban development and changes in the use for which the land is being subjected to. Human activities such as farming, grazing, land excavation especially for road construction might be responsible for the increase in bare land and reduction in vegetation in the study area as ascertained in other literature reviewed in chapter 2

4.4Extent and Rate of Built-Up Areas of Kaduna Metropolis in 1986, 2000 and 2016

The magnitude and rate at which each urban built-up is changing yearly is tabulated in square kilometer and percentage. Table 4.5 represents the magnitude and rate of urban expansion of Kaduna metropolis between 1986 and 2016.

Table 4.5: Magnitude and Rate of Urban Expansion between 1986 and 2016

	Urban		Magnitude of Expansion		Rate of Expansion	
Period	**Year**	**Km^2**	**Km^2**	**%**	**Km^2/Year**	**%/Year**
1986-2000	**1986**	**77.84**	**88.78**	**114.05**	**6.34**	**8.15**
14Years	**2000**	**166.62**				
2000-2016	**2000**	**166.62**	**27.65**	**16.59**	**1.73**	**1.04**
16Years	**2016**	**194.27**				
1986-2016	**1986**	**77.84**	**116.43**	**149.27**	**3.88**	**4.99**
30Years	**2016**	**194.27**				

Source: Researcher's Analysis, 2017

Analysis in 4.5 Table shows that from 1986 to 2000, there was an increase in the area covered by the built-up land at a rate of 6.34km^2yr^{-1} (8.15%yr^{-1}). This rapid increase signifies continuous urban expansion due to increase in population. This increase in the extent and rate of the expansion between 1986 and 2000 period could be attributed to with the period of rapid industrialization which ranked Kaduna second most industrialized state after Lagos in Nigeria.

The expansion of the study area reduced after 16years (between 2000 and 2016) at the rate of 1.73km^2yr^{-1}(1.04%yr^{-1}). The result also shows that the extent and rate of the expansion of the city between

2000 and 2016 is not as rapid as the rate of expansion from 1986 to 2000. Recurrent ethno-religious crisis that rocked the metropolis during the early 2000 and coupled with the pull effect the Federal Capital (Abuja) exerts on adjourning cities including Kaduna may have been the reasons.

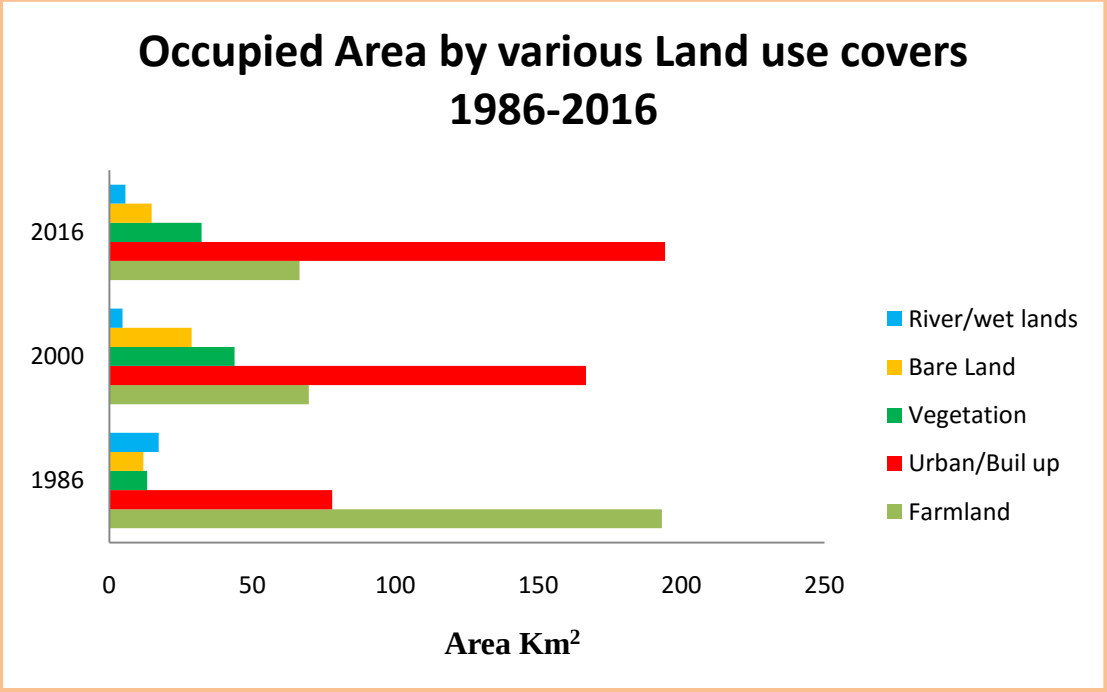


Fig 4.7: Variation in LULC from 1986-2016 at Kaduna Metropolis
Source: Researcher's Analysis, 2017

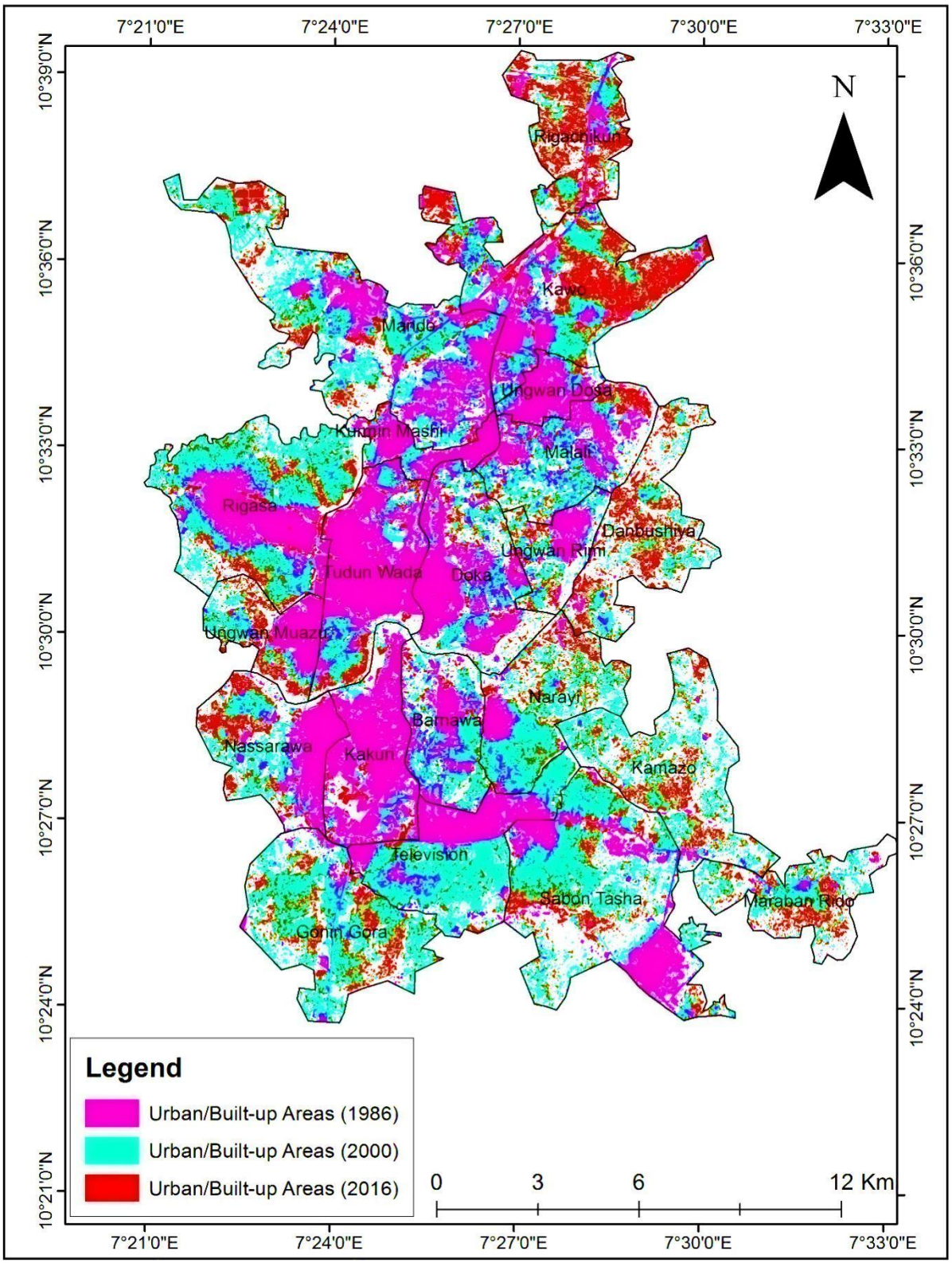


Figure 4.8: Urban/Built-up Areas of Kaduna Metropolis in 1986, 2000 and 2016
Source: Researcher's Analysis, 2017

4.5 Pattern of Urban Expansion in the Study Area.

The pattern of urban expansion in Kaduna Metropolis during the period from 1986 to 2016 was investigated and analysed usingthe Shannon's Entropy. The entropy of Kaduna Metropolis was determined for 1986, 2000 and 2016 are shown in Table 4.6 and Table 4.7

Table 4.6: Relative Entropy for Kaduna Metropolis: 1986-2016

Year	Total Landmass Area	Built-Up Area	Density	Relative Entropy	Period	Difference	% of Difference
1986	438.73	77.84	0.1774	0.1332	1986-2000	0.0264	19.84
2000	438.73	166.62	0.3798	0.1597	2000-2016	-0.0030	-1.89
2016	438.73	194.27	0.4428	0.1567	1986-2016	0.0234	14.95

Source: Researcher's Analysis, 2017

The calculated relative entropy values for the entire Kaduna metropolis as presented in Table 4.6showed a relative entropy value of 0.1334 in 1986. The relative entropy increased to 0.1597 in 2000 indicating a difference of 0.0264 from 1986 to 2000. This means that the city has expanded by 19.84% within this period. In 2016, the calculated relative entropy reduced to 0.1567 indicating a difference of -0.00030.For the entire period of study i.e. between 1986 and 2016, the difference in the relative entropy was found to increase by 14.95%.The result indicates that there is an increase in urban expansion and development and the pattern of the expansion tends to be dispersed shown by increase in the value of entropy. Specifically,higher relative entropy values reflect increase in urban sprawl rates and more dispersed urban growth and lower values indicate increase in urban growth rate and higher compactness levels in the crowded urban areas.This is not different from the study of Bununu (2011) that observed urban sprawl in the development of Kaduna metropolis and attributed sprawled pattern to first population increase and secondly the existing pattern of urban growth in Kaduna which is largely dispersed.The relative entropy values were further estimated for the different neighborhood within Kaduna metropolis the result is shown in Table 4.7

Table 4.7: Calculated Relative Entropy for Neighbourhood in Kaduna Metropolis 1986-2016

		Built-up Areas (Km^2)			Density ofneighborhoods			Relative Entropy ofneighborhoods		
S/N	**Name**	**1986**	**2000**	**2016**	**1986**	**2000**	**2016**	**1986**	**2000**	**2016**
1	Barnawa	2.95	6.38	6.47	0.0394	0.0383	0.0333	0.0554	0.0542	0.0492
2	Danbushiya	0.25	0.33	5.87	0.0034	0.0020	0.0302	0.0084	0.0054	0.0459
3	Doka	6.55	10.24	10.83	0.0876	0.0614	0.0558	0.0926	0.0744	0.0699
4	Gonin Gora	1.00	8.78	10.36	0.0133	0.0527	0.0533	0.0250	0.0673	0.0679
5	Kakuri	8.14	9.45	9.57	0.1088	0.0567	0.0493	0.1048	0.0707	0.0644
6	Kamazo	0.30	5.26	5.80	0.0040	0.0316	0.0299	0.0096	0.0474	0.0455
7	Kawo	4.96	11.76	17.95	0.0663	0.0706	0.0924	0.0782	0.0813	0.0956
8	KurminMashi	2.77	3.56	3.69	0.0371	0.0214	0.0190	0.0531	0.0357	0.0327
9	Malali	3.68	7.79	8.34	0.0493	0.0467	0.0429	0.0644	0.0622	0.0587
10	Mando	6.85	16.81	16.41	0.0916	0.1009	0.0845	0.0951	0.1005	0.0907
11	MarabanRido	0.35	3.08	4.10	0.0047	0.0185	0.0211	0.0109	0.0320	0.0353
12	Narayi	1.59	6.92	8.26	0.0213	0.0415	0.0425	0.0356	0.0574	0.0583
13	Nassarawa	3.99	7.28	8.26	0.0533	0.0437	0.0425	0.0679	0.0594	0.0583
14	Rigachikun	1.08	4.15	8.16	0.0145	0.0249	0.0420	0.0266	0.0399	0.0578
15	Rigasa	6.55	15.96	18.08	0.0876	0.0958	0.0931	0.0926	0.0976	0.0960
16	Sabon Tasha	5.32	14.21	14.26	0.0712	0.0853	0.0734	0.0817	0.0912	0.0833
17	Television	5.30	11.40	12.07	0.0709	0.0684	0.0621	0.0815	0.0797	0.0750
18	Tudun Wada	9.35	12.11	12.96	0.1251	0.0727	0.0667	0.1129	0.0827	0.0784
19	UngwanDosa	2.80	3.58	3.68	0.0374	0.0215	0.0189	0.0534	0.0358	0.0326
20	UngwanMuazu	2.47	4.35	5.39	0.0330	0.0261	0.0277	0.0489	0.0414	0.0432
21	UngwanRimi	1.58	3.23	3.75	0.0211	0.0194	0.0193	0.0354	0.0332	0.0331
	Total	**77.84**	**166.62**	**194.27**						

Source: Researcher's Analysis, 2017

Table 4.7 shows that the relative entropy values of 55% of the residential neighbourhoodshave increased during the study periods. While some are drastic and high, others are slow with low values. The result reveals that Tudun Wada had the highest relative entropy in 1986 with 0.1129 followed byKakuri with 0.1048 while Danbushiya, Kamazo and MarabanRido had the least entropy with 0.0084, 0.0096 and 0.0109 respectively. In 2000 the change in entropy levels of the neighbourhoods was not drastic.Mando experienced an increase in urban built-up with a high relative entropy of0.1005 followed by Rigasa (0.0976). Danbushiya and MarabanRido maintained the least entropy of 0.0054 and 0.0320 respectively. In 2016, Rigasa, Kawo and Mando neighbourhoods had attained high relative entropies of 0.0960, 0.0956 and 0.0907 respectively.UngwanDosa, KurminMashi and UngwanRimi had the least with 0.0326, 0.0327 and 0.0331 respectively in 2016. Neighbourhoods with moderate entropy have the values ranging from 0.04 to 0.07 and have the potentials of transiting to densely built up areas with time

Northern parts of the study area (Fig 4.7) revealed neighbourhoods with higher relative entropy values in 1986but between 2000 and 2016, the relative entropy values favoured the southern neighbourhoods. This could be as a result of the incessant occurrence of ethno-religious crises of year 2000 which have made many people that were staying in the Northern to relocate to the Southern parts of the study area. This result also conforms to the study of Bako (2017) that also concluded that the Southern parts of the metropolis are experiencing more urban growth than in the Northern.

4.6 Forecast of Possible Urban Expansion From 2016 - 2045 in the Study Area

The combination of Cellular Automaton and Makov Chain in IDRISI Selva was used in computing the transition probability matrix. The transition probability matrix records the probability of each land use category to change into the other category. This matrix is produced by the multiplication of each column in the transition probability matrix by the number of cells of

corresponding land use in the later image. Table 4.8 represents the transition probability matrix for the projected LULC of the study area while Table 4.9 shows the area coverage for 2045.

		2016				
	LULC	Vegetation	Built-up	Water body	Bare Land	Farmland
	Vegetation	**0.0092**	0.0001	0.0002	0.0641	0.3866
	Built-up	0.0221	**0.6073**	0.0005	0.3141	0.8012
2045	Water body	0.0000	0.0000	**0.0711**	0.0088	0.0033
	Farmland	0.1101	0.0033	0.2011	**0.0946**	0.21513
	Bare Land	0.1092	0.3930	0.0007	0.2387	**0.0552**

Table 4.8: Transition Probability Matrix for 2045 Projected LULCin the Study Area

Source: Researcher's Analysis, 2017

The row categories represent land use/ land cover classes in 2016 whilst column categories represents 2045 classes. From Table 4.8, built-up area has a probability as high as 0.6173 (60.73%) to remain as built-up area in 2045 which signifiesthat built-up land has a high tendency of changing to another land use/land cover classes. The probability of vegetation to change to urban built-up was found to be 0.0221 (2.21%). The result further reveals that farmland has very high probability of 0.8012 (81.12%) to transform to built-up land. The area covered by the various land cover categories projected to 2045 was also calculatedand the result presented in Table 4.9.

Table 4.9 Predicted Land Use change in Kaduna Metropolis: 2016 and predicted to 2045

	CA-Markov 2016		CA-Markov 2045	
LULC	**Area (Km^2)**	**%**	**Area (Km^2)**	**%**
Farm Land	66.47	21.21	51.48	16.43
River/Water body	5.58	1.78	5.52	1.76
Bare land	14.8	4.72	13.9	4.43
Urban/Built Up	194.27	62	213.31	68
Vegetation	32.19	10.27	29.1	9.28

Source: Researcher's Analysis, 2017

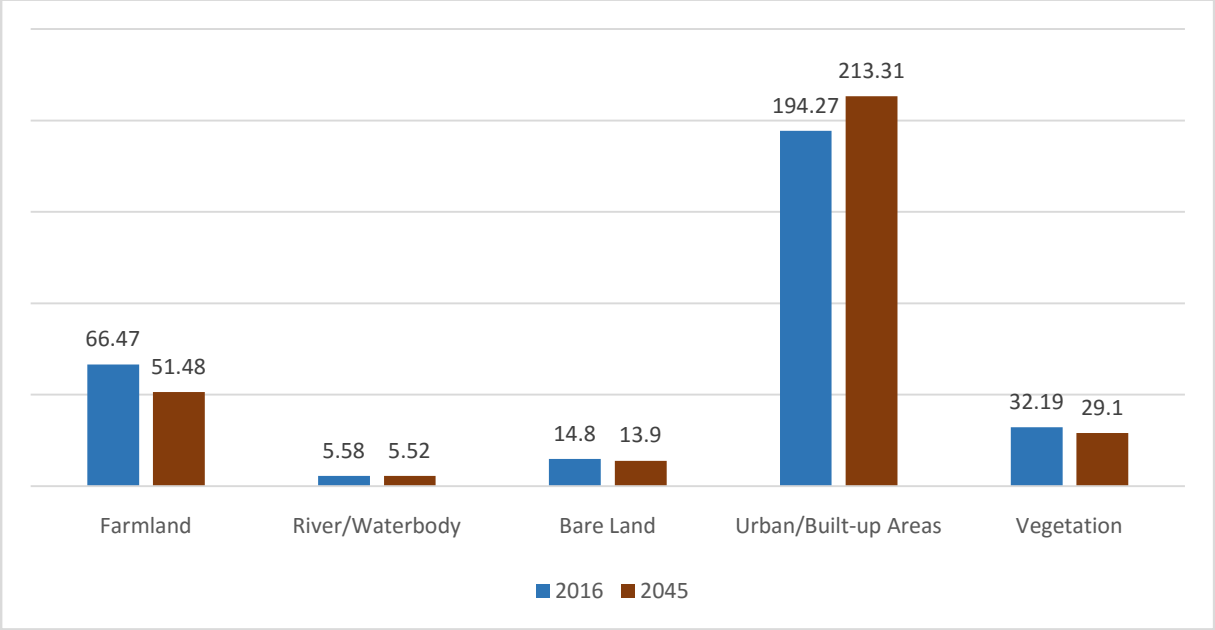


Figure 4.9:LULC 2045Projection for Kaduna Metropolis

Source: Researcher's Analysis, 2017

The result in Figure 4.9 shows that the urban built-up land increase from 194.27Km^2 in 2016 to 213.31Km^2 in 2045. The farmland reduced drastically from 66.47Km^2 to 51.48Km^2. Water body was observed to have least change occupying 5.58Km^2 in 2016 and was Projected to cover 5.52Km^2 in 2045. From the result obtained, it is clear that the built-upareas wereincreasing while the other land use/ land cover were decreasing. This means that all the land cover most especially the farmland will be decreasing due urban expansion and population growth. Figure 4.10 further depicts the 2045 projected map of the study area.

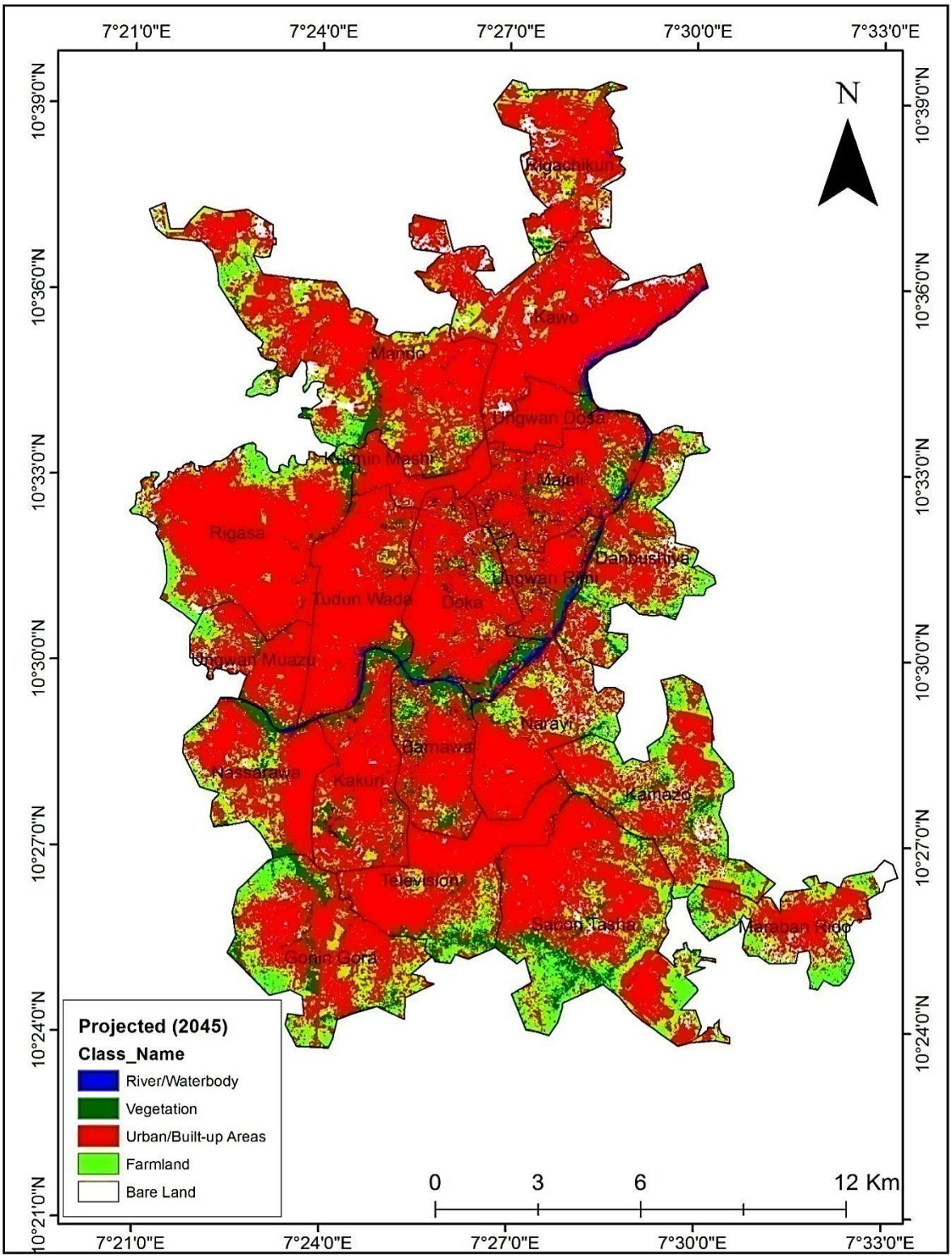


Figure 4.10: LULC 2045 Projection forKaduna Metropolis

Source: Researcher's Analysis, 2017

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the discussion of the major findings in relation with the background and literature review. The work views are also included arising from observation and interpretation of situations encountered during the study. The conclusions are given based on the findings and consequently recommendations were made based on the conclusions.

5.2 SUMMARY OF FINDINGS

This study is specificallyaimed atanalysingSpatio-Temporal process of urban expansion in Kaduna metropolis using the remotely sensed imageries and Geographic Information System (GIS). The study utilized the Landsat imageries of 1986, 2000 and 2016 to monitor the expansion of urban built-up land in the study area. The imageries were analysed using the supervised classification in Erdas Imagine version 9.2. The urban expansion was monitored by determining the extent and rate of the urban expansion, the pattern of urban expansion was determined using the Shannon's entropy and the projection was carried out using Cellular Automaton (CA) and Makov. The following are the summary of findings in the study:

1. Spatial extent of farmlands, vegetation, water bodies and bare land steadily decreased from 1986 to 2016
2. Spatial extent of built up areas steadily increased from 1986 to 2016
3. There was an inverse relationship between the spatial extent of farmlands, vegetation, water bodies and bare land with built up areas over the period of the study.The Transition Probability Matrix for 2045 indicated a more critical relationship; namely, built up areas in Kaduna metropolis will overshadow all LULC classes by more than 60 %

4. Rate of LULC change was found to be faster on built up areas than on the rest of the four categories of surfaces. However, the rate of change was found to have slowed down in 2000 but accelerated in 2016
5. Neighbourhoods in the southern portion of the study area have the highest relative entropy (0.0960) than the northern part (0.0331-0.0750).
6. The analysis shows that from 1986 and 2000, built-up land increased at the rate of $6.34km^2yr^{-1}$ ($8.15\%yr^{-1}$). The expansion of the city was found to reduce after 16years i.e. from 2000 and 2016 expanding at the rate of $1.73km^2yr^{-1}$ ($1.04\%yr^{-1}$).
7. The result shows that Kaduna metropolis has a relative entropy value of 0.1334 in 1986. The relative entropy increased to 0.1597 in 2000 indicating a difference of 0.0264 from 1986 to 2000 which means that the city has expanded by 19.84% within the period. In 2016, the relative entropy reduced to 0.1567 indicating a difference of -0.00030. For the entire period of study i.e. between 1986 and 2016, the difference in the relative entropy was found to increase by 14.95%.

5.3 CONCLUSION

Urban expansion is considered as the most influential driver of land use and land cover change associated with growth of population and economy. The integration of remote sensing (RS) and Geographical Information System (GIS) techniques in conjunction with Shannon entropy and Markov-CA acts as an effective tool for detecting urban growth and modelling. The present study aims to analyse Spatio-Temporal process of urban expansion in Kaduna metropolis from 1986 to 2016.The research has revealed that urban development in Kaduna metropolis is rapid, uneven and scattered. It can be concluded from the result obtained that further expansion of the city due to large numbers of driving factors such as population increase, economic growth and ineffective

implementation of land use planning will lead to possible considerable impacts on surrounding environment.

5.4 RECOMMENDATIONS

From the foregoing study conducted, in order to reduce problems that may result from urban expansion in Kaduna metropolis; the following are worth being considered:

1. Kaduna State Geographic Information System (KADGIS)should track future trends in urban spatial change within the study area for effective physical planning
2. Kaduna StateMinistries of Environment and Water Resources and the Survey Department should monitor and control the constriction of waterbodies and vegetation for a balanced ecology in the metropolis.
3. Residents within Kaduna metropolis should adoptbuilding of vertical structures so as to minimiselateral encroachment onto farmlands, green areas and surface waters of the study area
4. Kaduna StateGovernment should direct Kaduna State Ministry of budget and Planning establish social services and projects that will attract the movement of people from neighbourhoods with high relative entropies to areas of low entropy and beyond
5. Periodic Modelling of landuse and land cover changes be conducted for formulating effective environmental policies and management strategies by KADGIS and Kaduna State Urban Development Authority.
6. Relevant agencies, departments and ministries in Kaduna State should monitor and sustainably manage Kaduna land cover to minimise future land pressure that might probably set in as predicted from the 2045 projection.

5.5 CONTIBUTION TO KNOWLEDGE

The study has contributed to knowledge in the following areas:

1. It has established variations in the extent, rate and patterns of urban land space for 30 years in the study area
2. It has established the degree of variations of relative entropy among the 21 neighbourhoods in the metropolis, the most critical being in the southern part of the study area
3. It has established built up areas as the most critical class of land use likely to constrict other classes of LULC in the future
4. The 2045 projection has provided clues on the future extent and patterns of the LULC in the study area
5. It has added to the existing pool of knowledge on the subject matter

5.6 FOR FURTHER STUDIES

It is expected that researchers can employ the following areas for further studies

1. Extend the projections beyond 2045
2. Conduct a similar study in other municipal areas within specific regions and draw up comparisons
3. Repeat similar study in semi-urban settlements to track the relative entropies for future plans
4. Conduct similar study with different models to compare their efficacy in tracking patterns of rural changes or urban growths

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