THE USE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN LAND USE MANAGEMENT IN KARU, NASARAWA STATE, NIGERIA

BY

JONAH, KUNDA JOSHUA
M.Sc/SCIE/05624/2009/2010

A DISSERTATION SUBMITTED TO THE POSTGRADUATE SCHOOL,
AHMADU BELLO UNIVERSITY, ZARIA,
NIGERIA

IN PARTIAL FULFILLMENT FOR THE AWARD OF MASTERS IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

DEPARTMENT OF GEOGRAPHY,
AHMADU BELLO UNIVERSITY, ZARIA,
NIGERIA

APRIL, 2014

THE USE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN LAND USE MANAGEMENT IN KARU, NASARAWA STATE, NIGERIA

BY

JONAH KUNDA JOSHUA
M.Sc/SCIE/05624/2009/2010

A DISSERTATION SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

IN PARTIAL FULFILLMENT FOR THE AWARD OF MASTERS IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

DEPARTMENT OF GEOGRAPHY,
AHMADU BELLO UNIVERSITY, ZARIA,
NIGERIA

APRIL, 2014

DECLARATION

I declare that the work in the dissertation entitled "***The Use of Remote Sensing and Geographic Information System in Land Use Management in Karu, Nasarawa State, Nigeria***" has been performed by me in the Department of Geography under the supervision of Prof. EO Iguisi and Dr. DN Jeb. The information derived from the literature has been duly acknowledged in the text and list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

Jonah Kunda Joshua ---------- ----------

Signature ***Date***

CERTIFICATION

This thesis entitled "**THE USE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM IN LAND USE MANAGEMENT IN KARU, NASARAWA STATE, NIGERIA**" by Jonah Kunda Joshua meets the regulations governing the award of the degree of MASTERS of Remote Sensing and Geographic Information System, Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Prof. E.O. Iguisi	----------	----------
Chairman, Supervisory Committee	Signature	Date
	----------	----------
Dr. D.N. Jeb	Signature	Date
Member, Supervisory Committee		
Dr. I.M. Jaro	----------	----------
Head of Department	Signature	Date
Prof. A.A. Joshua	----------	----------
Dean, Postgraduate School	Signature	Date

DEDICATION

This project is dedicated to my parents Mr. A J Kunda and Mrs. S J Kunda for their remarkable interest in education.

ACKNOWLEDGEMENTS

I am grateful to God Almighty for his grace upon my life to have gotten the time, good health and strength to research.

I wish to use this medium to thank Prof. EO Iguisi of the Department of Geography, Ahmadu Bello University, Zaria and Dr. DN Jeb of the National Centre for Remote Sensing, Jos for supervising this research project. I am very grateful for the ideas, corrections, and materials they offered me during this study without which this project would not have been possible. May God Almighty continue to bless you. I also like to thank Dr. C Onosemuode of the Federal University of Petroleum Resources Effurun, Warri, Delta State for his contributions at the early stage of this research.

I am grateful to Mr. Simon Odaudu, Director, Labstaff Nigeria Limited, Abuja for his immense contributions to the success of this study. I am also grateful to Prof. SA Mashi, Prof. DU Sangari, Prof. ET Ologunorisa, Prof KO Ogunjobi, Dr. DN Marcus, and Mr. KS Ishaya for their contributions to the success of this study.

I wish to thank the Federal Ministry of Education, Federal Scholarship Board Abuja for their financial contributions to the success of my study by given me a Federal Government Scholarship Award. I am indebted to my brothers, sisters and friend for their prayers, advice, and understanding throughout the period of my study. I have among the five sisters four brothers library, Mr. Daniel B. Kunda, and Miss NC Anyanwu.

I am also grateful to my lecturers and M.Sc colleagues, Department of Geography, Ahmadu Bello University, Zaria for the role they played in making my academic a success. They include Dr. JA Ukoje, Dr. Miss B Akpu, Dr. JO Adefila, Dr. BA Sawa,

Mallam AA Jajere, Mr. D Inarigu, Mr. CM Mohammed, Mrs M Zubairu, Mallam A Zangina, Mr. Michael, Major A Ahmed, and Mr. M Ahmed. I also wish to thank my friends from the Department of Urban and Regional Planning, Ahmadu Bello University, Zaria; Mr. BD Gyuk and Mr. D Adamu for their useful criticisms and suggestions. I am equally grateful to Mr. A Isaac of the Federal University of Technology, Akure for his immense contributions. God bless you all.

TABLE OF CONTENTS

Title Page ..……i

Declaration……..... ii

Certification……..... iii

Dedication..... iv

Acknowledgement…….. v

Table of Content …….....vii

List of Tables …….....viii

List of Figures ……...……xiv

List of Plates …….……...xvi

Abstract .…….....xvii

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study …..……..…….....1
1.2 Statement of the Research Problem...…….....5
1.4 Aim and Objectives of the Study…….....8
1.5 Scope of the Study ….....9
1.6 Significance of the Study …….…… 9

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction….....10

2.2 Land.....…….....10

2.3 Factors Influencing Land Use Mgt.....…….....13

2.3.1 Availability of Information.....….....13

2.3.2 Land Use Management Framework..…….....15

2.4 Policy Framework for Land Use Mgt. in Nigeria .....….....16

2.4.1 Land Use Decree of 1978 .....….....16

2.4.2 Nigerian Town and Country Planning Law….....18

2.5 Instruments and Requirements for Efficient Land Use Mgt. System.....19

2.5.1 Land Use Regulation and Control ...…….....19

2.5.2 Land Value and Fiscal Control.....20

2.5.3 Direct Public Participation ...…….....21

2.5.4 Remote Sensing and GIS …….....23

2.5.4.1 The Component of GIS…….....25
2.5.4.2 Suitability Analysis.....….....28
2.5.4.3 MCDA and SDSS.....30
2.5.4.4 The Analytical Hierarchy Process…….……..... 33
2.6 Land Evaluation …….……..... 34
2.7 Land Use Planning …….……..... 36

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.1 Introduction.....41
3.2 The study area.....41
3.2.1 Location, Position and Size.....……..41
3.2.2 Population and Settlement…….45
3.2.3 Geology and Mineral Resources.....46
3.2.4 Topography ….....47
3.2.5 Climate...…….....48
3.2.5.1 Rainfall.……..... 49
3.2.5.2 Temperature.....50
3.2.5.3 Relative Humidity.....51
3.2.5.4 Wind Velocity.....51
3.2.5.5 Sunshine.....52
3.2.6 Hydrology.....…...52
3.2.7 Soils.....….. 53
3.2.7.1 Arenosols.....54
3.2.7.2 Lithosols.....55
3.2.7.3 Lixisols.....55
3.2.8 Vegetation..…….....56
3.3 Methodology…….....57
3.3.1 Reconnaissance Survey ……..... 57
3.3.2 Type and sources of Data required...…….....57
3.3.2.1 The primary source of data .....….....57
3.3.2.2 The secondary sources of data …….....58
3.3.3 Methods, Techniques and Procedures of data collection…...……...58
3.3.1 Scanning…….....58
3.3.4 Image processing.....….59
3.3.5 Digital Image Classification……..……..…….60
3.3.6 Groundtruthing.....……...61
3.3.7 Creation of land use suitability maps.....61
3.3.8 Suitability Scores .....….....61
3.3.9 Weighted Overlay.....….....62
3.3.10 Buffering Operation.....….....66
3.3.11 Overlay Operation .....….....66
3.3.12 Statistical Analysis.....67

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction 67
4.2 Land use and Land Cover of GKUA.....69
4.3 Land use Suitability Analysis.....81
4.3.1 Urban Development.....82
4.3.1.1 Land Suitability for Residential Use.....83
4.3.1.2 Land Suitability for Commercial Use.....87
4.3.2 Land Suitability for Agricultural Use... 90
4.4 Suitability and Preference Maps.....92
4.5 Encroachments into the Approved Setback Areas.....97

4.5.1 Abuja-Keffi High Way.....97
4.5.2 Local Distributors.....99
4.5.3 Access Roads / Streets.....100
4.5.4 Rivers, Streams, Lakes and Ponds 100

CHAPTER FIVE

SUMMARY, CONCLUSSION AND RECOMMMENDATIONS

5.1 Introduction.....103
5.2 Overview of the study.....103
5.3 Summary of major findings.....105
5.4 Recommendations.....106
References.....107

LIST OF TABLES

4.1: Land Use / Cover of GKUA for 1972, 1987, 1997 and 2012.....68

4.2: Magnitude and annual change rate of land use /cover (1972-1987) 71

4.3: Magnitude and annual change rate of land use /cover (1987-1997).....71

4.4: Magnitude and annual change rate of land use /cover (1997- 2012).....72

4.5: Weighted overlay table of lands economically suitable for residential use….....83

4.6: Weighted overlay table of lands physically suitable for residential use.....84

4.7: Weighted Overlay Table of Flood Potential Areas…….....84

4.8: Weighted Overlay Table of Lands Suitable For Residential Use….....84

4.9: Weighted overlay table of land physically suitable for commercial use.....87

4.10: Weighted overlay table of lands economically suitable for commercial use.....88

4.11: Weighted overlay table of lands physically suitable for agricultural use.....90

4.12: Road Hierarchy and Their Conditions …….....98

4.13: Class of Water Bodies and their Conditions…….....100

LIST OF FIGURES

2.1: Decision Flow Chart of Spatial Multicriteria Analysis..... ….....31
3.1: Nigeria Showing Nasarawa State.....42
3.2: Nasarawa State Showing Greater Karu Urban Area …….....43
3.3: Greater KaruUrban Area.....43
3.4: Geology of the study area.....47
3.5: Soils of the study area.....54
3.6: Research Design of Land-use Model of GKUA.....64
3.7: Geo-Processing Tools that were used in Model Builder.....65
4.1: Classified Land Use / Cover Map of GKUA 1972 73
4.2: Classified Land Use / Cover Map of GKUA 1987…….....74
4.3: Classified Land Use / Cover Map of GKUA 1997.....75
4.4: Land Use Map of GKUA 2012.....76
4.5: Trend in Land use / Cover Changes from 1972 to 2012 .....….....77
4.6: Flow Chart Showing the Flood Potential Areas …….....85
4.7: Flow Chart Showing the Creation of Objectives and Goals for Land Suitable for Residential Use.....86
4.8: Flowing Chart Showing the Creation of Objectives and Goals of Land Suitable for Commercial Use…….....89
4.9: Flowing Chart Showing the Creation of Objectives and Goals for Land Suitability for Agricultural Use….....91
4.10: Final Preference Map for Urban Land use …….....92
4.11: Final Preference Map for Commercial Land Use …….....93
4.12: Final Preference Map for Agriculture Land Use …….....94
4.13: Buffer Zone of Circulations and Water Bodies …….....101
4.14: Buffer Zone of Circulations and Water Bodies Overlaid on Land use / Cover of Greater Karu Urban Area.....…….....102

ABSTRACT

The purpose of this research is to apply Remote Sensing and GIS in land use management of Greater Karu Urban Area, Nasarawa State. Specific objectives are to; create land use/cover map of the study area from 1972 to 2012, determine the rate and magnitude of change, determine the suitability of the land for different uses and determine the extent of encroachment into the approved setback areas. Landsat MSS, TM, ETM and Spot-5 satellite imagery of 1972, 1987, 2000 and 2012 were used. A supervised classification approach using ILWIS 3.3 version was also used. Six categories of land use/cover types were generated as follow: built up areas, water bodies, agricultural land, vegetation, rock out crops and bare surfaces. Euclidean distance and weighted overlay from spatial analyst tool of ArcGIS 9.3 software was used for the suitability analysis using Multi-Criteria Decision Analysis and Analytical Hierarchical Process. The guidelines in line with Land Use Act Cap 202 of 1990 and the Nigeria Urban and Regional planning Act of 1990 to monitor and control all developments approved setbacks was adopted. Results from the analysis revealed the Increase in built up area resulted to changes in other land use/cover categories between 1972 and 2012 as follow: natural vegetation has drastically decline from 68.9% to 52.9% between 1972 and 1987. It further decline from 34.3% to 25.4% between 1997 and 2012. Agricultural land witnesses an increase from 8.7% to19.1% between 1972 and 1987. Thereafter, decreases from 25.9% to 15.2% between 1997 and 2012. Bare surfaces witness an increase from 7.8% to 9.1% between 1972 and 1987. Further decrease from 12.2% to 11.6% was observed between 1997 and 2012. Rock outcrops increases from 2.9% to 3.0% between 1972 and 1987. Further increase was experienced from 3.0% to 3.1% between 1997 and 2012 Water bodies covers 10.6% in 1972 and decrease to 6.1% 1987 before increasing to 7.7% in 1997 and subsequent decrease by 5.8% in 2012. The most dramatic increase experienced in built-up area is shown from 1990 to 2012, coinciding with the relocation of the FCT from Lagos to Abuja in 1991. This result to haphazard development and encroachment of built up areas into the approved setback of road network and water bodies are as follow: Highway; 2.5468 Sqkm, local distributors: 1.305 Sqkm, access roads/streets; 1.345 Sqkm rivers, 48Sqkm. It thus recommends the Nasarawa State Government and planners to use the final suitability maps for discussions and decision making in development of the area. At the absent of that, the final suitability map is recommended to guide development in the area.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Land is the foundation of all forms of human activity. From it humans obtain the food, shelter and the space to work and relax. Land is amongst man's most valuable resources. It is a means of life on which our continued existence and progress depends (Dale, Peter and John, 1988). Land is man's most valuable resource. It is the means of life without which he could never have existed and on which his continued and progress depend.

Land is a term with many meanings. To the physical geographer it is a landscape produced from natural processes, the product of geological and geomorphologic process. To the economist it is a resource which along with capital and labour is to be exploited in order to achieve economic production and development or conserved to guarantee future biodiversity. To the lawyer land is a volume of space stretching notionally from the centre of the earth to the infinite in the sky, and associated with it are a variety of rights which determine what may be done with it. To many it is simply the space for human activities as reflected in the many different forms of land use.

FAO (1976) defined land as a delineable area of the earth's terrestrial surface, involving all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil, the terrain forms, the surface hydrology (including shallow lakes, rivers, marshes, and swamps) and associated ground water and geo-hydrological reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity. Land comprises the physical environment of the earth's

surface from soils, topography and underlying geology, hydrology, plant and animal population and vegetation, with their influence on potential land use (Harcombe, 2010).

Land is required for various uses in both the urban and rural areas. It is a major factor of production and a vital element in the socio-economic development of any country (Dent and Young, 1981). Studies have emphasized that the quality of land is an important factor for various land uses, thus as nations grow in size and rural areas become urban centers and urban centers become large metropolitan areas, there is always increase in competition and demand of land for different purposes. This requires adequate management to ensure harmonious development and functional efficiency of these uses (Sodeinde, 2002).

Human use of land has been proved to alter the structure and functioning of the ecosystem. The most spatially and economically important human use of land globally include cultivation, construction, reserves, protected lands and timber extraction. Recently settlements are becoming large active land use changes especially in the developing regions of the world. This calls for effective land use management (Amos, 1986).

The need for thoughtful and careful stewardship of the land, together with the more intensive use and management of its resources has emerged as a matter of major global concern due to the rapid growth of population that have caused increasing pressure on land, while simultaneously a massive migration of people to cities and towns has led to the uncontrolled growth of urban centers *(Dele et al., 1988).* Land use management as discussed widely by Mabogunje (1992); Durand-Lasserve (1990) and Kombe (1995) is conceived as processes involving different stakeholders in planning, facilitation and controlling land use and subsequent activities in view of sustainable development.

Land use management entails decision making and the implementation of decisions about land. Land use management involves making fundamental policy decisions about the nature and extent of investment. The scope of land use management involves private and public sectors who develop and make use of land; law which sets out rules and procedures in the management system; agencies which make decisions on how land may be used at various levels of government; plans which inform decisions on how land may be used (Nags and Kudrat, 1998).

The content of land use management can be described in terms of three value sets (ecological, social and market values) that must be brought into balance by land planning (Sui, 1992). The analysis of land characteristics in identification of land suitable for development can play an essential part in the planning process. Among the many concerns of urban planners in guiding the spatial arrangement of activities is the optimum utilization of land for the benefit of society (Shuaib, 2005). This involves making choices between available alternatives and as such it requires a procedure for the analysis of available alternatives. Alternatives for development usually start though not necessarily with consideration for buildable land. "i.e. land on which if developments are installed would not have detrimental or adverse effects on the environment". The process of identifying such land is the assessment of the fitness of tracks of land for development. Land suitability analysis requires integration of several data sets to model land use requirements and the characteristics of the land for the alternatives (Shuaib, 2005).

Almost all African countries have a history of land use management processes dating back to their respective periods of colonial rule. However, formal land use management in Nigeria began in 1863 with the enactment of the Town Improvement Ordinance by the Colonial Government. The ordinance was meant to control development and urban sanitation in Lagos,

then the Federal Capital of Nigeria. However, modern land use management could be said to begin in the country in 1946 when the Nigerian Town and Country Ordinance was enacted (Mabogunje, 1992). The general inefficiency associated with majority of the developing countries land policies, the absence of secure tenure, and inadequate land use management capacity have been cited by Bernstein (1994), Hardoy and Satterthwaite (2001) as serious problems precipitating existing land use crises in Nigeria. In recent times, the often-destructive impact of human activity on the land has led to the global need for more careful management of land use and natural resources at sustainable level.

A number of policies that impinge on urban land use management has been articulated and implemented in Nigeria. These include the Land use Act of 1978, Urban Development Policy of 1992, Urban and Regional Planning Act as well as the Housing and Urban Development Policy of 2002. Similarly, land use planning and control measures have been introduced to improve urban land use planning and urban development (Aribigbola, 2008). Despite the existence of these laws and policies, land use management problems still persist in Karu area of Nasarawa State. Consequently, there is the need for a better understanding of the problems and also to articulate how to improve the existing ineffective land use management methods in the area. In evaluation of land use management, suitability plays a fundamental role in regional land-use planning. Its major objective is to evaluate the advantages and disadvantages of development in certain areas, so as to find out places which are most suitable for certain land use development in the future. In the field of suitability assessment for land use management, Geographic Information System, Remote Sensing and numerical modeling techniques have been proved to be efficient tools by recent studies *(Ahmed et al., 2000).*

GIS is an important tool in land use management. The demands of the different stakeholders is analyzed, visualized and presented to support decision-making. One of the most commonly used methods for land-use decision making is spatial Multi Criteria Decision Analysis (MCDA). This method combines all the spatial factors that are important and results in a map with the best location for a certain type of land-use. Most often with MCDA, the goal is to find the most suitable location for residential, commercial, agricultural and industrial use. In addition, existing Spatial Decision Support Systems (SDSS) which are decision making tools that make use of spatial MCDA often concentrate on a specific type of land-use, for example urban development. When applying land-use suitability on an area, it should contain not only urban development, but also agricultural land-uses. It is against this background that this research is formulated to use remote sensing and GIS that integrates land-use suitability, covering all relevant land-use categories (urban and agriculture) in land use management of Greater Karu Urban Area, Nasarawa State, Nigeria.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Greater Karu Urban Area of Nasarawa State is a principal satellite town of the Federal Capital Territory, Abuja that has no Development Master Plan since the creation of the State in 1996 (Yari, Hadziga and Ma-aruf, 2002). Lack of affordable accommodation for low and middle income workers of Abuja, the proximity of these settlements to Abuja and the low land prices have attracted many workers from Abuja and other migrants to settle there. As a result, the area has experienced rapid population growth and continuous expansion after the relocation of the Federal Capital Territory (FCT) from Lagos to Abuja in 1991. The upsurge in population of such towns was further encouraged by the desire of the FCT administration to restore Abuja to its master plan by the demolition of all forms of illegal structures within its territory. The implementation of these decisions has led to rapid population movements, massive construction

work, wide spread commercialization of local economy and rapid urbanization. This has imposed significant pressure on the environment and natural resources with serious implications on socio-economic development and spatial organization within the territory and beyond its boundaries. In addition, the spatial expansion of the settlements in the area has been going on without significant control. Thus urban sprawling is on the increase.

The Food and Agricultural Organization (1995) maintains that sustainable land use management is of key importance in the development of a country. FAO indicates that an integrated physical and land-use planning and management are eminently practical ways to move towards more effective and efficient use of the land and its natural resources. Such integration should take place at two levels, considering on one hand all environmental and socio-economic factors and on the other all environmental and resources components together. Thus, there is the need for a GIS technology for sustainable land use management in Greater Karu Urban Area particularly in a situation where the current conventional methods of planning are unable to cope with the rapid rate of development and growth of the area. There is therefore the need for more robust, accurate and timely procedure for planning. Hence, this study seeks to apply remote sensing and GIS in land-use management in Greater Karu Urban Area.

Many studies were conducted in this area; Yari *et al.* (2005) in their study on governance and management institution in Karu, Nasarawa State, Nigeria showed that the institutions charged with the responsibility of managing the sustainable development of Karu are ill equipped to carry out their duties. There are no up to date base maps, adequate information storage and retrieval systems and equipments for efficient operation. Adamu (2012) carried out a research on urban management implication on informal land delivery in Karu area and revealed that, formal channels of land allocation cannot meet the current demand; as a result there is an active

informal land market in the area. Many people who bought large tracks of land subdivide them into plots and sell. There are large numbers of land brokers, surveyors and town planners who earn a living through sales of land sell in the area.

Ezekiel (2010) made a comprehensive research on the effect of the federal capital territory development on rural transformation in Karu, Nasarawa State. The study showed that the provision of urban services has proved to be very elusive because of the rapid rate of population growth, poor management capacity and dwelling resources available to the governments. The situation reflects a failure to adequate respond to the need of fast growing settlements in the provision of key urban services.

However, there is still a lack of integrated land use planning for this area, leading to many socio-economic and environmental consequences such as poor living environment and haphazard development among others. Integrated land use planning if successfully implemented will bring improvement to the environment, promote the sustainability of the environment, improvement of the socioeconomic value of the environment, wealth creation and distribution opportunity will be ensured through the various design concepts that will be employed in the plan making. The focus of this study is therefore to apply remote sensing and GIS in land-use management of Greater Karu Urban Area of Nasarawa State, Nigeria. How then can GIS be used to create land use/cover maps of the study area? How can levels of suitability that characterize each parcel of land be generated?, How effective is the use of GIS in land use management? Hence, the need for this study

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to apply Remote Sensing and Geographic Information System in Land-use management of Greater Karu Urban Area. To achieve this aim, the specific objectives are to;

(i) Create land use/cover maps of the study area for 1972, 1987, 1990 and 2012.

(ii) Determine the rate and magnitude of the land use/cover changes.

(iii) Determine the suitability of the land for different land uses.

(iv) Determine the extent of encroachment of buildings into the approved setbacks areas.

1.4 SCOPE OF THE STUDY

This work seeks to demonstrate the usefulness of remote sensing and GIS in land-use management of Greater Karu Urban Area from 1972 to 2012. The study covers such major settlements in the area as Mararaba, Masaka, Ado, New Nyanya and New Karu. The variables considered in the study include; soils, topography (slope), water bodies and proximity of buildings to drainage, schools, markets, bore holes and road networks which were used to generate the suitability map of the study area.

1.5 SIGNIFICANCE OF THE STUDY

The study presents a role playing approach to Remote Sensing GIS in land-use management of Greater Karu Urban Area, aimed at improving planning of the area and identifying areas of land use conflict. The study uses remotely sensed data and GIS technique to determine suitable areas for future land use in order to provide a better reference for future development of the area. The created suitability and preference maps provide a firm mean for discussions and decision making. The suitability maps based on the sub-objectives, objectives, and goals provide insight in detailed themes on the suitable areas for residential, commercial and agricultural

development. Finally, the buffered maps show the areas of road and water bodies encroached by residential and commercial land use.

CHAPTER TWO
LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, factors influencing the effectiveness of land use management, Policy framework for land use management in Nigeria, Instruments and requirements for efficient land use management system, remote sensing and geographic information system were examined. Others include Component of GIS, Suitability analysis, Multi-criteria decision analysis system, land evaluation and land use planning.

2.2 LAND

Dale and McLaughlin (2003) describe three attributes of land that every country must manage as tenure, value, and use. Tenure refers to ownership rights: who has them and what are they. The value of the land, a country's most fundamental and irreducible resource is important for taxation and the land market (if any). How the land is used by those who possess ownership rights is important to optimize land productivity for economic growth and equitable distribution of wealth. Governments must develop national land policies that address these three attributes of land for optimum benefit of its citizens.

Irrespective of the various attributes of land, it is imperative that policies be directed towards land to provide the avenue for streamlining and aligning all the countervailing forces affecting its disbursement and management. From the planning perspective, land represents a mosaic that ought to be regulated to ensure conformity and balance of the built environment (Bailey 1975; Raticliffe 1976). However, the general inefficiency associated with majority of the developing countries land policies, and the absence of secure tenure, adequate land use management

capacity, among others have been cited by Bernstein (1994) and Satterthwaite (1989) as serious problems precipitating existing land crises in these countries.

Skidmore (1997) is of the view that land has certain characteristic which influences its supply and demand. The quantity of available land is fixed. The supply of land can only be increased by converting fringe land to urban uses. Land location is also specific. Increase in demand means a competition for land in the most suitable and accessible location. The result is price increases. Natural constraints such as mountains, gullies, and rivers all contribute in limiting the supply of available land for use. The ability of most countries to also convert rural land to urban uses and to effectively manage the existing stock of land is severely limited.

Ratcliff (1976) is of the view that the allocation, use and management of land should be done to guarantee access and equity, which the Land Use Act of 1978 aimed to achieve in Nigeria. In particular, population increase arising from uncontrolled natural births and rural-urban migration, and a growing commercial sense have combined to re-orientates the traditional communal land holding status of the Nigerian lands. In the same token Ola (1984) stressed that land use problems in urban areas of developing countries arise because of several factors. The first is the rapid increase in urban population. Between 1950 and 1980 for instance, urban population in third world countries increase from 267 million to 972 million. It is expected to reach 1971 million by the end of this century. The highest rate of increase occurs in the largest cities such as Lagos, Mexico city, Delhi, Bombay, Kuala Lumpur etc. The increase in population means an increase in demand for land for productive activities, and a competitive demand for land between agriculture, needed to feed the extra population, and for other productive uses (Harcombe, 2010).

Again, Armstrong (1987) stated that the urban population in Africa is growing faster than any other continent. It is predicted that by 2030 about 5 billion people, approximately the population size of the entire continent today will be in urban areas and that these figures will be in the less developed regions (Armstrong, 1987). The driving forces behind the rapid urbanization in Africa today are the combination of rural-urban migration and natural increase within the towns and cities themselves.

Despite the provisions of the land use decree, Aribigbola (2008) observed that the poor have been mostly denied access to legal land through the formal process; they have been forced in most countries to adopt extra-legal means of acquiring building land; i.e. through squatting, illegal subdivision, and slum creation resulting in insufficient use of land. In Lagos, Abuja, Cairo, Bangkok, Bombay, and Delhi, more than a million people live in illegally developed settlements. The pressures on land orchestrated by increase in rate of urbanization brought with it intractable urban problems, such as poor environmental sanitation, pollution, crime, unemployment and overcrowding among others.

While the trend is lateral growth, the pattern and direction of sprawl developments in many cities in Nigeria are limited by physical barrier such as lagoon, rocky outcrops and other natural features. The population increase naturally creates adjustment and readjustment of human and land use activities within urban systems thus causing lateral and structural changes. Lateral changes occur when the city expands in geographic boundaries leading to sprawl and peripheral developments while structural growth relates to increase in land use density within urban centers. The low density areas gradually become subjected to intensive use and thus become high density or medium density use (Mabogunje, 1992).

2.3 FACTORS INFLUENCING LAND USE MANAGEMENT.

In this section, factors influencing the effectiveness of land use management are presented. These include availability of information, land use management framework, appropriateness of policy measures, coordination of policy measures and allocation of adequate resources and administrative system.

2.3.1 Availability of Information

The availability of adequate information on land is a necessary prerequisite for the effective implementation of land use management system and land policy measures. As Adeniyi (1999) points out, even the most unsophisticated and rudimentary effort to establish positive control requires information. At the very minimum, it is necessary to have records of existing land use, development density, and ownership, along with accurate information on soil characteristics, the location and capacity of existing utilities and services. For planning purposes, information on economic and social characteristics of the population and its activities are essential. The availability of adequate information determines the ability to control and regulate the use of land, and the ability to develop an effective taxation system. It also affects the ability to acquire land for public uses. The lack of information on land is one of the major problem hindering effective land use management and development control, and the creation of an effective taxation system in most developing countries (Masser and Campbell, 1995).

Earth observation from space through various satellite remote sensing allows retrospective and synoptic viewing of large areas and thus can provide the potentials for geographical and temporal detailed assessment of regional development and resultant land use/land cover (Adeniyi, 1999). Besides the well known advantages of digital image analysis such as cost effectiveness, repetitive coverage, independence of data, expediency in retrieving spectral

information, digital image analysis provides a sound basis for enhancing framework for spatial sampling there by reducing considerable effort during field work.

Adeniyi (1999) observed that information on land use can now be more easily and reliably obtained from remotely sensed imagery. The continuous process of change and development in the urban environment has assumed such dimensions that efficient and effective methods of collecting, analyzing and storing reliable spatial data on the physical, social and economic features are indispensable for dealing with the manifold and complex problems of land use management. The most commonly used approach to qualify land use changes has been the acquisition of aerial photographs, visual interpretation and the comparison with existing photographs and land use map data (Onosemuode, 2004).

Adeniyi (1999) used aerial photographs and other remote sensing to explain and map the spatial relationship between different land uses in urban areas. Generally remote sensing image do not record activity or the way land is being used directly but acquires response based on characteristics of land surface. Onosemuode (2004) states that satellite remote sensing is effective in providing multi-temporal and multispectral data along with the required information for understanding and monitoring land development patterns and processes for building land use and land cover datasets.

2.3.2 Land Use Management Framework

According to Baba (1994) land use management framework is the most important factor in the successful formulation and implementation of land policies. Land is usually administered by a group of government departments, ministries, autonomous or semi autonomous government agencies, with each overseeing a specific aspect of land management. Some common aspects

overseen by the agencies include the distribution of land rights, the regulation and monitoring of market processes, public lands, development planning and control, technical standards, and fiscal matters.

The adequacy and effectiveness of a land use management system affects the ability to implement all aspects of an urban land policy, and the achievement of the desired policy objectives. It affects the ability to plan and regulate the use of land, the ability to enforce regulations, and the ability of the public sector to successfully participate directly in the land management system. The effectiveness of a land use management system is a reflection of the collective effectiveness of the individual institutions overseeing the different aspects of land management (Berstein, 1994).

Among the factors that improve the effectiveness of land management institutions are: the availability of definite and unified policy guidance; the clear definition of institutional responsibilities; the degree of coordination between the different institutions; the capacity of the institutions in terms of manpower, resources, and equipments; the availability of adequate information on land; and the level of decentralization in decision making (Berstein, 1994).

Ratcliff (1976) has identified some specific problems faced by land use management institutions in most developing countries. The problems include: a general lack of policy guidance; over centralization of decision making; inadequate planning and programming capability; inadequate data sources; manpower problems; insufficient resources; intra agency conflicts; and political interference in land management.

2.4 POLICY FRAMEWORK FOR LAND USE MANAGEMENT IN NIGERIA

The framework for urban land use management is established by two laws: the Land Use Decree of 1978, and the Town and Country Planning Law of 1946. The objective of Land Use Decree's is the protection of the right of all Nigerians to use and enjoy land, while the objectives of the Town and Country Planning law is to control the development and use of land in planning areas, and to preserve buildings or other objects of architectural, historic or artistic interest.

2.4.1 1978 Land Use Decree

The Land Use Decree is closely modeled after the 1916 Land and Native right ordinance of Northern Nigeria. The decree vests all land within the territory of each state in the governor of the state. It also vests the control and management of land in the urban areas in the governor. The control and management of land in the rural areas was vested in the local government councils within the area of jurisdiction in which the land is situated. The decree provides for the establishment of a land use allocation committee, which is to advise the governor on any matters connected with the management of land, including the resettlement of persons affected by revocations of rights of occupancy and disputes concerning compensation for land (Mabogunje, 1992).

There was also a provision in the decree for the setting up of a land allocation advisory committee to advise local governments on similar matters in connection with rural land. Other powers conferred on the governor by the decree include the right to designate urban areas, to grant statutory rights of occupancy to any person for all purposes (not exceeding half a hectare to individuals), to demand rent for land granted to any person, to revise such rents from time to time, and to impose penal rent for the breach of any covenant in a certificate of occupancy. Local governments are also authorized to grant land for agricultural, residential and other

purposes on a customary basis. The decree empowers the governor to acquire land for overriding public interests, with the injunction that compensation be paid to those whose rights and interest in land are disturbed by such measures. The decree, in similar fashion with the Land and Native rights ordinance also declares the alienation of land by assignment, mortgage, and transfer of possession, sublease, or in any other form illegal without the consent of the governor (Mabogunje, 1992).

2.4.2 Town and Country Planning Law

The Town and Country Planning Law, first enacted in 1946 are closely modeled after the English Town and Country Planning Act of 1932 (FMH&UD, 2003). It has since its enactment been the object of several minor modifications, the last being by Edict Number 7 of 1972. The principle of land use regulation in the legislation is based on the designation of a planning area, and the preparation and approval of a planning scheme according to specified procedures. Before the coming into effect of a planning scheme, the law empowers the governor to enact a general or specific interim development order to guide development in a designated planning area. The law specifies that no development may take place in a planning area except according to an approved scheme, or interim development permission.

To oversee the planning and regulation of land use in the planning areas, the Town and Country Planning Law provides for the establishment of planning authorities for one or more of the planning areas. The planning authorities are empowered to purchase land in designated planning areas either compulsorily or by agreement, to charge betterment levies (of up to 75 percent of the increase in land value) on landowners as a result of increase in land value resulting from the action of the authorities, and to levy planning rates in either part or all of a planning area. The authorities are also empowered to provide housing to low-income groups who are displaced in

the execution of any scheme under the provision of the legislation. The 1972 amendment to the legislation gives the authorities power to require any person to remove or pull down any building or work in any planning area, which has not been executed according to an approved scheme or interim development permission. Where there is a failure to comply, the planning authorities are empowered to execute the removals and to recover the cost of doing it (Jiboye, 2005).

2.5 INSTRUMENTS FOR EFFICIENT LAND USE MANAGEMENT SYSTEMS.

The wide variety of factors influencing the formulation of land policies and the establishment of a land use management system makes it impossible to develop a prescription or have a perfect recipe for an effective land use management system. There appears, however, to be a consensus in the literature on land on the instruments and requirements for an effective and efficient system. These instruments and requirements are generally used to achieve broad objectives of land policies. Mabogunje (1992) and Kombe *et al.* (2000) have however, identified some of the objectives generally put forward for the creation of an effective system. The objectives include: the provision of an adequate supply of land for urban productive activities, including the provision of basic services; the facilitation of good planning that minimizes the use of resources relative to social and economic benefit; the achievement of greater equity in wealth and income, including access by low income families to land and shelter; and a spatial distribution of population and activities at regional and national levels consistent with general national priorities.

2.5.1 Land Use Regulation and Control

Land use regulation and control are used to restrict the rights of private land holders in the use of land. The regulations are used to protect public interest in the use of private land. The

regulations stem from the need to provide public amenities, to increase the efficiency of land use, to limit urban sprawl and unnecessary encroachment on agricultural land, and to achieve economies of scale and least-cost production of public services (Owei, 2010).

The regulations are also used to ensure the availability of land to all groups, and to ensure that the benefits of development go to the community as a whole. There are numerous ways through which land use is controlled and regulated. Land use planning is used in the allocation of space for different purposes in a local, regional, or national setting. Zoning regulations are used to specify permitted land uses, and to define norms (such as bulk, height, shape, etc.) for the different land use categories. Subdivision regulations are used to govern the parceling of land for development. The regulations "prescribe standards for lot sizes and lay-out street improvements, procedures for dedicating private land for public purposes, and other requirements in far more detail than in the zoning plan" (Kombe, 2000). Building regulations are used to limit or define the way structures may be built or altered. They specify standards relating to materials of construction, and the assembly of buildings. The land use regulations are enforced through the use of permits and approvals by public agencies and institutions.

2.5.2 Land Value and Fiscal Control

Fiscal control measures provide another means for controlling the use of land. Such measures are also used to control the value of land, to recoup the cost of pubic investment in land development, and to recapture unearned increments resulting from increases in land value. A principal objective of land policy is to ensure that land is transferred at a just and fair value affordable to all income groups. The value of land is determined by the value of goods and services that can be produced on it. This value as Beek (1987) observes is not determined by the present use of land but by the potential use that could generate the highest value. Both the

potential use and the highest value of land are determined by two major factors: first is the level of demand for it, which is mostly a product of changes in urban population and the location characteristic of land, and secondly by public actions such as the provision of services and infrastructure or changes in the intensity of land use, which influences the economic, social, and cultural value of the land. The relationship of land values to planning policy stems from the fact that the actions that produce the highest land values are incidental and therefore unearned by land owners.

The Habitat Conference recommends that the unearned increments resulting from the rise in land value resulting from change in use of land, from public investment or decision or due to the general growth of the community must be subject to appropriate recapture by public bodies (the community), unless the situation calls for other additional measures such as new patterns of ownership, the general acquisition of land by public bodies (Afolabi, 1975). Apart from unearned increments, other tax measures can also be used to penalize the use of land for speculation, thereby influencing its supply and controlling its value. Tax measures can also be used to control the use of land by using taxes as incentives for a desired course of land use action, and as a penalty for undesired courses of action. Some of the common taxes applied include site value taxation, vacant land taxation, capital gains taxation, betterment levies, and the sale of development rights.

2.5.3 Direct Public Participation

The public sector can improve the equity and efficiency in the allocation and use of land by participating directly in the land use management. Direct public participation is also essential to ensure the availability of land for the provision of public services. Direct participation may be in the form of the provision of basic services. Government usually provides such services as roads,

sewers and water lines, and treatment facilities. Some governments go farther in providing secondary services such as health centers, hospitals, and community facilities (Mabogunje, 1992).

The provision of these services can be used to make the areas more accessible and attractive for development. This enables control over the pattern of land development. Government may also participate directly in the market through both the assembly and servicing of land, and in its supply for development. The assembly of land can be for a specific purpose or, as in land banking, to acquire land in areas of urban expansion so as to maintain effective control over developments. The participation of public bodies in land assembly and development is viewed as essential, in order to ensure equitable access to land and effective control over development (FAO, 1993).

The acquisition of land for public land development programmes can be done either through participation in the private land market, or by the use of compulsory powers of acquisition. In some countries such as France and Sweden, legislation exists which compels land owners to notify the government of any intention to sell private land. The government then has the option of purchasing it. Another means of direct participation by the public sector in the land market is through mixed public and private development programmes. Land pooling and land readjustments are examples of such participation. In land pooling, "a public authority acquires an area with many plots and many owners, consolidates and develops the holding and eventually reallocates the land in demarcated and serviced plots to its former owners in proportion to their original holdings" (Beek, 1997).

2.5.4 Remote Sensing and Geographic Information System

Masser and Campbell (1995) focus on the shift in land use management style in terms of spatial information requirements and potentials use. They are of the view that manual method of land use planning is time consuming there by gradually been replaced by more flexible and strategic approaches that emphasize on hardware, software, data, numerical modeling techniques and organizational procedures. Hence, relies on computer systems and participatory methods for building consensus on development strategies and actions. Spatial information therefore comes in with the central planning practice to achieve the decision process system in land use management.

In the study of Worrall (1990) it was found out that 80% of information handled by land managers and planners was spatially related. However, data accessibility pose problems as most database management systems especially in developing countries are manually operated. Data process management problems normally lead to poor decision making process. Keech (1979) stated that; the tools for land use management and planning that have been used to facilitate land management have evolved over time, and they included a number of techniques and technological considerations to enhance the practice. Among earlier ones were the aerial photography, maps, and computers. More recent ones include remote sensing, Geographic Information System (GIS) and numerical modeling techniques.

Aerial photography was in the last century used to address the need for accurate and objective survey information as a basis for land use management in various countries of the world. It provides a valuable tool to record information which is directly observable, and it may be used in conjunction with ground work to obtain information that can only be inferred from evidence which can be seen directly. Land use maps can be readily prepared from aerial photography (Keech, 1979). Chulvick and Waugh (1979) stated that; a computer is yet another tool that is used and it is essentially an electronic devise which receives input, processes it and generates

output. There are many current developments which are of interest to land use planners, and these include remote sensing procedures to encompass aerial photography at large and medium scales, and satellite imagery at small scales. The sophistication of these new procedures allows new detailed and almost continuous analysis of land use patterns, with the effects that new developments can be easily recognized.

Spatial multi criteria decision problems typically involve a set of geographically-defined alternatives (events) from which a choice of one or more alternatives is made with respect to a given set of evaluation criteria (Jankowski, 1995; Malczewski and Ogryczak, 1996). Spatial multi-criteria analysis is vastly different from conventional multi-criteria decision making techniques due to inclusion of an explicit geographic component. In contrast to conventional multi-criteria decision making analysis, spatial multi-criteria analysis requires information on criterion values and the geographical locations of alternatives in addition to the decision makers' preferences with respect to a set of evaluation criteria. This means analysis results depend not only on the geographical distribution of attributes, but also on the value judgments involved in the decision making process. Therefore, two considerations are of paramount importance for spatial multi-criteria decision analysis:

(1) The GIS component (e.g. data acquisition, storage, retrieval manipulation, and analysis capability); and

(2) The Multi-criteria decision making analysis component (e.g. aggregation of spatial data and decision makers preferences into discrete decision alternatives) (Carver, 1991; Jankowski, 1996).

For the last three decades, GIS techniques have been used in solving land suitability problems. According to Jankowski (1996) although GIS is often described as a decision support system, there have been some disputes regarding whether the GIS decision support capabilities are sufficient since current GIS do not provide decision-making modules that reason a decision and are primarily based on manual techniques and human judgments for problem solving, the individual should have the decision rules in place before GIS can be utilized. Other limitations in current GIS approaches include the incapable of processing multiple criteria and conflicting objectives (Carver, 1991). They are also limited in integrating geographical information with subjective values/priorities imposed by the decision maker (Malczewski, 1999).

2.5.4.1 The Component of GIS in Land Use Management

GIS technology when applied in land use management context becomes useful as planning tools in urban planning and development control. The demands of the different land managers should be analyzed, visualized and presented to support decision-making (Arnoff, 1995). The use of GIS infrastructure in urban land use management has been perceived as a viable strategy to decision making in land regularization process for sustainable development of informal settlements in developing countries (George, 2003). GIS in this context refers to a process of using combination of tools (computers hardware and software), data (spatial and non-spatial) and people/users (i.e decision makers, managers, technicians, operators and public) in land use management and urban planning (Kombe, 1995).

GIS is the tool for input, storage and retrieval, manipulation and analysis, and output of spatial data. GIS functionality can play a major role in spatial decision-making. Geographical Information system incorporate database systems for spatial data were designed and developed enabling the acquisition, compilations analyzing and displaying topological interrelations of

different spatial information. Moreover the surface and overlay analysis capabilities of GIS can effectively facilitate in handling vast amount of spatial information .In this respect, geographical information system provide a tool in integrating and analyzing of land resources to determine the suitability for a land use (Jankowski, 1995).

Land analysis is commonly done with map overlay and it used to be done manually. McHarg (1969) describes how using manual map overlaying can do systematic land use planning. As the use of computer technology has grown, the more efficient digital form has progressively replaced manual map preparation. This technology has developed so rapidly over the past two decades and it is now accepted as an essential tool for effective use in geographic information system to support complex decision-making. With the rapid advancement taking place in computer hardware and GIS software, more complex models are being developed. These models help researchers and planners to simplify complex systems and to develop theory to understand the process at work better (Marble, Calkins and Pequet, 1984).

The idea of a GIS based information system is a relatively new phenomenon in land use management and urban planning fields. According to Chulvick and Waugh (1979), the growth of GIS based land use management of the developing world was driven by population growth and urbanization, while in the developed world technology edge was the main factor. Decision makers see GIS as an opportunity to improve the economic development process of industrialization and compete in the global market place. Masser and Campbell (1995) talk on the dynamic nature of planning and management work carried out by GIS which has caused land managers and planners major users of GIS based information system both in developed and developing countries. These organizations use large data sets which are geographical in nature to support their decision process.

Goodchild *et al.* (1996) cites that one of the main limited factors for GIS progress in Land use management and urban planning applications is that until recently, urban planning modeling programmes and statistical analysis functions used to stay separate from the spatial analysis components and communicated with each other via import-export functions. GIS have the ability to perform numerous tasks utilizing both spatial and attribute data stored in it. It has the ability to integrate variety of geographic technologies like GPS, Remote Sensing, etc. The ultimate aim of GIS is to provide support for spatial decisions making process. In multi-criteria evaluation many data layers are to be handled in order to arrive at the suitability which can be achieved conveniently using GIS (Foote and Lynch, 1996).

Mabugunje (1992) discussed the linkage of GIS infrastructure with land regularization process for effective land use management in informal settlement. This is important potential for understanding ways of improving policy formulation and practical gap for country development. The study is also important as it exposes to human dimension challenges on need for effective decision making in participatory planning approaches. It also depicts the growing critique of the indispensable role of grassroots institutions in urban land management, in a situation where public resources capacities are declining and inadequate for meeting problems arising from rapid urbanizing settlements.

Considerable effort is involved in information collection for the suitability analysis for Land use. This information should present both opportunities and constraints for the decision maker. Remote sensing provides the information about the various spatial criteria/factors under consideration. Remote sensing can provide information about land use/cover, drainage density, topography etc. Many of the non-spatial parameters can also be inferred by looking at the various spatial parameters. Remote sensing in combination with GIS is a powerful tool to

integrate and interpret real word situation in most realistic and transparent way. Leingsakul *et al* (1993) stress that integrated GIS and Remote Sensing technology apart from saving time and yielding good data quality have the ability to locate potential new land use sites.

2.5.4.2 Suitability Analysis

According to Miller (1993) and McHarg (1996), Charles Eliot and his associates were one of the first to use overlay maps for land-use suitability analysis, which was during the late nineteenth and early twentieth centuries. They used sun prints, the overlay of transparent sheets on a window to view site characteristics. At a later stage halfway the twentieth century, new methods were applied. Tyrwhitt (1950) published an article about town and country planning, gave an example of a new overlay technique. Four maps were drawn on transparent paper about soil, relief, hydrology and rock types, all at the same scale and referenced to common control features. Sieve mapping was used, where areas with constraints were eliminated and the remaining areas were defined as suitable (Steinitz *et al*, 1976). This method was widely accepted and used for planning purposes in both North America and Great Britain (Lyle and Stutz, 1983).

The Land Inventory branch of the Canadian government and the Harvard Lab for Computer Graphics and Spatial Analysis contributed greatly to the development of GIS in the early 1960s. To illustrate, in 1963 the project Development of Canada Geographic Information (CGIS) started. During this project many basic GIS concepts were contrived, such as topology, separating attribute and location information in different files, and the use of layers (Malczewski, 2004). Since that time, the combined use of computers and land-use suitability maps has increased rapidly. The publication of McHarg's Design of nature in 1969 was an important step in suitability analysis. He was the first to use transparent maps with light and

dark values for different factors, and then superimposed them over each other to create suitability maps (Belknap and Furtado, 1967; McHarg, 1969).

Scat *et al.* (2005) reviewed the land-use suitability analysis based on GIS in the United States. Ahmed *et al.* (2000) presented a GIS-based geo-environmental evaluation for urban land-use planning. Gordon (1985) built up an integrated GIS-based analysis system for land-use management and Analytic hierarchy process (AHP) method was adopted to derive weights for the evaluating model (Bello-Dambatta *et al.*, 2009). GIS and Analytical Hierarchy Process were also used together for land suitability analysis for urban development in the studies conducted by Malczewski (2006). In general, recent studies indicated that combine use of these technologies can present a platform to support multi-level and hierarchical integrated analysis on human activities, resources and environment (Marull *et al.*, 2007).

2.5.4.3 Multi-Criteria Decision Analysis and Spatial Decision Support System

Recent literature surveys show that MCDA has attracted significant interest over the past 15 years **(**Malczewski 2004**,** 2006; Mendoza and Martins, 2006). Malczewski (2006), an expert in the field of MCDA did a review of literature published between 1990 and 2004, and found 319 relevant articles. He defined MCDA as a process that transforms and combines geographical data and value judgments (the decision makers' preferences) to obtain information for decision making.

Basically, MCDA can be subdivided in two parts: Multiattribute and Multiobjective decision analysis, (MADA and MODA). With Multiattribute analysis, there are a limited number of predetermined outcomes (option A, B, C or D). Weightings will determine which of the options the best solution is (Malczewski, 2006). With Multiobjective analysis however, the possible

outcomes are undefined beforehand. Solutions are found using algorithms and standard linear-integer programming (Cohon, 1978).

Goicoechea *et al.* (1982) stated that MADA and MODA can be further subdivided by the number of goals of decision makers. If there is one interest group involved, the problem is referred to as a single decision makers problem. The number of people containing this interest group is not relevant because they all have the same interest. On the other hand, if there are more interest groups involved, it is called a group decision-making problem. An example is forest management planning. Different groups with different opinions will be involved like property owners, environmentalists, the government, forestry companies, tourism, and many others (Sheppard and Meitner, 2005).

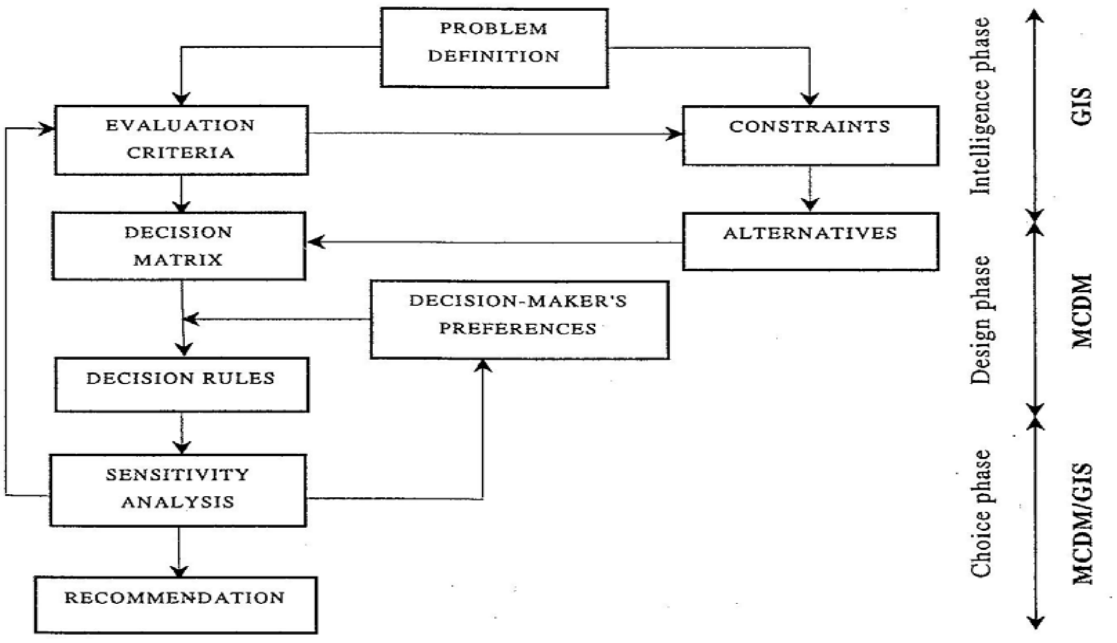


Figure 2.1: Decision flowchart of spatial multicriteria analysis
Source: (Malczewski, 1999).

The literature surveyed carried out by Malczewski (2006) shows that almost 70% of MCDA problems is of the MADA type. Over 60% of the MCDA are single decision-makers problems. Only seven papers contained group decision making in MODA. Depending on the type of MCDA, different decision rules can be used to select one or more alternatives available to the decision maker(s) (Malczewski, 1999). MCDA are often integrated in spatial decision support system (SDSS). SDSS is an application that uses analytical methods and models to define alternatives, it is able to analyze their impact, and interpret and select the best option for implementation (Ochola and Kerkides, 2004). Most SDSS focus on a specific field, and are therefore adapted to the characteristics of the problems in this field. Urban planning is by far the most popular field; other examples are forestry, natural resource management and rural land-use planning (Santé-Riveira *et al.*, 2008).

Van Ittersum *et al.* (1998) describe three main stages in the process of land-use planning:

i. An evaluation of land suitability for each land-use type;
ii. The optimization of the different land-use areas;
iii. The spatial allocation of land-uses.

Many methods and SDSS deal with one of the earlier mentioned stages. Only a few systems, however deal with all three stages. Examples of systems that do contain all stages are What-If? (Klosterman, 1999), (FAO, 1995), the Rural Land-use Exploration System (RULES) (Santé Riveira *et al.*, 2008) and the Land-Use Conflict Identification Strategy (LUCIS) model (Carr and Zwick, 2007), What-if? has been applied in numerous land-use planning studies, but has a focus on urban planning (Klosterman *et al.*, 2003; Kim, 2004). However, if the focus of a certain study is on urban planning, it is a highly suitable Spatial Decision Support System. According to Pettit (2005), What-If? is a transparent, flexible and user friendly system with a

simple and easy to use graphic user interface (GUI). On the other hand, What-If? Lack a firm theoretical basis. Its strength of simplicity is a weakness at the same time. In contrast to What-If?, Other urban models include measures of spatial interaction, like accessibility to employment, shopping and recreation, which are of key importance in urban models (Klosterman, 1999).

Again, Santé-Riveira *et al.* (2008) stressed that the SIRTPLAN system which is in Spanish and therefore especially popular in South America is a group of independent programs, and misses a strictly defined methodology which makes it difficult to apply RULES is a planning support system for rural land-use allocation, and is demonstrated with a case study in northwest Spain. It is innovative because all three land-use planning stages are incorporated in one tool. However, the focus of this tool is on rural planning, which makes it less suitable for the current study.

2.5.4.4 The Analytical Hierarchical Process

The most frequently raised problem in Multi-criteria decision making is how to establish weights for a set of activities according to importance. Location decisions such as the ranking of alternative communities are representative multi-criteria decisions that require prioritizing multiple criteria. Saaty (1980) has shown that this weighting of activities in Multi-criteria decision making can be dealt with using a theory of measurement in a hierarchical structure. The analytic hierarchy process (AHP) is a comprehensive, logical and structural framework, which allows improving the understanding of complex decisions by decomposing the problem in a hierarchical structure.

The incorporation of all relevant decision criteria and their pairwise comparison allows the decision maker to determine the trade-offs among objectives. Such multi-criteria decision problems are typical for land use sites selection. The AHP allows decision-makers to model a complex problem in a hierarchical structure showing the relationship of the goal, objectives (criteria), sub-objectives, and alternatives. Uncertainties and other influencing factors can also be included. It is not only supports decision makers by enabling them to structure complexity and exercise judgment, but also allows them to incorporate both objective and subjective considerations in the decision process (Saaty, 1980).

2.6 LAND EVALUATION

According to FAO (1984) Land evaluation surveys started in 1950 and the most important of these surveys was land capability classification carried out by Soil Conservation Service (S.C.S) of the United States, in which major kinds of land uses were determined by soil information. It was specified that other factors are effective in land utilization. So, the scientists paid more attention to land characteristics and qualities. According to Austin *et al.* (1978), Land evaluation is concerned with the assessment of land performance when used for specific purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

Dent *et al.* (1981) noted that urban development land evaluation fulfills two main tasks:

i. Identifying the most suitable location for a specific land use (many location-single

use).

ii. Identifying the most unsuitable location that involved much economic resources for a specific urban development.

According to FAO (1976), assessment of land quality for specific use is made in terms of production, sustainability, the inputs needed to obtain that production, and economic return. This process includes: identification, selection and description of land use types relevant to the area under consideration; mapping and description of the different types of land that occur in the area and the assessment of the suitability of the different types of land for the selected land use types. Land evaluation may be concerned with present land performance. Frequently, however, it involves change and its effects: with change in the use of land and in some cases change in the land itself. Evaluation takes into consideration the economics of the proposed enterprises, the social consequences for the people of the area and the country concerned, and the consequences, beneficial or adverse, for the environment (FAO, 1976).

According to Beek (1997) the approach of Land evaluation as the process of assessing the potential production for various land uses should be based on the matching of qualities of different land units in a specific area, with the requirements of actual or potential land use. The results of land evaluation should be useful for rational land use planning. Rossiter *et al.* (1997) discusses a theoretical framework for the classification of land evaluation models and concludes that there is no single land evaluation modeling approach. The choice of technique affects the reliability and scope of the application, and also the predictions and purpose. Rossiter added that predictions on land performance are useful only if they are used by decision-makers to make better decisions, 'we should take a step back, away from the question "what predictions can we make with the data we have?" i.e. a data - driven approach to the question

"who are the decision- makers, who actually affect land use, how are they making their decisions, and how could their decision be better informed? i.e. a demand-driven approach.

According to Bronsveld *et al.* (1994) Land evaluation provides essential information on land. However this information is often not used in the planning and implementation of better land use system or land use practices, for a number of reasons. Firstly, the information produced is frequently incompatible both to government's objectives and/or the preferences of the local people. Secondly, data processing is in adequate, resulting in low quality information. Thirdly, land evaluation is based on a top-down approach; such an approach does not take sufficiently into account the aspirations, capabilities are constraints of the local land users. Added to which land use plans tend not to consider sufficiently the limitations of interventions (subsidies, policy prices, input supply, extension, credit etc.).

2.7 LAND USE PLANNING

According to Oyesiku (2009) the forms and patterns of distribution of structures in general to promote the good health, accessibility, convenience and harmonious land use in environment are a function to a considerable extent of the rights and methods of dealing with land. Thus, effective urban land management particularly in areas with rapid urban sprawl such as Nigeria is crucial to tackling growing land use problems such as slum formation, rising costs of land, accessibility to urban land for land housing, incompatible use, flooding, overcrowding and congestion among others for the purpose of achieving sustainable city development and ensure the safety and health of the people. Thus, great attention has been paid by researchers, professionals and decision makers to the urban land use planning and management problems and the design of policies to combat it.

According to Peacock (2002) land use planning is a component of land management which involves the approval and regulation of urban and rural land use. It refers to a "systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt best land use options". FAO (1993) view Planning as a decision-making method that leads to the transformation of a current situation into a more acceptable future situation by distributing scarce resources among multiple objectives in order to minimize costs and maximize benefits under a dynamic social equilibrium. To Rodriguez (1995) land use planning means to indicate what is possible in the future with regard to land and its use (potentials) and what should be done to go from the present situation to the future one, in other words, how to improve land and its use. In a similar sense Dent (1988) defined land use planning as a means of helping decision-makers to decide how to use land: by systematically evaluating land and alternative patterns of land use, choosing that use which meets specified goals and the drawing up of policies and programs for the use of land. The essence of land use planning in urban centre's is to ensure that urban activities are organized and developed in physical space with due consideration for the protection of the public interest which include health, safety, convenience, efficiency, energy conservation, environmental quality, social equity, social choice and amenity (Nnah *et al.*, 2007). These are also features of sustainable development. In the same token, FAO (1993) stated that; Alternatives for land use and other physical, economic and social conditions, for the purpose of selecting and adopting land use options which are most beneficial to land users without degrading the environment, together with the selection of measures most likely to encourage such land uses is systematic to Land use planning assessment of land potential. It is directed at the best use of land in view of accepted objectives and of environmental and social opportunities and constraints.

Peacock (2002) observed that Land use planning has two arms, namely, development planning and development control. Development planning refers to a situation where physical environment including the presence or absence of transport, water and other utilities are evaluated and plans prepared about how different land uses and development can best be implemented in the public interest. Such type of planning stipulates broad outlines of land use policy to be applied, and these broad policy plans operate at various levels. Development control is the implementation side of development planning, because it is where plans that were decided in the outline or policy plan are implemented. Where there is no zoning, which is a subdivision of development control, development of land is controlled in terms of conditions of titles.

FAO (1993) is of the view that Land use planning can help decision- makers (such as government or land users) to use land in such a way that current land use problems are reduced and specific social, economic and environmental goals are satisfied (sustainability, income generation, self-sufficiency, etc.). The main objective of land use planning is to identify the uses that best satisfy specific goals for different tracts of land and the formulation of projects, programs or management plans to implement these uses. Land use planning becomes important when the government or land users feel that there is a need for land use change. This requires not only the political will and the ability (instrument, budget, manpower) to support and implement the plan. It is also essential that the planned changes are acceptable to the people and land users involved (FAO, 1993).

In the same token FAO (1976) stated that; The function of land use planning is to guide decisions

on land use in such a way that the resources of the environment are put to the most beneficial use for man, whilst at the same time conserving those resources for the future. This planning must be based on an understanding both of the natural environment and of the kinds of land use envisaged. There have been many examples of damage to natural resources and of unsuccessful land use enterprises through failure to take account of the mutual relationships between land and the uses to which it is put. It is a function of land evaluation to bring about such understanding and to present planners with comparisons of the most promising kinds of land use.

Land use planning, tries to choose the best use of resources through diagnosing land use problems, generating viable options and monitoring the implementation of proved alternatives (Dent, 1988). According to Rodriguez (1995) some techniques used in land use planning are cost/benefit analysis, optimizing land use policies, linear programming, land suitability, and land use comparison. An important activity in land use planning is the selection of the preferred land use for a certain tract of land. Land which aims at improved sustainable use of land and management of resources. In another study by Mabogunje (2002) on land use planning process experiences in sub-saharan cities of Harare, Lusaka, Gaborone, Nairobi, Dares Salaam, Abuja and Lagos, he found out that there was low compliance of land use planning and development control regulation by the general public due to restrictive nature of planning legislatures and regulations in these countries.

According to Owei *et al.* (2010) many developing countries lack well established effective and efficient land use planning and management. The most patent manifestation of this is the chaotic state of land use activities in the cities. The physical, economic and social conditions of the African city have been well documented. Rapid rates of urbanization have resulted in unplanned and unregulated growth. Millions of Africa's urban dwellers live in poverty in sub –

standard housing and degraded environments. Much has been written highlighting the underlying factors to which this state of affairs can be attributed (Nwaka, 2005; Oyesiku 2009, Mabogunje, 2002).

CHAPTER THREE

THE STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter describes the study area and method used to collect and analyze the data. The chapter contains components of the location, position and the size of the study area, population and settlement, geology and mineral resources, topography, climate, hydrology, soil and vegetation. Others include field data collection; type and sources of data, technique of data collection, equipments used, technique of data analysis and procedures of data analysis.

3.2 THE STUDY AREA

3.2.1 Location, Position and Size

Greater Karu Urban Area (GKUA) popularly referred to as New Karu is the administrative headquarter of Karu Local Government Area of Nasarawa State. The area lie within latitude 8^0 43'N and 9^0 08'N, and longitude 7^0 32'E and 7^0 51'E; some 100 km north west of Lafia, the state capital and about 15km east of Abuja, the Nigerian new Federal capital (Marcus and Bimbol, 2007). The entire area called Greater Karu Urban Settlements was declared and designated Urban by law passed by the Nasarawa State House of Assembly on March, 2001 and occupies a land area of about 72, 500 hectares.

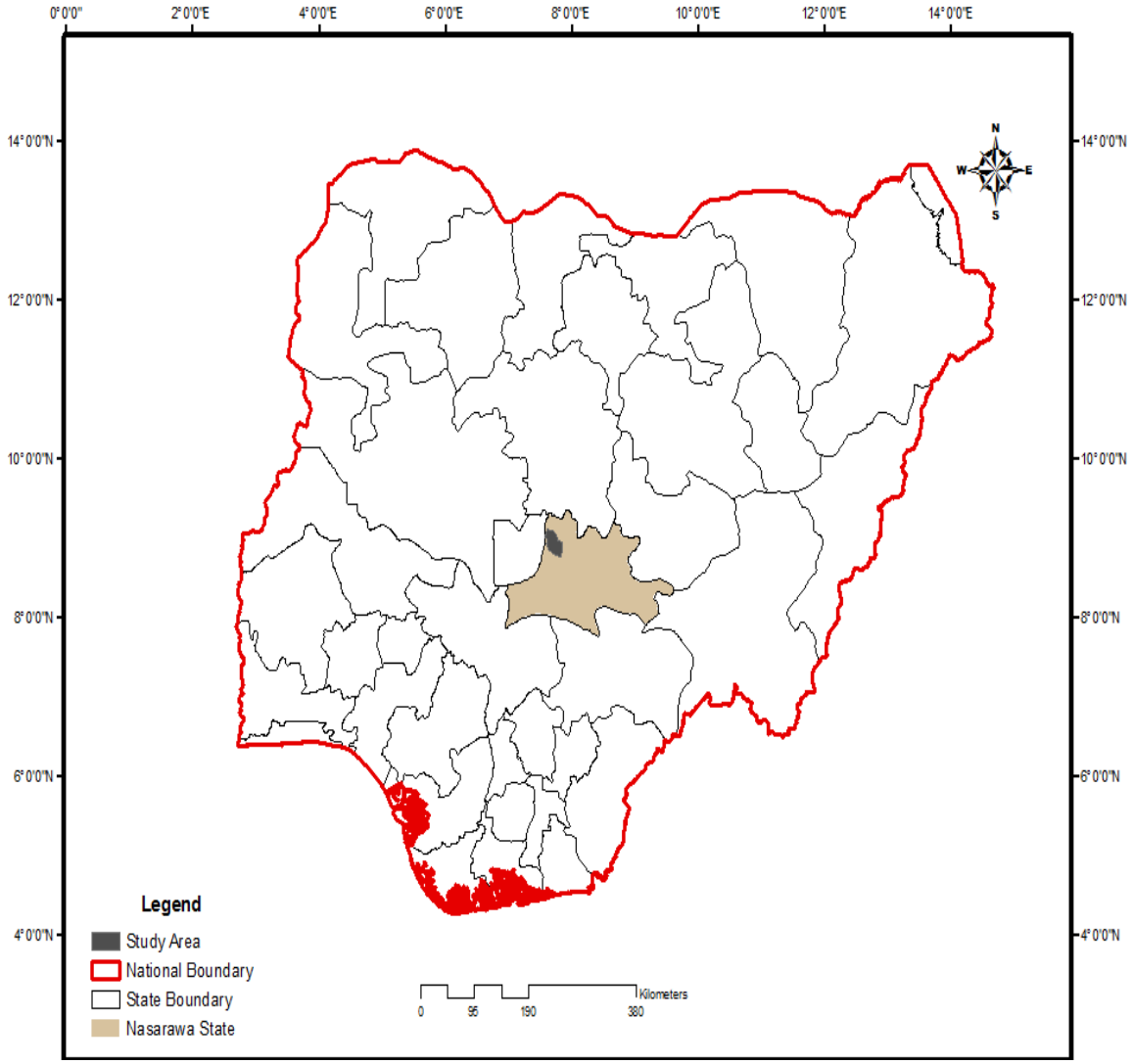


Figure 3.1: Nigeria showing Nasarawa State
Source: Authors GIS Analysis, 2012

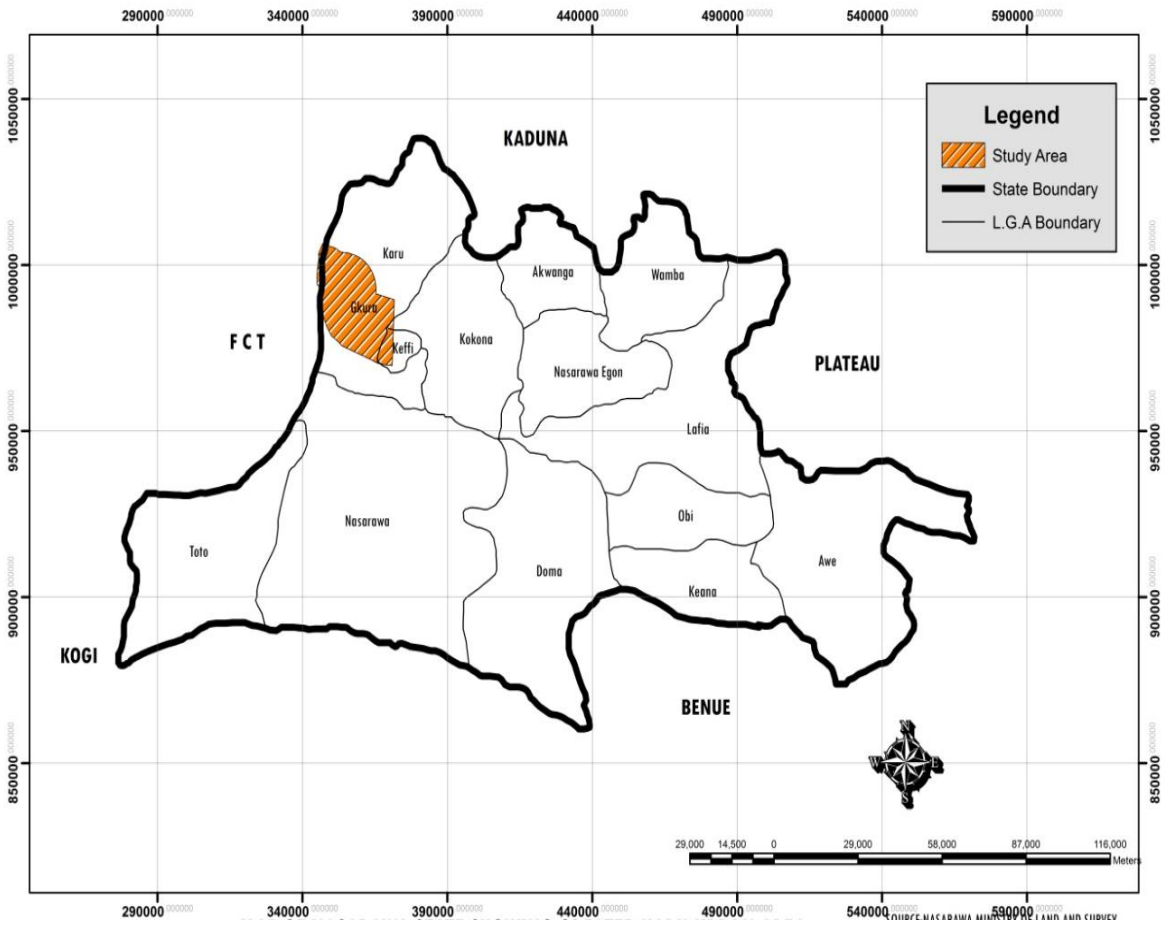


Figure 3.2: Nasarawa State showing Greater Karu Urban Area.
Source: Authors GIS analysis, 2012

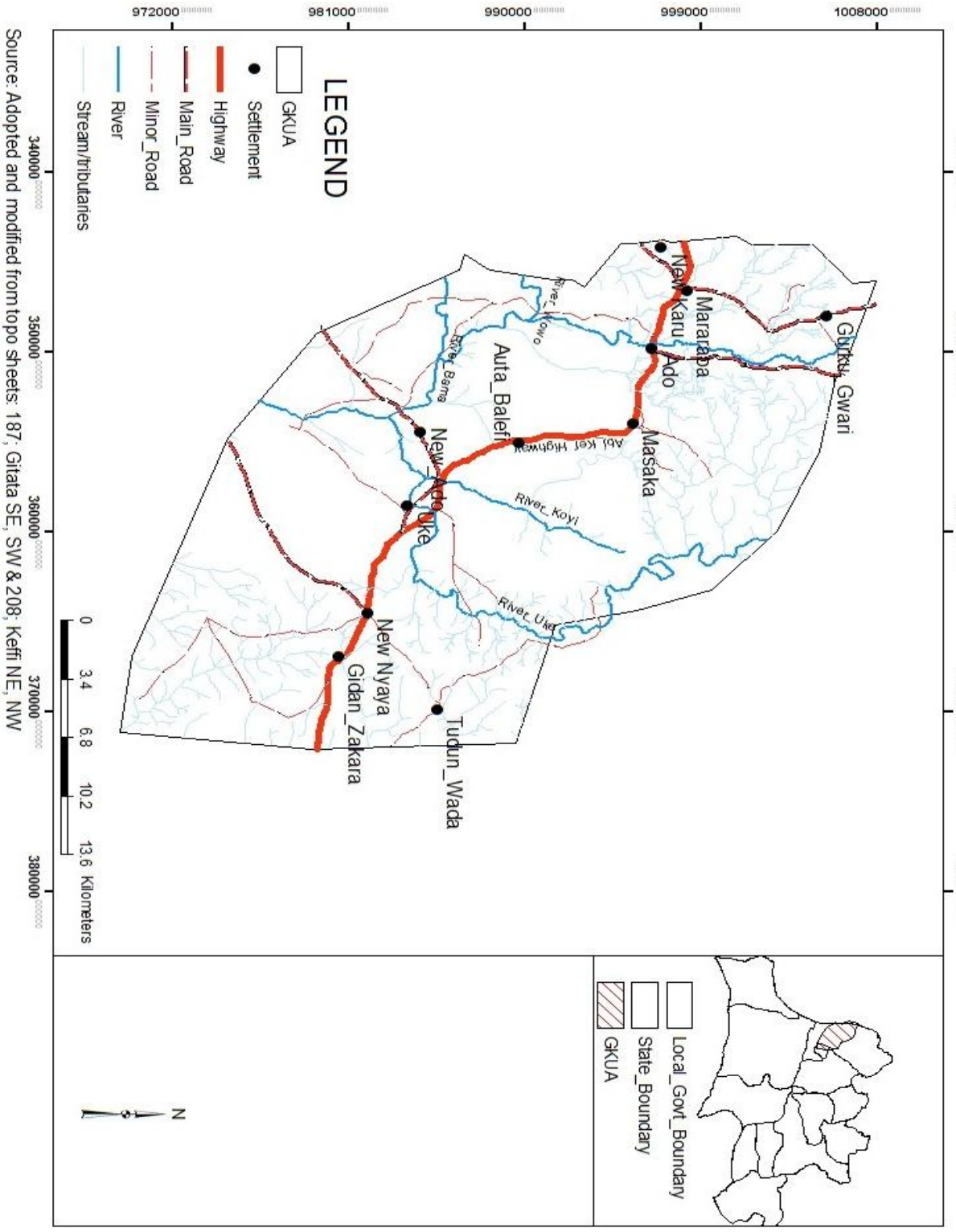


Figure 3.3: Greater Karu Urban Area
Source: Author's GIS Analysis, 2012

The area is sharing boundary with Abuja, the Federal Capital Territory to the west, Keffi LGA to the South and Jaba LGA of Kaduna State to the North (Yari *et al.*, 2001). (Figures 2, 3 and

4). Located in the North Central Geo-political zone of Nigeria, GKUA stretches a distance of about 20 kilometers from the Federal Capital Territory boundary toward Abuja-Keffi Federal Highway that traverses the area and connects Abuja with Northern and Eastern States of Nigeria viz: Nasarawa, Plateau, Kaduna, Benue, Enugu, Cross River, among others.

3.2.2 POPULATION AND SETTLEMENT

Up to early 1980s the study area remained a somewhat cultural island of the native Gbagis. The opening-up of the area to urban settlement and modern commerce owes its origins to the development of Abuja, the new federal capital. Immigrants from virtually all over Nigeria drawn to the employment or business opportunities created by the growth of Abuja from late 1980s find it convenient to reside in close-by settlements of adjoining states, such as the present study area. It is these strangers that dominate the urban population of the study towns. These include Igbo, Hausa, Yoruba, Tiv, Gbagyi, Koro, Yeskwa, Gwandara and Gade. Other settlers includes: Mada, Eggon, Hausa, Fulani, and other Nigerian ethnic groups who migrated to the area to take advantage of its economic potentials (Yari *et al.*, 2001).

GKUA and similar towns in the region indeed represent new towns designed to help take off, or reduce the pressure on Abuja in terms of accommodation and shops for building materials. Due to inappropriate planning and poor financing however, the development of these centers has not comes up as expected and this has resulted in the number of environmental problems currently being experienced in the towns, including problems of refuse management, pollution, drainage and erosion control, crime, HIV-AIDs pandemic, poor living environment and haphazard development among others (Marcus and Bimbol, 2007). Settlement pattern are largely nucleated, showing a strangely continuous ribbon appearance along Keffi – Abuja expressway. The major settlements in the area include Mararaba, Masaka, Ado New Karu and New Nyanya

some few minutes' drive from the FCT. The settlements stretch in some places over a Kilometer on both sides of the Abuja-Keffi Highway (Yari *et al.,* 2001).

3.2.3 Geology and Mineral Resources

Nasarawa state is blessed with abundant mineral resources and for this reason it is appropriately tagged the 'Home of Solid minerals'' In Nigeria. The state is endowed with abundant solid mineral resources with also the possibility of petroleum occurrence in parts of her sedimentary basin (Obaje *et al.*, 2007). Prominent among the mineral deposits of the State are coal, barytes, salt, limestone, clays, glass sands, tantalite, columbite, cassiterite, marble, iron ore and gold. The three rock types that constitute the components of Nigeria geology, namely the rocks of the Basement Complex, the Younger Granites and Sedimentary rocks are all exposed in Nasarawa State.

Basement Complex rocks cover about 60% of the total superficial area of the state while the remaining 40% is made up of sedimentary rocks of the Middle Benue Trough. The Younger Granites intrude the basement complex at Mada and Afu thereby not occupying any separate landmass of their own (Obaje *et al.*, 2007).

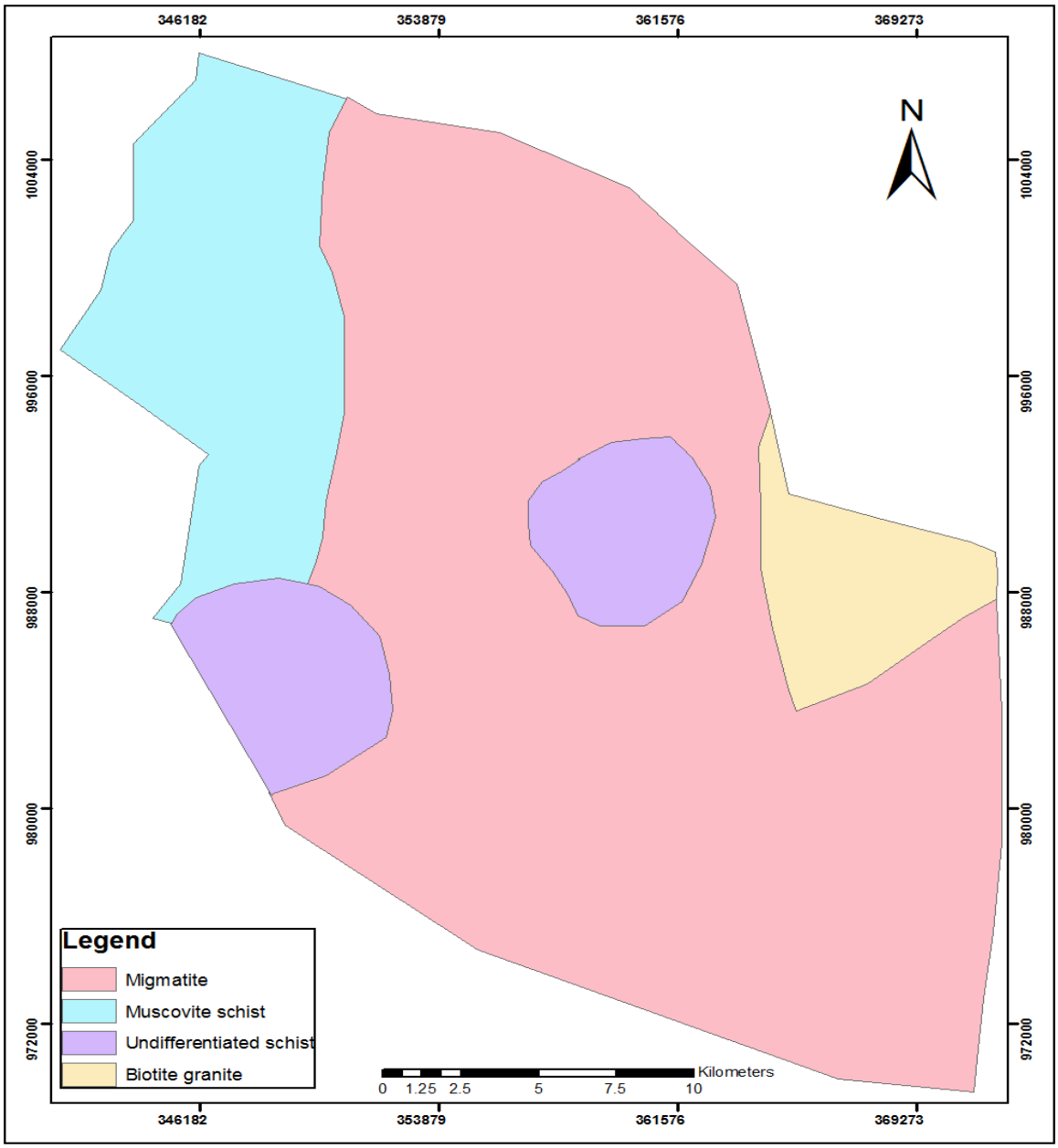


Figure 3.4: Geology of the study area
Source: Author's GIS Analysis, 2012

3.2.4 TOPOGRAPHY (Relief, Landforms and Drainage)

GKUA is located on the Keffi Plain. The plain form part of extensive plains collectively referred to as Jama'a Platform in north central Nigeria. The plain stands at an elevation between 500m around Karu and 330m above sea level in Nasarawa town. It is separated from the Gwagwa plains on which the Federal Capital Territory is located by a mostly solid rock granite

escarpments which ranges in height between 100m north of Maitama to 402m where it leads up to the Aso Hills peak at about 936m above sea level, and forming part of the Agwai – Karu Hills (Samaila and Binbol, 2007). Ignoring the residual hills, the characteristic form of landscape on the plains may be broken down into four major slope elements:

- A gentle-sloping interfluves which is characteristically broadly convex, with slopes varying from less than half degree at the crest to 2^0, 3^0, or 4^0 at its distal end, over a distance which is commonly half a km or more;
- The next slope element is the bluff over which the slope steepens to $6^0.7^0$ or, more appreciably, but more rarely, to up to 14^0;
- Below the bluff is a short foot slope of 4^0, 3^0 or less, which is either planar or concave in form.
- The lowest slope element is the valley floor which may be a complex feature, with a low terrace or terraces in addition to the contemporary flood plain. It is a depositional slope unlike the others which are essentially erosional. It is usually narrow, except along some of the larger rivers (Samaila and Binbol, 2007).

3.2.5 CLIMATE

The importance of the study of regional climatology cannot be over emphasized as demonstrated in the work of Adebayo (1999), Adefulalu (1989) and Olaniran (1988). Regional analysis of climate has helped tremendously in the planning of agricultural activities in the study area because of its vast agricultural potentials. The spatial and temporal pattern of climatic elements in the study area include; rainfall, temperature, relative humidity, wind velocity and sunshine.

3.2.5.1 Rainfall

The spatial pattern of rainfall in the area is slightly influenced by the north central highlands. The entire region represents a wet 'island', disturbing the otherwise east-west alignment of the isohyets in this part of Nigeria. Such rainfall distinctiveness is as a result of the position of the land mass of the Jos Plateau and associated hill ranges in relation to the south-westerly and westerly rain-bearing prevailing winds. As the winds are forced upward by the high southerly aspect of the Plateau and associated lines of hills, it result in a zone of higher rainfall, both on the plateau surface itself, and on the lowland plains before it. The area also enjoys a rather longer rainy season than is to be expected for the latitude, about 170 days on the average (Binbol, 2007).

Tropical humid climate characterized by two distinct seasons is experienced in the study area and occurs as intense thunderstorms. The wet (rainy) season last from the ending of March and ends in October while the dry season is experienced between November and February, Monthly total can vary widely, and so the annual total. Annual rainfalls range between 1100mm to about 2000mm with about 90 percent of the rainfalls between May and September. The months with the heaviest rain are July and August. The early rains in the study area are characterized by thunderstorms and squally activities. These phenomena are also noticeable towards the cessation period of rainfall (Yari *et al.*, 2001).

3.2.5.2 Temperature

Temperature is generally high in the area during the day between the month of March and April partly because of its location in the tropical sub-humid climatic belt. The high radiation income in this part of the globe, which is also evenly distributed throughout the year, also accounts for

the high temperature recorded in the area. However, there is a marked seasonal variation in temperature in the area. There is a gradual increase in temperature from January to March. The onset of rains in April ushers in a noticeable decline in temperature. This is made possible by the blanket effect of cloud cover over the region. This continues in the cessation periods by October ending when further decline is made possible in November/December by the coming of the harmattan winds. A single maximum is achieved in March when maximum temperatures can reach 39^{o}C. Minimum temperatures on the other hand can drop to as low as 17^{o}C in December and January (Binbol, 2007).

Generally, the area experienced low temperature and humidity in the dry season. Their patterns follow closely the pattern of two dominant tropical air masses, leading to the emergence of distinct climatic regimes as follows:

- Hot and humid period: April - June
- Cool and Humid period: July – October
- Cool and dry Period: November - January
- Hot and dry period: February – March (Yari *et al.*, 2001).

The mean monthly temperature of the area range between 20^{o}C -34^{o}C with the hottest month being March and the coldest being January.

3.2.5.3 Relative Humidity

Relative humidity is a measure of the dampness of the atmosphere which varies greatly from place to place at different times of a day. The actual amount of water vapor present in the air which is expressed in grammes per cubic meter is called the absolute humidity. This is the ratio

between the actual amount of water vapor and the total amount the air can hold at a given temperature expressed as a percentage (Binbol, 2007). Relative humidity in GKUA continues to rise as from February to a maximum of 88% in July. Steady rains commence in April, when the relative humidity will be at 75%. At this period, the southern part of the study area is coming under the influence of the humid maritime air mass. By August when the Inter Tropical Discontinuity (ITD) is at its northernmost position, the entire area will be under the influence of the tropical maritime wind (mT). This high relative humidity will continue to December, though with noticeable slight decline from October through to December (Binbol, 2007).

3.2.5.4 Wind Velocity

Wind velocity in the study area is relatively steady. Generally, places near the equator normally experience very low wind velocity. A peak is reached in April/May just prior to the rains. This has inhibited the use of this element as a resource in the area. However, there seems to be a slight increase in wind velocity at the onset and cessation of rains. Although, even these peaks are comparatively low, the highest on record being 180km only represents 2.1m/s. Most of the wind occurs in the day light hours. The prevailing wind is southerly, but northerly winds are experienced more frequently in the dry season. This is the dust-laden northeast trade or Harmattan (Binbol, 2007).

3.2.5.5 Sunshine

Sunshine is a very important element of climate that is vital to human existence. The study area by virtue of its location has the advantage of double passage of the sun overhead. This means that insolation is relatively constant and sunshine hours high. Generally, sunshine hours are high in the area averaging about nine hours in the dry season but little lower for the wet season because of the effect of cloud cover (Binbol, 2007). The climate is typically tropical continental

in nature. Consequently upon the apparent movement of the sun across the Tropics, is the relative stability of the inter-tropical convergence zone (ITCZ) is responsible for the stability of the temperature in the study area, though variations are experienced between dry and wet seasons. The climate controls the natural forces that affect all components of the ecosystem. It modifies the structural differences between them and maintains a balanced equilibrium for the macro environment (Yari *et al.*, 2002).

3.2.6 HYDROLOGY

Karu area is well endowed with enormous water resources both surface and underground and is drained by many rivers most of which originate from the North Central Plateau and have a dendritic pattern outlook because the streams and rivulets join the main rivers at oblique angles. The topography of the area is undulating terrain occasionally punctuated by outcrops of hills that are dissected by a network of small and seasonal rivers. Major River systems in the area include Uke river system which is a tributary of the Okawa River and flows through the north-western corner of Karu hills. The river flows through towns like panda and Nasarawa and empties into the River Benue east of Umaisha. Its major tributaries are river Ado, Antau and Obi flow all year round (Samaila and Binbol, 2007).

Stream flow in the study area strongly reflects the climatic environment and, in particular, the seasonal and torrential nature of the rainfall. Thus three main types of stream flow pattern have been recognized in the area:

(i) Perennial flows: low dry season discharges; flash floods superimposed on high rainy season discharges. This flow pattern occurs on the largest stream;

(ii) Seasonal flow: zero dry season flow; flash floods superimposed on rainy season flow which may be high or low depending on catchment area;

(iii) Flash flow only i.e., there is flowing water in the stream channel only during and for a short while after run-off-producing storms (Yari *et al.*, 2002).

The smaller streams are seasonal and intermittent while the larger streams are perennial in nature. In the dry season the volume of water is greatly reduced whereas flash flood is experienced for most rivers in the rainy season. Flooding is a major potential environmental hazard in the area because of torrential rain falls, which tend to seal up soil pores and reduce infiltration capacity, thus causing accelerated runoff; this is likely to increase with urbanization. The rivers transport a lot of materials in suspension, which affect color and turbidity of the water. Streams are characterized by seasonal flooding, and deposition of large quantities of sediments along their banks (Samaila and Binbol, 2007).

3.2.7 SOILS

The soil formation in the study area is a product of the interaction of myriad of factors such as rock types, local climate, organic matter (plant and animals), topography and time. The major soil units of the area as observed by Samaila and Ezeaku (2007) belong to the category of the tropical ferruginous soils. The soils are derived mainly from the basement complex formation and older sedimentary rocks. The soils of the study area are classified into three broad soil types. These are:

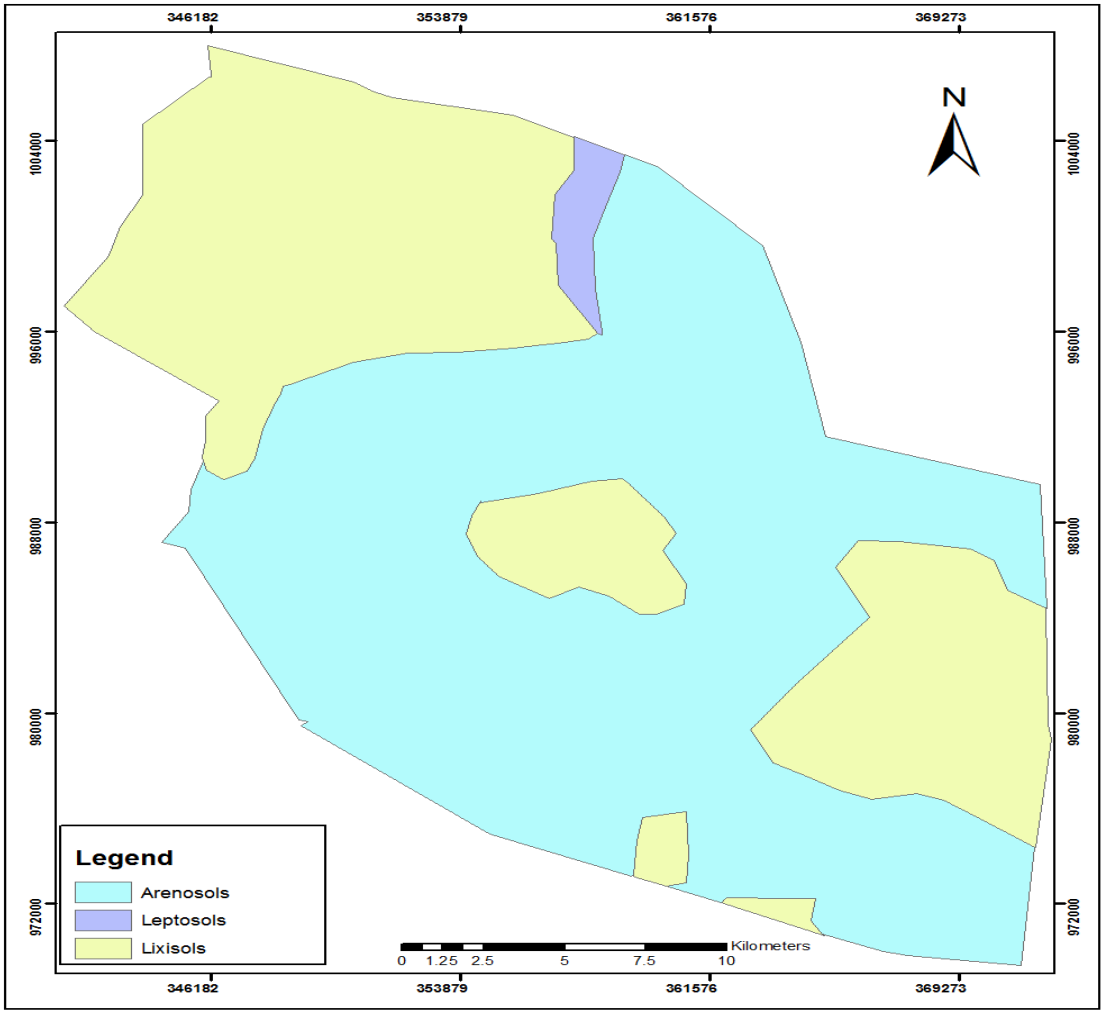


Figure 3.5: Soils of the study area
Source: Author's GIS Analysis, 2012

3.2.7.1 Arenosols

Arenosols soil consist of sandy and loamy soils that developed in residual sands, in situ after weathering of old quartz-rich rock and soil developed in recently deposited sand. Arenosols are associated with almost any type of vegetation. They are the most extensive reference soil group in the area and are typical azonal soils. They are marked by ease of cultivation, rooting and harvesting of root and tuber crops such as coconut, cassava, groundnut and yam, especially where good quality ground water is within the reach of the root system (USDA, 1999). Good yields of grains, Mellon and vegetables have been realized on Arenosols. In horticulture, the low water storage of Arenosols is considered advantageous because the soil warm up early in

the season. They occupy the dominant land mass of the Karu area and are member of entisols order of the U.S soil taxonomy.

3.2.7.2 Lithosols

These occur principally close to rock outcrops in any topographical position, or over an impenetrable ironpan. They also include very shallow and very gravelly soils containing within 30cm of the surface abundant ferruginised fragments of rocks, and a variable amount of quartz gravel and stones overlying weathered rocks. They are characterized by poor horizon development and are mainly less than 50 cm deep. Color range from pale brown to light yellowish brown in the surface layer to yellowish red at the lower layer. Some prominent mottles often associated with weathering rock fragments may occur at depth. Structure are mostly moderate sub angular blocky throughout, while texture range from sandy loam in the top layer to sandy clay loam at the lower layer. The soils contain many angular quartz and feldspar grains, and a few stones (Samaila and Ezeaku, 2007).

3.2.7.3 Lixisols

Lixisols are soils with subsurface accumulation of low activity clays and high base saturation. They are defined by the presence of a subsurface layer of accumulated kaolinitic clay where at least half of the readily displaceable ions are calcium, magnesium, sodium or potassium but are also identified by the absence of an extensively leached layer below the surface horizon (uppermost layer).Their age and mineralogy have led to low levels of plant nutrients and high erodibility, making agriculture possible only with frequent fertilizer applications, minimum tillage and careful erosion control. Perennial crops are thus more suitable for this soil than root or tuber crops (USDA, 1999). This soil type occupies about 45% of the study area

3.2.8 VEGETATION

Given the climate of the area, the original vegetation must have been a thick woodland or dry forest. Evidence of such vegetation still exists in the forestry reserves close to the study area. As in many parts of Nigeria, the long period of occupation of the region has led to profound modification of much of the vegetation cover (Peter *et al.*, 2007). The vegetation type within which the study area lies is the Guinea Savannah which itself is a derivative of tropical deciduous forest that existed centuries ago. Largely the vegetation is characteristics of Northern Guinea Savannah or park Savannah with dense tropical woodland with trees, shrubs grasses, and leguminous fauna that provide dry season grazing grasses with interspersion of thicket, grassland, tree savannah, fringing woodlands or gallery forest common along major streams, valleys and pronounced depression (Illoeje, 1985). The influence of relief, soil and human activities leads to variations in the general pattern of the vegetation in the area. These can be identified as follows:

- Distinct natural vegetation along streambeds characterised by tropical rain forest.
- Sparse vegetation on the slope of the hills especially on the granitite outcrops.
- Shrubs savannah with less density in the tree cover and more of the grasses and shrubs where cultivation occurs (Yari *et al.*, 2001).

3.3 METHODOLOGY

This section set out to presents field data collection, type and sources of data, technique of data collection, equipments used, technique of data analysis and procedures of data analysis.

3.3.1 RECONNAISSANCE SURVEY

A reconnaissance survey was carried out in order to be well acquainted with and get a better perspective of the study area and collect data that would be useful for the study.

3.3.2 TYPES AND SOURCES OF DATA REQUIRED

In order to achieve the stated objectives, the following data were required from both primary and secondary sources

3.3.2.1 The Primary Sources of Data

i. Landsat Multi Spectral Scanner (MSS) satellite image of 1972 with spatial resolution of 30m was acquired from the National Centre for Remote Sensing, Jos-Nigeria.

ii. Landsat Thematic Mapper (TM) satellite image of 1987 with spatial resolution of 30m was acquired from the National Centre for Remote Sensing, Jos-Nigeria.

iii. Landsat Enhance Thematic Mapper (ETM+) satellite image of 1997 with spatial resolution of 30m was acquired from the National Centre for Remote Sensing, Jos-Nigeria.

iv. SPOT 5 satellite image of 2012 with spatial resolution of 5m was acquired from the National Population Commission, Abuja- Nigeria.

v. Nigeriasat-1 image of 2012 with spatial resolution of 32m was acquired from the National Centre for Remote Sensing, Jos-Nigeria.

vi. Coordinates of Schools, markets, Health centres, Public water (Bore holes) data were acquired with Global Positioning System.

3.3.2.2 The Secondary Sources of Data

i. Topographical map of Nasarawa State at a scale of 1:50,000 were acquired from the office of the Surveyor's General of the Federation.

ii. Soil map of Nasarawa State at a scale of 1:50,000 were acquired from the Geologic Survey Office, Abuja.

iii. Geological map of Nasarawa State at a scale of 1:500,000 were acquired from the Geologic Survey of Nigerian Agency, Abuja.

iv. Existing literature from journal articles, conferences proceedings, past theses and reports, books and web references.

3.3.3 METHODS, TECHNIQUES AND PROCEDURES OF DATA COLLECTION

3.3.3.1 Scanning: A scanner is a device that converts hardcopy analog media into digital images by scanning successive lines across a map or document and recording the amount of light reflected from a local data source (Longley *et al.,* 1999). Large-format feed scanner was used to transform the analogue topographic, geological and soil maps of the study area into digital format and import them into the GIS software for extraction and analysis.

3.3.3.2 Digitization: The vectors data for the study were obtained from scanned map**s** through manual onscreen digitization using ArcGIS 9.3 software package and a computer screen using a mouse or digitizing cursor to digitize roads and drainage networks, contour, soils and geological maps of the study area.

3.3.4 IMAGE PROCESSING

Sub-set: Satellite image covering GKUA were extracted from full scene of Landsat Multi Spectral Scanner (MSS) of 1972, Thematic Mapper (TM) of 1987, Enhanced Thematic Mapper (ETM+) of 1997, NigeriaSat-1 of 2012 and SPOT-5 of October 2012.

Image restoration: The satellite data were subjected to image correction, calibration and restoration process in order to remove flaws and deficiencies from the raw satellite data and achieve as faithful a representation of the earth surface and the originality of the data.

Image enhancement: The satellite image was modified to optimize their appearance to the visual system. Visual analysis is key element as they alterate the appearance of the image in such a way that the information contained in the image is more readily interpreted visually in terms of a particular need.

Geometric rectification: The SPOT 5 data, acquired from National Population Commission, Abuja, was rectified and georeferenced to the UTM map projection (zone 32), Minna, Nigeria, horizontal datum, and Clark 1880 ellipsoid.

Data Extraction: The land use/land cover data for change analysis was generated from digital image processing of Landsat MSS, TM, ETM+ and NigeriaSat-1, while the SPOT-5 data was used to extract Road intersections, roads and drainage network. Topographic Map was used to generate contour for the creation of digital elevation model. Soil and Geological maps were used to generate data for land suitability analysis**.** The extraction of the datasets was by digital image processing and manual onscreen digitization using the combination of the software packages listed above.

3.3.5 DIGITAL IMAGE CLASSIFICATION

A supervised classification approach was adopted using maximum likelihood with a threshold of 50. Sample set of the classified satellite images were created which contains the domain of all the land use/cover classes selected. The classification scheme that was adopted for this research is the United State Geological Survey classification scheme level one (1), which provides a basis for land use/land cover assessment. the classification obtained in this research are;

i. Built up areas

ii. Water bodies

iii. Agricultural land

iv. Vegetation

v. Rock out crops and

vi. Bare surfaces.

The aerial extent of each land use/cover types were automatically calculated by the computer. To compare these sets of data, the resulting values were converted to percentage and used as absolute data for the presentation of the rate and magnitude of the changes using statistical analysis.

3.3.6 Ground truthing: Ground truthing was carried out with GPS to check, verify areas of doubt features on the maps. The Global Positioning Systems is a network of satellites, monitoring stations, and inexpensive receivers used for primary GIS data capture and field work.

3.3.7 CREATION OF LAND-USE SUITABILITY MAPS

The Model Builder in ESRI's ArcGIS 9.3 was used to create the models for all individual goals and objectives. The Model Builder can be seen as a graphic programming environment within ArcGIS. All tools from the toolbox, which is a large set of geo-processing tools, can be used to create complex geographical analysis. The tools that were used to create the suitability maps depended on the aim of the concerning goal, objective and sub-objective. However, the outcome is always a map with suitability values between 1 and 10. Nevertheless, it was not inevitable for a suitability map to contain all values between 1 and 10.

3.3.8 SUITABILITY SCORES

For each criterion, a suitability score was applied using a 10-point scale to determine the qualitative rankings of the suitability on each criterion. The rankings range from 1 (Not suitable) to 10 (Highly suitable). This "positive direction" Voogd (1983) is chosen to keep the scores understandable since the higher the score, the more suitable the site is. The suitability classes are given below:-

Not suitable (1): This is attributed to sites with characteristics imposing certain constraints, which cannot be overcome or technically excluded for development e.g. ecological areas. For agriculture, these include sites with soil characteristics that are not suitable for agricultural purpose and sites with steep slopes.

Moderately Suitable (5): A level for sites with characteristics imposing constraints, which can be overcome, but by moderate and massive investment. For agriculture, this includes sites with gentle slope and soil with nutrient constraints, which can be overcome by the application of fertilizer and other organic minerals.

Highly Suitable (10): Areas with characteristics imposing no significant constraints for development. These include sites with flat topography, good soils for residential use and lands free from flooding. Lands economical suitability was based on the distance from a specific feature. For instance, the closer a lands to a schools, existing residential areas, roads, health care, public water, and existing commercial areas the higher the suitability for residential and commercial use. Though this type of suitability ranges between 1 and 10, however, the distance between value 1 and 10 may differ between features. For a certain sub-objective the suitability value of 5 could be at 1 km from the feature, while for another sub-objective the value 5 is at 5 km. This depended on the importance of a feature to be at close range.

3.3.9 WEIGHTED OVERLAY

The weighted overlay technique is a GIS-based method of modelling the suitability in any particular situation. This involves setting up of an evaluation scale. For this study, the attributes of each datasets were ranked based on a scale factor of 1-10. Also an influence value of each factor based on their suitability for urban expansion and agricultural production was determined using the Analytical Hierarchical Process.

If an objective contained sub-objectives, the result was a weighted combination of all the sub-objective maps. However, if the objective did not contain sub-objectives, it was created the same way as a sub-objective. In both cases, though, the final result was a map; the creation of the goals was more or less similar as the objectives. The resulting maps of the objectives were combined and weighted, which resulted in a final map for that goal. Figure 3.3 shows the research design of Land-use model for GKUA after Carr and Zwick (2007).

Sub-objectives were based on one or more layers, depending on what they represented. Sometimes a combination of layers was needed to cover a topic. To illustrate, a sub-objective from the urban expansion aimed at finding places proximal to medical centers. One dataset with hospitals and another dataset with medical centre were combined to cover the topic of health care. Then the Euclidean distance from these health centers was calculated, and reclassified in values between 1 and 10, where 10 represent highly suitable areas, and 1 low suitable area. All these steps were modeled within ArcGIS, with a map as final result. Figure 3.4 shows the geo-processing tools that were used in Model Builder to create suitability and preference maps. Source: ESRI ArcGIS help**.**

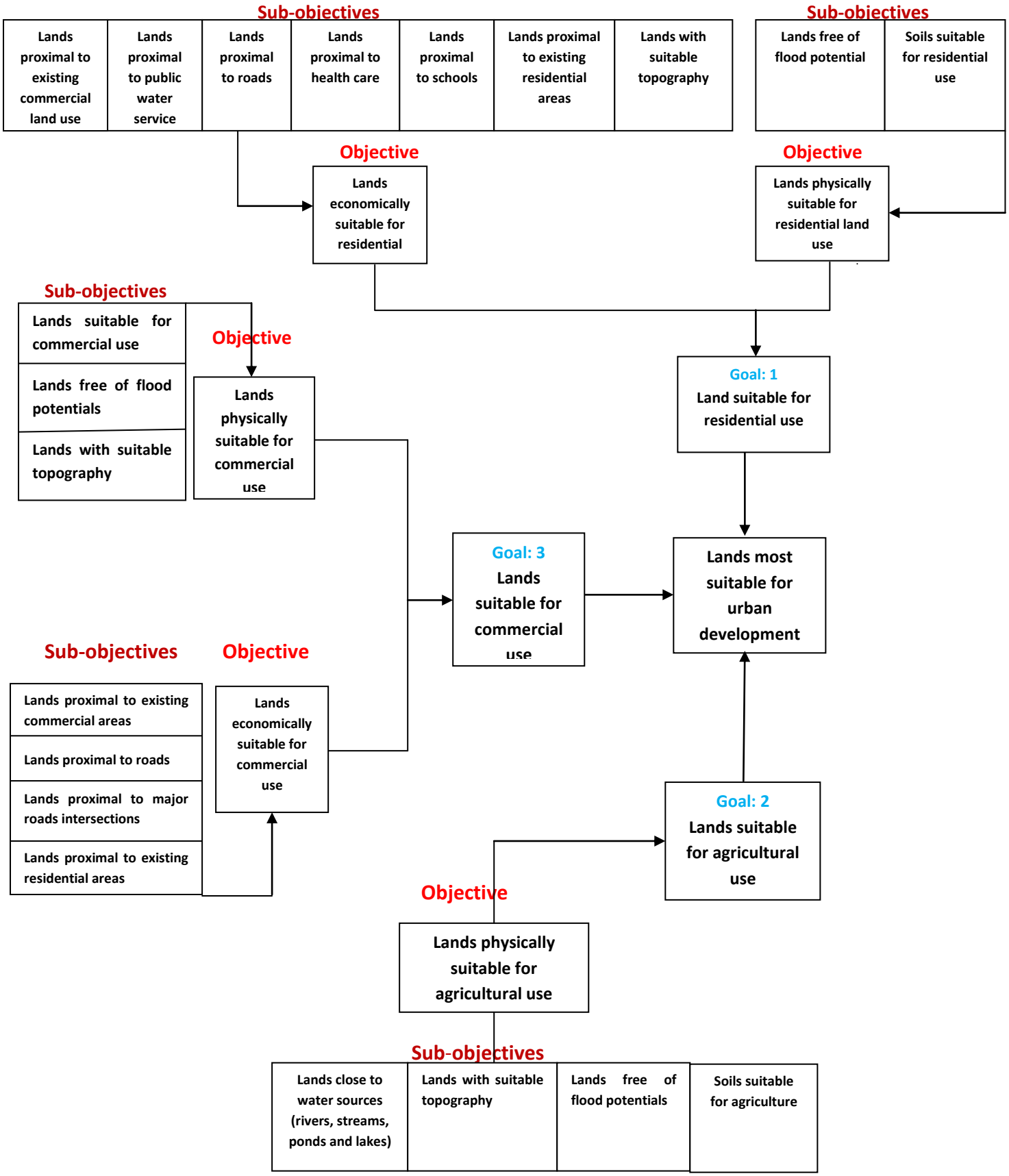


Figure: 3.6: Research Design of Land-use Model of GKUA

Source: Adopted from Carr and Zwick, (2007).

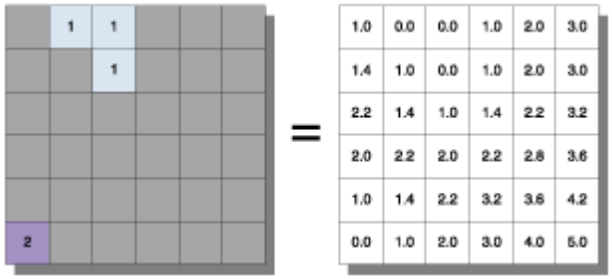
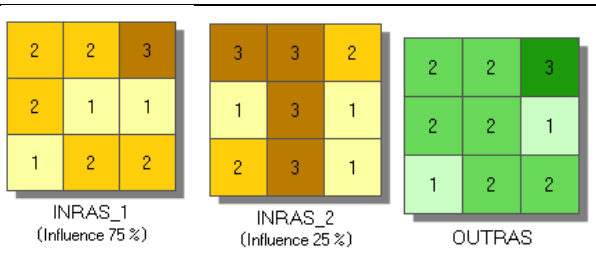
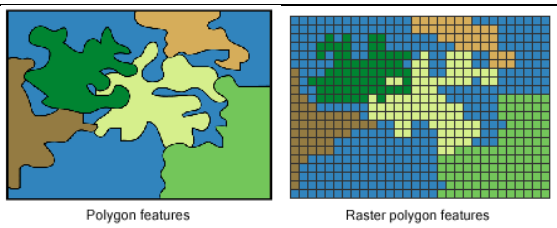
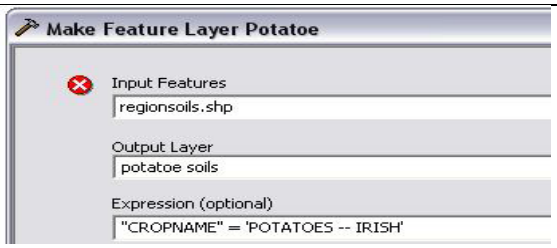
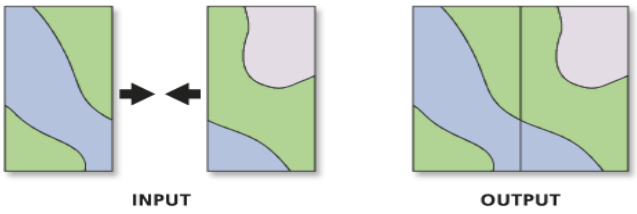
Reclassify By reclassifying, you can modify the values in an input raster and save the changes to a new output raster.	**Old values** **New values** 0-29 1 30-58 2 59-87 3 88-115 4 116-142 5 143-170 6 171-197 7 198-226 8 227-255 9 255-above 10
Euclidean distance Calculates, for each cell, the Euclidean distance to the closest source	
Weighted Single output map algebra Overlays several rasters using a common measurement scale and weights each according to its importance.	
Polygon to raster Converts polygon features to a raster dataset.	
Make feature layer The Make Feature Layer tool is used to create a feature layer from an input feature class or layer file.	
Merge Combines input features from multiple input sources (of the same data type) into a single, new, output feature class.	

Figure 3.7: the geo-processing tools that were used in Model Builder to create suitability maps. Source: ESRI ArcGIS help

3.3.10 BUFFERING GENERATION/OPERATION

Buffering is a process of processing a zone of interest usually of specified width around a map element such as roads, rivers, marshy areas, etc. In this study, a buffer zones was created around water bodies (rivers and marshy area), and road networks to satisfy the set criteria of distance. The guidelines in line with Land Use Act Cap 202 of 1990 and the Nigeria Urban and Regional planning Act of 1990 to monitor and control all developments approved setbacks was adopted, which include;

i. Highway "A". Buildings must observe 45m to the Centre line of the road.
ii. Local Distributors: Buildings must observe 30m to the Centre of the road.
iii. Access Roads within Neighbourhood: - Buildings must observe 5m to the Centre of the road.
iv. Rivers: Buildings must observe 30m and 15m to the edge of the rivers, streams, etc.

3.3.11 OVERLAY OPERATION

Overlay Operation involved bringing two input data layers together to form a new layer. The principle of spatial overlay is to combine the characteristics of the same location in the output data layer. In this regards, the buffer zones generated were grouped together using the union operation. This operation was used to compute the geometric intersection of the buffered zones. All the features were then written to the output feature class with the attributes from the input features, which were overlaid on the land use map. This automatically generates the areas that were encroached into the approved setback areas.

3.3.12 STATISTICAL ANALYSIS

Statistical analysis using Microsoft excel package was used to present the rate and magnitude of the changes, using the resulting values generated from satellite imagery. To compare these sets of data, the resulting values were converted to percentage and used as absolute data.

The magnitude of changes was calculated as: C= B-A

Where:

C= is the magnitude of changes
B= Base year (1972 and 1987)

A= Reference year (1997 and 2012)

Percentage of changes (E)

$$E = \frac{C}{base\ year} \times 100$$

Where

C= magnitude of changes of each Land use/cover

$$\text{Annual rate of changes (D)} = \frac{C}{number\ of\ \ years\ between\ the\ \ period}$$

Where:

C= magnitude of changes of each land use/cover divide by the number of years between The periods i.e. 15 years for 1972 and 1987, and 15 years for 1997 and 2012.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter looks at the various uses that the land in Greater Karu Urban Area should be put into. The results of land suitability and buffering were also presented. The land use/cover change analysis is based on the satellite imageries of Landsat MSS of 1972, Landsat TM of 1987, Landsat ETM+ 1997 and Nigeriasat-1 2012. The results of the analysis are presented in the form of maps, tables and bar graphs which formed the basis of discussion. The categories of land use/ land cover identified in the study area are; Agriculture, bare Surfaces, built-up areas, natural vegetations, rocky outcrops and water bodies. Land use/cover in the area was observed to vary among classes and decades. Table 4.1 shows the tabulated land use/cover coverage and the percentages of the various years (1972, 1987, 1997 and 2012).

Table 4.1: Land use/cover of GKUA for 1972, 1987, 1997 and 2012

Land use/cover Categories	1972		1987		1997		2012	
	Areas in Hectares	percentage	Areas in Hectares	Percentage	Areas in Hectares	percentage	Areas in Hectares	Percentage
Agriculture	6178.60	8.7	13638.30	19.13	18462.2	25.90	10825.2	15.18
Bare Surfaces	5600.10	7.8	6450.2	9.05	8700.3	12.20	8300.1	11.64
Built-up Areas	1033.8	1.4	6974.8	9.9	11976.3	16.80	27662.5	38.81
Natural Veg.	49124.40	68.92	37706.6	52.90	24420.1	34.26	18121.7	25.42
Rock Outcrops	2096.20	2.94	2147.2	3.01	2188.4	3.07	2203.4	43.09
Water Bodies	7236.10	10.16	4352.1	6.10	5521.9	7.74	4156.3	5.83
Total	71,269.20	100.00	71,269.20	100.00	71,269.20	100.00	71,269.20	100.00

Source: Author's GIS Analysis, 2012

4.2 LAND USE AND LAND COVER OF GKUA

From table 4.1 agricultural land witnesses an increase from 6178.6 hectares (8.7%) to 13638.30 Hectares (19.1%) between 1972 and 1987, with magnitude changes of 7459.7 hectares and annual change rate of 497.3 hectares. Thereafter, decreases from 18462.2 hectares (25.9%) to

10825.2 hectares (15.2%) between 1997 and 2012 with magnitude changes of -7637 hectares and annual change rate of -509.1 hectares respectively as shown in figures 4.1, 4.2, 4.3 and 4.4.

Bare surface refers to areas that are exposed and vacant land. They include the playing ground at Mararaba which is used by the police for sporting activities and parades, the front of Esu's palace which is used for sporting activities; institutions play grounds for the use of student, and open spaces between buildings. Bare surfaces witness an increase from 5600.1 hectares (7.8%) to 6450.2 hectares (9.1%) between 1972 and 1987 with magnitude changes of 850.1 hectares and annual change rate of 56.7 hectares. Further decrease from 8700.3 hectares (12.2%) to 8300.1 hectares (11.6%) was observed between 1997 and 2012, with magnitude change of -400.2 hectares and annual change rate of 26.7 hectares, as shown in tables 4.1, 4.2, 4.3 and 4.4, and figures 4.1, 4.2, 4.3 and 4.4.

Built up areas increases from 1033.8 hectares (1.4%) to 6974.8 hectares (9.9%) between 1972 and 1987, with magnitude change of 5941 hectares. The annual rate of change is 396.0 hectares respectively. Further increase from 11976.3 hectares (16.80%) to 27662.5 (38.81%) hectares were witnessed between 1997 and 2012, with magnitudes changes of 15686.2 hectares and annual change rate of 1045.7 hectares, as shown in tables 4.1, 4.2, 4.3 and 4.4, and figures 4.1, 4.2, 4.3 and 4.4.

Natural vegetation includes forest, shrubs and tall grasses found in most part of the study area, especially at the fringes of the urban area where cultivation and settlements have not occurred. Result from the analysis shows that natural vegetation covers a dominant part of the study area in 1972. This has drastically decline from 49124.4 hectares (68.9%) to 37706.6 Hectares (52.9%) between 1972 and 1987 with magnitude change of -11417.8 and annual change rate of -761.2 Hectares. It further decline from 24420.1 hectares (34.3%) to 18121.7 hectares (25.4%)

between 1997 and 2012 with magnitude changes of -6298.4 hectares and annual change rate of -419.9 hectares, as shown in tables 4.1, 4.2, 4.3 and 4.4, and figures 4.1, 4.2, 4.3 and 4.4.

Rock out crops increases from 2096.2 hectares (2.9%) to 2147.2 hectares (3.0%) between 1972 and 1987 with magnitude changes of 51 hectares and annual change rate of 3.4 hectares. Further increase was experienced from 2188.4 hectares (3.0%) to 2203.4 hectares (3.1%) between 1997 and 2012 with magnitude changes of 15 hectares and annual change rate of 1 hectares respectively, as shown in tables 4.1, 4.2, 4.3 and 4.4, and figures 4.1, 4.2, 4.3 and 4.4.

Water body comprises rivers, ponds, lakes and marshy areas. Satellite data confirmed that water bodies covers 7236.10 hectares (10.6%) in 1972. Water bodies then decrease and by 1987 it covered 4352.1 hectares (6.1%) indicating a magnitude decrease of -2884 hectares and annual change rate of -192.3 hectares. Water bodies then increase to 5521.9 hectares (7.7%) in 1997 and subsequent decrease to 4156.3 hectares (5.8%) in 2012 with magnitude changes of -1365.3 hectares and annual change rate of -91.0 hectares respectively, as shown in tables 4.1, 4.2, 4.3 and 4.4, and figures 4.1, 4.2, 4.3 and 4.4. Figure 4.5 shows the bar chart of Land Use/land Cover Change from 1972 to 2012.

TABLE 4.2: MAGNITUDE AND ANNUAL CHANGE RATE OF LAND USE/COVER FROM 1972 TO 1987

Categories	A	B	C	D	E
	1972 Areas in Hectares	1987 Areas in Hectares	Magnitude of change (B-A)	Annual rate of change $\frac{C}{15}$	% change C/A X 100
Agriculture	6178.60	13638.30	7459.7	497.3	120.7
Bare Surfaces	5600.10	6450.20	850.1	56.7	15.2
Built-up Areas	1033.8	6974.8	5941	396.1	574.7
Natural Veg.	49124.40	37706.6	-11417.8	-761.2	23.2
Rock Outcrops	2096.20	2147.2	51	3.4	2.43
Water Bodies	7236.10	4352.1	-2884	-192.3	39.9

TOTAL	**71,269.20**	**71,269.20**	**28603.6**	**1906.88**	**776.1**

Source: Author's GIS Analysis, 2012

TABLE 4.3: MAGNITUDE AND ANNUAL CHANGE RATE OF LAND USE/COVER FROM 1987 TO 1997

Categories	A	B	C	D	E
	1987 Areas in Hectares	1997 Areas in Hectares	Magnitude of change (B-A)	Annual rate of change $\frac{C}{10}$	% change C/A X 100
Agriculture	13638.3	18462.2	4823.9	482.4	35.4
Bare Surfaces	6450.2	8700.3	2250.1	225.0	34.9
Built-up Areas	6974.8	11967.3	5001.5	500.2	71.7
Natural Veg.	37706.6	24420.1	-13286.5	-1328.7	35.2
Rock Outcrops	2147.2	2188.4	41.2	4.12	1.9
Water Bodies	4352.1	5521.9	1169.8	117.0	26.9
TOTAL	71,269.2	71,269.2	26573	2657.3	206

Source: Author's GIS Analysis, 2012

TABLE 4.4: MAGNITUDE AND ANNUAL CHANGE RATE OF LAND USE/COVER FROM 1997 TO 2012

Categories	A	B	C	D	E
	1997 Areas in Hectares	2012 Areas in Hectares	Magnitude of change (B-A)	Annual rate of change $\frac{C}{15}$	% change C/A X 100
Agriculture	18462.2	10825.2	-7637	-509.13	41.4
Bare Surfaces	8700.3	8300.1	-400.2	-26.68	4.6
Built-up Areas	11976.3	27662.5	15686.2	1045.74	131
Natural Veg.	24420.1	18121.7	-6298.4	-419.9	25.8
Rock outcrops	2188.4	2203.4	15	1	0.7
Water Bodies	5521.9	4156.3	-1365.3	-91.0	24.7
TOTAL	71,269.2	71,269.2	31402.1	2092.49	228.1

Source: Author's GIS Analysis, 2012

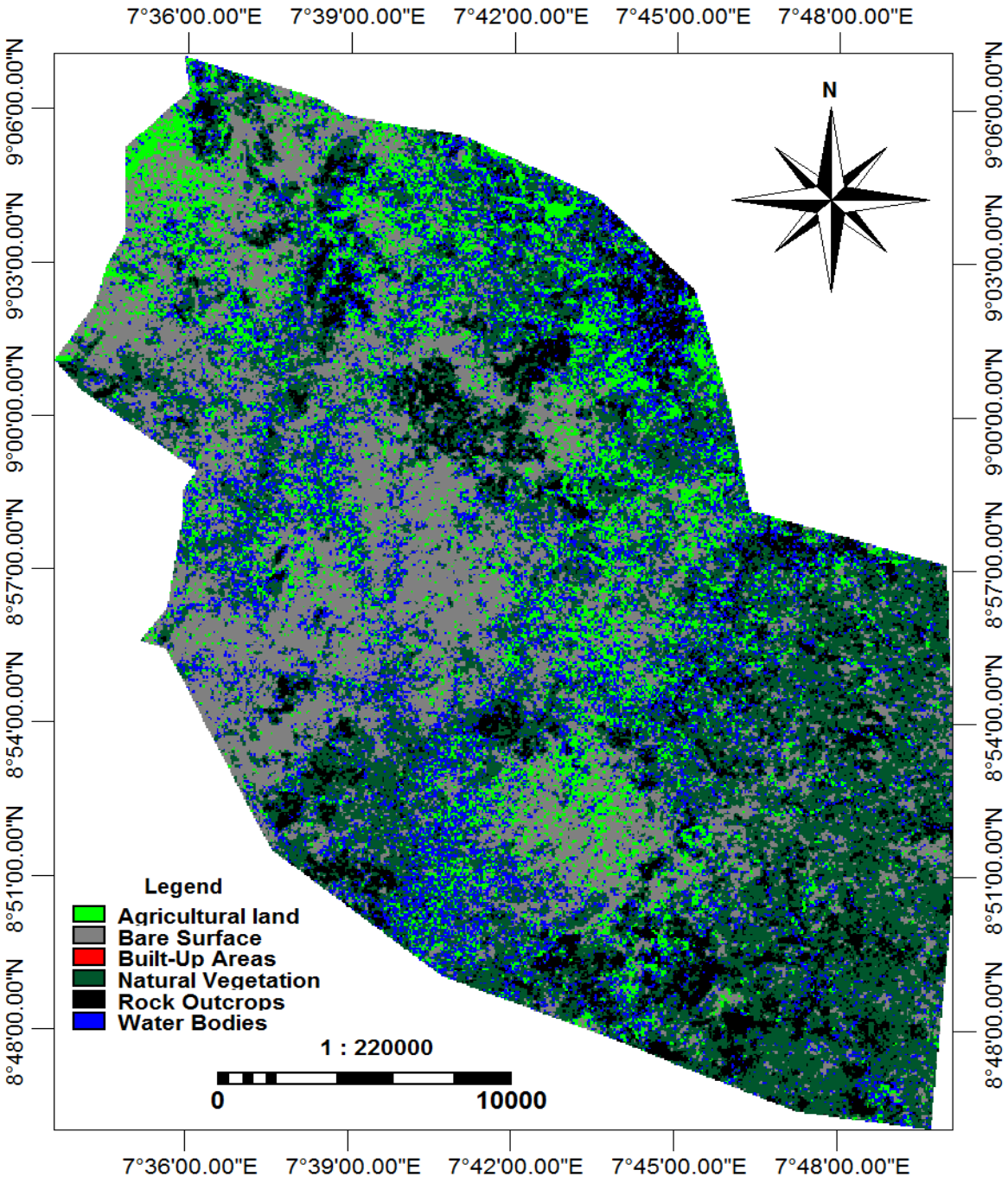


Figure 4.1: Classified Land Use Land Cover Map of GKUA 1972
Source: Author's GIS Analysis, 2012

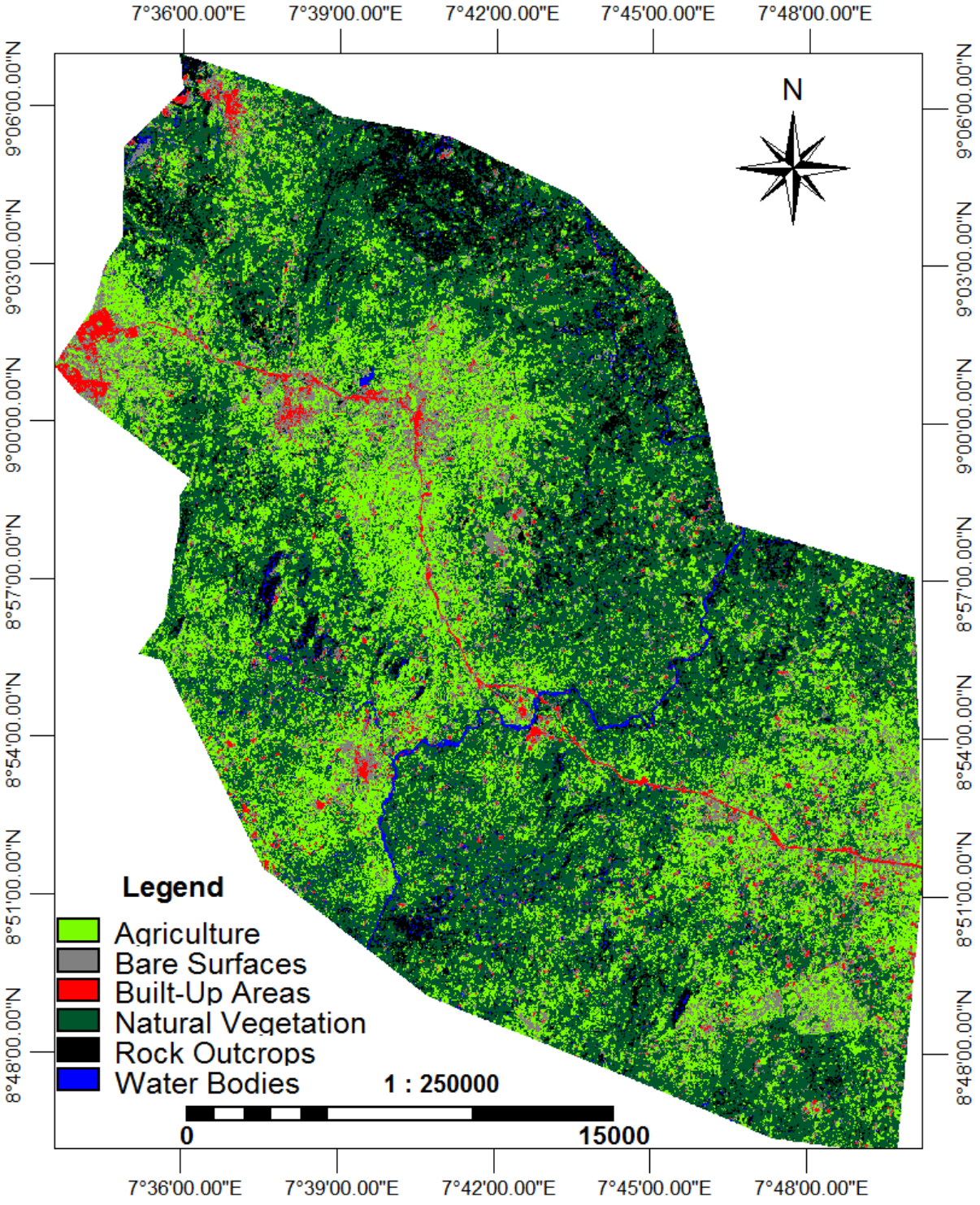


Figure 4.2: Classified Land Use Land Cover Map of GKUA 1987
Source: Author's GIS Analysis, 2012

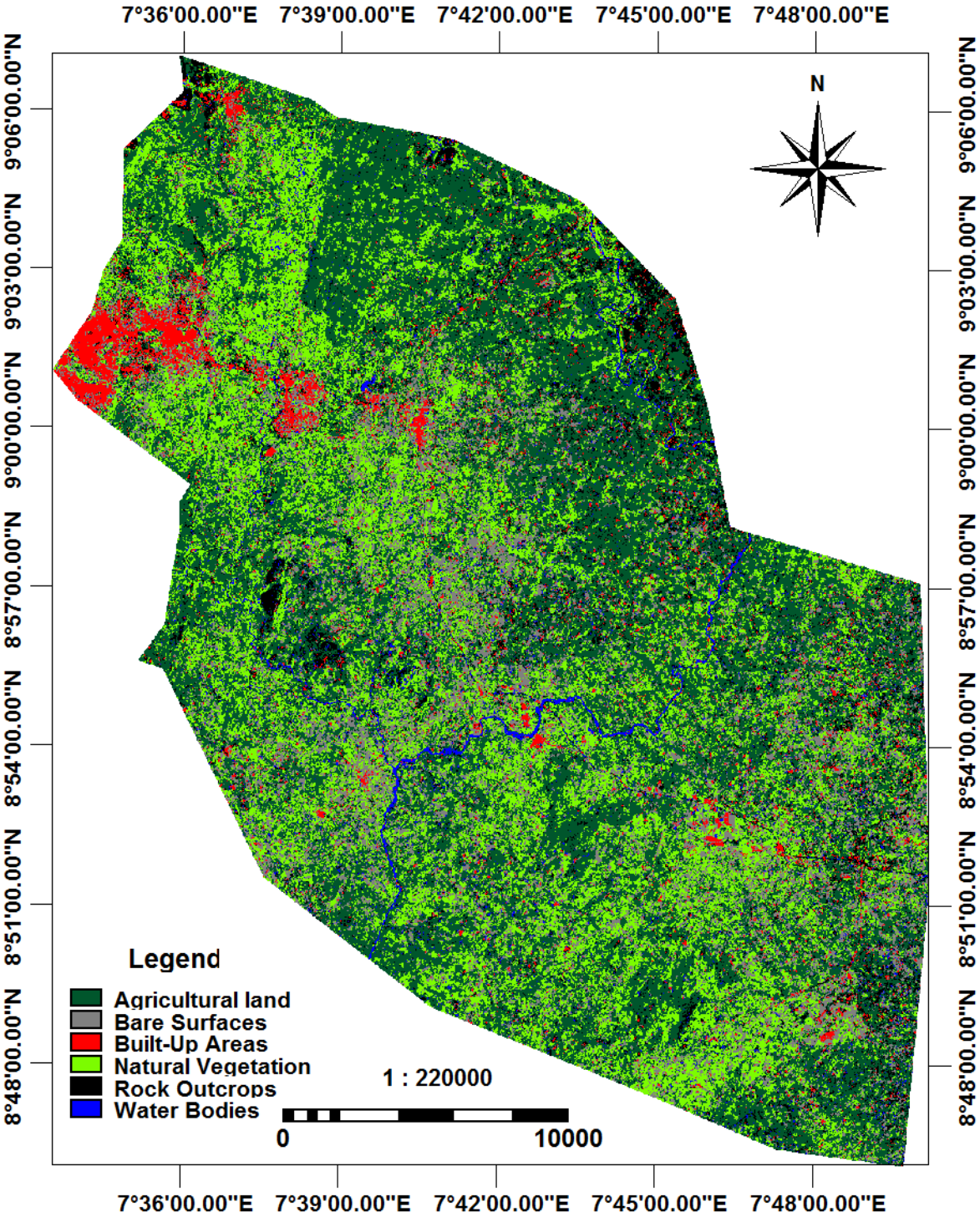


Figure 4.3: Classified Land Use Land Cover Map of GKUA in 1997
Source: Author's GIS Analysis, 2012

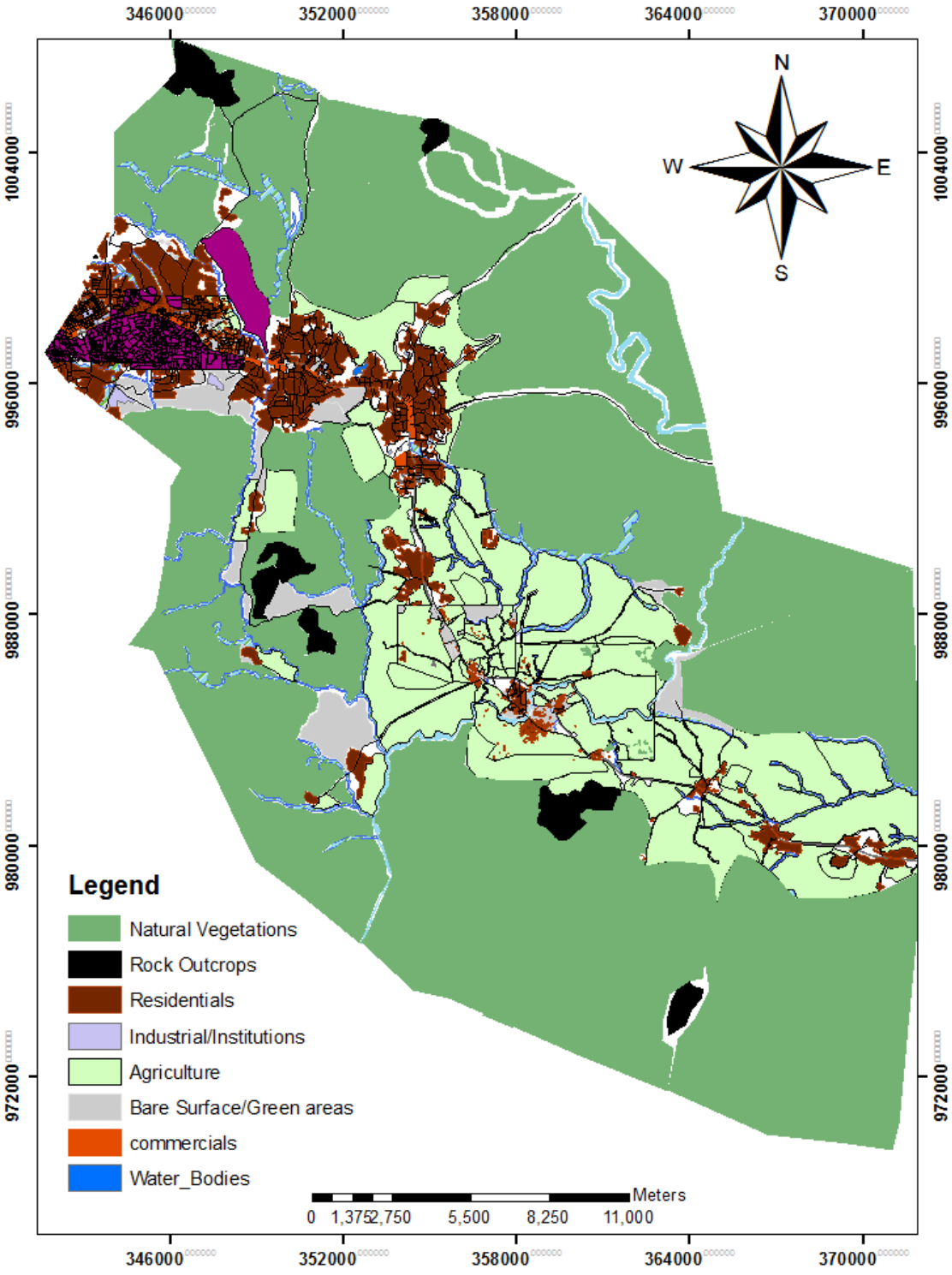


Figure 4.4: Land Use Map of GKUA 2012
Source: Author's GIS Analysis, 2012

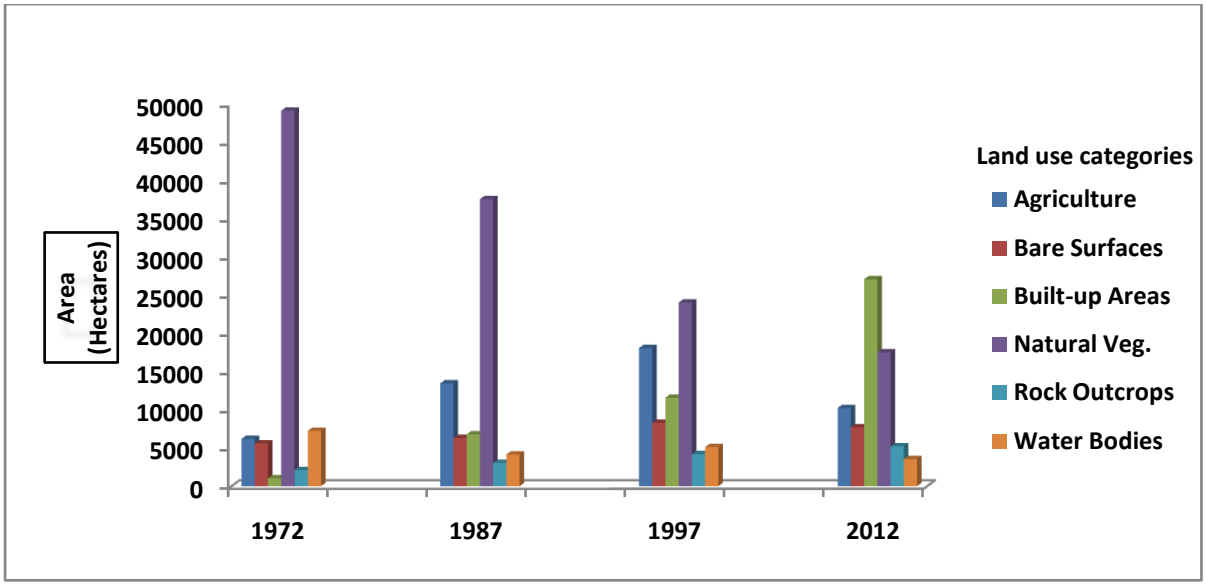


Figure 4.5: Bar chart of Land Use/land Cover Change From 1972 to 2012
Source: Author's GIS Analysis, 2012

It can be observed from the figures, tables and graphs above that the growth rate of Greater Karu Urban Area varied with time and class of land use, while in 1972 and 1987 the growth rate is little, it become higher between 1997 and 2012 due to the population increase and development brought about by the relocation of the Federal Capital Territory (FCT) from Lagos to Abuja in 1991. The maps reveals that most of the areas covered by natural vegetation have been converted to built up and agricultural use within these periods. Result from the analysis shows that natural vegetation covers a dominant part of the study area in 1972. This has drastically decline from 49124.4 Hectares (68.9%) to 37706.6 Hectares (52.9%) between 1972 and 1987. It further decline from 24420.1 Hectares (34.3%) to 18121.7 Hectares (25.4%) between 1997 and 2012.

Natural vegetation is fast disappearing due to the effect of human activities and urban expansion. This result is inferred on the fact that increase in population due to the influx movement of people to the Federal Capital Territory, Abuja result to increase in demand for shelter as such natural vegetation is been cleared for built up area. Also, fuel wood represents

the traditional energy source in use especially by the indigenous people and the low income in general. It is used as the main source for cooking at homes and in the catering industry, bakeries and restaurant. Access to fuel wood is either by cutting trees directly from the nearby vegetations or from the cleared vegetations for construction sites and agricultural development. This further enhanced to the decrease in natural vegetation in the area.

The conversion of agricultural land to build up area is rapid. Agricultural land witnesses an increase from 6178.6 Hectares (8.7%) to 6178.6 Hectares (19.1%) between 1972 and 1987, with annual change rate of 497.3 Hectares. Thereafter, decreases from 18462.2 Hectares (25.9%) to 10825.2 Hectares (15.2%) between 1997 and 2012 with annual change rate of -509.1 Hectares respectively.

This result implies that between the period of 1997 and 2012, there is a decrease in agricultural activities likely due to the changes in the occupation of the work force of the area. The people are taking advantage of the FCT for employment opportunity. The relocation of the Federal Capital Territory from Lagos to Abuja creates employment opportunities due to the massive construction work, wide spread commercialization of local economy and rapid urbanization, as such the youths of this area and other migrants move to the city in search for a greener pasture, there by abandoning agricultural activities for women and old people. Most other studies such as Mundia and Aniya (2005) who studied land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS showed that the urban expansion has been accompanied by loss of natural vegetation and urban sprawl. Agricultural land is on the increase in all of these studies because of the need for increase food production to feed the fast growing population. In contrast, this study revealed a decrease in agricultural production.

Bare surfaces witness an increase from 5600.1 Hectares (7.8%) to 6450.2 Hectares (9.1%) between 1972 and 1987 with annual change rate of 56.7 Hectares. Further decrease from 8700.3 Hectares (12.2%) to 8300.1 Hectares (11.6%) was observed between 1997 and 2012 with annual change rate of 26.7 Hectares. This increase is as a result of clearing of natural vegetation for urban development, there by exposing the land to direct contact with rainfall, leading to gully erosion in the area.

The rocky outcrops form part of the numerous hills and granite Inselbergs that slope into the rivers and provide water shed. This land cover increases from 2096.2 Hectares (2.9%) to 2147.2 Hectares (3.0%) between 1972 and 1987 with annual change rate of 3.4 Hectares. Further increase was experienced from 2188.4 Hectares (3.0%) to 2203.4 Hectares (3.1%) between 1997 and 2012 with annual change rate of 1 Hectare respectively. This change could be attributed to the facts that the processes of erosion and denudation erode the soils around the rocks outcrops and exposing them the most, thereby increasing their aerial coverage and making them to look as if they are growing.

Water bodies cover 7236.10 Hectares (10.6%) in 1972. Water bodies then decrease and by 1987 it covered 4352.1 Hectares (6.1%) indicating an annual change rate of -192.3 Hectares. Water bodies then increase to 5521.9 Hectares (7.7%) in 1997 and subsequent decrease to 4156.3 Hectares (5.8%) in 2012 with annual change rate of -91.0 Hectares respectively.

This could be attributed to climate fluctuation and the increase demand of water by the fast growing population of the area for irrigation and other uses. Most of the streams has dried up or are seasonal while the size of the rivers and other water bodies are changing. However, the exposed river beds provide a good source of sand and gravel for the construction industry. The

construction companies excavate these materials. In the process, large open shallow pits are left behind that are sometimes converted into refuse disposal site or get filled with water during the rainy season.

The period of forty (40) years from 1972 to 2012 witnessed considerable increase in population in the study area, this can be inferred from the fact that the land area covered by built-up area, comprising of residential, commercial, industrial and institutional land uses are on the increase, there by affecting other land use/cover categories. For instance, the maps confirmed that built up areas increases from 1.4% to 9.9% from 1972 and 1987. Further increase from 16.80% to 38.81% was witnessed from 1997 to 2012.

The most dramatic increase and the continuous expansion experienced in built-up area are shown between 1990 and 2012. Coincide with the relocation of the Federal Capital Territory (FCT) from Lagos to Abuja in 1991. This results to rapid population growth due to the proximity of the area to the Federal Capital Territory with affordable accommodation for low and middle income workers, low land prices. The upsurge in population of the area was further enhanced in recent time by the desire of the FCT administration to restore Abuja to its master plan by the demolition of all forms of illegal structures within its territory.

This rapidly growing population area with a mixture of low and high density developments is characterized by mixed land use. In this case, the frontage of the houses are used as shops, workshops and other small scale economic activities while the inner rooms are used for residences. Mixed used is more common near the major roads in Mararaba, New Nyanya, New Karu, Ado, Koroduma and Masaka. However, other specific land uses are also identified such as commercial land use comprising of banks, markets and shopping complexes, serviced oriented activities such as retailing finished products and petrol filling stations. Industrial land

uses include privately owned informal businesses like welding, furniture making, and general electrical and engineering works. It is difficult to determine the spread of these informal industries.

Analysis and field work revealed that most of the areas with mixed land uses are unplanned, with high density developments within the right of way of the Abuja-Keffi highway, local distributors, streets and water bodies. Masaka is a major indigenous settlement that has grown organically without much planning and has the highest record of encroachments. The residences are clustered and accommodate many low income workers from Abuja. Koroduma, hitherto an independent small settlement, having a large span of land has almost engulfed by urban growth spilling from Mararaba. The densely populated parts of the settlements are those adjoining the unplanned part of Mararaba with a mixture of modern and traditional houses. However, standard is maintained in some parts of Mararaba. For instance, Nasarawa State Investment and Property Development Company (NIPDCO) housing estate, which is a high income low-density area, is well planned. Also there are some few planned residential developments, especially the official estate accommodating the leadership and staff of Karu Local Government in Ado.

4.3 LAND SUITABILITY ANALYSIS

The development of the GIS suitability analysis is the major part of this research. Two major land-use categories were developed: urban expansion and agricultural development. Each of them has been visualized in a scheme in such a way that relationships between goals, objectives and sub objectives can be clearly seen. The weighting system for the goals and objectives are presented. Finally, the results of the suitability maps are presented.

4.3.1 URBAN DEVELOPMENT

The aim is to include everything that is important when it comes to urban development. Carr and Zwick (2007) have the following statement on it. The category which includes all land-uses commonly found within the umbrella of urban use. These include residential, commercial, institutional uses. Two goals were particularly stressed in the urban development: Lands most suitable for residential and commercial use. Each goal was subdivided in two objectives; lands most suitable from both physically and economically point of view. These were then further subdivided in themes that were of relevance for the concerning objectives. In dialogue with Nils Viking (personal communication, 2009), project manager and urban planner, it was decided to try to create mixed development instead of block zoning. To achieve this, all urban types, except industrial land-use, are included in each other's preferences, and defined as suitable. This means that residential and retail areas are also suitable for office and commercial land- uses.

4.3.1.1 Lands Suitable for Residential Use

The first goal, which aimed at finding the most suitable lands for residential uses, consists of two objectives and nine sub-objectives based on economical and physical suitability. First, the objective dealing with economical suitability revealed that, it is important to live close to facilities like schools and health care for the vast majority of the population. In general, people prefer to live near one another, and therefore lands proximal to existing residential areas were included as most suitable. Furthermore, it is convenient to live close to roads. It is cost-effective to have residential areas close to existing public water services. Finally, lands proximal to existing office/commercial and retail land-uses were also identified as suitable, as shown in table 4.5 and figure 4.7.

Table 4.5: weighted overlay table of Lands economically suitable for residential use

Parameters	Influence (%)	Scale value

Existing residential land use	50	Ranked between 1-10 based on proximity
Land proximal to schools	10	Ranked between 1-10 based on proximity
Land proximal to health care	10	Ranked between 1-10 based on proximity
Land proximal to roads (buffered)	10	Ranked between 1-10 based on proximity
Land proximal to bore holes	10	Ranked between 1-10 based on proximity
Land proximal to existing commercial land use	10	Ranked between 1-10 based on proximity

Source: Author's GIS Analysis, 2012

Apart from sub-objectives dealing with economical suitability, there were also a number of Sub-objectives describing the physical suitability for residential land-use. Three sub-objectives were included to model this type of suitability. First of all, the soil should be suitable to build on. Lixisols is most suitable for urban development, as such ranked the highest-7. Secondly, the land must be free of potential floods, in order to be a safe place to live. Finally, the topography must be suitable for residential development; flat topography is more suitable than high topography, as shown in table 4.6, 4.7, and 4.8 and figure 4.6 and 4.7.

Table 4.6: weighted overlay table of Lands physically suitable for residential use

Parameters	Influence (%)	Scale value
Soils	25	Lixisols -7 Arenosols -2 Leptisols -1
Flood potential	40	5- Very low 4- Low 3- Moderately low 2- High 1- Not suitable (very high)
Slope	35	Low -5 Medium -3 High -2

Source: Author's GIS Analysis, 2012

Table 4.7: weighted overlay table of Flood potential areas

Parameters	Influence (%)	Scale value
Slope	20	Low -5 Medium -3 High -2
Water	65	Ranked from 1-10 based on proximity to water bodies

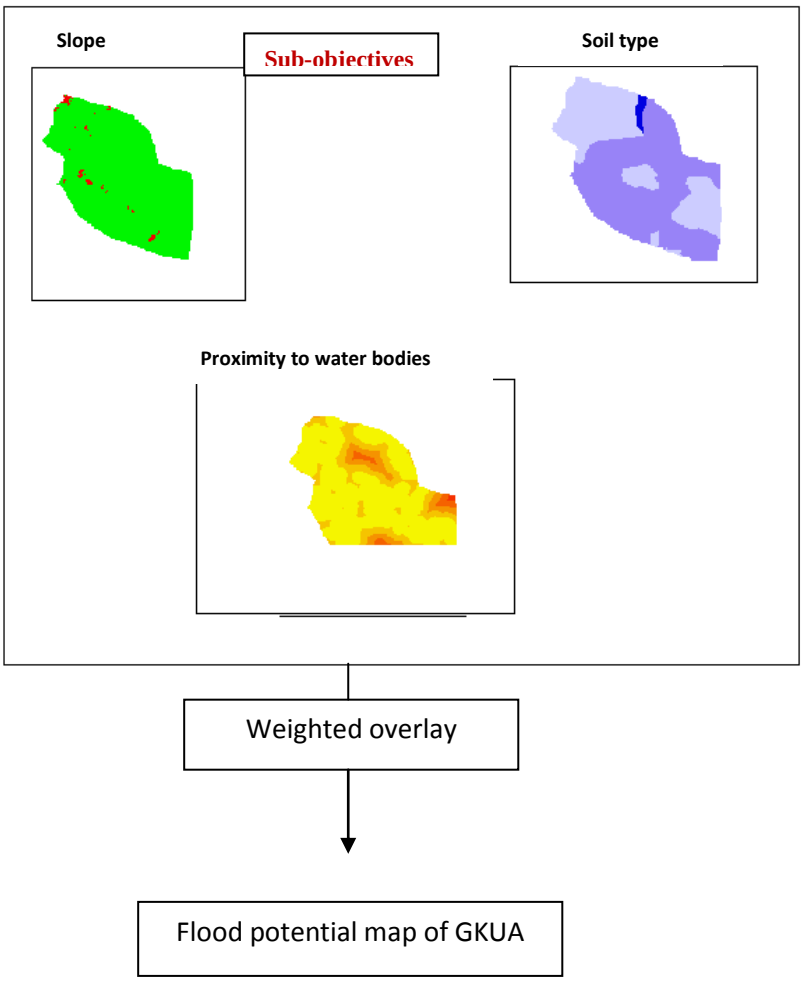
Soils	15	Arenosols -7 Leptosols -2 Lixisols -1

Source: Author's GIS Analysis, 2012

Table 4.8: weighted overlay table of Lands suitable for residential use

Parameters	Influence (%)	Scale value
Land physically suitable	70	5 High 3 Medium 2 Low 1 Restricted (Not suitable)
Land economically suitable	30	5 High 3 Medium 2 Low Restricted (Not suitable)

Source: Author's GIS Analysis, 2012



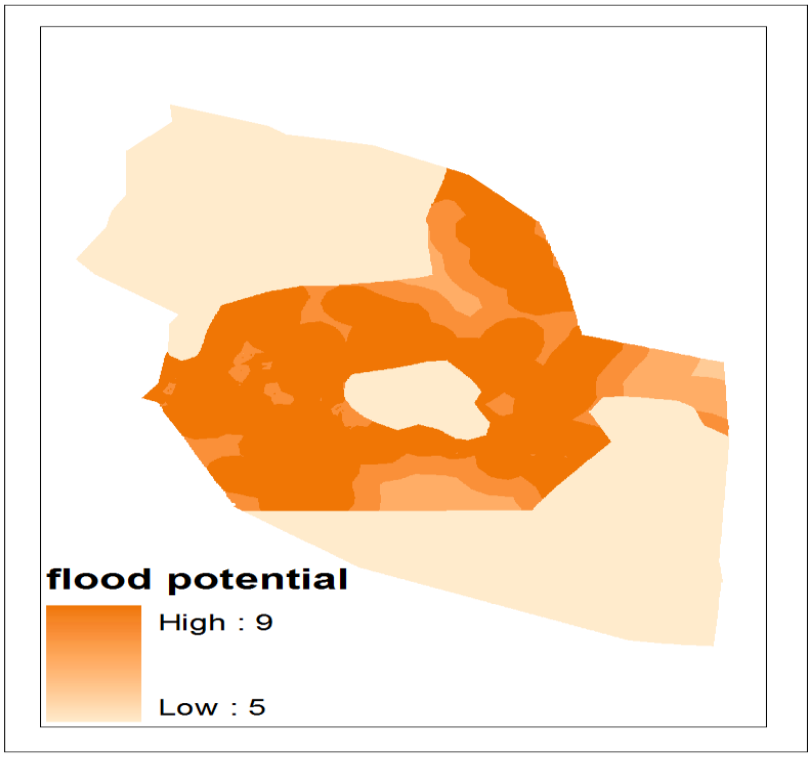
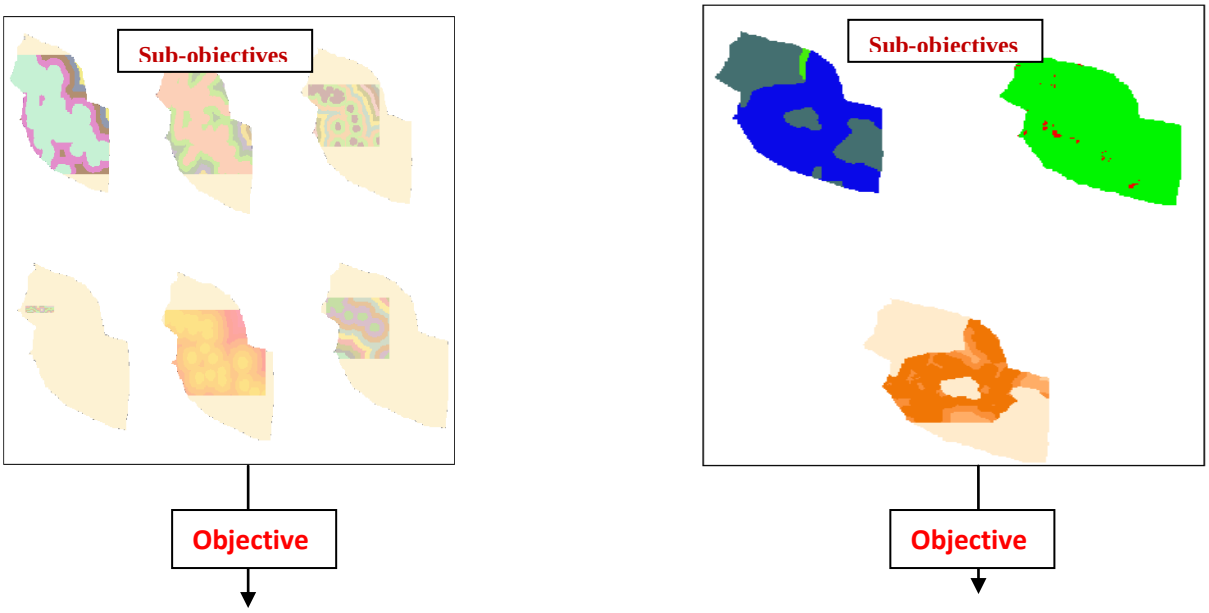


Figure 4.6: Flowchart showing the flood potential areas.
Source: Author's GIS Analysis, 2012



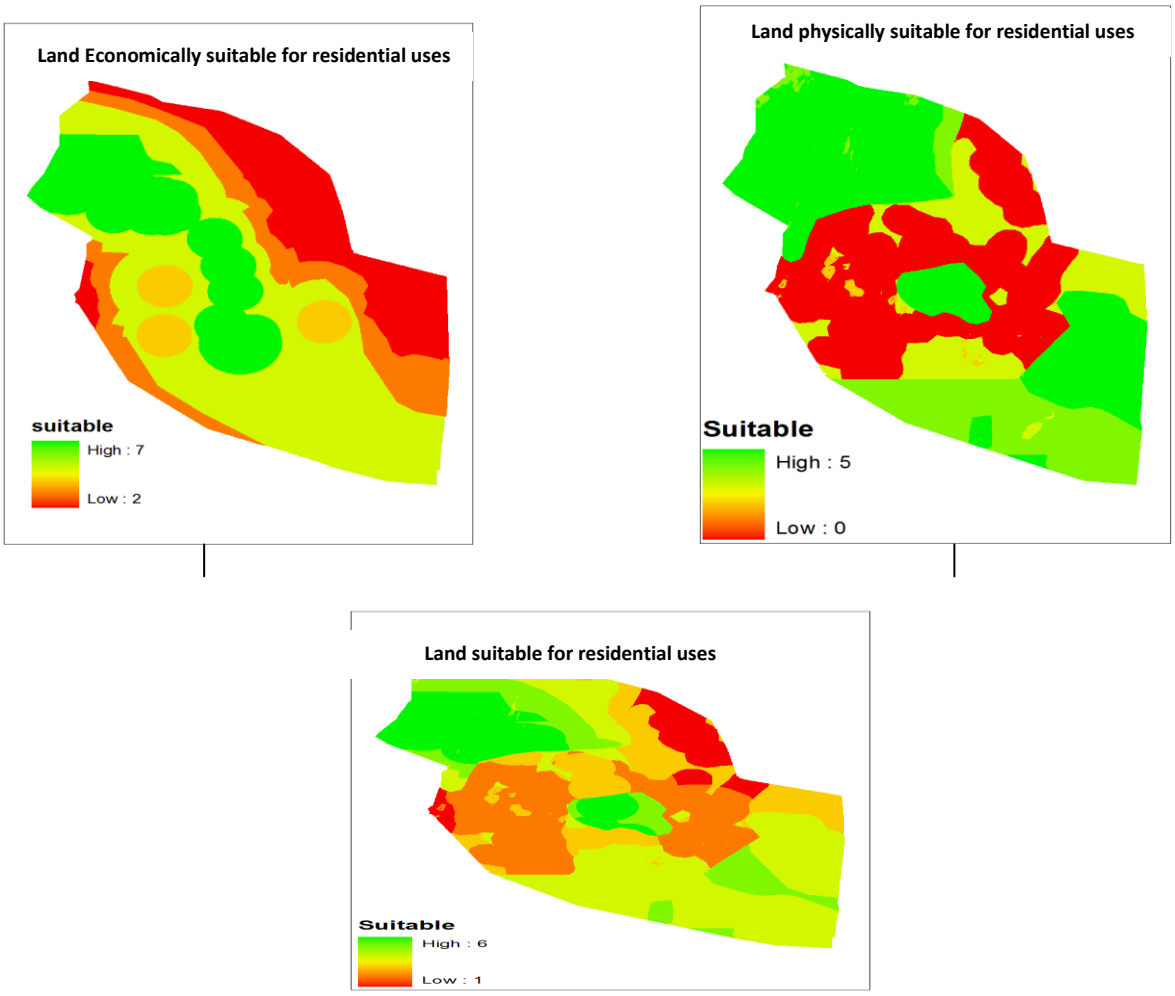


Figure 4.7: Flowchart showing the creation of objectives and goals for Lands suitable for residential uses. Fictive weights have been added to illustrate the method. Source: Author's GIS Analysis, 2012.

4.3.1.2 Lands Suitable for Commercial Use

The second goal is aimed at finding lands suitable for commercial use. The sub-objectives describing the physical suitability for commercial land-use were identical to the ones for residential land-use, as shown in table 4.8.

Table 4.9: weighted overlay table of Land physically suitable for commercial use

Parameters	Influence (%)	Scale value
Soils	20	Lixisols -7 Leptisols -2 Arenosols -1
Flood potentials	50	5- Very low 4- Low 3- Moderately

		2- High 1- Restricted (very high)
Topography	30	Low -5 Medium -3 High -2

Source: Author's GIS Analysis, 2012

With relation to economic suitability, there were differences in what was important compared with residential land-use. For commercials, it is important to be located along roads to be easily reachable for customers. To amplify this, a sub-objective was included that such lands should be proximal to major roads, which are even more attractive for offices to be located. Also lands proximal to major roads intersections are suitable for commercial uses. Furthermore, it is preferable to develop commercial areas/offices proximal to existing residential areas to increase the chance of success. Finally, areas close to existing commercial areas such as markets were identified as preferable concerning cost effectiveness, as shown in table 4.8 and figure 4.8.

Table 4.10: weighted overlay table of lands economically suitable for commercial use

Parameters	**Influence (%)**	**Scale value**
Land proximity to existing commercial land use	50	Ranked between 1-10 based on proximity
Lands proximity to roads	30	Ranked between 1-10 based on proximity
Land proximal to road intersections	15	Ranked between 1-10 based on proximity
Land proximal to residential	5	Ranked between 1-10 based on proximity

Source: Author's GIS Analysis, 2012

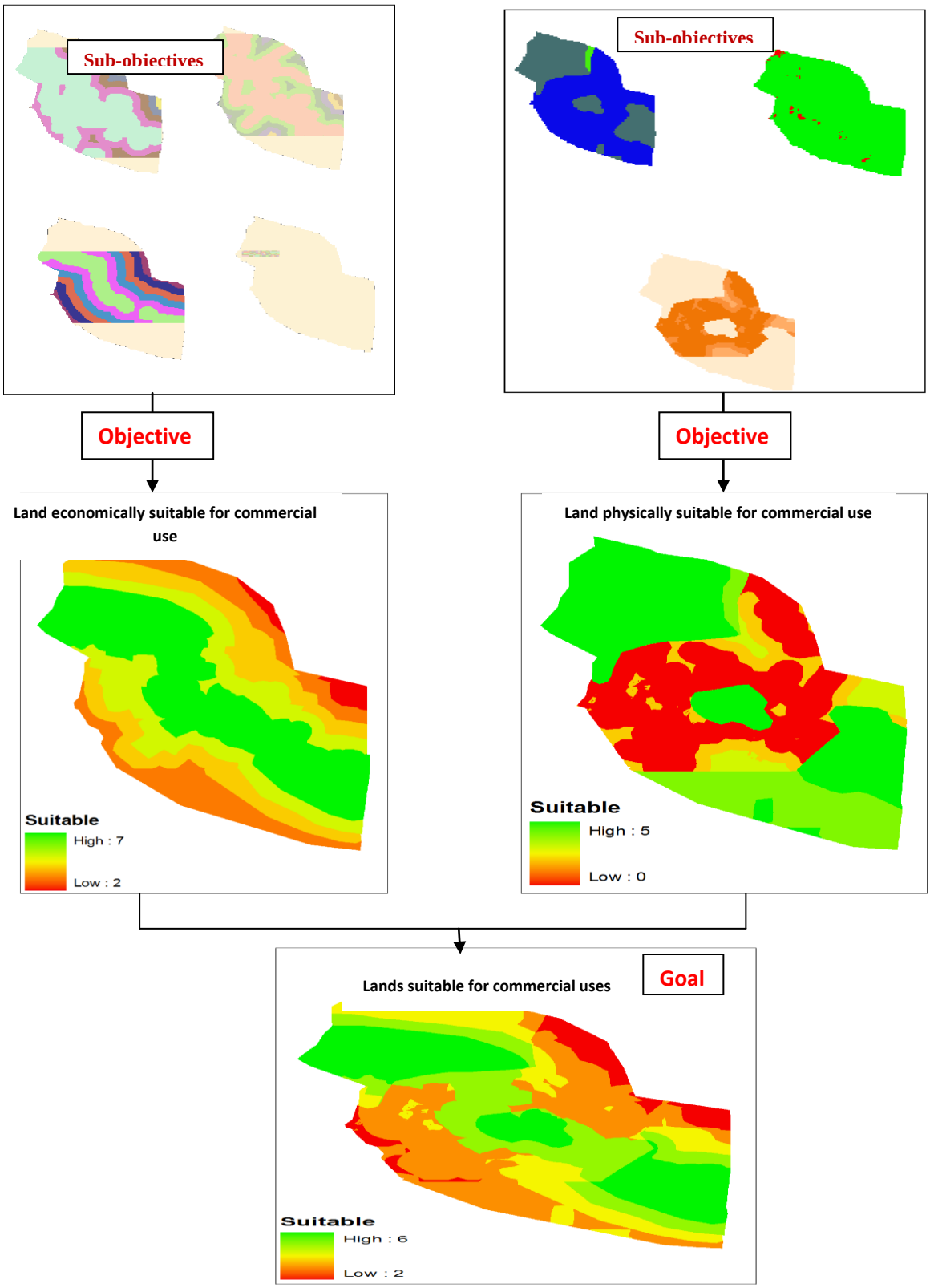


Figure 4.8: Flowchart showing the creation of objectives and goals of Land suitable for commercial use. Fictive weights have been added to illustrate the method. Source: Author's GIS Analysis, 2012

4.3.2 AGRICULTURAL LAND USE

Carr and Zwick (2007) defined agriculture as follows: "This category includes the full range of Agricultural uses and can be customized depending upon one's region and character of agriculture to be found there ". Agriculture has a goal, the goal identified lands that were suitable for crop productions based on physical suitability.

Physical suitability was further subdivided in three Sub-objectives. The first sub-objective identified lands with suitable soils for crop production. This is important to ensure good growth of crops. Arenosols was discovered to be the most suitable. Secondly, the topography was also considered for its suitability for crop productions Verdoodt and Van Ranst (2003) introduced eight capability classes that tell something about the possibility of sustainable forms of agricultural land uses in a certain area. This capability is not only based on the risk of erosion, but also on soil depth which is an important characteristic for vegetation and whether or not it is possible to build terraces. In this regards, low slope areas are the most suitable. Finally, lands close to water were identified as suitable. Crops need water to grow, which makes lands close to water more interesting than lands far away from water, as shown in table 4.10, and figure 4.9.

Table 4.11: weighted overlay table of lands physically suitable for agricultural use

Parameter	Influence (%)	Scale value
Soil	60	Arenosols -7 Lixisols -2 Leptesols -1
Water	25	Ranked from 1-10 based on proximity to water bodies
Topography (slope)	15	Low - 5 Medium -3 High -2

Source: Author's GIS Analysis, 2012

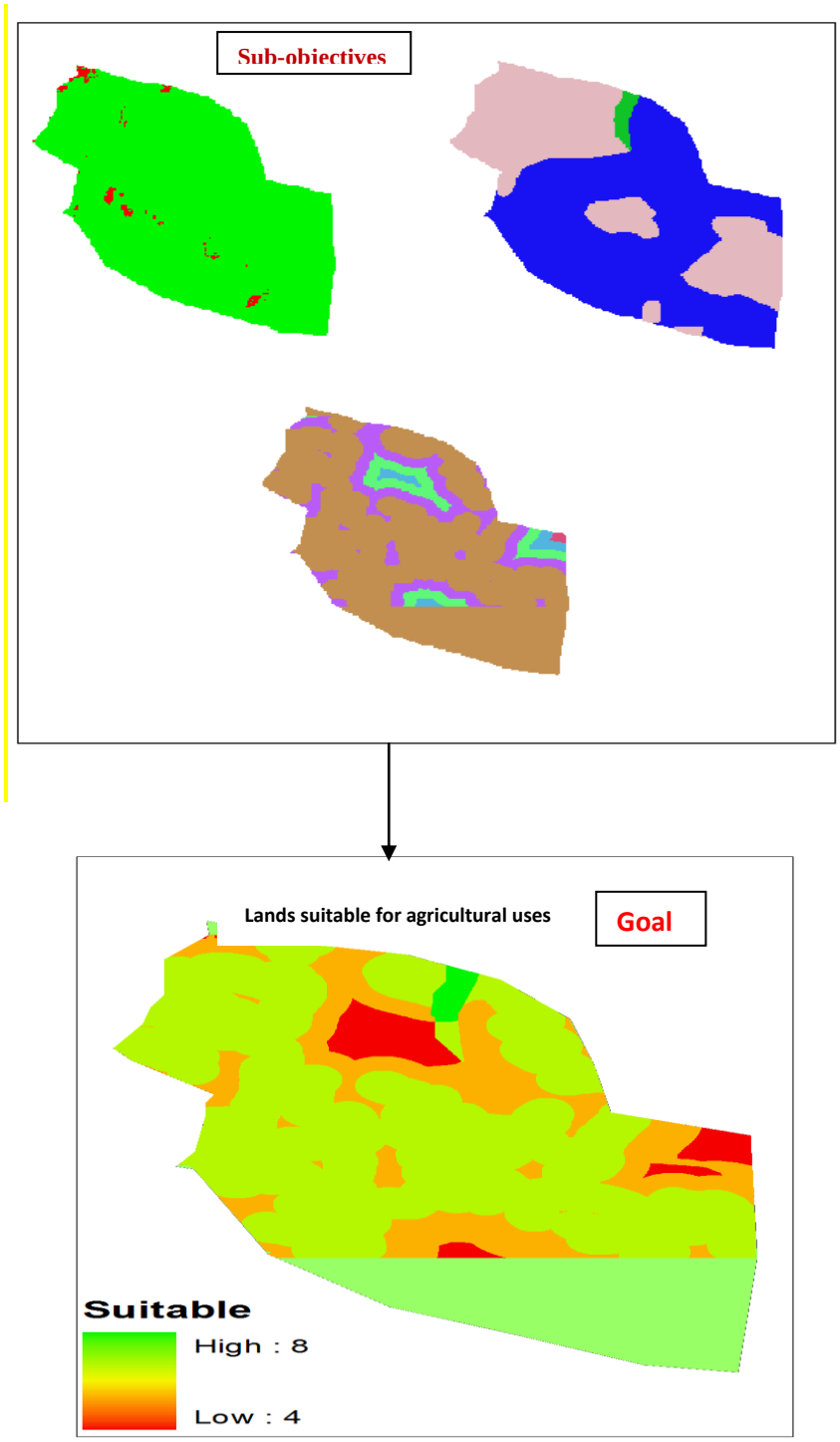


Figure 4.9: Flowchart showing the creation of objectives and goals for lands suitable for agricultural uses. Fictive weights have been added to illustrate the method. Source: Authors GIS Analysis, 2012

4.4 SUITABILITY AND PREFERENCE

All sub-objectives and objectives of the land-use categories were combined into three final maps, representing the preference for each land-use category. This is done by using weighted overlay, in spatial analysis ArcToolbox of ArcGIS 9.3, based on suitability and Land Use Act Cap 202 of 1990 of the Nigerian Urban and Regional planning guidelines. The areas delineated as highly suitable are the most suitable for urban development, commercial and agricultural production in the Area. The suitability maps are shown in figures: 4.10, 4.11 and 4.12. Suitability maps themselves are interesting and informative for land use planning which shall be used for land use management purposes.

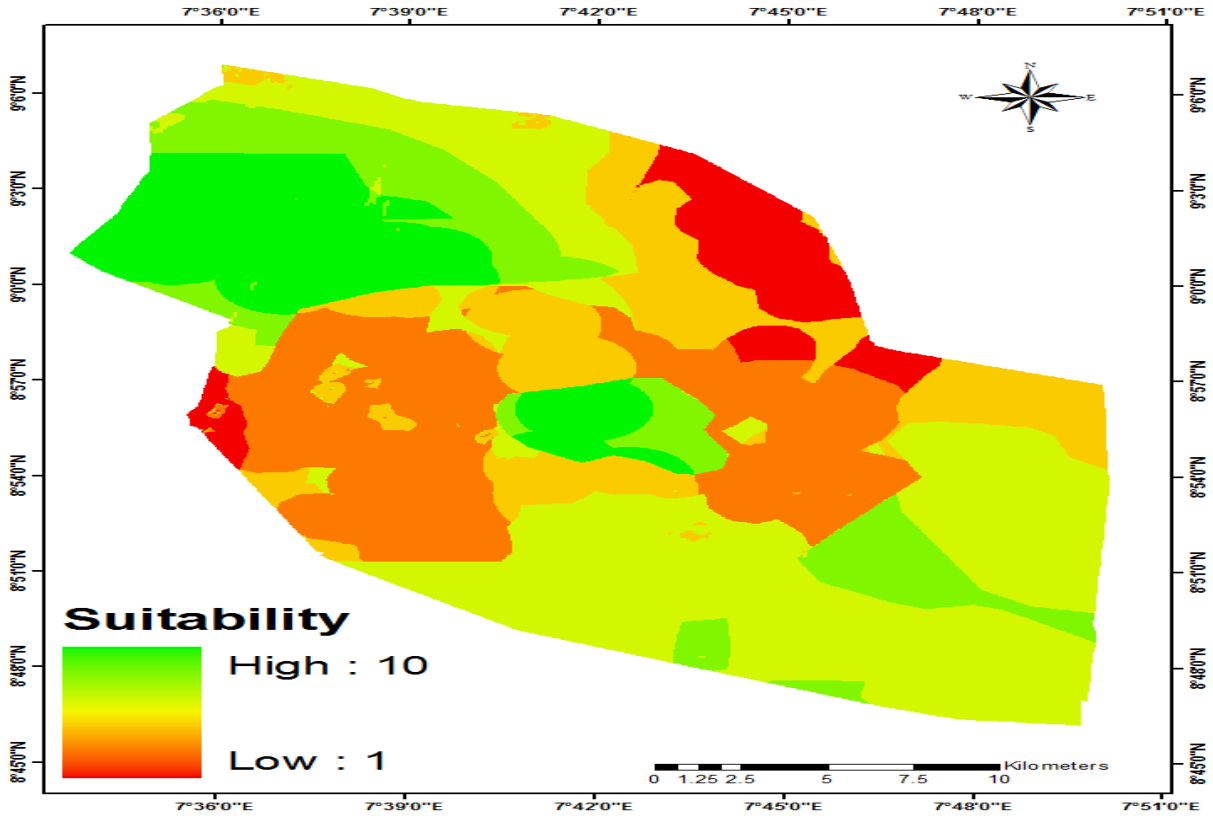


Figure 4.10: Final preference for urban land-use. Source: Author's GIS Analysis, 2012

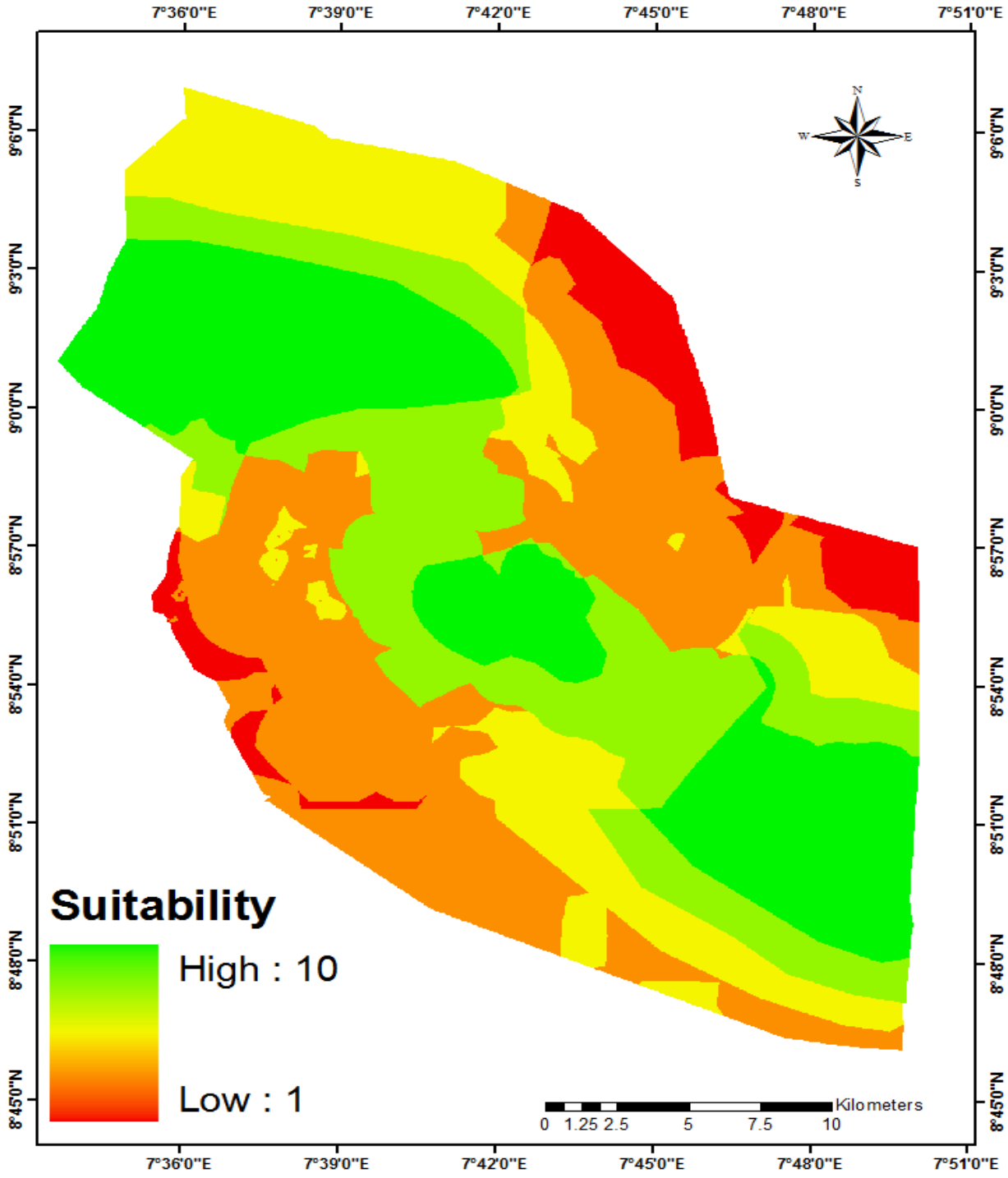


Figure 4.11: Final preference for commercial land-use.

Source: Author's GIS Analysis, 2012

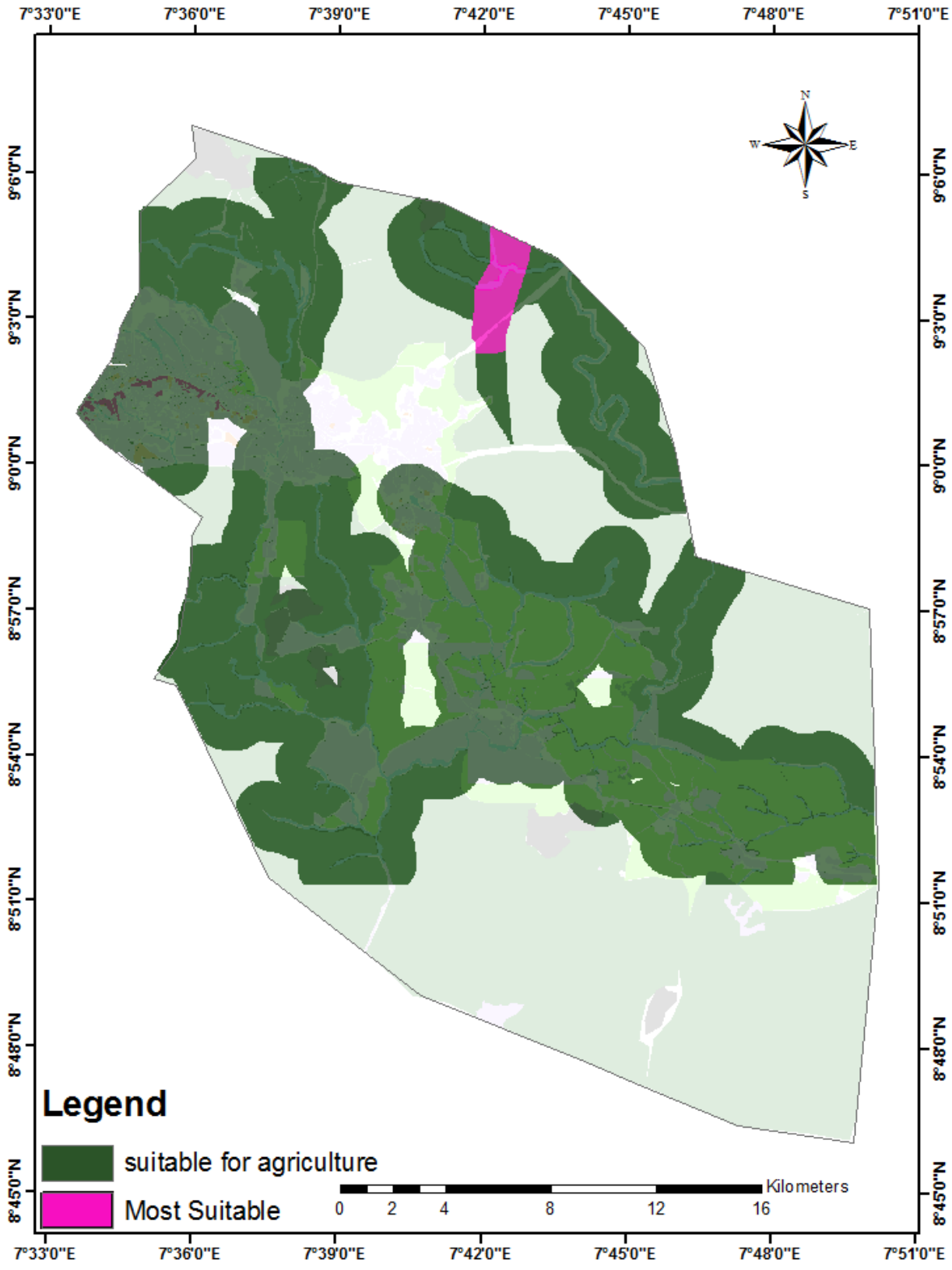


Figure 4.12: Final preference for agriculture land-use. Source: Author's GIS Analysis, 2012

Land-use suitability analysis is one of the most useful applications of GIS for planners and land managers. The most frequently raised problem in GIS Multi-criteria decision making is how to establish weights for a set of activities according to importance. Saaty (1980) has shown that this weighting of activities in Multi-criteria decision making can be dealt with using AHP. The analytic hierarchy process (AHP) is a comprehensive, logical and structural framework, which allows improving the understanding of complex decisions by decomposing the problem in a hierarchical structure. AHP is a widely used and proven method for obtaining weights when dealing with multiple variables. The areas delineated as highly suitable are the most suitable for urban development, commercial and agricultural production in GKUA. In contrast with most other land-use suitability applications for land use management, this method combines all the spatial factors that are important, and results in a map with the best locations for a certain type of land-use. Most often with spatial MCDA, the goal is to find the most suitable location for urban expansion and agricultural development. In this case however, more than one stakeholder might be interested in a certain location.

In contrast, most existing Spatial Decision Support Systems (SDSS), which are decision making tools that make use of spatial MCDA, often concentrate on a specific type of land-use; For example much research done in the area of GIS suitability model' in the decision making process of urban development by Malczewski (2004); Sheppard and Meitner (2005); Hajkowicz (2007) concentrate on urban development. The original Land Use Management suitability model (Carr and Zwick, 2007) use urban development, Agricultural and Conservation land use and therefore it was decided to be adopted in the GKUA Model. A real comparison between the results obtained by the original LUCIS model (Carr and Zwick, 2007) and the results presented in this work is that, the original model integrates stakeholders' wishes and other spatial factors

that are important in decision making process. It also consists of all land-use categories that give shape to a country.

In contrast, the stakeholders were not involved in the GKUA Land Use Suitability Model. This makes it impossible to discuss the model and weights with them. When developing a countrywide GIS land-use model, it is important that all involved groups have the possibility to comment on the proposed model. Due to the limited time, resources, and small aerial coverage, this was not possible in this work. However, this study create a buffer zones around water bodies (rivers and marshy area), and road networks to satisfy the set criteria of distance. The guidelines in line with Land Use Act Cap 202 of 1990 and the Nigeria Urban and Regional planning Act of 1990 to monitor and control all developments approved setbacks was adopted. Using union operation and ArcGIS transparency tool, the buffer zones generated were grouped together and overlaid on the land use map generated from digitized higher resolution satellite imagery (Spot-5) to determine encroached areas.

In contrast with the Florida case study, Carr and Zwick (2007) make use of aerial photographs to serve as reference for the suitability, preference and conflict maps. When looking at these maps, the ease to orientate is striking. On the other hand, using transparency is always a trade-off between two layers. A high transparency of the suitability layer makes sure that the aerial photograph is clearly visible, but suitability colors are then harder to distinguish. In the opposite way are suitability colors easy to distinguish, but is the visibility of the aerial photograph in jeopardy. Playing around with transparency values often works best to determine the best visibility for both layers. However, the created suitability, preference, and conflict maps provide a firm mean for discussions and decision making. The suitability maps based on the sub

objectives, objectives, and goals provide insight in detailed themes the suitable areas for residential, commercial and agricultural development so that patterns can be discovered.

In conclusion, a GIS-based model has been developed base on important spatial factors that are important for urban expansion and agricultural development. It is focusing on two main land-use categories: urban and agricultural development. This combination, for as far as known, is very rarely used before. Due to its potential, it is certainly worth more attention, and hopefully more research will be done in this area.

4.5 ENCROACHMENTS INTO THE APPROVED SETBACK AREAS

In this section, the extent of encroachment into the highway (Abuja-Keffi), local Distributor, access roads and water bodies were look into. This is to capture and determine the encroachment of buildings into these approved setback areas.

4.5.1 Abuja- Keffi Highway

The Abuja- Keffi Highway is the main arterial route in the circulation system and serves as a major regional highway linking the Federal Capital Territory with the northern and eastern part of the country. As such, it plays an important role by virtue of this position as the most important factor in the growth and development of GKUA. Field work revealed that, the road is surfaced with asphalt and designed to the standard of a trunk 'A' highway with a 90 meters Right Of Way (ROW). However, analysis shows that most of residential buildings and commercial activities are located within the right of way of the highway, through the use of temporary structures like kiosks and other structures fronting the road.

Field survey revealed that Mararaba has the largest concentration of encroachments especially around building materials, timber shed, fruits and vegetables market and livestock market. For instance, of the total length of 9.6138 sqkm Highway, 2.5468 sqkm along this route was encroached by commercial activities and refuse disposal as shown in table 4.11 and figures 4.13 and 4.14. Most of the commercial activities of retailing, hawking and transportation companies are located within the right of way. This attracts a heavy flow of traffic which peaks in the morning and evening hours, reflecting the patterns of journey to work to Abuja. The volume of traffic on the road is clearly beyond its design capacity as indicated by the acute delays in the traffic during peak hours and frequency of vehicle accidents.

Table 4.12: Road hierarchy and Conditions

ROUTE TYPE	No	Total Area (SqKm)	Right of way	Encroachment (SqKm)	Surface material	Condition
Express way	1	9.6183	90 m	2.5468	Bitumen	Fair
Local distributors	12	4.6212	30m	1.305	Earth	Poor
Access roads	208	3.1319	15 m	1.345	Earth	Poor/fair

Source: Author's GIS analysis, 2012

4.5.2 LOCAL DISTRIBUTORS

GKUA is linked to other settlements in the area by sub-regional roads branching from the Abuja-Keffi highway. The roads lead to several rural settlements such as old Karu, Aso, Panda and Gurku. These roads are unsurfaced but with laterite dressing. Furthermore, the roads are without maintenance and are out of service during periods of heavy rain. However, these roads

provide the only access depended on by most of the settlements in the sub-region. Results from this study revealed encroachment of 1.305 sqkm on both side of these roads by commercial activities. Further encroachments by residential and work shop were observed as given on table 4.12 and figure 4.13 and 4.14.

4.5.3 Access Roads/Streets

Access road/streets provide the main means of access to different developers all over the settlements. The roads also set the boundary of landed property and are well defined in the settlements. Most properties are served by access roads in the form of streets of 15 meters wide. This standard is maintained in some parts of Mararaba. For instance, Nasarawa State Investment and Property Development Company (NIPDCO) housing estate, which is a high income low-density area contains a network of 28 streets, most of which are surfaced and in fair condition. Also, the standard of 15 meters wide is maintained. In Masaka, parts of Mararaba and new Karu, the standards vary but are generally less due to encroachments. In some areas of these settlements, the streets terminated abruptly probably due to the challenges of informal land delivery and its consequences of haphazard buildings with little or no plans as shown in figures 4.13 and 4.14. Of the 3.31319 sqkm streets in the area, 1.345 sqkm have been encroached by residential and commercial activities, as given on table 4.12.

4.5.4 Rivers, Lakes and Ponds

Major rivers in GKUA are river Uke and Ado. Others are small seasonal rivers. The analysis revealed the encroachments of buildings and fishing communities in the approved set back areas around rivers in the area, as given in the table 4.12.

Table 4.13: class of water bodies and their conditions

Feature	No	Total Length (SqKm)	Setbacks (SqKm)	Encroachment (SqKm)
Rivers	2	130.5	30	21
Streams/marshy	21	304	15	48
Water bodies	3	052	10	19

Source: Author's GIS analysis, 2012

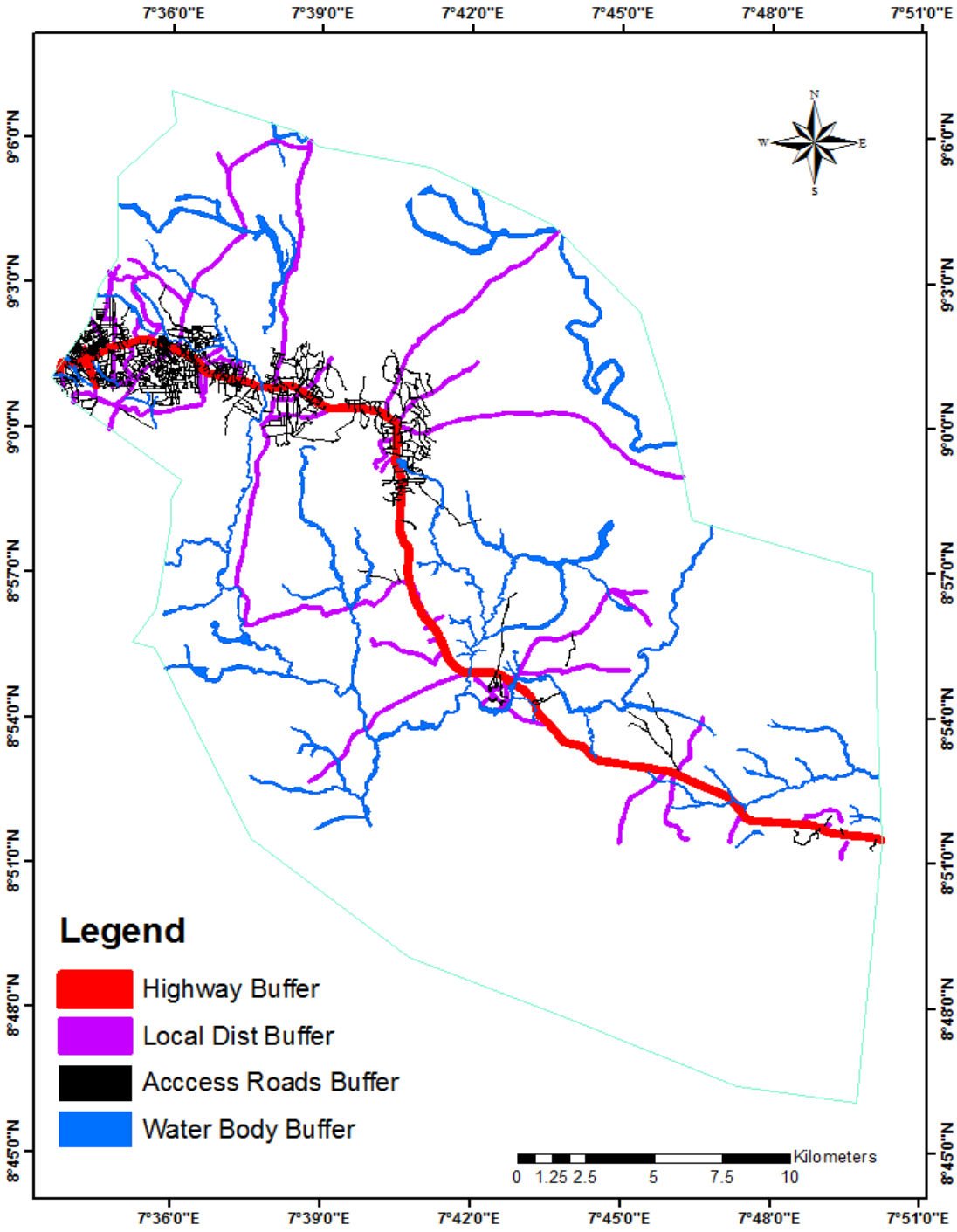


Figure 4.13: Buffer zone of circulations and water bodies.

Source: Author's GIS Analysis, 2012

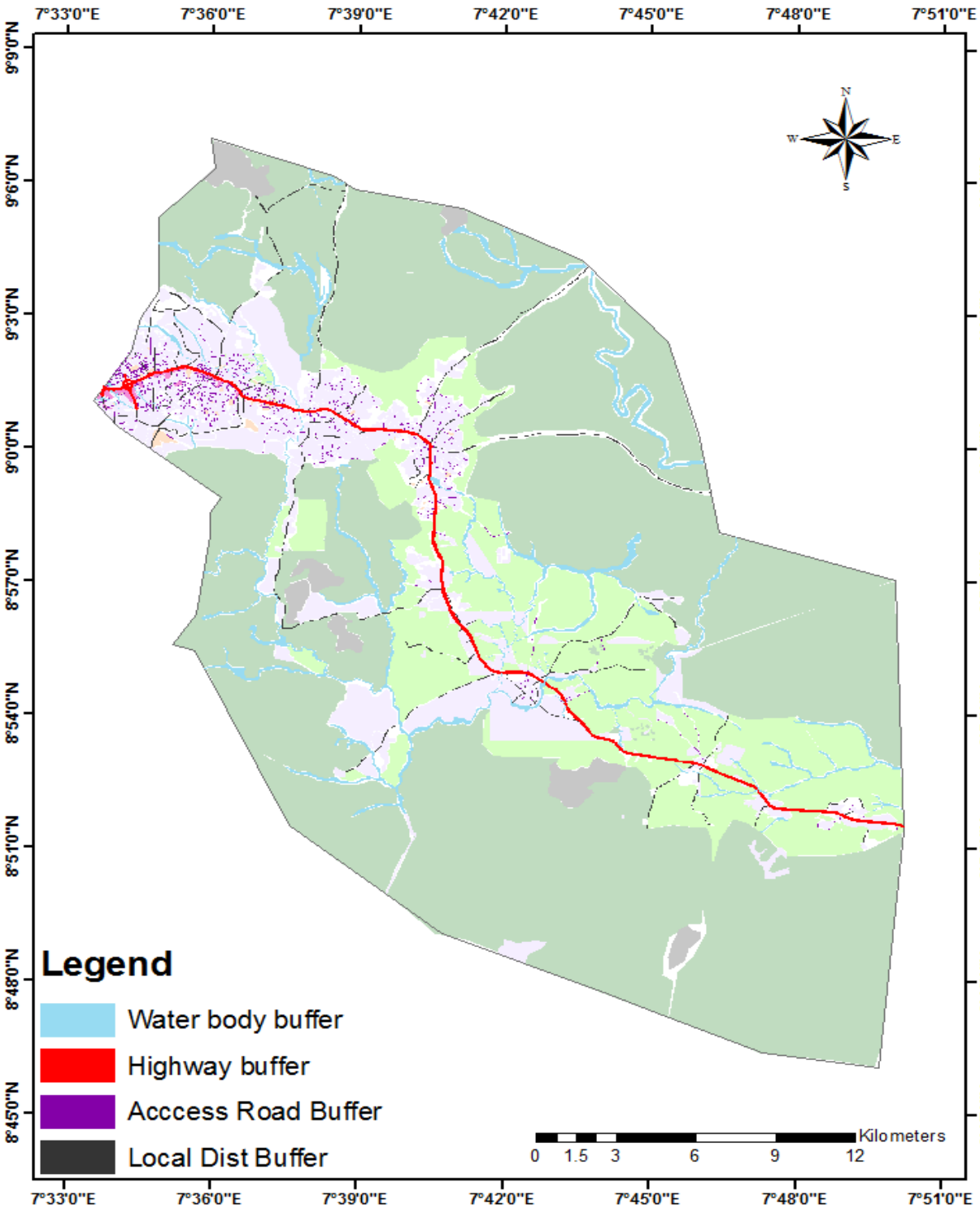


Figure 4.14: Buffer zone of circulations and water bodies overlaid on land use/land cover map of GKUA
Source: Author's GIS Analysis, 2012

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMMENDATIONS

5.1 INTRODUCTION

This chapter sets out to presents the overview of the study and the summary of major finding. Recommendations of the study were also presented.

5.2 OVERVIEW OF THE STUDY

This study demonstrates the usefulness of Remote Sensing and GIS in land use management in GKUA of Nasarawa State. The study make use of Landsat MSS satellite image of 1972, Landsat TM satellite image of 1987, Landsat ETM+ satellite image of 1997, Nigeriasat-1 satellite image of 2012 and SPOT 5 satellite image of 2012 to determine the land use/land cover situation of the area. The study also make use of Topographical, Soil, Geological map, and Global Positioning System to acquired data on Schools, Health centers, markets and Public water (Bore holes). ArcGIS 9.3 and ILWIS 3.2 software were used for data analysis using digital image processing algorithm and spatial analyst tool of the above mentioned software packages. Multi-Criteria Decision Analysis and Analytical Hierarchical Process were also used.

Findings from the results of this study revealed there is a considerable increase of population in the study area, leading to increase in built-up areas and its effects on other land use/land cover categories. The most dramatic increase and the continuous expansion experienced in built-up area are shown between 1990 and 2012. Coincide with the relocation of the Federal Capital Territory from Lagos to Abuja in 1991, GKUA have affordable accommodation for low and middle income workers and the proximity of the areas to Abuja with low land prices contributed to the problem. The increase of built up area resulted to changes in other land use/cover categories between 1972 and 2012 as follow: natural vegetation covering a dominant part of the study area has drastically decline from 68.9% to 52.9% between 1972 and 1987. It further decline from 34.3% to 25.4% between 1997 and 2012. Agricultural land witnesses an increase

from 8.7% to 19.1% between 1972 and 1987. Thereafter, decreases from 25.9% to 15.2% between 1997 and 2012 respectively. Bare surfaces witness an increase from 7.8% to 9.1% between 1972 and 1987. Further decrease from 12.2% to 11.6% was observed between 1997 and 2012. Rocky outcrops increases from 2.9% to 3.0% between 1972 and 1987. Further increase was experienced from 3.0% to 3.1% between 1997 and 2012 respectively.

A water body covers 10.6% in 1972. Water body then decrease and by 1987 it covered 6.1%. Water body then increases to 7.7% in 1997, and subsequent decreases to 5.8% in 2012. Encroachment of built up areas into the approved setback of road network and water bodies are as follow: Highway have total length of 9.6138km^2. 2.5468km^2 along this route was encroached by residential, commercial activities and refuse disposal, local distributors have a total length of 4.6212 km^2, 1.305km^2 on both side of these roads are encroached by shopping and commercial activities, access roads/streets have a total length of 3.31319km^2, and 1.345km^2 have been encroached by residential and commercial activities. Also 21km^2 of rivers, 48km^2 streams, and 19km^2 ponds and lakes were encroached by buildings and fishing communities.

The settlements of GKUA do not have a master plan or Strategic plan to guide their development. The absence of a general development plan, zoning regulation and density control for the area limits effective control and management of land uses. It is a general trend, therefore for land use to change indiscriminately from one type to another type over a short period of time. For example, the conversion of residential dwelling units to commercial and light industrial uses is very common. However, the created suitability, preference, and conflict maps provide a firm mean for discussions and decision making. The suitability maps based on the sub objectives, objectives, and goals provide insight in detailed themes on the suitable areas for residential, commercial and agricultural development.

5.3 SUMMARY OF MAJOR FINDINGS

The use of remote sensing and GIS in Land use Management of Greater Karu Urban Area reveal an increase in built up areas due to continuous expansion, massive construction work, wide spread commercialization of local economy and rapid urbanization of the area as a result of the relocation of the Federal Capital Territory from Lagos to Abuja in 1991. This has imposed significant pressure on the environment and natural resources with serious implications on socio-economic development and spatial organization within the area and beyond its boundaries. Lack of land use planning and zoning regulation results to haphazard land use pattern and unplanned, uncontrolled and informal growth process of settlements in the area. This reduces the quality of life and economic attraction. The search for a way forward will therefore require a synthesis of present situation and the identification of options for feasible intervention. The aim is to cater for present and future needs through approaches that are financially, technically and environmentally suitable. It is recommended that such approaches should reflect important considerations of the environmental effects and the use of locally available human and natural resources.

5.4 RECOMMENDATIONS

Based on the research findings, it is an established fact that the relocation of the Federal Capital Territory from Lagos to Abuja in 1991 results to population increase, rapid urbanization and land use/cover changes in the area. There is therefore the need for Nasarawa State Government to equip the planning authorities and other ministries involved in decision making with adequate spatial data to ensure broad based decisions. This can be achieved by investing in the acquisition and management of remotely sensed data and Geo-Information Technology in order to develop a data base which will enhance the management of land use in the area.

Nasarawa State Government and Karu Area Planning Development Authority should take urgent steps to finalize the master plan being prepared. In view of the shortcoming of master plan approach, the authorities should prepare a development strategy to guide the orderly growth and development of the area. Also, stake holders must participate in decision making on developmental issues that affect them.

Workshops and seminars in remote Sensing and GIS should be organized to help in updating and creating awareness to the major stake holders in the planning and development department of the ministries on the trend on the use of the technology in monitoring and management of land resources and development of the area.

REFERENCES

Adamu, D. (2011). Urban Management Implication of Informal Land Delivery in Karu Urban Area of Nasarawa State. An unpublished M.Sc Thesis, Department of Urban and Regional planning, Ahmadu Bello University, Zaria.

Adebayo, A. A. (1999). Climate II. In Adebayo and Tukur (eds) Adamawa State in map. Yola Paraclete publisher.

Adefolalu, D.O. (1989). Precipitation, Evapotranspiration and the Ecological zones in Nigeria. Theor. Appl. Climatology.

Adeniyi, P.O. (1999). Cited in "Geoinformation Technology Application for Resources and Environmental Management in Africa". Pp 144-148.

Afolabi, A. (1975). "The Role of Cadastral Surveying in Land Development in the Western State of Nigeria." B.S. Department of Surveying Engineering, University of New Brunswick.

Ahamed, N. R. GopalRao, K. Murthy, J. S. R. (2000). GIS-based fuzzy membership model for crop-land suitability analysis. Agricultural Systems, ESRI Press.

Ajayi, F.A, Yakubu, A. and Okunsebor, S.A. (2007). Livestock and Fish Production in Nasarawa State. In: Geographic Perspectives of Nasarawa State. A Publication of the

Department of Geography, Nasarawa State University, Keffi-Nigeria.Onaivi publisher, Keffi.

Akosim, O. Tella.I. O. Jatau D. F. (1999). Vegetation and Forest Resources. In: A.A Adebayo and A. L Tukur (eds) Adamawa State in maps, Yola Paraclete.

Amos, F.J. (1986). 'Plans, Policies and Pragmatism. A Review of the Century of Physical Planning', *Habitat International*, Vol.10, No.4, pg.135-46.

Anonymous, (2001). "Annual Report of Nasarawa State Agricultural Development Programme (NADP).Lafia, Nasarawa State.

Areola, O (1983). Soil and Vegetation Resources. In: Oguntayinbo, J. S., Areola, O. O and Filani M. (eds) Geography of Nigerian Development. Ibadan, Heinemann Education Books, Nigeria.

Aribigbola, A. (2008). Improving Urban Land Use Planning and Management. The Built Environment: Innovation Policy and Sustainable Development. Covenant University, Nigeria. 179-185.

Armstrong, A. (1987). 'Master Plans for Dar es Salaam-Tanzania', *Habitat International*, Vol.11, No.2, pg.133-145.

Arnoff, S. (1995). Geographic information systems: a management perspective, WDL publications, Ottawa, Canada.

Astin, M.P. and J.J. Basinsky. (1978). Biophysical survey techniques. CSIRO, Australia.

Ayoade, J. O. (1988). Introduction to Climatology for the Tropics. Abi prints and park.

Baba, J.M. (1994). "Sustainable Development and the Nigerian Environments". The Nigerian Geographical Journal, Ibadan University Press. Pp 1 - 19.

Bailey, J. (1975). Social Theory for Planning. Rougledge and Kegan Paul Ltd, Pergamon Press. Pp 69-94.

Beek, K. J., A. De Bie and P. Driessen. (1997). Land evaluation for sustainable land management. ITC, Enschede, The Netherlands.

Beek, K. J., P. A. Burrough and D. E. Mc Cormack (1987). "Quantified land evaluation procedures: Proceedings of the international workshop on quantified land evaluation procedures held in Washington, DC 27 April - 2 May 1986". International workshop on quantified land evaluation procedures, Washington, DC.

Belknap, R.K. and Furtado, J.G. (1967). *Three Approaches to Environmental Resource Analysis*. Washington D.C.: The Conservation Foundation.

Bello-Dambatta, A., Farmani, R., Javadi, A.A. and Evans, B.M. (2009). The Analytical Hierarchy Process for contaminated land management. Advanced Engineering Informatics Analysis. International Journal of Applied Earth Observation and Geoinformation. Pp 270-277.

Berman, S. (1997). "Civil Society and political Institutionalization" In Edwards, B. and Foley,M. (Eds.) Social Capital, Civil Society and Contemporary Democracy: A Thematic Issue of The American Behavioral Scientist 40. Pp 552-574.

Berstein, J. (1994). Land Use Considerations in Urban Environmental Management, UNPD/ UNCHS/World Bank Urban Management Programme, Washington DC. Pp 1-8.

Betalanffy, L, (1971). General System Theory. Allen Press

Binn B.O. (1953). Cadastral surveys and records of rights in land, p.1. F.A.O land tenure study, Rome.

Binbol, N.L, (2007) Climate of Nasarawa State: "Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria. Onaivi Publisher, Keffi.

Bouma, J., Wagenet R.J., Hoosbeek M.R. (1993). Using Expert Systems and Simulation Modeling for Land Evaluation at Farm Level: A Case Study from New York State. Soil Use and Management, Vol. 9. Pp. 131-139.

Bronsveld k. Huizing, H. and Omakupt M. (1994). Improving land evaluation and land use planning. ITC journal 4, Pp 359-365.

Carr, M.H., and Zwick, P.D., (2007). *Smart land-use analysis: the LUCIS Model*. Redlands, C.A.: ESRI Press.

Carver, S. J. (1991). Integrating multicriteria evaluation with geographical information systems. International Journal of Geographical Information Systems, 5, Pp 321–339.

Chulvick, C. E., and Waugh, T. C. (1979). Computers in Land Use Planning. In D. Lovejoy, Land Use and Landscape Planning. Bishopsbriggs: Leonard Hill. Pp. 315-320.

Cohon, J.L. (1978). *Multiobjective Programming and Planning*. London: Academic Press.

Dale, P.F. and John McLaughlin (1988). Land Information Management: An Introduction with Special Reference to Cadastral Problems in Third World Countries . Oxford: Clarendon Press.

Dale, Peter and John McLaughlin, (2003) *Land Administration* New York: Oxford University Press, pp. 8–9.

Densham, P. J. Armstrong, M. P. and Kemp, K. K., (1995). *Collaborative spatial decision making .Scientific report for the Initiative 17* (Santa Barbara: NCGIA), pp. 95–14.

Dent, D. (1988). Guidelines for Land Use Planning in developing countries. Soil survey and land evaluation. Allen and Unwin, London.

Dent, D. and A. Yong. (1981). Soil survey and land evaluation. Allen &Unwin, London.

Durand-Lasserve, A. (1990): Articulation Between Formal and Informal Land Markets in Cities in Developing Countries. Issues and Trends. In Baross, P. and Van der Lindery, V. (eds.). The transformation of Land Supply Systems in Third World Cities, Alder-shot, Ashgate.

Enemark, S., Williamson, I. and Wallace, J. (2005). Building Modern Land Administration Systems in Developed Economies. *Spatial Sciences Journal, 50* (2), Pp 51-68.

Ezekiel. C, (2010) The Effect of the Federal Capital Territory Development on Rural Transformation of Karu area of Nasarawa State. An Unpublished P.hD thesis, Department of Geography, Nasarawa State University, Keffi-Nigeria.

Falade, J.B. (2003). "The Urban and Regional Planning Process, the Old Order and the New Paradigm." A paper presented at the 2003 Mandatory Continuing Professional Development Programme (MCPDP) of the Nigerian Institute of Town Planners (NITP) held in Calabar, Asaba and Kaduna.

FAO, (1990). Guidelines for soil profile description. FAO, Rome, Italy.

FAO, (1993). Guidelines for land use planning. FAO development series 1.Food and Agriculture Organization of the United Nations. Rome.

FAO, (1995). Planning for Sustainable Use of Land Resources towards a New Approach. Land and Water Bulletin 2, FAO, Rome.

FAO, (1984). Land evaluation for forestry, forestry paper 48. Food and Agriculture Organization of the United Nations. Rome.

FAO. (1976). A framework for land evaluation. Soils bulletin 32. Food and Agriculture Organization of the United Nations, Rome.

Federal Ministry of Housing and Urban Development (FMH&UD), (2003). Sustainable Human Settlements Development: National Urban Strategies. Petral Digital Press, Abuja.

Foote, K. E. and M. Lynch (1996). Geographic information systems as an integrating technology: context, concepts and definition. Austin, University of Texas.

Funnpheng, P., T. Chitchumnong, S. Mekpaiboonwattana, P. Pramojanee, S. Patinavin, K. Saifuk, K.Bronsveld, and H.G. Huizing. (1994). Implementation of an information system as a tool for land use planning in Thailand. ITC., Pp 447.

George J., (2003). "foundermental of remote sensing" 3rd edition Cambridge University press. India.

Ghafari, A., H. F.Cook and H. C. Lee (2000). Integrating climate, soil and crop information: a land suitability study using GIS. 4th International Conference on Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs, Banf, Alberta, Canada.

Goicoechea, A., Hansen, D.R., and, Duckstein, L. (1982). *Multiobjective Decision Analysis with Engineering and Buisiness Applications*. New York: John Willey and Sons.

Goodchild, D. M and D. Rhind, (1996). *Geographical information systems: Management issues and applications.* Vol. 2. New York: John Wiley & Sons.

Gordon, S.I. (1985). Computer *Models in Environmental Planning*. New York: Van No strand Reinhold.

Habibi, R. (1998). Evaluating Land Evaluation. M.Sc, ITC, Enschede, the Netherlands.

Hajkowicz, S.A. (2007). Supporting multi-stakeholder environmental decisions. *Journal of Environmental Management*, 88 (4), p.607-614.

Harcombe, P. R (2010). A Cadastral Model For Low Value Lands The NSW Western Lands Experience. An M.Sc. Thesis Submitted to the Department of Geomantics, University of Melbourne.

Hardoy, J. E and D. Mitlin, (2001). Environmental Problems in an Urbanizing World: Finding Solutions for Cities in Africa, Asia and Latin America. London, Sterling, Earthscan publications Ltd.

Huizing, H., A. Farshad and C. Debie. (1995). Land evaluation. ITC lecture notes. ITC, Enschede, The Netherlands.

Huizing, H., and K. Bronsveld. (1994). Interactive multiple-goal analysis for land use planning. ITC Journal 19994-4, Enschede, The Netherlands. Pp 366.

Iloeje, N. P (1985). Geography of West Africa. London, Longman Group in Nigeria: A Case Study of Akure. Theoeretical and Emperical Research in Urban Management Adekunle ajasin University, Nigeria.

Jankowski, P. (1995). Integrating geographical information systems and multiple criteria decision-making methods. International Journal of Geographical Information Systems, volume 9, Pp 251–273.

Jiboye A. P. (2005). "Globalization and the Urban Growth Process in Nigeria" Culture and Nigerian Built Environment. Faculty of Environmental Design and Management, OAU, Ile-Ife, Nigeria. 2, Pp 342 -345.

Keech, M. A. (1979). Aerial Photography in Land Use Planning. In D. Lovejoy, Land Use and Landscape Planning. Bishopsbriggs: Leonard Hill. Pp. 309-314.

Kim, J.-W. (2004). A simulation of the growth of the Seoul Metropolitans built-up area with a GIS based PSS model. *Journal of the Korean Planners Association*, 39 Vol. 7, Pp.69–84.

Klosterman, R.E. (1999). The WhatIf? Collaborative Planning Support System. *Environmental Planning B*, 26, P p.393–408.

Klosterman, R.E., Siebert, L., Ahmadul, M., Kim, J,-W., and Parveen, A., (2003). Using an operational planning support system to evaluate farmland preservation policies. *Planning Support Systems in Practice*, Pp. 391–408.

Kombe, W (2000). 'Reconciling Informal and Formal Land Management. An Agenda for Improving Tenure Security and Urban Governance in Poor Countries', *Habitat International*, Vol. 24, pg. 231-240.

Kombe, W. J. (1995).'Community Based Land Regularisation-Prospects for Decentralized Planning', *TRIALOG*, Vol.55, Pp.27-31.

Kreibich, V. and Olima, W. (eds.) (2002). Urban land Management in Africa. Spring

Leingsakul, M., S. Mekpaiboonwatana, P. Pramojanee, K. Bronsveld and H. Huizing (1993). "Use of GIS and remote sensing for soil mapping and for locating new sites for

permanent cropland a case study in the highlands of northern Thailand." Geoderma Vol.60 Pp 293-307.

Lillesand, T.M. and Kiefer, R.W. (2004) "Remote Sensing and Image Interpretation", 5th Edition, John Wiley & Sons.

Longley, P.A., Goodchild, M. F., Maguire, D. J., Rhind, D. W. (eds) (1999). Geographical Information Systems: Principles, Techniques, Management and Applications. John Wiley, New York.

Lyle, J. and Stutz, F., (1983). Computerized Land Use Suitability Mapping. *Cartographic Journal*, 20, Pp.39–49.

Mabogunje, A. L. (2002). "Re – constructing the Nigerian City: The New Policy on Urban Development and Housing". A keynote address in Amole, D. et al. The City in Nigeria: Perspective, Issues, Challenges, Strategies. Proceedings of a National Conference. Obafemi Awolowo University Ile – Ife, Nigeria, pp 1 – 9.

Mabogunje, A.L. (1992). A New Paradigm for Urban Development. The World Bank, Washington D.C.

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*, 62, Pp.3-65.

Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*, Vol. 62, Pp.3-65.

Malczewski, J. (2006). GIS-based Multi-criteria Decision Analysis: A Survey of the Literature. *International Journal of Geographical Information Science*, 20 (7), Pp.703-712.

Malczewski, J. and Ogryczak, W. (1996). The multiple criteria location problem: 2. Preference-based techniques and interactive decision support. Environment and Planning A, Vol. 28, Pp 69–98.

Malczewski, Jacek (1999). GIS and Multicriteria Decision Analysis. New York: John Wiley and Sons, Inc.

Marble, D. H., H. W. Calkins and D. J. Pequet (1984). Basic Readings in Geographic Information Systems. Williamsville, NY., SPAD Systems Limited.

Marcus, N.D and Binbol, N.L, (2007). "In Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria. Onaivi publisher, Keffi.

Marull, J. Pino, J. Mallarach, J. M. Cordobilla, M. J. (2007). A Land Suitability Index for Strategic Environmental Assessment in metropolitan areas. Landscape and Urban Planning, 81, Pp 200-212.

Masser, I and Campbell, H. (1995). GIS in Organizations in Royal Town Planning Institute. National Statistical Report. RTPI Services, London.

McHarg, I.L. (1969). *Design with nature*. Garden City, N.Y. Doubleday/Natural History Press.

McHarg, I.L. (1996). *A Quest for Life.* New York: John Wiley and Sons.

Medyckyj-Scott D, Hearnshaw H. M. (1993). *Human factors in geographical information systems*. London, Belhaven Press.

Mendoza, G.A. and Martins, H. (2006). Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms. *Forest Ecology and Management*, 230, Pp.1-22.

Miller, L. (1993). Charles Eliot, preservationist, park planner, and landscape architect. Pennsylvania State University, Department of Landscape Architecture, State College, Pennsylvania.

Msuku, I.R. (1990). Land Evaluation of Mangochi project area in Malawi for grazing by Application of ALES. MSc, ITC, Enschede, The Netherlands.

Mundia C.N and Aniya, M. (2005). Analysis of land use/cover changes and urban expansion of Nairobi city using remote sensing and GIS. International Journal of Remote Sensing, Vol. 26, Pp 2832

Nag, P and Kudrat, M. (1998). *Digital Remote Sensing.* New Delhi. India

Nisar, A. GopalRao, K., Murthy, J. S. R., (2000). GIS-based fuzzy membership model for crop-land suitability analysis. Agricultural Systems, 63. Pp 75-95.

Nnah, W. W., O. B. Owei and M. Ikpoki (2007). "Development Control and the Public Interest in Obio/Akpor Local government Area of Rivers State, Nigeria". Journal of the Nigerian Institute of Town Planners. Vol. XX No. 1.

Noroozi, A.A. (1997). Land Evaluation and the effect of land use systems on soil erosion using RS and GIS techniques supported by ALES. M.Sc, ITC, Enschede, The Netherlands.

Nwaka, G. I. (2005). "The Urban Informal Sector in Nigeria: Towards Economic Development, Environmental Health, and Social Harmony." Global Urban Development Magazine, Vol. 1 Issue 1. pp 1 – 11.

Obaje, N.G, (1994). Coal Petrography, microfossils and paleoenvironments of Cretaceous coal measures in the Middle Benue Trough of Nigeria. TuebingerMikropalaeontologische Mitteilungen 11.

Obaje, N.G, Lar, U.A, Nzegbuna, A.I, Moumouni, A, Chaanda, M.S. and. Goki, N. G, (2007). Geology and Mineral Resources of Nasarawa State. (Preliminary Investigation):"In Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria. Onaivi Publisher, Keffi.

Ochola, W.O. and Kerkides, P. (2004). An integrated indicator-based spatial decision support system for land quality assessment in Kenya. *Computers and Electronics in Agriculture*, Vol. 45,Pp.3–26.

Odum, E.P., (1969). The Strategy of Ecosystem Development. *Science*, 164, Pp.262-270.

Ogu, V. and K. Adeniji, (1998). "The Concept of Sustainable Physical Development in the context of Developing Countries." In: Adeniji, Kunle and Vincent 1. Ogu (eds.) Sustainable Physical Development in Nigeria. Nigerian Institute of Social and Economic Research (NISER), Ibadan. pp 1 – 15.

Ola, C.S. (1984). Town and Country Planning, and Environmental Laws Nigeria. University Press Limited, Ibadan. Pp 73.

Olaniran, O. J. (1988). Climate and the planning of Agricultural Land Use in Nigeria. NRBDA area as Case Study. Jour. Agro Met. 43 (4) Pp 286-294.

Onosemuode, C. (2004). The use of SPOT Remotely Sensed data in Monitoring Environmental changes in the Warri Metropolis. Nigeria. *Journal of Research and Production.* Vol. 4 No. 1, Pp 69-78.

Owei, O.B, Obinna, V.C and Ede P.N, (2010). The Challenges of Sustainable Land Use Planning in Nigerian Cities: the Case of Port Harcourt. 46th ISOCARP Congress.

Oyesiku, O. K. (2009). "City Live ability: Implications and Challenges". Lead Paper presented at the Commonwealth Association of Planners, West Africa Workshop. Lagos.

Peacock, P. (2002). A Framework for Applying Spatial Decision Supprt System in Land Use Planning. Durban: University of Natal.

Peter M. A., Mohammed A. M. and Patrick A. O. (2007). Vegetation and Forest Resources of Nasarawa State. Geographic Perspectives of Nasarawa State. A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria. Onaivi publisher, Keffi.

Pettit, C.J., (2005). Use of a collaborative GIS-based planning-support system to assist in formulating a sustainable-development scenario for Hervey Bay, Australia. *Environment and Planning B: Planning and Design*, 32, Pp.523-545.

Putnaum, R.D. (1993). Making Democracy Work. Princeton: Princeton University Press.

Rahman, S. A, (2007). Crops Production in Nasarawa State. Geographic Perspectives of Nasarawa State".A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria. Onaivi publisher, Keffi.

Ratcliff, J. (1976). Land Policy: An Exploration of the Nature of Land in Society: The Built Environment, Pp1-27 Research Series, Vol.40, Dortmund.

Robert, D.P. (1994): Making Democracy Work, Civic Traditions in Modern Italy. Princeton, New Jersey.

Rodriguez, P. O. S. (1995). Land use conflicts and planning strategies in urban fringes. A case study of western Caracas, Venezuela. PhD thesis, ITC, Enschede, The Netherlands.

Rossiter, D. G. and Armand R.VanWambeke, (1997). Automated Land Evaluation System (ALES) version 4.65 user,s manual. Cornell university, dept. of Soil, Crop and Atmosphere Sciences SCAS teaching series no.T93-2 revision 6. Ithaca, NY USA.

Rossiter, D.G., (1990). ALES: a framework for land evaluation using a microcomputer, Soil Use and Management, Vol. 6 .Pp. 7-20.

Saaty, T.L. (1980). The Analytic Hierarchy Process. McGraw-Hill, New York, pp 20-25.

Samaila K.I and Binbol, N.L. (2007). Hydrology and Water Resources of Nasarawa State."Geographic Perspectives of Nasarawa State".A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria.Onaivi publisher, Keffi.

Samaila, K.I and P.I, Ezeaku, (2007). Soils and Erosion in Nasarawa State. " Geographic Perspectives of Nasarawa State". A Publication of the Department of Geography, Nasarawa State University, Keffi-Nigeria. Onaivi Publisher, Keffi.

Santé-Riveira, I. Crecente-Maseda, R., and Miranda-Barrós, D. (2008). GIS-based planning support system for rural land-use allocation. *Computers and Electronics Agriculture*, Vol. 63, Pp.257-273.

Satterthwaite, D. (1983), "Public Land Acquisition and Shelter for the Poor". In UN-Habitat in Land for Housing the poor. Habitat and Swedish Council for Building Research, Stockholm. Pp 49 – 60.

Scat R. S., Carranza E. J. M., Nidumolu, U. B. (2005). Fuzzy modelling of farmers' knowledge for land suitability classification. Agricultural Systems, 83(1), Pp49-75.

Shepande, C. (2002). Soils and land use with particular attention to land evaluation for selected land use types in the Lake Naivasha Basin, Kenya. M.Sc Thesis, ITC, Enschede.

Sheppard, S.R.J. and Meitner, M. (2005). Using multi-criteria analysis and visualisation for sustainable forest management planning with stakeholder groups. *Forest Ecology and Management*, 207, Pp.171-187.

Shuaib, L., (2005) A Geo-Information Approach for Urban Land Use Planning in Kampala From Pharaohsto Geoinformatics FIG Working Week, Cairo, Egypt. Available on line at www.fews.org/fb 970527/fb97sr4.htm. Accessed December, 2011.

Skidmore, A.K., Witske Bijer, Karin Schmidt and Lalit Kumar, K. (1997). Use of Remote sensing and GIS for sustainable land management. *ITC Journal*. 3 Vol.4, Pp 302-315.

Smith, T, (1997). Factors Relating to Misanthropy in Contemporary American Societal" Social Science Research Vol.26: Pp 170-196.

Sodaide. O.R, (2002). Spatial Information and land management. International congress, Washington D.C, U.S.A

Steinitz, C., Parker, P., and Jordan, L. (1976). Hand drawn overlays: their history and prospective uses. *Landscape Architecture*, 9, Pp. 444–455.

Sui, D.Z, (1992). A Fuzzy GIS Modeling Approach for urban Land Evaluation, *Computer Environment and Urban Systems*, Vol. 16, pp, 101-115. Available online at http://www.britanica.com. Accessed December, 2011.

Tyrwhitt, J. (1950). *In Town and Country Planning Textbook*. London: Architectural Press.

UN- HABITAT (2008). The State of African Cities, 2008. Nairobi, Kenya.

UNHABITAT, (2005). Land Equity International preliminary report prepared for the `World Bank. *Comparative Study of Land Administration Systems: Available at* Http://www.unhabitat.org/campaigns/tenure/tenure.est.three. Accessed: July, 25, 2011.

United States Department of Agriculture, Natural Resources Conservation Service, (1999). Soil Taxonomy, A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agricultural hand book. Natl. Soil Surv. Cent., No 436, Second edition. Pp 389, 665 and 721.

VanIttersum, M.K., Rabbinge, R., and Latesteijn, H.C. (1998). Exploratory land use studies and their role in strategic policy making. *Agricultural Systems*, 58 (3), Pp.309–330.

VanLanen, H.A.J. (1991). Qualitative and quantitative physical land evaluation: an operational approach. P.hD thesis, Agricultural University, Wageningen.

Verdoodt, A., and Van Ranst, E., (2003). *A Large-Scale Land Suitability Classification for Rwanda*. Ghent: Ghent University.

Viking, N., (2009). Personal communication about using mixed zoning instead of block zoning. *International congress, Washington D.C, U.S.A*

Worrall L (ed.) (1990). *Geographic information systems: developments and applications*. London, Belhaven Press.

Yari, K., Hadziga, B., and Ma-aruf, S. (2002). Karu City Alliance Initiatives, Karu Governance and Management Institutions, land use Management and Urban Services Management. In: Technical Report for the UN-HABITAT Component of Karu Development Strategy.