# EFFECTS OF LAND USE AND LAND COVER DYNAMICS ON ENVIRONMENTAL QUALITY OF NAIROBI CITY AND ITS ENVIRONS

## BY

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## A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS OF URBAN MANAGEMENT OF THE UNIVERSITY OF NAIROBI

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# DECLARATION

## DECLARATION BY STUDENT

I, Peter Mungai Mwathi, hereby declare that this research project is my original work. To the best of my knowledge, the work presented herein has not been presented for a degree award in any insititution of higher learning.

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Signature _____          Date _____

**Peter Mungai Mwathi.**

## DECLARATION BY SUPERVISORS

This research project has been submitted for examination with our approval as university supervisors.

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**Dean, School of The Built Environment**

# DEDICATION

I dedicate this work to my entire family and friends who stood by and encouraged me throughout the research period

A special feeling of gratitude to my loving wife Dr. Anne Mungai whose words of encouragement and support went along way in motivating me to complete the work

To my children Karen, Benson, Fredrick and Naomi for allowing me to utilize family time to conduct the research and giving me a hearty smile however late I got home

To the Mwathi foundation staff of Limuru who presided over various philanthropic functions at Limuru constituency on my behalf whenever I was undertaking the research.

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## LIST OF ABBREVIATIONS AND ACRONYMS

**SC**      Sub-County

**NCC**      Nairobi City County

**DEM**      Digital Elevation Model

**DPSIR**      Driving-Pressure-State-Impact-Response

**GIS**      Geographical Information System

**LULC**      Land Use Land Cover

**NEC**      National Environment Council

**NEMA**      National Environment Management Authority

**OECD**      Organization for Economic Cooperation and Development

**PSR**      Pressure-State-Response

**SPSS**      Statistical Package For Social Scientists

**UNEP**      United Nations Environment Program

# ABSTRACT

Land use and land cover change is considered one of the major drivers of global change and has significant implications for many international policy issues as well as key element in the current approaches and strategies in environmental management and natural resources. Despite this, the various interactive nature of land change and dynamics is not fully understood, hence the difficulty in developing effective adaptation strategies for urban development. The study sought to establish the effects of land use and land cover dynamics on the environment of Nairobi city and its environs. This was done through examination of land use and land cover schema for the city between the years 1988 to 2010, evaluation of the trend, nature, and rate of land use and land cover dynamics over the years, assessment of Land Consumption Rate and Land Absorption Coefficient for the City and highlighting the environmental implications of the land use and land cover changes. The study utilized satellite images and field study. Primarily satellite imagery was used to classify the land cover of the region. Additionally, a field study was undertaken to confirm and improve mapping accuracies of spatial changes. Landscape observations, meetings with experts and structured interviews were conducted in the study areas. The study established that Nairobi city has, in a period of 12 years (1988-2010), experienced an increase of 438.29% in urban built-up areas and open lands, forest cover decreased by 38% while agricultural and riparian vegetation decreased by 98%. The agricultural and riparian vegetation, rangeland and shrubs and forests have mainly given way to expansion in built up areas and open lands. Deductively, the land use and land cover dynamics of the city are influenced by population growth, income levels, its physical attributes, land availability, land taxation, land accessibility, urban development policies, weak enforcement framework, technology and political power. The study notes that land use and land cover changes have led to various environmental effects, namely land degradation, destruction of habitat, erosion, air and water pollution as well as urban heat island. The major cause of this being institutional weaknesses and proliferation of the informal settlements in the urban periphery. These have impacted significantly on natural resources and habitat quality. The study recommended enhanced development control, Expansion and Maintenance of the Infrastructure, Environmental Impact Assessment, and formulation of up to date and relevant policies as well as embracing a Multi-Sector Partnership Approach to Urban Development.

## CHAPTER ONE: INTRODUCTION

### 1.1:    Background

Land use and land cover change are recognized as  key drivers of environmental change (Shi *et al*, 2009) with  significant implications for many international policy issues (Liu *et al*., 2010) and a central component in current strategies in managing natural resources and monitoring environmental changes (Minale and Rao, 2011). The land-use and land-cover pattern of a region is an outcome of natural and socio-economic factors and their utilization. For the last 300 years the impacts of Land use and land cover change have increasingly moved from significant to threatening proportions and with a few exceptions, anthropogenic activities explains the changes, magnitude and severity (United Nations, 2006). The greatest casualties of these changes are the forest and agricultural land use and land covers which manifests in loss of significant amount of natural vegetation and agricultural land consequently leading to environmental degradation (Dewi and Ekadinata, 2010). Land-cover changes account for approximately 30% of historical anthropogenic efflux of carbon dioxide, making it the second largest driver of anthropogenic carbon dioxide efflux behind only fossil fuel burning (Robinson *et al*., 2010).

In the context of urbanization, a large amount of agricultural land has been converted to built-up or urban land uses. Nairobi City which is Kenya's principal economic and cultural centre has for the past 48 years experiencing a lot of land-use and land-cover changes due to both socioe-conomic and natural factors. These include the increased spatial expansion arising from high rural-urban migration rates which has made the city one of the fastest growing cities in Africa (Rimal, 2011). It is therefore important to develop an explanatory model for understanding the rate, causes and consequences of the same which consequently aids in formulation of sustainable urban development strategies and in detecting environmental changes (Sultana and Weber, 2007).

Great efforts and methods have been done to understand land use and land cover dynamics but most of which are descriptive rather than quantitatively predictive. However, it is the quantitative predictive models which have a niche in aiding the development of sustainable urban development strategies. Technologies such as Geographical Information Systems (GIS) and remote sensing are currently presented as  dynamic tools for monitoring land use and land cover changes and environmental quality which has continued to present challenge to sustainable urban development ((Mahmood *et al*., 2010; Minale and Rao, 2011).These technologies provide a cost

effective and accurate alternative to understanding landscape dynamics. Digital change detection techniques based on multi-temporal and multi- spectral remotely sensed data have demonstrated a great potential as a means to analyzing landscape dynamics to detect, identify, map, and monitor differences in land use and land cover patterns over a period of time, irrespective of the causal factors. In addition, the recent improvements in satellite image quality and availability have made it possible to perform image analysis at much larger scale than in the past. It is therefore imperative to employ these tools for comprehensive study.

Towards this end, this study presents an analysis of land use and land cover dynamics of Nairobi City with a focus on environmental degradation arising from the changes. To achieve the study's goal, multi-temporal Landsat imageries acquired in the years 1988, 1995 and 2000, 2005 and 2010 and topographical maps of the area compiled in 2008 were used to identify land cover and land use dynamics.

## 1.2 Problem Statement

Land use land cover (LULC) is a global change driver and has notable implications to many of the international policy issues (Vitousek and Field, 1999). Over the years, human activities have modified the environment with significant population increase, migration, and accelerated socioeconomic activities. The process of urbanization has been characterized not only by population growth but also by industrial expansion, increasing economic and social activities and intensified use of land resources (Karuga, 1993). The environment and social consequences of a growing population in a loosely planned urban/build area system could be dramatic especially when urban areas experience accelerated growth in a short period of time as is being witnessed globally (Mundia and Murayama, 2010).

The interactive nature of land change dynamics is not fully understood, making it difficult, if not impossible, to develop effective adaptation strategies for urban development (Jiaguo *et al*., 2012, p.1). Most studies especially on urban land change dynamics done using such methods as (environmental) impact assessment or post project analysis have resulted in no quantifiable changes. Again, the urban land use and land cover dynamics have raised new challenges for urbanization theory.

In Nairobi, land use and land cover changes have been mostly planned and executed without appreciation of their implications, mainly due to absence of quantitative information which makes it difficult to anticipate the possible socio-economic and environmental consequences of such changes (Karuga, 1993). Unfortunately, efforts which have been formulated to postulate theoretical knowledge and explanations for its occurrence are often descriptive rather than quantitative thus leading to lack of comprehensive information. Karuga (1993) attributes the failure to anticipate the possible socio-economic and environmental consequences of such changes to lack of accurate predictive model. Rapid urbanization of the city has resulted in high development densities, environmental degradation, proliferation of slum and squatter settlements and general low productivity (Linn, 1983; Nzioki, 1988; Obudho, 1983).

The city's environment is affected by the planning process which can be traced back to the first *Master Plan Study of 1948*, which was prepared by a team of South African and British planners containing guidelines for legitimizing the city's growth as a colonial city by earmarking land for residential, industrial and other uses (White *et al.*, 1948). Later another attempt at enhancing planning for the city was done through the *Metropolitan Growth Policy of 1973*, which was a multi-sectoral development plan that provided a strategy for integrated urban development through recommending future space requirements in light of rising city population. However, the plan, whose horizon ended in the year 2000, achieved very little owing to poor articulation of the statutory rules and regulations governing planning systems and plan implementation (Oyugi and K'Akumu, 2006). Further attempt to address the built environment challenges was done through the *Rezoning Policy of 1979*, which went against fundamental recommendations of the metropolitan policy by intensifying developments within the city, through advocating for a concentrated Central Business District and allowing higher densities of development. Since then, planning has been done on an ad hoc basis not linked to the city's general plan and dealing with specific aspects of the city's growth.

No study has been done to quantify the effects of the ad hoc planning of the city on its environmental quality. Therefore there is need for a comprehensive methodological framework for quantifying the city's land use and land cover changes and their environmental implications. With the advent and subsequent advancement in the geospatial technology such as Remote Sensing and Geographic Information Systems, it is possible for the acquisition of quantitative

pre-and-post land use and land cover information in a consistent manner. This enables the integration of multi-source and multi-date data for the generation, depiction and the analysis of the trend, nature, pattern, and magnitude of the land use and land cover change(s).

Therefore the study sought to analyze the dynamics of land use and land cover of Nairobi city with a focus on the implication of the phenomenon on the city's environmental quality. This was prompted by search for most suitable approach for studying and quantifying land use and land cover changes in order to facilitate the formulation of a sustainable land-use policy for the city and its environs. This is imperative taking into cognizance that the current land-use and/or management paradigms operational in the city are archaic devoid of policy measures meant to promote urban land use functionality.

## 1.3 The Aim and Objectives of the Study

This study was occasioned by the need to analyze the implication of land use and land cover dynamics on the environment quality of Nairobi City County at different epochs in order to detect changes that have taken place and their likely socio-economical and environmental implications.

It was also occasioned by the need to establish factors that have influenced the land use and land cover changes in Nairobi City County between 1988 and 2010, the nature of the changes as well as the environmental implications of those changes

In order to achieve the aim above, the study was guided by the following specific objectives:

i. To establish the trend and nature of land use and land cover variations for the city between the years 1988 to 2010.
ii. To establish the factors that influence land use and land cover dynamics within Nairobi City County
iii. To assess Land Consumption Rate and Land Absorption Coefficient for the City.
iv. To establish the socio-economical and environmental implications of the land use and land cover changes.

## 1.4 The Research Questions

This study sought to answer the following research questions: -

i. What is the trend and nature of land use and land cover variations for the city between the years 1988 to 2010?

ii. What are the factors that influence land use and land cover dynamics within Nairobi City County?

iii. How does the Land Consumption Rate correspond to Land Absorption Coefficient for the City between the years 1988 to 2010?

iv. What are the major socio-economical and environmental implications of the land use and land cover changes?

## 1.5 Research Hypothesis

**Null hypothesis (H₀):** The land use decision making mechanism in the city as embodied by statutory legal and /or urban planning regulations as well as socio-cultural, economical, political and technological advancement in society does not determine the land use and land cover dynamism; hence the quality of urban environment.

**Alternative hypothesis (H₁):** The land use decision making mechanism in the city as embodied by statutory legal and /or urban planning regulations as well as socio-cultural, economical, political and technological advancement in society determine the land use and land cover dynamism; hence the quality of urban environment.

## 1.6 Research Assumptions

This study having its niche in applied social science would necessitate making assumptions on factors which could not be controlled while they could act in concert to influence the outcome of the study. In this regard, the study was guided by the following assumptions:

i. The land use and land cover dynamics in the city has been accentuated by high rates of urbanization that the city has experienced since Kenya attained its independence in 1963.

ii. Nairobi shall continue to bear the burden of urbanization relative to other towns in the country.

iii. The land use and land cover dynamics currently witnessed in the city is a major explanatory variable in the environmental degradation of the city of Nairobi.

iv. The evolution of land uses in Nairobi has been guided by the principles of rational decision making, which postulates that the developers have perfect knowledge of

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opportunities and market frontiers.

v. The infrastructure capacity of the city such as sewage and water systems as envisaged by earlier plans has not expanded in the period spanning to 20 years to accommodate the emerging land uses and land covers.

## 1.7 Justification of the Study

Over the years, the challenge to Nairobi's sustainable urban development has remained achieving proper balance between land uses and the environmental quality. However, the *ad-hoc* manner in which the city's development planning has been undertaken has not integrated land uses with controlled environmental quality consequently leading to environmental degradation. Consequently, it is clear that Nairobi needs a development strategy informed by the spatio-temporal analysis of the land use and land cover dynamics which provides the benchmark for projecting future land use and land cover differentiation rate, pattern, magnitude and trend (Devas, 1993). Over the years, Nairobi has continued to experience land use and land cover dynamics manifesting through the built up areas invading other land uses and land covers with the greatest casualties being forest resources, rangelands, shrubs and agricultural lands. This has consequently led to the loss of a significant amount of agricultural land and other natural resources which can only be mitigated through a comprehensive urban development strategy. However, this must begin with quantitative evaluation of land use and land cover dynamics which entails building of land use and land cover inventory and the assessment of the type, magnitude, pattern and trend of land use and land cover dynamics within the city. This was equally important in projecting future land development demand, environmental quality assessment as well as aiding in directing infrastructural facilities to the parts of the city where they are needed most to support development. Therefore, it was imperative that a better understanding of the rate, causes and consequences of land use and land cover change be modeled in a quantifiable manner towards aiding in the formulation of sustainable urban development strategies.

As earlier noted, urban land use and land cover dynamics have raised conceptual challenges to urban development theories and attempts to develop comprehensive explanatory model for understanding the same has mostly yielded descriptive rather than quantitative models, yet it is the quantitative models which have a niche in aiding land use decision-making (d'Aquino *et al.*,

2002). It is gainful stating that the analysis of land use and land cover dynamics requires application of geospatial techniques such as Geographic Information Systems and Remote Sensing which provides an extensive synoptic coverage of the environmental condition of large areas than either aerial photography or any other methodology. Indeed, a multi-spectral analysis of land use and land cover dynamics of Nairobi, a focus on environmental degradation is significant in aiding the evolution of an alternative land-use planning model to accommodate the anticipated changes bearing in mind that since the expiry of the Nairobi's Metropolitan Development Strategy 1973-2000, the city currently operates without a structured plan. The approach of this work was based on a comprehensive methodology for undertaking urban planning to sustain the envisaged land use and land cover differentiations.

## 1.8 Significance of the Study

Regional governments globally are charged with the responsibility of enacting and enforcing the development control measures. However in majority of the cases, the development controls are only based on human intuition rather than rational quantitative basis. This has always hampered developments of these urban centers as they hinder the aspirations of the developers to undertake investments due to what they view as punitive development control measures. It is in this regard that the study will inform development planning and processes, which creates a balance between land use and land cover as well as land use functionality. This was demonstrated by this study. The land use and land cover changes are often a reflection of urban developments which should be accompanied by infrastructural expansion. However, the regional governments are known to be expanding infrastructure in a way that sometimes is contrary to urban growth pattern and direction. A study of this nature, which uses satellite imageries, can form the basis of knowledge upon which proposals for the direction and patterns of infrastructure expansions as well as zoning requirements such as floor index, plot coverage, sky limit and plot size can be based. The infrastructure envisaged here included water reticulation, sewer and road network.

The study also provided a deductive basis for undertaking land suitability analysis which is imperative in protecting the fragile ecologies like the riparian vegetation and forests covers against encroachment by other urban anthropogenic activities and protection of human life and property (Liu *et al*., 2010). The use of high resolution imageries promotes object oriented land use and land cover dichotomy in a faster and accurate manner. It also enables direct segmentation of the objects as they appear on the ground as granted by their higher spatial

resolutions which is very productive in the production of small scale maps for the evolution of urban strategic plans.

The major beneficiaries of this research will include two distinct groups: (1) resource managers at the county and national levels of government, and (2) regional as well as urban planners who want better urban planning in broader social and economic settings.

## 1.9 The Scope of the Study

This study was undertaken within what legally defines the area of the jurisdiction of Nairobi City County. It was also extended to some urban areas of the neighbouring Kiambu, Kajiado and Machakos Counties since these directly relate and affect the land use patterns in the City. The spatial scope of the study is bounded within the coordinates 360 40' and 370 10'E and between 1°09′S 36°39′E and 1°27′S 37°06′E covering an area of 696 km$^2$. The scope for this study focused on the five land cover categories  as modified from Anderson *et al*. (1976) notably the urban built-up and open lands, agriculture and riparian vegetation, rangeland and shrubs, forests and water bodies and how they have been changing from the year 1988 to 2010. The study was guided by both the Pressure-State-Response (PSR) and Driving-Pressure-State-Impact-Response (DPSIR) as both theories explain more about  land use and land cover dynamics as well as their Environmental implications.

Further in this study, the scope for the environmental quality was limited to how the land use and land cover dynamics which manifests through spatial and temporal changes in the urban/built-up and open lands, agriculture and riparian vegetation, rangeland and shrubs, forests and water bodies may have future implications on the urban surface runoff (flooding), loss of vegetation cover, water pollution, urban heat islands and a decline in air quality. In terms of its methodological framework, the study mainly relied on primary satellite imagery to classify the land cover of the study area and used socioeconomic data to explore the implications of land use and land cover changes.

## 1.10    Limitations of the Study

This study took cognizance of the differences in the characteristics of the images used for the study as granted by the fact that images of 1988 and 1995 are from Thematic Mapper while the images of the years 2000, 2005 and 2010 will be derived from Enhanced Thematic Mapper

(ETM+) Plus. The radiometric resolutions of the two sensors are different in terms of azimuth angle. Further the images gathered for different seasons of the years under consideration correspond to different environmental conditions and precipitation which influences land covers, with likelihood of lowering the accuracy of the classifications.

## 1.11    Definition of Terms

**Environment:** This literally means surrounding and everything that affect an organism during its lifetime, collectively known as its environment. In other words, environment is sum total of water, air and land interrelationships among themselves and also with the human being, other living organisms and property. It includes all the physical and biological surrounding and their interactions (Ullah and Wee, 2009). In the context of this study, environment entails vegetations, air, water, and land/soil and temperature .

**Environmental quality**: This is a set of properties and characteristics of the environment, either generalized or local, as they impinge on human beings and other organisms. It is a measure of the condition of an environment relative to the requirements of one or more species and or to any human need or purpose. Environmental quality is a general term which can refer to varied characteristics that relate to the natural environment as well as the built environment, such as air and water purity or pollution, noise and the potential effects which such characteristics may have on physical and mental health caused by human activities (Johnson *et al*., 1997). Thus in the context of this study, environmental quality was limited to how the land use and land cover dynamics which manifests through spatial and temporal changes in the urban built-up and open lands, agriculture and riparian vegetation, rangeland and shrubs, forests and water bodies may have future implications on the urban surface runoff (flooding), loss of vegetation cover, water pollution, urban heat islands and a decline in air quality.

**Built Environment:** This refers to the human-made surrounding that provide the setting for human activity, ranging from individual dwelling and Building to neighborhoods and cities that can often include their supporting infrastructural services (Roof and Oleru, 2008)

**Development:** Pursuant to Section 3 (a) of the Physical Planning Act (Cap. 286-Laws of Kenya), development denotes making of material change, alteration of building density or land subdivision.

**Sustainable Development:** The concept first came into usage in the development literature in 1980 but was subsequently popularised by the Brundtland Report through the publication of 'Our Common Future' which defines sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs and aspirations (WCED, 1987).

**Sustainable Urban Development:** This term denotes urbanization accompanied with environmental conservation. It's characterized by environmental, social and economically self sustained urban society (Brandon *et al*., 1997).

**Urban Sprawl:** This term denotes rapid and haphazard urban expansion to the urban periphery (Galster *et al*., 2001) and /or the growth outside a predetermined distance from the city centre leading to the consumption of forest and agricultural lands by low density suburban residential and commercial development as well as the development displaying non-contiguous growth (El Nasser and Overberg, 2001; Transportation Research Board, 2002; Yang and Lo, 2002; Hayden, 2004, p.7).

**Remote Sensing:** This is the art, science and technology of gathering information about a phenomenon, object and/or area using devices called sensors  mounted on satellites without physically coming into contact with the a phenomenon, object and/or area under investigation as occasioned by differences in interactions between earth surface materials and electromagnetic energy (Lillesand *et al*., 2004, p.1).

**Geographic Information System:** A computer assisted system for the acquisition, storage, analysis, and display of geographic data or can be defined simply as a computer system designed to work with geo-referenced data (Star and Estes, 1990).

**Land Use:** This relates to the economic functions (utility) associated with a specific piece of land such as agriculture, industrialization, residential, transportation, public purpose, recreation, public utility and educational (Meyer, 1995).

**Land Cover:** This is the biophysical state of the earth's surface and immediate subsurface" (Turner *et al*. 1995, 20). In other words, land cover "describes the physical state of the land surface: as in cropland, mountains, or forests" (Meyer, 1995).

**Land Use and Land Cover change detection:** The process of identifying differences in the state of land use and land cover by observing variations of their state at different times (Singh, 1989).

**Land Consumption Rate and Land Absorption Coefficient.**

Land consumption rate denotes a measure of compactness which indicates a progressive spatial expansion of a city while. Land absorption coefficient simply means a measure of consumption of new urban land by each unit increase in urban population (Paria and Bhatt 2012, p.98). About two thirds of land consumption result from urban sprawl (Thomas, 2011, p.85).

## 1.12    Organization of the Study

The study is   organized into six chapters of which chapter one introduce the study by stating the research problem and a presentation of the study justification. The chapter further gives details of the study objectives, research questions, assumptions and definition of key terms as applied in the text. Chapter two relates to descriptive information on study area.  It give the physiological background of the study area, population dynamics its geology as well as major environmental issues. It also gives the outline of governance in the area. Chapter three focuses on the literature review and the conceptual framework for the study based on scholarly arguments on what constitutes urban land use and land cover dynamics and the role of geospatial techniques in studying the same. This chapter further highlights the factors responsible for the spatio-temporal dynamism of land use and land cover which aids in building the conceptual framework for the study. Chapter four gives the methodology employed in the study including the methods and tools employed for data collection as well as analytical framework. Chapter five is the analysis and the presentation of the research findings as well as discussions of the land use and land cover dynamics and the implications of the phenomenon on the environmental quality of the city. It also provides the basis for the evolution of an alternative urban development plan for the city. Chapter six is a culmination of the study summary, conclusions and recommendations.

**CHAPTER TWO: BACKGROUND TO THE STUDY AREA**

**2.1 Introduction**

Nairobi is the capital city of Kenya and occupies around 696 km² and is situated 1661 metres (5450 ft) above sea level (Plate 2.1). It originated as the headquarters of the Kenya Uganda Railway, established when the railhead reached Nairobi in June 1899. The city grew into British East Africa's commercial and business hub and by 1907 became the capital of Kenya (Mitullah 2003, Rakodi 1997).

**Plate  2.1 :  Nairobi in relation to Kenya, Africa, The world**



**Source:** National Peace Corps Association, Washington, USA**,** December 2009

## 2.2    Location of the Study Area

The study area is located within the emerging Nairobi metropolitan region, which encompases the Nairobi City County and the neighbouring urban areas. Nairobi town is the capital city of Kenya has continued to exhibit primacy in Eastern and Central Africa in terms of commercial, industrial and financial functions owing to its strategic position as a communication hub in the region. The city's location is bounded within the geographical coordinates $360^040$' and $370^010$'E and between 1°09′S 36°39′E and 1°27′S 37°06′E  covering an area of 696 km$^2$ (CBS 2001). The city borders the following counties which form part of the study area: Kiambu to the North West, North, and North East, Machakos to the East and South East, Kajiado to the South, South West, and West ( Figures 2.1 and 2.2). Since development and growth of the peripheral areas in influenced by the growing population of the city (Kenya Open Data, 2011), its paramount to consider the immediate neighbourhood where construction boom is being experienced .

## 2.3.    Physiographical Background of the Study Area

Nairobi region altitude varies between 1,600 and 1,850 metres above sea level (Mitullah, 2003) and lies at the edge of the Great Rift Valley to the west. The western part is on high ground (approximately 1700–1800 meters above sea level) with rugged topography, the eastern side is generally low (approximately 1600 meters above sea level) and flat (Saggerson 1991). Nairobi's topography features deep valleys dissected by the natural river drainages such as Nairobi, Mathari, Masongawai and Ngong Rivers and other streams flowing from the foothills of Aberdare Mountains. The indigenous Karura forest is situated at the northern part of Nairobi while the Ngong hills stand towards the west, Mount Kenya towards the north and Mount Kilimanjaro towards the south-east.  Its geology and topography have been greatly influenced by tectonic forces associated with the formation of the Great Rift Valley . The growth and sprawl in the built up areas is mainly towards the eastern and southern parts mainly because this topography reduces the cost of construction. Therefore, these parts of the city have continued to witness increase in real estate developments relative to the higher topographical areas to the northern and western parts of the city towards the Kikuyu escarpment.
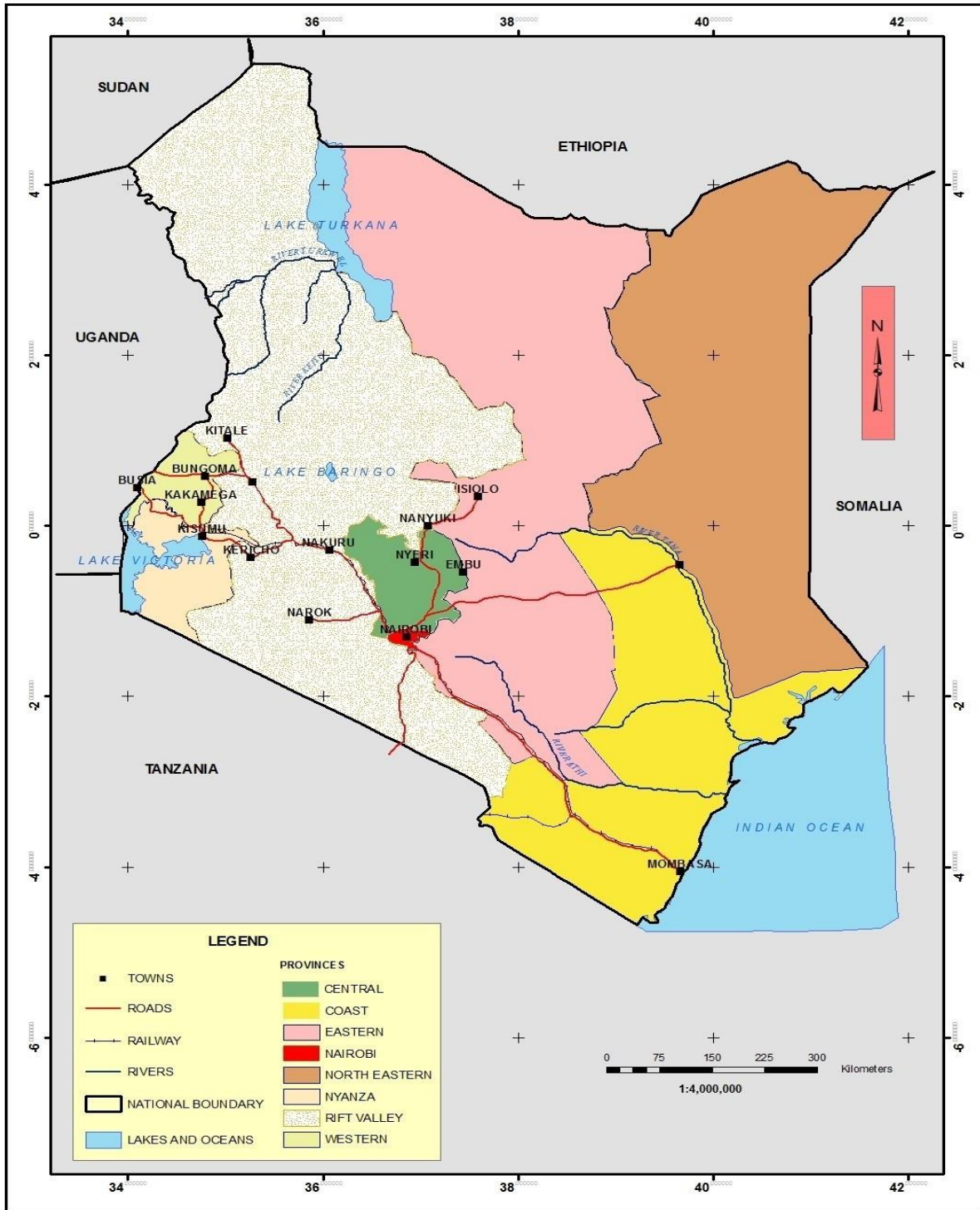
**Figure 2.1: Nairobi In The National Context**
Source: Mutisya and Yarime (2012)
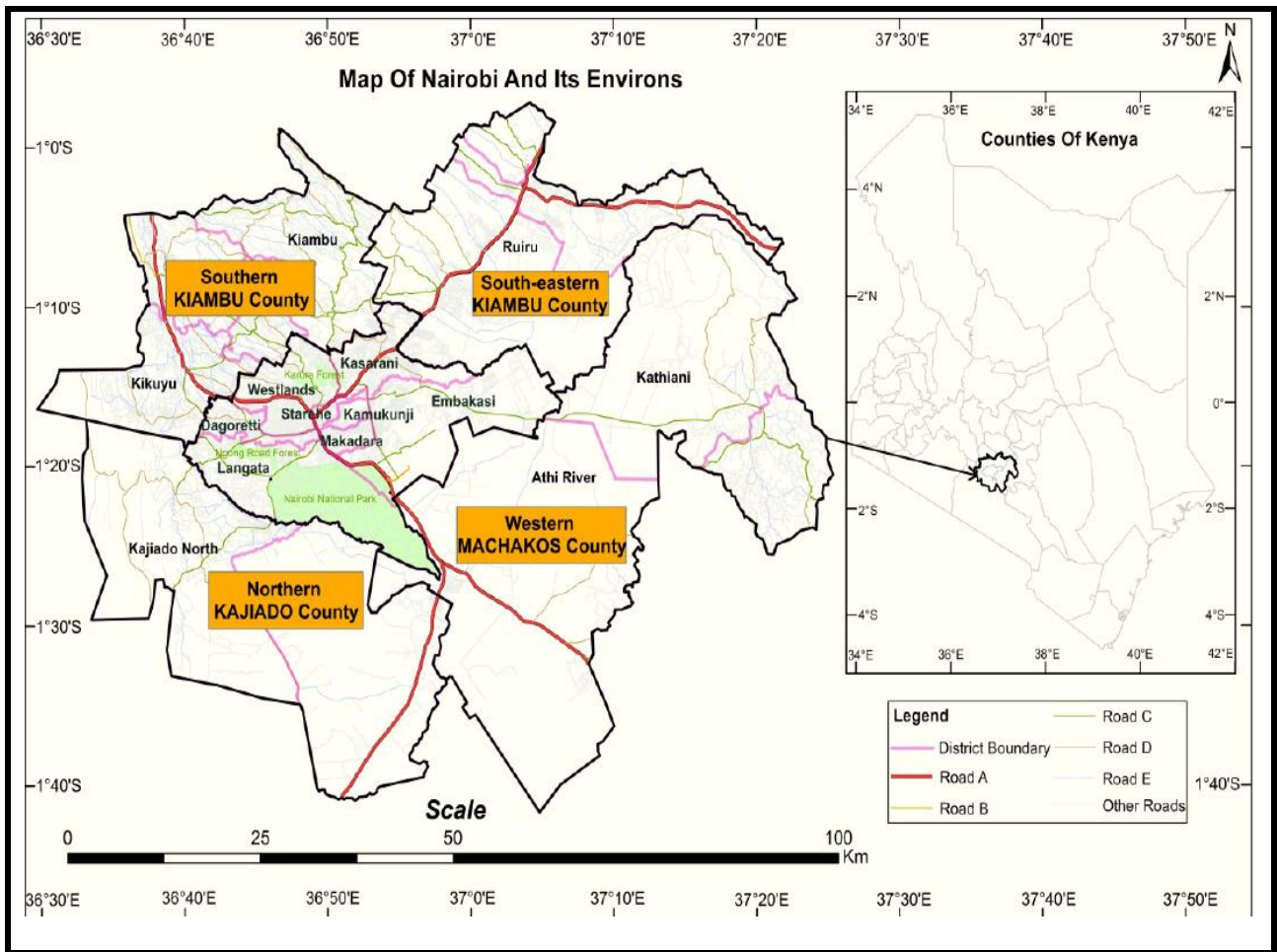
**Figure 2.2: Map of the area of
study (Nairobi and its environs)**
Source: JICA Study Team (JST) (2014).

Nairobi has generally a temperate tropical climate, with cool evenings and mornings becoming distinctly cold during the rainy seasons. There are long rainy periods between April and June, while the short rains come in November and early December. There is a constant of 12 hours of daylight. Average daily temperatures range from 29º C in the dry season to 24º C during the rest of the year.

Healthy vegetation characterizes the higher topography to the east and northwest of Nairobi while the south and eastern part comprise scarce vegetative cover with the main land use being livestock grazing. The areas which used to be forest and fertile agricultural land have been fragmented to urban built-up areas for residential, commercial, industrial, transportation, communication, and utilities. The southern and eastern part of the city whose climate and soils are not favourable for agriculture and forest growth are characterized by disturbed bushes, shrubs, perennial grasses and under storey trees which are rarely above 5m in height.

## 2.4    Population Dynamics

The City of Nairobi is among the key urban areas in Kenya that has continued to experience high population growth rates as occasioned by rural migration and natural population increase. Table 2.1 presents a summary of population growth in the city since 1962 to 2009. Population growth is partly explained by net migration into the city. The net immigration flow into the city between 1979 and 1989 was 772,624 (NEMA, 2003). The forces motivating rural-urban migration to Nairobi include better economic prospects, opportunities for higher education and higher wage employment, and the attraction of Nairobi as a market for goods and services. But there is also the phenomenon of diurnal migration of people from the environs who commute daily into Nairobi for purposes of employment, education or trade. Projections are that diurnal migration will continue unless deliberate efforts are made to develop satellite towns and employ strategies to reduce the daily influx of people to the city. With an inter-censal population growth rate of about 4.5%, the city's population is projected at 5,852,736 by the year 2020. This underscores the fact that the city's population will subsequently lead to an increased demand for services such residential facilities, commercial, educational as well as employment opportunities, consequently leading to urban expansion at a time when the urban infrastructure is already constrained.

**Table 2.1: Population Census for the City of Nairobi Between 1969 to 2009**

| Year | Demographic Attributes | | |
| | Total Population | Population Density | Area (Km$^2$) |
|---|---|---|---|
| 1969 | 509286 | 745 | 684 |
| 1979 | 827775 | 1210 | 684 |
| 1989 | 1324570 | 1936 | 684 |
| 1999 | 2143254 | 3133 | 684 |
| 2009 | 3,273,783 | 4786 | 684 |

**Source:** (Government of Kenya-Population and Housing Census Surveys1969, 1979, 1989, 1999 and 2009)

As at 2009, Nairobi consisted of eight constituencies namely:- Starehe, Makadara, Lang'ata, Kamukunji, Westlands, Kasarani, Dagoretti, and Embakasi. According to the Kenya Open Data (2011), the population of the Nairobi area in 2009 was as contained in Table 2.2.

**Table 2.2: Population distribution per Constituencies**

| Constituency | Population: Males | Population: Females | Population: Total | Number of Households | Size of Avg. Household |
|---|---|---|---|---|---|
| Dagoretti | 166,391 | 163,186 | 329,577 | 103,818 | 3.175 |
| Embakasi | 468,097 | 457,678 | 925,775 | 296,942 | 3.118 |
| Kamukunji | 136,920 | 124,935 | 261,855 | 75,555 | 3.466 |
| Kasarani | 266,684 | 258,940 | 525,624 | 164,354 | 3.198 |
| Lang'ata | 185,836 | 169,352 | 355,188 | 108,477 | 3.274 |
| Makadara | 114,457 | 104,184 | 218,641 | 72,924 | 2.999 |
| Starehe | 142,097 | 132,510 | 274,607 | 87,519 | 3.138 |
| Westlands | 124,748 | 122,354 | 247,102 | 75,427 | 3.277 |

Sources :( Kenya Open Data, 2011)

## 2.5    Geology

Nairobi's geology is dominated by volcanic activities which influenced the type of landforms, drainage pattern and climate of the city. All the volcanic rocks within Nairobi have undergone extensive faulting and sub-aerial weathering particularly near the flanks of the Rift Valley. As such, the rock outcrops are closer to the ground surface and are covered by very thin layers of overburden soils. The city has a varied composition of three basic geological structures namely, the Mbagathi phonolitic trachyte which contains numerous closely spaced felsar phenocrysts which are rather coarse groundmass containing little nepheline (Onyancha *et al.,* 2011). This type of rock occurs across the Nairobi National Park and part of Athi plains.  The phenocrysts often display sub-parallel alignment, indicating the direction of flow of the lava. The second geological structure is the Nairobi trachyte (Pliocene), which dominates northern and western part of the city.  The Nairobi trachyte (pliocene) originates from pale grey moulted lava having a glistening appearance due to numerous tiny feldspar crystals. Finally, there is the Kirichwa valley tuff which is an agglomeration of different rock types with the most important being devitrified welded tuffs (the Nairobi stone) used extensively for building purposes. Nairobi area and its environs lies within the seismic intensity zone of between 6 to 7 on the Richter's scale and is prone to moderate seismic risk with occasional shocks and tremors which predisposes developments to seismic risk and thus requires considerations of the same in the design of structures.

The implications of the geological structure of Nairobi on the city's land use and land over dynamics is evident due to the fact that the basement rocks that characterizes the larger part of the city are only covered by thin layer of soil. Therefore laying of the development foundations does not require extensive excavation. This has consequently led to the reduction on the development cost all over the city. This has generally encouraged the development of real estate within the city as there are no serious physical thresholds to such developments. The geological structure also provides the much needed construction materials in the form of the stones for the walls and sand for construction. These stones are available in the eastern part of the city which correlates with the high rate at which the built up areas are sprawling in that part of the city.
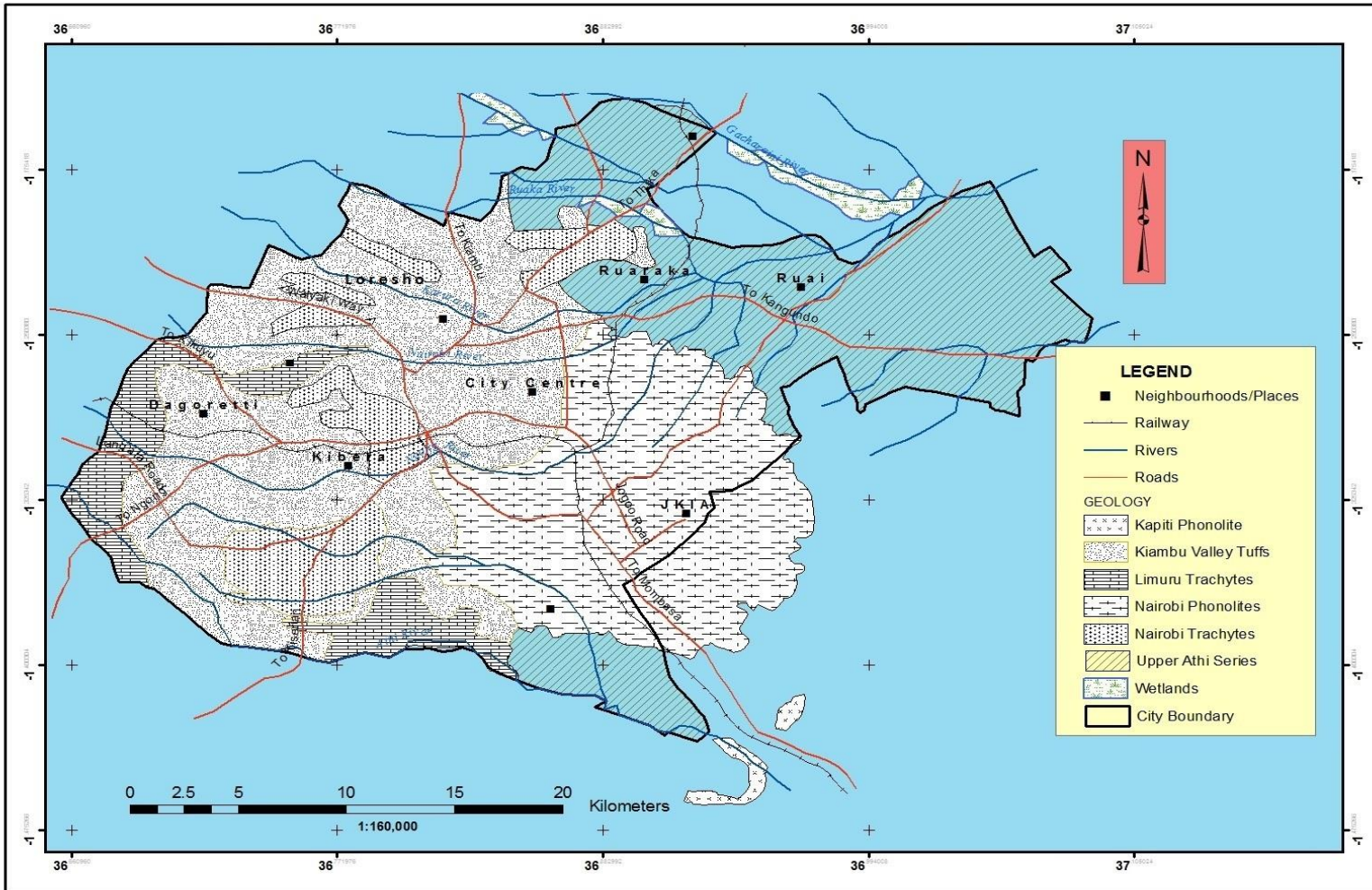
**Figure 2.3: The Geology and Drainage of Nairobi**
**Source:** Adopted from Tibaijuka (2007)

## 2.6 Major Environmental Issues

As Nairobi's settlements sprawl outwards, they take over forested and agricultural land, fragmenting and degrading remaining natural areas. In addition, rapid population growth has outstripped the city's ability to deliver adequate services such as education, health care, safe water, sanitation, and waste removal. It has also led to an explosion in the number of cars and other types of motor vehicles, leading to ubiquitous traffic jams and high levels of air pollution. As it continues to grow, Nairobi faces the challenge of planning for sustainable urban development that provides adequate housing and services at the same time as it protects air and water quality and the natural environment within and around the city. With the environment deteriorating over many years, the repercussions are increasingly felt, key among them include water shortages, informal settlements, pollution, and poor waste management

### 2.6.1. Water Shortages

The high rate of urbanization in the city has caused a great demand for resources and services. Currently, it is estimated that water demand in Nairobi metropolitan region stands between 1,621,312 $m^3$/ day and is estimated to grow to 2,117,194 $m^3$/day by 2035 (2011 Feasibility Study cited in Mwaura and Tsuma, 2012). The water demand of the rapidly growing Nairobi city with a growth rate of 3.8% for the 10 year period (1999 – 2009) has outstripped the supply. With the households growth rates of 5.28 and 4.17 of 1989 -99 and 1999 -09 periods ,( 2009 Population & Housing Census Results ) the city has far outstripped its average water supply of 460 $m^3$/day (147litres per capita) to a demand 837 $m^3$/day. The deficit of 377 $m^3$/day will not be covered by the proposed Northern collector (expected to be completed by 2017) with an additional production capacity of 138 $m^3$/day, still falls short of the city's current water demands. The situation is even compounded further by the high Non Revenue Water (NRW) levels of averagely 40% of production (i.e. 189 $m^3$/day of water losses), leaving only 271 $m^3$/day for consumption (Mwaura and Tsuma, 2012).

### 2.6.2. Informal settlements

Nairobi's rapid growth increased the demand for land and led to land speculation, forcing the poor to settle in fragile and unsavory areas where they face hardships due to a lack of proper

housing and public services and where they are vulnerable to environmental change. People living in Nairobi's informal settlements, particularly the slums, usually find themselves in the city's most fragile areas, such as flood plains, steep slopes, river valleys, or adjacent to sewers or dump (Mitullah, 2003)

### 2.6.3. Sanitation

Nairobi faces an enormous challenge in providing adequate public sanitation facilities, sewage disposal, and refuse collection, a problem that is compounded as the population increases. Improperly treated sewerage and uncollected garbage have contributed to a vicious cycle of water pollution, water-borne diseases, and environmental degradation (NEMA, 2008).

### 2.6.4. Air pollution

The main sources of atmospheric pollution are vehicles, industries and other city sources such as the open burning of waste. The increasing number of cars in the city intensifies traffic and pollution problems. Vehicles emit significant levels of air pollutants, including greenhouse gases and the precursors of smog (NEMA, 2008).

### 2.7 Governance

In terms of governance, the City of Nairobi falls under the Nairobi City County (NCC), which is composed of elected members who form the oversight assembly and the executive staff who run the day-to-day activities of the county. The Nairobi City County is governed in its operations by a variety of National and County statutes. The County Governments Act 2012 is the main legal statute that governs most of the operations of the NCC.

# CHAPTER THREE: LITERATURE REVIEW AND THEORETICAL FRAMEWORK

## 3. 1 Overview

Urban land use and land cover dynamics has continued to generate scholarly debates at a time when estimates by the United Nation's Population Fund (2009) shows that by the year 2025 approximately 80 percent of the world's population will live in cities. This translates to more land being converted into urban land use. This chapter examines literature on urban land use and land cover by focusing on dynamics and change detection as a phenomenon, its basis as well as the approaches used in undertaking the same; notably through the geospatial techniques. Towards this end, arguments are advanced which culminates into a conceptual framework-a deterministic model for urban land use and land cover dynamics. It emerges that land use and land cover dynamics debate as an indicator of sustainability has attracted varied scholars. Leading the pack are the Urban Planners, Geographers and Ecologists. The debate has led to a comprehensive knowledge that can be utilized for the achievement of sustainable urban development. Therefore, the concept can now be modelled in spatial and philosophical terms even though quantification of the rate, pattern, and trend of the changes have not extensively been explored.

## 3. 2 Review of related studies

### 3.2.1 Studies from other countries

Eludoyin *et al*. (2011) did a GIS Assessment of Land Use and Land Cover Changes in OBIO AKPOR Local Government Area, Rivers State, Nigeria. The study reveals that farmland, mangrove, primary forest and sparse vegetation reduced over time by 45.34, 37.06, 43.06 and 8.09%, respectively while secondary forest, built up area and water increased by 5.88, 74.55 and 3.43%, respectively. One of the recommendations was the need to promulgate laws and legislations to prevent unlawful expansion of construction of any form and that the people in the communities in the study area should be enlightened and educated on the effects of deforestation on the environment.

The study gives important insight into the trend of land cover changes. However, it does not give any implications of the changes yet the two are related. Further, the study has only relied on GIS

assessment. This has several methodological challenges in terms of integrating socio-economic and geospatial technologies and especially in establishing who defines what classes of land cover or even interprets the same classes (Olson *et al*., 2004). It would have been wise to consider the locals' perception of the changes through the use of household survey.

Another related study is that carried out by Alphan (2003) entitle "land-use and land-cover (LULC) changes in Adana city, Turkey". He employed the use of satellite data of 1984 and 2000. Study of the expansion of the city over adjacent agricultural fields and semi-natural areas was the major focus. Among the major findings was that Urban and built-up area changed  by a factor of 70% during the 16 years; about 30 per cent on agricultural land and 70 per cent on previously semi-natural land. Alphan (2003) argues that permanent immigration and urban development strategies were the main driving forces for the observed changes.

### 3.2.2   Local Research/studies

Mundia and Aniya (2005) adopted three Landsat images  and socio-economic data in a post-classification analysis to map the spatial dynamics of land use and cover changes as well as identifying  the urbanization process in Nairobi city. The study revealed that  urban expansion has been accompanied by loss of land cover and  urban sprawl.  Through  the use of demographic and socio-economic data  together with land use and cover change, Mundia and Aniya  revealed that economic growth and proximity to transportation routes have been the major factors promoting urban expansion. Topography, geology and soils were also analysed as possible factors influencing expansion. The integration of remote sensing and Geographical Information System (GIS) was found to be effective in monitoring land use and cover changes and providing valuable information necessary for planning and research.

Olang *et al*. (2011) studied spatio-temporarl changes in land cover changes and their environmental implications within Nyando Basin. The researchers used six Landsat images of 1973, 1986 and 2000. From the findings, it was revealed that forest in the basin had declined significantly, by approximately 20 percent while agricultural fields expanded by approximately 16%. This was related to hazardous land use activities (Olang *et al*., 2011, p.389).

Njoroge, Maina and Nda'Nganga (2011) in their research entitled "Change in landscape cover types and pattern within Nairobi city and its environs' used landsat satellite data for 3 decades spanning from the year 1976 to 2000. Image data were geo-referenced, classified and analyzed along watershed zones delineated from a digital elevation model (DEM) of Nairobi city and peripheral region on a geographical information system (GIS) platform. Land cover categories of riverine vegetation and forest land showed the most marked decrease in real coverage by about 67 and 60%, respectively, while barren surfaces and urban areas increased by more than 100 and 98%, respectively, between 1976 and year 2000.

The above study is quite valuable except that it is mainly focused on the water level yet there are other aspects of the environment which can be significantly affected by land use and land cover changes. The study also relied mainly on GIS which has a share of its shortcomings (Kim, Bettinger and Cieszewski, 2012). Thus, the current study employed a combination of both GIS and survey method to complement each other. Survey was particularly valuable in capturing the various perception of local in relation to various environmental impacts of land use and land cover changes.

A more recent study is that of Ongoma, Muthama and Gitau (2013) who investigated urbanization and its environmental implications and found that urbanization was evidenced by the reducing urban land surface reflectivity and the increasing population. They also found that wind magnitude exhibited a reduction with time which they believe is harmful to human and animal comfort and the environment at large. The study recommends for proper planning of the cities to minimize further modification as a result of urbanization. The choice of residential and industrial places is also emphasized with regard to these findings. The findings of this work are thus important for multi-sectoral use in the urban centers however, it does not comprehensively discusses the environmental implications of urbanization especially in respect to land use and land cover changes.

In 2014, an attempt to address the land use planning challenges of Nairobi city and its environs was undertaken by a study team funded by the Government of Japan through Japan International Cooperation Agency (JICA), a governmental agency that coordinates official development assistance (ODA) for the government of Japan.

The resultant project, the *"Integrated Urban Development Master Plan for the City of Nairobi (NIUPLAN)"* is to be implemted between 2014 and 2030, therefore linking the growth of the city to Kenya's vision 2030. The Plan was meant to accelerate sound and sustainable development through an integrated urban master plan aimed at improving transport network, water supply and sewerage, solid waste management, and living environment.

The above project is quite valuable except that it is mainly focused on quantitative data of the current challenges facing the city but does not utilize the qualitative method of analyzing the rate of change in land use and land cover of the affected area. A methodological best practice of such work should combine both quantitative and qualitative approaches. According to Zainal (2009, p.1), "by including both quantitative and qualitative data, a case study can assist in explaining both the process and outcome of a phenomenon through observation analysis of the subject under investigation." This was lacking in the NIUPLAN. Again, the project should have provided deductive basis for undertaking land suitability analysis which is imperative in protecting the fragile ecologies like the riparian vegetation and forests covers against encroachment by other urban anthropogenic activities and protection of human life and property (Liu *et al*., 2010).

Nairobi City County was responsible for developing and implementing the NIUPLAN and ensuring the sustainability of the Plan from 2014-2030. However, the stakeholders to the consultative forums did not include membership from the counties to be affected and therefore it may face implementation challenges outside the boundaries of Nairobi City County.

### 3. 3    Principles of Urban Land-Use Differentiation

Various scholarly postulations have been done on land use and land cover differentiation within the cities. Miller (2001) postulated that the link between communities and natural systems begins with recognition that natural equilibrium must be maintained in the human settlements. Therefore, as human culture is shaped by ecological conditions; human behaviour on the other hand impacts on urban nature through city design. However, Hall (1977) argues that the critical problem for cities today is the management interventions that have destroyed much of the innovative entrepreneurship that was once the significant determinant of the urban morphology. As a reaction to the sentiments expressed by Hall (1977), proactive urban planning have since

envisaged urban development corridor concept which involves transforming city thoroughfares into strategic business hubs that promotes commercial activities making urban developments take linear form. This concept has been noted to work if augmented with the concept of the city of towers which advocates for vertical densification of development as was advanced by *Le Corbusier* in the early 1920s (Hall, 1977).

Alonso (1964) gives an account of urban land use differentiation based on land values. He details how individual households faced with the desire to buy land is faced with making double decision on the size of land to purchase and how close should it be to the city centre. The model assumes a city of single employment and shopping zone with equal transportation in all directions. The theory also assumes that the households or firms have perfect knowledge of the price of land, the cost of commuting to the city centre and that the cost of land drops as one moves away from the city centre. In this regard, individual household's locational equilibrium is achieved through selective combination of the desired quantity of land and distance from the city centre. He further uses the concept of bid rent curve to denote locations at which deferent land uses will locate based on the above stated considerations. Alonso (1964) observes that the most central site goes to the user with the steepest bid rent-curve notably the high order commercial activities with the second steepest bid rent curve locating on the next site outward from the city centre making urban land use and land cover pattern a function of bid-rent curves. The theory fairly explains the urban expansion of Nairobi as commercial acitivities intensify within the city centre and compete for space with the other land uses. The effect is that those land uses whose bid-rent curves are gentle such as the residential are the ones that mostly expand to the periphery.

Wingo (1961) postulates a theory called *Transportation-Oriented Theory* of land use and land cover which mainly explains the distribution of urban residential developments by considering transportation demand as an explanatory factor in the spatial distribution. Wingo (1961) assumes equal land supply and demand so that the city is just large enough to accommodate all land uses. He achieves the location equilibrium by substituting transportation costs for space costs. He further uses transportation costs to establish the distribution of household sites at varying location rents which he notes are the equivalent of the annual savings in transportation costs. This theory enables him to determine the spatial distribution of residential densities, rents, value and extent of land required for residential land use and notes that the most accessible areas

experience higher density in developments as opposed to the less accessible areas. However, in Nairobi, a city whose origin is dominated by colonial legacies of racial segregation, choices of location are still to some extent being influenced by social values, symbols and ethnicity. Towards this end, Firey (1974) in his study of a section of Boston city determined how cultural values and ideals influence land values and land use patterns. He notes that socially rooted values exert causative influence on urban land use patterns and that the market forces are only secondary causative factors as they stem from the larger cultural systems. He concludes that failure to recognize cultural values in spatial adaptation by Wingo (1961) and Alonso (1964) was an omission in seeking to explain urban morphology.

Weber (1929) views the city in terms of spatial patterns of human interaction which involves transportation network, the flow of people, goods and services as well as physical form which constitutes the urban space adapted for various anthropogenic activities. This gives a city the configuration of the spatial distribution of economic and social functions. He uses this concept to measure the spatial linkages as the determinants of the space forms adapted for human interaction and locations of activities. To advance his theory, Weber (1929) focuses on the distribution of physical facilities over the urban landscape by defining the facilities as distributed facilities and undistributed facilities all being a function of transportation. The rationale for this dichotomization is that if the transportation is poor, the work places and community services will tend to assume a pattern of distributed facilities and *vise –versa* if the transportation is good. Guttenberg (1960) advances the concept further by conceiving the urban morphology in terms of accessibility which promotes interactions. Therefore compatible land uses will cluster together to overcome distance that hinders their interaction. In this regard, human interaction is seen as the basic determinant of urban spatial structure.

Burgess (1925) postulated *Concentric-Model* to explain urban land use differentiation. He postulates that a city consist of five series of concentric zones namely the Central Business District, Zone in transition, working men's homes, residential zone and the commuter zone (Figure 3.1). He notes that the Central Business District has facilities such as the shopping areas, theatres, hotels, offices, banks and other high order facilities seeking central locations while the zone in transition is characterized by the presence of markets and older wholesale district. The zone is further defined by dynamism in land uses such as commercial activities co-existing with

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high-rise residential apartments. The third zone - the zone of working men's home is homes to factory workers while the fourth zone comprises of the large residential areas of the city where the white-collar workers and middle-class families are found. The fifth ring being the commuter's zone is zone of suburban communities where the urban upper-income groups having their personal mode of transportation reside. Burgess (1925) observes that as urban growth occurs each inner zone tends to invade the next outer zone similar to ecological invasion and succession. In contrast, when urban areas are decreasing in population, the outer zones tend to remain stationary but the inner fringe of the transitional zone tends to recede into the commercial district. While the model provides a useful explanation to urban land use patterns, in many respects it is has been noted to be an oversimplification.

Hoyt (1939) postulates sector model which arose from his study of residential developments in the United States. The model holds that different income classes in the city tend to locate their residents in distinct areas of the city in circular manner centered on the central business district with graduation of rentals downwards from the central business district (Figure 3.1). This pattern he explained is determined by access to urban transportation arterials making similar land uses to cluster together forming a distinct land use sector. The theory further notes that higher-income residential areas which develops along the fastest transportation corridors tend to pull high order commercial activities such as banks and stores to the neighborhoods. Despite the simplicity and over focus on residential development, the model provides a profound explanation to the urban land use differentiation than the concentric model.

The criticism of the above stated models made Harris and Ullman (1945) to come up with Multiple nuclei model which notes that there exist series of nuclei in the patterning of the urban land uses rather than a single central core as advanced by the other two models. The nuclei may take the form of industrial or wholesaling centers where specialized economic activities of similar or complementing characters have gravitated over the years (Figure 3.1). The theory identifies four factors that tend to account for the emergence of separate nuclei in urban areas namely the inter-dependence of certain types of activities and their need for close proximity, natural clustering tendency among certain types of activities that find it mutually profitable to cluster together, the appearance of centers to accommodate activities that may have no particular affinity for one another but are inimical to other uses by virtue of the traffic they generate and

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high land rents which have the effect of attracting or repelling users. The model is within the realities of contemporary metropolitan land use differentiation. However, it needs modification before it can operationally be used as deterministic model for urban land uses.

The urban land use as occasioned by land value speculations was also noted by the 19th Century scholars as characterized by works of Ruskin, Geddes, Carlyle, Dickens, Engels, Disraeli and Howard (Gallion, 1963). Among these luminaries was Patrick Geddes whose 1892 Edinburgh Outlook Tower writings postulates that urban land uses represents the level of environmental and socio-economic integration. Ebenezer Howard disturbed by haphazard urban land uses envisaged a town of communal land ownership with residential facilities and civic buildings distributed along a large central court while the shopping centre and the industries located on the edge of the town. Howard's visionary city would have a population of some 30,000 in an area of 1,000 acres surrounded by a permanent 5,000 acres of agricultural land.

Inspired by Howard, Milton Keynes Development Corporation (1970) made a plan for new town of Milton Keynes which sought to anticipate the forces which create cities and facilitate their healthy development. It recognised the close connection between transport systems and the arrangement of land uses and the need to consider these two basic elements together. The masterplan aimed at balancing housing and employment so that the City could be self-contained without large numbers of people needing to commute in or out. The predominant character of the city was the green spaces which punctuated the low rise buildings. The masterplan identified a number of key structuring principles which would meet its goals and define the character of the city and provided the framework for its development mainly regarding transport system, commercial zones, residential areas, open parks and clear pedestrian circulation (MKDC, 1970).

Peter Hall (2013), disturbed by the urban planning of cities in United Kingdom, set out to discover the lost art of urbanism in Europe. He outlined five societal challenges that the United Kingdom faced as being spatial economic inequality between (and within) regions; stuttering housing delivery and poor quality new developments; dated and poorly connected public transport; a mediocre record on environmental sustainability; a fiscal and governance structure which is not fit for purpose. He postulates that for there to be created better cities and towns in which to live work and play, then there must be economic resilience, adequate housing, connecting key cities via major investment in high- speed rail infrastructure, significant changes

in governance to truly empower city-regions, real devolution of the control of financial levers and a central state which prioritises investment in infrastructure throughout the country.

He further asserts that the effects of political power on growth and development of cities in United Kingdom is exhibited by the governments progressive dismantling of existing regional development agency structures and unprecedented budgets reductions that have emasculated the strategic planning function at the local level. The technical and financial strengthening of devolved units as well as national prioritization of transport infrastructure then becomes key for urban land use dynamics.
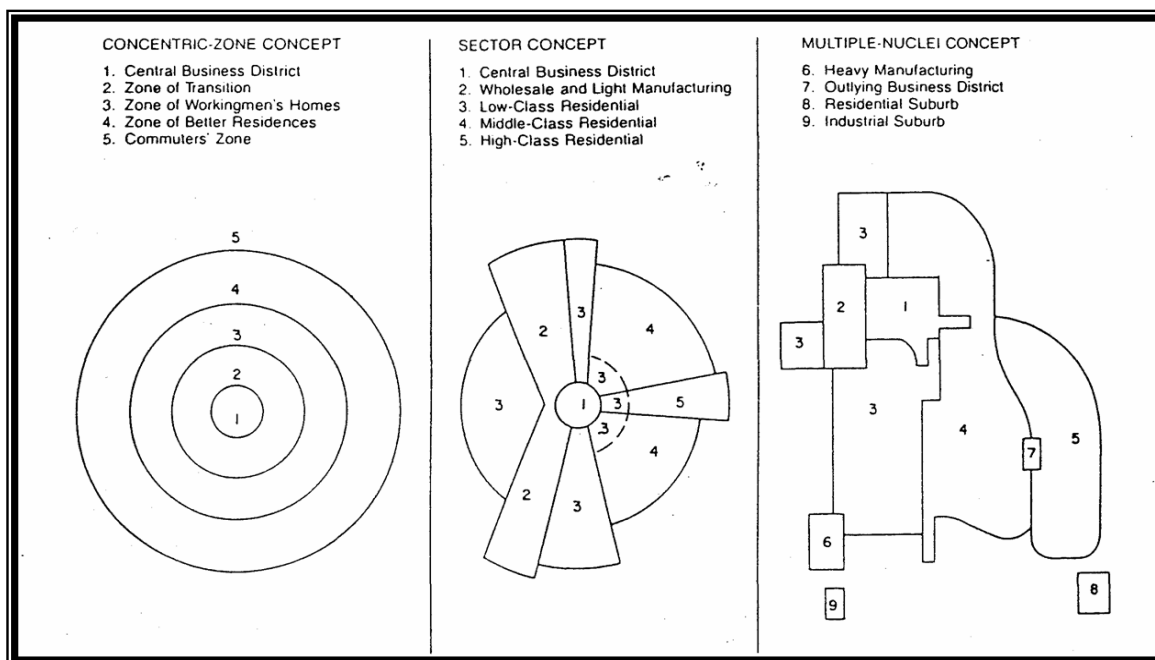


**Figure 3.1: Urban land use Models**
**Source:** (Hartshon, 1980)

## 3. 4    The Urban Land Use and Land Cover Dynamics

Urban land use and land cover dynamics is a product of the interaction between nature and society's socio-economic development phase (Bicik *et al.,* 2001). According to Bibby and Shepherd (1990), the rate of land use and land cover change is determined by demand and supply for houses and population growth. However, Bourne (1976)  identifies four main processes controlling urban land use and land cover dynamism namely the extension of urban edge or suburbanisation,  the expansion of infrastructure especially transport, the migration of industrial

developments from the inner city as well as the expansion of institutional, commercial and recreational land uses to the suburbs. Bourne (1976) further postulates that population increase alone is no longer the main stimulus of urban land use and land cover dynamism.

Meyer (1995) asserts that every parcel of land on the Earth's surface has unique land cover which closely links to the land use. The land uses are broadly categorised as residential, educational, commercial, industrial, public utility, public purpose, transportation and the deferred land whose user has not been identified and is serving as land bank. In the formative stages of the term, land cover denoted vegetation, soil and water body. However, in the recent past the term has been broadened to include human structures, soil type, biodiversity, surface and ground water (Meyer, 1995). The dynamics in land cover as occasioned by land use may not necessarily imply degradation of the land. According to Riebsame *et al.* (1994), shifts in land use patterns as arising from societal aspirations result in land cover changes that affects the earth's biogeochemical processes consequently affecting the atmosphere, lithosphere, hydrosphere and the biosphere.

The above stated views are further advanced by O'Sullivan (2007) who notes that anthropogenic activities such as agriculture, lumbering, livestock rearing, establishment of urban and suburban settlements as well as infrastructural facility creation acts in concert with natural events such as flooding, fire disaster and climate fluctuations in altering land use and land cover. There are also incidental impacts on land cover stemming from indirect anthropogenic activities such as the burning of fossil fuel that leads to the creation of acid rain which consequently lead to the damage of natural resources such as the forests, eutrophication of lakes as well as corrosion of human artefacts (Meyer, 1995). The above annunciations illustrates that optimal utilisation of land requires an up to date inventory of the existing land use and land cover.

## 3. 5    Land Use Decision Making Mechanism

Land Use decision making is determined by various factors. Olaleye *et al*. (2009) observes that the analysis of land use and land cover dynamics revolves around two questions notably the causes and the impacts of the same. However, determination of land use and land cover dynamics is not clear as they are debatable but it is agreed that the two main categories of such

agents of change are bio-physical and socio-economic (Mengistu and Salami, 2007: 2). The bio-physical drivers include geo-processes such as climatic variations, tectonic forces, plant succession and drainage regime (Olaleye, 1992). The socio-economic drivers comprises of demographic dynamics, social values, economic growth, political and institutional factors, technological change and public policies related to land use which varies over space with time (Turner, 2002). The next section discusses the legal framework, socio-economic and political factors in the context of Nairobi City.

### 3.5.1 Legal Framework

The essence of regulations is development control and maintainance of acceptable standards of physical development ( Oke & Fagbohun, 2009) . Land Use in the city is controlled by various instruments but not limited to the following: Physical Planning Act, Cap 286, Local Authorities Zoning Policies, Environmental Management and Coordination Act (EMCA) of 1999 and The Forest Act, Cap 385 of 1996 (revised 2009).

### 3.5.1.1 Physical Planning Act, Cap 286

Physical Planning Act, Cap 286 has explicit powers on development control matters in urban areas. It provides for the formulation of National, Regional and Local physical planning guidelines, policies and strategies (Kimani and Musungu, 2010). The physical planning act provides for the preparation and implementation of physical development plans and other connected purposes. Under the Act, Local Authorities are given powers to prohibit or control use and development of land and buildings for orderly development in the following manner: control of sub-division of land, consideration and approval of development proposals, ensuring proper execution and implementation of approved physical development plans, formulation of by-laws to regulate zoning in form of density of development and to preserve and maintain open spaces, parks, urban forest, green belts in accordance with approved physical development plans (Kimani and Musungu, 2010).

### 3.5.1.2  Local Authorities Zoning Policies

In Kenya, local governments regulate and control the type of location of land uses within their borders through zoning (Munroe *et al*., 2005). Zoning is based on a comprehensive land-use plan, enforced to encourage or regulate development along pre-determined areas or permissible uses in terms of commercial, industrial, residential, and recreational areas. Land use zones separate one set of land uses from another based on the optimum and sustainable use of resources. Theoretically, the primary purpose of zoning is to segregate uses that are thought to be incompatible. In practice, zoning is used to prevent new development from interfering with existing physical and geological setting. Linked to this is the zoning by-laws or an ordinance defined simply as the statements upholding and supporting the zoning plan (Hodge, 1991). By-laws are the equivalent of local legislation and are enforceable. By-laws can permit or restrict activities across zones; they are not necessarily spatially specific. They govern how land may be used, where buildings and other structures can be located, the types of buildings that are permitted and how they may be used, the lot sizes and dimensions, parking requirements, building heights and setbacks from the street. Zoning laws are vital in quality of urban environmental since they direct the manner in which important areas are to be utilized and thus have the potential to ensure that resources are sustainably managed.

However, zoning is considered as highly political and receive many critics. For instance, regulations fail to care for established neighborhoods' and to prevent sprawl on the fringes of cities, and the administration of regulations is often associated with favouritism and corruption (Listokin, 1974). As Munroe *et al*. (2005) argued "zoning plans generally reflect a variety of political interests and stakeholders. Local government also faces a balancing act in attempting to maintain broad political support, keep service costs low, and maximize the residential tax base. In many cases, zoning or re-zoning are strongly influenced by land developers and neighborhood interests are disregarded (Fischel, 1985). Or, the decisions maybe influenced by some home-owning voters, since these small groups of people can sometimes influence the political campaign.

Apart from the zoning laws, the forest Act Cap 385 is also important in controlling environmental management. It provides the legal framework for the conservation of forests and under it, the minister responsible for the natural resources is empowered to declare any forest area a nature reserve for the purposes of preserving the natural amenities thereof and the flora and fauna therein.

### 3.5.1.3  The Environmental Management and Co-ordination Act (No. 8 of 1999)

This act provides for guidelines for environmentally sustainable development. The Act requires that development plans embrace the preparation of Participatory National Environment Plans that have sectoral coordination and linkages as well as environmental conservation measures. It also requires that environmental impact assessment be carried out for all development projects that are likely to pose negative environmental impacts. For complete projects, the act requires that yearly environmental audits be carried with clear mitigation measures (Kimani & Musungu, 2010). To manage the environment in a holistic manner, the Act establishes two administrative bodies: the National Environment Council (NEC) and the National Environment Management Authority (NEMA). While NEC has the responsibility of formulating policies, setting national goals, and promoting cooperation among stakeholders, NEMA's role is to supervise and coordinate overall matters relating to the environment. It is instructive to note that the Act creates NEMA (Section 7) as the body charged with implementing the provisions of the Act.

The Environmental (Impact Assessment and Audit) Regulations, 2003, stipulate that lead agencies should subject all public policies, plans and programs (PPP) to Strategic Environmental Assessment (SEA). During the SEA process, the likely significant effects of a PPP on the environment shall be identified, described, evaluated, and reported. The full range of potential effects and impacts should be covered, including secondary, cumulative, synergistic, short-, medium- and long-term, permanent, and/or temporary impacts.

### 3.5.1.4  The Forest Act, Cap 385 of 1996 (revised 2013)

This is also one of the statutes that have a bearing on the planning and building sector. The Act provides for the establishment, control, and regulation of forests in Kenya. It encourages the

conservation of all types of vegetation thus contributing to the greening of urban areas immensely (Kimani & Musungu, 2010). The Forest Act is applicable to gazetted forest areas (Forest Reserves) and specifically covers:  Gazettement, alteration of boundaries and de-gazettement of Forest Reserves (Section 4); Declaration of Nature Reserves within Forest Reserves and regulation of activities within Nature Reserves (Section 5). Despite these provisions, it's noteworthy that broadly speaking, the declaration of areas as protected forests is an aspect of land use planning which is contained in the Physical planning Act Cap 286. This may cause conflict on which of the laws takes precedence over the other.

Additionally, the Act provides for the power of local authorities and the state to regulate the development and use of property (including private property) for the good of the community or country as a whole.

Conversely land use planning provides a guide for integrating different land uses for the benefit of an entire range, especially in ecologically important regions where different property-rights regimes operate.

Forest management affect the land use and land cover dynamics within Nairobi as the need to expand built up areas exerts pressure on the forests while endeavoring to ensure that resources are sustainably managed.  However, the expansion of the city which may consume any gazetted forest would have to go through the procedures of degazettement provided for in the Forests Act.

Apart from state forests, the Act allows for forest officers to make arrests in local authority forests and provisional forests. To ensure strict protection of forests and illegal encroachment to forests, the Act confers prosecution powers to forest officers  Further, in the revised Act,  the levels of penalties has been raised to ensure deterrence.

### 3.5.1.5  National Land Commission Act, 2012

The National Land Commission Act, 2012 gives effect to the establishment of the National Land Commission as the main regulator of public land. The Act further mandates the Commission to create County Land Management Boards (CLMBs) for purposes of managing public land at the county level.

According to the National Land Commission (NLC) progress report of January 2014, the Commission has taken steps and measures to stop encroachment and sale of public land belonging to the county and national governments. NLC has also initiated action to recover encroached public land by supporting court cases filed by resident associations against private developers. It has furhetr advised and notified all Counties to complete their inventories of lands that have encroachments for immediate repossession (NLC, 2014). As most the infill development that affect the environment of the city are done on the enchroached land, the action by the NLC will give planning authorities of the affected areas time to undertake suitability studies for development of those spaces.

### 3.5.2 Shortcomings of the Legal Framework

Despite the existing legal framework, development control in the urban areas in most cities including Nairobi has been inadequate and ineffective. This can be attributed to a number of factors. For instance, the existing framework for land administration and management is highly centralized, complex and exceedingly bureaucratic, consequently leading to corruption and failure to deliver efficiently (Sessional Paper No 3 of 2009). In addition, the existing development institutions and legal framework are weak and lack a comprehensive land use planning policy to guide the way in which land is utilized thus causing disharmony in land utilization (Odhiambo and Nyangito, 2002).

Another challenge relates to laxity in approving plans in that despite the fact that the law requires that all developers must submit their development proposals to local authorities for approval, this has been reported to take unnecessary long period of time thus delaying developments in most of the local authorities. Developers have had to go ahead with their developments with no regard for submitted plans. Local Authorities have been also slow in making decisions on planning application. This has been attributed to the complicated procedures the applications have to go through; laxity among the officers and the councilors and the over-centralization of decision making (Munroe *et al*., 2005).

There is also the challenge of multiplicity and incoherent organization of planning institutions. Institutional coordination is handicapped by the fragmented nature of local government and planning institutions inherited from the colonial era. Although there are 100 legislations

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governing land use and management, there is no concise national policy framework from which holistic and integrated land use strategies and directions can be generated. The multiplicity of laws in these legal entities has also caused various conflicts. There is also lack of a mainstream mechanism for physical development planning thus creating a conflict between the national, regional, and local levels of planning. Whereas the plan formulation/preparation is undertaken by the central Government, plan implementation is the responsibility of the Local Government. (Kimani & Musungu., 2010). In addition, there is limited institution coordination of development control agencies especially during development application permission, supervision, and inspection of the projects. Further, some instruments contradict each other and multiplicity of laws domiciled in different institutions is making their implementation uncoordinated. (ibid)

### 3.5.3   Economical Factors in Land Use Decision Making

Economical factors influence decision of a land use and is often influenced by marketability of a of the type of land use, availability of land and security of tenure, the price and availability of technology. While studying determinants of land use in the densely populated Kigezi highlands of Southwestern Uganda household, Bamwerinde and his colleagues assert that factos such as access to resource (e.g. labour, land) will also affect the net returns from the portfolio of plots and affect general land use decision-making especially at the farm level (Bamwerinde *et al*., 2006)

### 3.5.4   Political power and Land Use decision-making Mechanisms

Patterns of land use and urban development can "reflect social meanings, institutional values, and political goals within a geographical context" (Lo, 2010). According to Saint *et al*. (2009), politics of land use revolve around four questions, that is; who are the stakeholders? Who makes the choices about land use? Who is excluded from use? Lastly, who benefits from use? Most land-use decisions are primarily local and individual, however, the regional and national land-management agencies own a considerable amount of authority, thus land is the key to planning and control at broader levels regulated by state and national governments. In this respect, the land-use decision-making process is inherently political (Saint *et al*., 2009).  In the same vein, Dafe (2009) asserts that land use/allocation  is essentially a political decision linked to the fact that land has  a strong spatial aspect and can be used to benefit the people living together in a specific location, for instance, residents in ethnic enclaves or high income areas. In addition, land

values / goods are highly visible so that their allocation can easily be attributed to political actors by increasing their chances of re-election (Dafe, 2009).

The government has the ability to affect the demand side of the market for land in various ways, for instance, through its use of tax incentives or other types of subsidies. In this way, government may increase the demand for certain land-use types beyond a level the market would have otherwise achieved. The Government is itself a demander of land, and so by increasing or decreasing its consumption of land directly affects the demand—and the expected net rent—for land in various use types. Similarly, the government may affect the supply side of the market for land for instance, through rezoning land from one use type to another. In this way, government increases the supply of land in the latter use type while decreasing the supply of land in the former use type. In addition, by annexing land into its political boundaries, government increases the supply of land of the relevant use types. Lastly, Government may also impact the expected net return for a particular land-use type through actions that affect conversion costs. Such action could take the form of permits, fees or other requirements that apply disparately to different types of land-use conversions, for instance making it more costly to convert from one land use to another thus reducing the relative number of conversions.

### 3.5.5 Technology as a factor in Land Use Decision Making Process

Technological factors conditions land use decisions by influencing the profits accruing to land managers. The availability of new technologies and the ease with which they can be applied to land affect significantly the productivity of labour and capital employed. It is difficult in mountainous areas, and this constrains the type of lands use changes in these areas. The ease and rate of adoption of available technologies by land managers influences the potential for land use changes. Technological development such as the extension of basic transport infrastructure such as roads, railways, and airports, can open up previously inaccessible resources and lead to their exploitation and degradation .In a broader sense, knowledge resources that land managers possess (as in the case with traditional knowledge) or are able to obtain (eg technical assistance) largely affect land use decisions (Saint *et al*., 2009)

**3.6     Implications of the Land Use and Land Cover Changes**

**3.6.1    The Role of Geospatial Techniques in Land Use and Land Cover change Detection**

The last two centuries have witnessed technological developments which have brought tremendous change in urban land use and land cover variations. However, for sustainable development there is need for planning of such developments. Urban planning being futuristic oriented, it must be informed by reliable data on the inventory of the existing land use and land cover (Kerry, 2003). Accomplishment of this task without geospatial techniques as noted by Billah and Gazi (2004) is almost impossible granted that conventional surveying methods of land use and land cover mapping are labour intensive, time consuming and unreliable in terms of temporal frequency of data acquisition within a rapidly changing environment, making the maps produced become outdated as they are produced. Therefore, spatio-temporal analysis of land use and land cover is impractical using the traditional surveying methods (Olorunfemi, 1983).

In recent years, satellite remote sensing techniques have proved accurate in the preparation of land use and land cover maps which aid in change detection. Shosheng and Kutiel (1994) investigated the advantages of remote sensing techniques in relation to field surveys in providing a regional description of vegetation cover. The results of the study were used to produce four vegetation cover maps that provided spatio-temporal information for quantitative assessment of the vegetation cover.  Towards this end, the geospatial techniques have been noted to be cost effective due to its ability to instantaneously acquire data of large areas which includes inaccessible regions (Jensen, 1983; Ford, 1979). The results of many studies demonstrate that medium resolution satellite data such as Landsat and SPOT are useful in gathering land use and land cover information for change detection (Jadkowski and Ehlers, 1989; Ehlers *et al*., 1990; Martin, 1986; Kam, 1994).

Ever since the launch of Landsat-1 in 1972, land use and land cover studies have been carried out on different scales depending on the purpose. For instance in 1982, waste land mapping of India was carried out on 1:1 million scales by National Remote Sensing Agency using Landsat MSS data. More recently, researchers in developing countries have investigated the feasibility of satellite data in providing accurate information for surveying, identification, classification, mapping as well as monitoring  urban environment in general and Land Use and Land Cover

change detection in particular (Gastellu-Etchegorry, 1988). Towards this end, Mahavir and Galema (1991) used SPOT data to monitor the land use and land cover dynamics of Chiangmai, Thailand by visually interpreting panchromatic print of a SPOT image of 1:20000 scale which yielded 92.7 percent overall accuracy. The study concluded that for quick and quantitative assessment of urban land use  and land cover dynamism, SPOT data are useful (Kam, 1994). Dimyati and Kitamura (1990) used multistage and multi-data LANDSAT MSS and SPOT-HRV images separately to analyze the growth of Samarinda city in Indonesia for the year 1984 and 1987 and the study's level of accuracy legitimizes the use of the technology. Brouwer *et al*. (1990) further validates the legitimacy of the technology through their assessment of the urban growth of Barranquilla, Colombia through the use of multi-date SPOT satellite imagery of the city taken in May 1986 and 1982 to highlight land use and land cover changes which later on aided the policy makers to redirect the urban development resources equitably.

In 1985, the U.S Geological Survey carried out a research to produce 1:250,000 scale land use and land cover maps for Alaska using Landsat MSS data while the State of Maryland Health Resources Planning Commission also used Landsat TM data to create a land use and land cover data set for inclusion in their Maryland Geographic Information (MAGI) database. In both the studies, all the seven TM bands were used to produce 21-classes of land cover maps (Fitz *et al*., 1987; EOSAT, 1992). In the year 1992, the Georgia Department of Natural Resources completed wetland and other land use and land cover mapping using Landsat Thematic Mapper. In these studies it emerges that the analyses of land use and land cover using satellite images are accurate in comparison to topographical maps (Dimyati, 1995; ERDAS, 1992).

While examining the use of GIS and Remote Sensing in mapping Land Use and Land Cover in Greater Doha between 1995 and 2007 so as to detect the changes that has taken place in this status between these periods, Perumal and his colleagues introduced the use of Land Consumption Rate and Land Absorption Coefficient to help in the quantitative assessment of the change. According to the scholars, there was a rapid growth in built-up land between 1995 and 2000 while the periods between 2000 and 2007 saw nearly three times increase in this class (Perumal *et al*., 2011).

The above discussed applications corroborate the significance of geospatial techniques in urban resource analysis and management for they allow detailed survey, mapping, modeling and monitoring of the resources. However as pointed out by Nasreen (1999), the accuracy of such analysis significantly depend on the image quality, image classification procedure and/or schema used as well as the technical and indigenous knowledge of the analyst on the study area. Nasreen (1999) further notes that no single classification schema can universally apply thus the analysts have to device a schema which represents the study area. To date, the most successful attempt in developing a general purpose classification schema compatible with remote sensing data has been by Anderson *et al*. (1976) and majority of the studies are basically a modification of the schema. To corroborate this, Daniel (2002) in comparing Land Use and Land Cover change detection methods, made use of 5 methods *viz;* traditional post -classification cross tabulation, cross correlation analysis, neural networks, knowledge-based expert systems, image segmentation and object-oriented classification for classification of nine land use and land cover classes. The study observes that there are merits to each of the five methods and that no single approach can wholly solve the land use change detection inaccuracies associated with geospatial techniques.

Macleod and Congation (1998) list four aspects of change detection which are important when monitoring land uses and land cover as the detection of changes that have occurred, identifying the nature of the change, measuring the spatial extent of the change and the assessment of the spatial pattern of the change. According to Ursula *et al*. (2004), Land Use and Land Cover change detection through geospatial techniques is possible due to alteration of the spectral radiance occasioned by the phenomenon making the techniques have increased versatility with the advent of digital image processing and increased computer power. Towards this end, a variety of digital change detection techniques have been developed over the last two decades. Singh (1989) and Coppin and Bauer (1996) summarize eleven different change detection algorithms commonly used as mono-temporal change delineation, delta or post classification comparisons, multidimensional temporal feature space analysis, composite analysis, image differencing, multi-temporal linear data transformation, change vector analysis, image regression, multi-temporal biomass index, background subtraction and image rationing.

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However, there is need to augment remote sensing operations with GIS for increased utility of spatial data (Howard, 1991).

### 3.6.2   Environmental Implications of Land Use and land Cover Dynamics

Land use and land-cover changes have significant impacts on a range of environmental and landscape attributes. (Sundarakumar *et al*. 2011:170). Land use and land dynamics changes lead to disruption of atmospheric temperature and its climate forcing (Mahmood *et al*., 2010).

Tan *et al*. (2010) in their article titled "Landsat data to evaluate urban expansion and determine land use and land cover changes in Penang Island, Malaysia"  investigated analytically the possible effects of land use changes with respect to Land surface temperature. They conducted empirical studies using Two Landsat satellite images captured in 1999 and 2007 to classify the land use and land cover types with the help of the maximum likelihood classification method, determined from visible and near-infrared bands. A finding from the studies was that changes in land use and land cover caused significant difference in land surface temperature (LST) between urban and rural areas under a modified land cover. In addition, there was a reduction in moisture recycling due to less evapo-transpiration, which encouraged a decrease in humidity in the lower atmosphere (Minale and Rao, 2011).

The bio-geophysical climate impacts of Land Use and Land Cover change have also been investigated by a range of other modeling and observational studies (Przekurat *et al.*, 2011) . Land cover changes in response to climate change include sea-level rise, invasion of non-native plants and shifts in ecosystem boundaries (Mölders, 2012). However, while there are many and varied studies on the effects of climate, most have found that general impacts are consistent for a specific land cover change in a given geographic locality. For instance, Lawrence and Chase (2010) found that in the tropical forests, land cover change enhanced warming, with the lower transpiration and canopy evaporation of grasslands and crops resulting in reduced latent heat flux and increased sensible heat flux in response to the increased residual surface energy budget. However at higher latitudes they found that land cover change results in cooling due to higher albedo from crops and grasslands that replace darker boreal forests that mask snow albedo. In mid-latitudes their findings were mixed with the albedo forcing competing against the hydrological forcing for a given land cover change (Lawrence & Chase, 2010).  The simulated

warmer and drier climate with enhanced climate extremes are cumulatively impacting the soil moisture and surface runoff, and are likely to affect turbulent transport of water vapour and partitioning of available surface water between surface runoff and evapotranspiration (Minale & Rao, 2011). Other driving force to land cover change are the earthquake or otherwise induced landslides, and volcanic eruption. In a broader sense of surface changes, we may consider break-off of ice shelves, glacier retreats, permafrost retreat and /or warming as near-surface response to climate change (Mölders, 2012)

Land use change is also a major driver of changes of biodiversity and of biogeochemical as well as biological ecosystem processes and services (Abbott & Maitre 2010). Significance changes of land use and land cover could influence the structure and function of landscape ecosystems and result in profound change to the regional eco-environment, particularly in an eco-social transition zones. (Yu, Li & Chen 2010). In the real-world landscape context positive correlations between biodiversity and ecosystem processes was reported. For instance in the forest ecosystems, there is indirect effects of browsing ruminants, and enhanced by displaced alien species, by industrial emissions of nitrogen, organic compounds and heavy metals, and by climate change.(Biswas & Mallik 2010). In Germany, forests and grasslands are, along with cropland, among the most important ecosystems affected by increased land use changes. The natural vegetation cover of deciduous forests is now restricted to rather small and highly fragmented areas. Furthermore, nutrient-poor grasslands, formerly only used at low intensities by humans and forming the most species-rich assemblages, are now threatened by land-use intensification (Maskell *et al*., 2010). The foregoing environmental implication are rather inconclusive hence the need for an explicit incorporation of the interactions between environmental changes and land use dynamics to understand what are current impacts and indicators and be able to isolate real environmental changes

## 3.7    Towards a theoretical Model for Land Use and Land Cover Dynamics

### 3.7.1   Theoretical Framework/Model

As observed in the previous paragraphs, many theories have advanced to explain land use and land cover change to urban development including transportation oriented theory, concentric and sector models. However, the theories only describe various approaches of urban land use

distribution ranging from transport system, zones and income classes. Thus they fail to highlight the links between land-use and land dynamics and environmental implications.

The current study has used Pressure-State-Response (PSR) and Driving-Pressure-State-Impact-Response (DPSIR) Models. Pressures-State-Response framework was first proposed by OECD and UNEP in 1994 and used to measure ecosystem health (Shilong, 2010). According to this approach, land use/ land dynamics like urban activities exert pressures on the environment and change the quality and quantity of natural resources (the State). The model provides a means of selecting and organization indicators in a way useful for decision-makers and the public. It also relates to the society responses to these changes through measures of environmental, economic or sector policy (the Responses), to correct the pressure and the state.

Shilong (2010) conducted a similar study where he linked his preferred PSR model to the characters of land resource in Loess hilly region and analyzed the land use and land cover changes of the study area from 1982 to 2005 year and observed that before 1982 year, the inappropriate land use patterns in response to the pressures of population growth and socio-economic development caused eco-environmental degradation and poverty, while from "the Sixth Five-Year Plan" to "the Tenth Five-Year Plan", the rational measures of responses promoted the regional sustainable development, the net annual income per farmer increased from 47.7 Yuan(RMB) to 2093.2 Yuan(RMB), while the soil loss intensive decreased from 6000 t·km-2·yr-1 to 1000 t·km-2·yr-1. Although this study gives important insight, it was not in any way related to urban environment thus leaving out important aspects of land-use and land dynamic and environment.

Driving-Pressure-State-Impact-Response (DPSIR) simply represents PSR modified and developed by European Environmental Agency and includes five basic elements: Drivers, Pressures, State, Impacts and Responses (Kagalou *et al*., 2012). The drivers emerge from people's needs to satisfy their basic needs including food, water, shelter and energy. On the other hand, secondary requirements involve mobility, entertainment and culture. Drivers also include the underlying population increase and corresponding need to satisfy the increased demand (Shilong, 2010). All these Drivers lead to pressures on the environment, which often result in

production and consumption processes, such as an excessive use of resources and emissions into the environment. The Pressures, in their turn, change the state of the environment, which represents a degree of quality usually reflected in physical, biological and chemical conditions of the environment. (Sekovski te al., 2012). The changes in these conditions may eventually have environmental implications such as altered biodiversity or reduced resource availability, and ultimately on social and economic features of the society and human health as well. Responses present a set of societal and policy makers' prioritizations with the final aim of reducing the undesired impacts as much as possible by affecting any part of the chain between the drivers in land use and land dynamics and the impacts (Sekovski *et al*., 2012).

In the context of urban land use and land dynamics, driving forces may include urbanization, energy consumption (impacts of environment) and the transport sector. Pressures consist of solid and liquid waste, gas emission, alteration of natural hydraulic and sediment flux and loss of habitat. On the other hand, state of the environment composed of air quality, water quality, and state portable water with high concentration of metals and suspended solids. Impacts which are directly linked with this study generally include erosion, decline in biodiversity, change in ecosystem and climate.Lastly, response relates to measures/policies to cut the overall environment implications of land use and land cover dynamics. (Sekovski *et al*., 2012).

DPSIR has proved very useful in analysis on land use and land change dynamics. Kagalou and his colleques employed the same model as a guide to Integrated River Management Framework. In their research, the main driving forces, leading to pressures, were the agriculture, the livestock and the many point-pollution sources at the catchment area. Elevated nutrients concentrations (NO3-N: 0.1–2.6 mg/L, NH4-N: 0.01–1.29 mg/L, SRP: 0.03–5.76 mg/L) along with high chlorophyll-a values (0.54–6.14 mg/ $m^3$) which indicated river eutrophication. They suggested several actions/Response like elimination of diffuse pollution as well as reduction of the organic load through the optimization of the existing treatment plants as well as specific measures for protecting biodiversity (Kagalou *et al*., 2012).

The main weakness of the two approaches to land use and land change dynamics is that they consider urban activities only as sources of environmental pressures, where they also produce

goods and services resulting (together with the impacts of the urban environment) in living conditions for the urban population. The relationships between drivers, pressures and responses seems more complex. In addition, positive and negative feedback loops exist between different urban activities as a result of economic and social mechanisms. Policy measures too may have multiple effects. All in all, the two models are quite relevant to the current study as they are able to show the causal linkages missing in other models. Unlike the study by Shilong (2010), Kagalou *et al*. (2012) research was restricted to River Management Framework hence not conclusive enough and cannot be extended to urban development. This study therefore seeks to fill the current gaps.

### 3.7.2 Conceptual Framework

In an attempt to derive a unifying explanatory model for the urban land use and land cover dynamism, cognisance should be taken of how land use and land cover decisions are made and how the urban set up supports the aspirations of its inhabitants alongside maintaining the spatial compatibility between competing land uses. These considerations draw significantly from the principles of sustainable development and ecological concepts. According to Ahern (2002), the amalgamation of the two concepts provides an embodiment to urban land use differentiations and dynamism underpinned by the statutory regulations such as the land use planning, socio-economic aspirations and the environmental factors in favour or against the same. The principles of urban ecology which employs systems theory provides a unifying model for explaining urban land use and land cover dynamics as an advancement from the bid rent and transportation models. It incorporates multi-variables such as natural ecology, socio-economic, political and legal factors not taken cognisance of by the bid rent curve and transportation models ( Jiang *et al*., 2012). The ecological model is holistic, futuristic and probabilistic in nature providing deterministic approach to the prediction of land use and land cover dynamics. The basic principle in this model is that human activities are driven by response to the environmental circumstances and any modification on their ecology triggers equilibrium shift. However, ecosystems are mosaics of abiotic and biotic components depicting man as actors in the city with their action(s) having impact on the ecological functioning of the city granted that different land uses and land covers require specific ecological niches to thrive (Loreau *et al.,* 2001).

The above stated interactions influences the urban demographic composition and social interactions by creating mental perception among the residents as to whether the urban landscape provides a healthy environment for interaction and/or establishment of economic activities (Loreau *et al*., 2001). If the perception is negative, then there is likelihood of migration and establishment of the activities in another neighbourhood that is positively perceived, which consequently determines land use and land cover dynamism in the urban setup. The economic component of the theory grants that the urban vibrancy depends on its ability to provide goods and services to its inhabitants (De Groot *et al*., 2002). Therefore, with increased or decreased urban economic opportunities, there is bound to be migration of land uses and land covers which were supporting the economic activities making other land uses of low value, notably agriculture, take over with consequence of changes in the land use and land cover. Finally, the land use decision-making mechanisms in the city as embodied by the statutory, legal and/or urban planning regulations as well as political and technological advancements in the society determines the land use and land cover dynamism.

It is imperative to re-emphasis the effect of globalisation as it amplifies or attenuates the effects of the factors discussed above in determining urban land use and land cover changes due to its ability to remove regional barriers as well as the interdependency among people and between nations through enabled free movement of people, goods and services. Therefore, depending on the location, stage of development and opportunities provide by a city, it is likely to attract investments consequently altering the land use and land cover within it as low order functions such as agricultural land uses are likely to give way to industrial developments (Martin, 1986). However, the above stated factors vary over the urban space with time making urban land use and land cover changes not uniform within the urban landscape. The above stated annunciation as illustrated by Figure 3.2 provides a unifying view of the conceptual framework for understanding the origin of Nairobi's land use and land cover dynamism as well as providing a way forward for controlling the changes which are understood to be undesirable.

### 3.7.2.1 Land use and land cover changes in Nairobi

There are many factors that drive land use and land cover changes, key among them being population and economic growth. The dynamics of land use and land cover changes affect

environmental and socio-economic conditions (Barnsley and Barr, 1996). The land use and land cover changes for Nairobi have occurred as a result of interactions of a number of environmental as well as demographic and socio-economic forces. According to Mundia *et al*. (2006) and Thuo (2010) changes in land use and land cover in Nairobi can be attributed to population growth, economic development and more recently to land use decision making factors. These are mainly related to regulatory factors focusing on the ability of various institutions mandated with the role of planning and managing urban land development satisfactorily. As noted by Briassoulis (2010), the socio-economic drivers comprise demographic, social, economic, political and institutional factors and processes such as population and population change, industrial structure and change, technology and technological change, the family, the market, various public sector bodies and the related policies and rules, values, community organization and norms, and property regime (Figure 3.2).

### 3.7.2.2 Population Growth

Mainly due to rural-urban migration, Nairobi's population has risen from slightly over half a million in 1969 to 3.14 million in 2009 (KNBS, 2009). This population has created demand for several goods and services which require space leading to change of various land uses and land covers to accommodate new functions at the expense of previous functions.

Nairobi's economy, public services and infrastructure have not managed to keep up with the increasing population. The city management has been unable to cope with the increasing demand for efficient city services since the rapid urban growth has outpaced the capacity of local authorities to provide and maintain infrastructure and basic services (Stren and White, 1989). The population, which has been growing at a rate of 4 per cent per annum, has contributed to shortage of decent residential housing leading to the mushrooming of slums, hence increased land use and land cover changes. Aguilar and Ward (2003) indicate that rapid urban population growth has led not only to an increasing demand for urban land, particularly for housing, but also for other various urban uses like, industries, educational institutions, commercial zones, administrative centres, roads and public utility areas.

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### 3.7.2.3 Economic Development

The economic development of the city has led to a boom in the construction industry and subsequent expansion of built-up areas. This has resulted in pressure and need for more land to accommodate the housing, commercial and industrial needs for the increasing city population. The unregulated small-scale businesses have also expanded rapidly and the employment in this sector was estimated at 500, 000 people (GoK, 2002). The increase in economic development as measured by the changes in the GDP values reflects in the change in urban expansion. Nairobi's gross domestic product (GDP) was about £254 million sterling in 1975, £645 million in 1985 and £1.1 billion in 1995. The economy, which grew much faster in the period 1975 to 1985 led to a cumulative growth of 153 per cent which also led to a higher rate of urban expansion. The period 1988–2000 had a lower rate of urban expansion, which can be explained by the slow economic growth (70 per cent) during the period 1985–1995 (Mundia *et al*., 2006).  Zimmere and Basset (2003) acknowledges that economic factors influence lands use and land cover transformation both across scale and through time. The economic development and pace of land use changes in Nairobi has not taken place evenly in all directions but has occurred much faster and further in certain direction, which can be attributed to ad hoc land use planning, zoning regulations and more importantly control of development in the City. This is supported by Hirst and Lamba (1994) who noted that with vibrant urban economy and lack of proper land use planning and guidance, urban areas are being developed only because of availability of space.

### 3.7.2.4 Land use Decisions

Land use and land cover changes result from direct or indirect decisions to alter the current uses of land at the level of an individual land owner, of a regional or national authority, of an international body, or of any other land-related interest. Whatever the form these decisions take, the important point is that they involve decision making units and decision making processes at particular levels of one or more scales. In other words, the analysis of land use change necessarily asks "who decides to change the use of land, where, when, and why". The factors which are taken into account in the analysis relate to the particular decision making units and processes as well as to those influences which impinge on the range of choices open to the decision making units (Blaikie and Brookfield, 1987). The assessment of land use and land cover

changes and the evaluation of the resulting impacts as well as the decision to act are all related to the pertinent decision making units and processes (Figure 3.2). Briassolus (2010) noted the land management and land use planning in response to land use and land cover changes or with the purpose of effecting desirable land use change are tied to decision making units at various scales. The meaningful and useful analysis of land use change in support of these functions should, therefore, pay due attention to the different scales involved and to their relationships.

## 3.8    Summary of Literature Review

The current literature on land use and land cover change  clearly indicates important implications on the environment. It is however evident from the literature reviewed that there exist very few studies which address the effect of land use and land cover on the environment quality of Nairobi City County and that the few available literature on the topic is in isolated forms. Further, none of the previous studies  have dealt comprehensively on the topic especially with regards to  the trend, nature, and rate of land use and land cover dynamics over the years as well as  the environmental implications of the land use and land cover changes. For instance the study by Njoroge *et al*. (2011) mainly focused on the water level at the expense of  other aspects of the environment which can be significantly affected by land use and land cover changes. Olang *et al*. (2011) studied spatio-temporal changes in land cover changes and their environmental implications but within the context of river basin.  Most studies done so far also have different methodological flaws as most of them have relied mainly on Geographical Information System (GIS) which has a share of its shortcomings.  Only Mundia and  Aniya (2005) adopted the use of both Landsat images  and socio-economic data in a post-classification analysis to map the spatial dynamics of land use and cover changes as well as  identifying  the urbanization process in Nairobi city. However, the study was not comprehensive. It is on this note that this study attempted to  investigate into the implications of land use and land cover dynamics on the environment quality of Nairobi City County. Thus, the current study employed a combination of both GIS and survey method to complement each other and to assist in  capturing the various perception of local residents in relation to various environmental impacts of land use and land cover changes. The study also put forward some suggestions on how to address associated challenges. The next chapter introduces  the various tools and methods that were used to achieve the study objectives.

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# LAND USE AND LAND COVER CHANGES
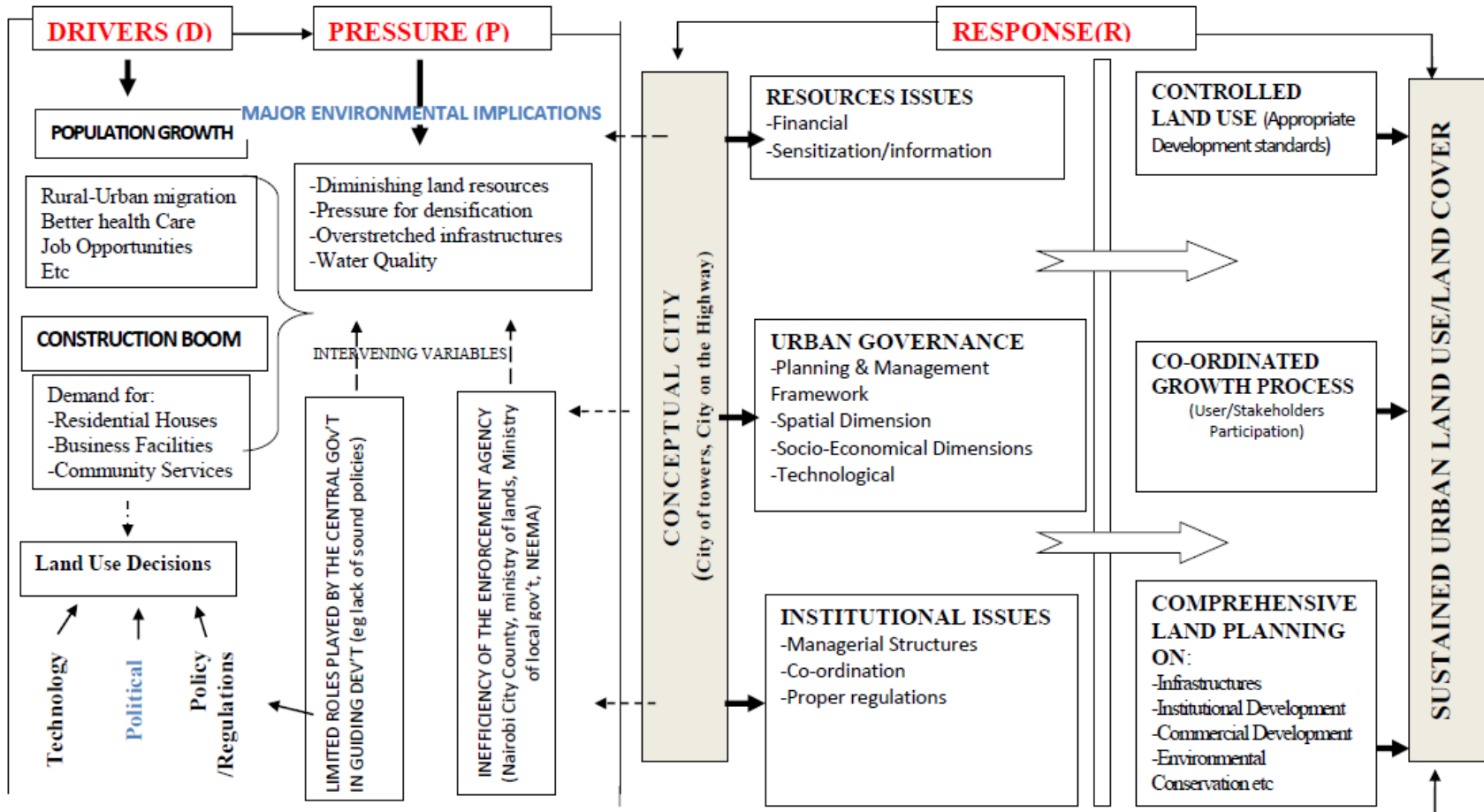


**Figure 3.2: Conceptual Framework**

## CHAPTER FOUR: RESEARCH METHODS

### 4.1    Introduction

This section describes the approaches which were employed in the study towards fulfilling the set goal and the objectives of the study. The section further highlights the materials and types of data used in the study as well as the sources of the same. The Chapter further details out the data processing techniques used, image classification and accuracy assessment as well as giving account of how the findings of the study are presented.

### 4.2    Research Design

A research design is a programme to guide the researcher in collecting, analyzing and interpreting observed facts (Messah and Kigige, 2011).The study was carried out through a case study design of Nairobi City. A case study design was considered as the research aimed at understanding the phenomenon in great depth (Skivington, 2012). In particular, Nairobi city was considered on the grounds that it has not been able to meet the growing demand of its inhabitants. To achieve the set objectives, this case study drew on methodological best practice of previous work and adopting an integrated study which combines both quantitative and qualitative approaches. According to Zainal (2009, p.1), "by  including both quantitative and qualitative data, a case study can assist in  explaining  both the process and outcome of a phenomenon through observation analysis of the subject  under investigation."

In particular, the study utilized a combination of multispectral satellite remote sensing and descriptive survey in studying implications of land Use and land cover dynamics on environmental quality of Nairobi City. Primary satellite imagery were used to classify the land cover of region supplemented by a field work study to acquire first hand data required for the research to improve mapping accuracies of land cover/ spatial changes. This approach has been quite significant in previous studies for instance; Mundia and Murayama (2009) used an integrated design while studying Land Use and Cover Changes and Animal Population Dynamics in a Wildlife Sanctuary in East Africa. Similarly, Codjoe (2007) employed an integrated research design while looking at Land Use and Land Cover Nexus in Ghana. An integrated study of this nature has potential scientific value particularly for the land Use and land dynamics-environment interaction (Codjoe,2007). In addition, an integrated design allows for complimentary roles. Remotely sensed images can only show land cover change, but may not

clearly show how land use decision making is reflected in images hence the important of descriptive survey. On the other hand, images offer a source of rich detail to aid in the interpretation of quantitative findings from the survey including construction of validation/internal validity and interpretation of observed associations (Gable, 1994).

## 4.3 Data Acquisition and Sources

Both primary and secondary data were considered for the study. Primary data included land use cover patterns and changes, socio-economic characteristics, perception and the current status of land use management. Secondary data comprised of experience of land use changes and their implications. Data from publications, research journals and various websites were taken into consideration. In the same way, the published and unpublished research papers, articles, books, government documents, and official records provided important sources of information. Primary data was gathered from structured interviews using questionnaires, in-depth interviews of key informants, field observation and a mosaic of land sat Landsat ETM+ images at the same bands were obtained for the years 2000, 2005 and 2010. Secondary data was obtained from literature survey, reports, field, and documents.

## 4.4 Unit of Analysis and Variables
### 4.4.1 Zone/Land-Scape System

Mugenda and Mugenda (2003) defines unit of analysis as the units that we initially describe for the purpose of aggregating their characteristics in order to describe some larger group or abstract phenomenon. In terms of unit of analysis, the study took specific number of respondents specifically targeting the developers, residents and various institutional representatives of Nairobi City County.

Econometric estimation of equation requires an appropriate unit of analysis. For this study, the different zones/land-scape systems formed the unit of analysis. Some of the variables under land are as outlined in Table 4.1.

**Table 4.1: Land Use and Land Cover Classes for the Study**

|  | Classes/Variables | Description |
|---|---|---|
| i | Urban/built-up areas and Open Lands | Residential, commercial and services, industrial, transportation, communication and utilities. Open land constitutes bare, exposed areas, quarries and transitional areas |
| ii | Agricultural and Riparian Vegetation | Cropland, coffee plantations, horticultural farms, greenhouses, other agricultural crops as well as the riparian vegetation |
| iii | Forests | Evergreen forests, mixed forests with higher density of trees, little or no under storey vegetation |
| iv | Rangeland and Shrubs | Sparsely distributed scrub species. Ground layer covered by grass. Species include *Acacia mellifera* and *Lawsonia inermis.* The shrubs constitutes perennial grass under storey, trees rarely above 5 m, impoverished woodlands near the forests. Other dichotomy entails very sparsely distributed, low-lying scrub species. Usually less than 1m tall, typical species include *A. reficiens, Salvadora dendroides*, ground usually bare or covered by annual grasses |
| v | Water Bodies | Rivers, natural dams, reservoirs and waste water lagoons |

**Source:** Advanced from Anderson *et al*. (1976).

In terms of measurements, the comparisons of land cover statistics are crucial in identifying the percentage change, trend, and rate of change over the study years. Towards this end, the main analytical techniques adopted in this study in quantifying the detected changes included:

    i.    Calculation of the area in hectares of the resulting land cover/land use types for each study year and subsequently comparing the results.

    ii.    Overlay Operations

    iii.    Image thinning

    iv.    Maximum Likelihood Classification

    v.    Land Consumption Rate and Absorption Coefficient

The above classification schema is consistent with the observations by scholars such as Yang and Lo (2002) who argue that spectral confusion, which occurs due to several land use and land cover classes having similar spectral response, is the major cause of inaccuracy in classifications based on spectral response granted that as the image spatial resolution decreases, the number of mixed pixels increases and spectral confusion tends to be more serious. Further, spatial and contextual properties of the images were used in resolving spectral confusion. In this regard, visual interpretation, which allows use of spectral as well as spatial content and local knowledge, was used to split the land use and land cover into their correct classes.

### 4.4.2   Respondents (Household head, developers, and Local Authorities personnel)

Respondents formed the second unit of analysis represented by household heads, developers, and local authorities' personnel. The household unit, in particular the head or next senior member in the family was one of the major players in land use dynamics and consists of two components. Codjoe (2007) assert that although land use/cover change trends can be easily accessed and linked to population data if the unit of analysis is the national or regional level,  comprehensive study  of the actual factors that influence land use require very small unit of analysis level with a very small scale, hence the need for household as a unit of analysis. The first component relates to socioeconomic and demographic variables including gender, Age Education level, Position in Household, Size of Household and Occupation. Previous studies indicate that socioeconomic factors have a significant role in influencing respondent's perception (Chen, 2012; Southavilay, Nanseki & Takeuchi, 2012) which in the context of the research is land use and land cover changes as well as their environmental impacts. The age of the household head may affect the probability of a given land use. Household size tends to have a negative or positive relationship with land use (Taruvinga & Mushunje, 2010). The level of education was expected to improve land use management and influence land use of high returns.

Developers formed the second sub-unit under respondent. They play a key role in land-use and land cover change, as they directly make land development decisions and bridge the land and housing markets. They determine the initial landscaping states of developed parcels, affecting the state and future trajectories of residential land cover, as well as land market activity. Despite their importance, developers are underrepresented in land use change models due to paucity of

data and knowledge regarding their decision-making (Parker *et al.*, 2012). Further, as argued by Parker *et al.* (2012), developer's strategies combine their specialty in developing of particular subdivision types, their perception of and attitude towards market uncertainty, and their learning and adaptation strategies based on the dynamics of the simulated land and housing markets. It was also imperative that, since the greatest change component in the city is the built- up areas, the aspirations of developers and what they think should be done to reduce the various challenges be measured. Variables under developers mainly included length of time measured in terms of years, major attractions to the areas, perception on land degradation, and other environmental impacts. Other important variables included the use of development permit, choice of development, development challenges, and suggestions.

The last element of human system as unit of analysis was local authorities who were mainly enforcement agents to various policies and regulation related to land use and defined by such variables as factors influencing zoning, effectiveness of zoning laws/regulations, challenges and solutions (Table 4.2). Unlike land-scape system measured by the help of images, all aspects of human system were captured by the use of semi-structured questionnaires (Table 4.3).

### 4.5 Population and Target Population

A population is defined as a complete set of individuals, cases or objects with some common observable characteristics (Mugenda & Mugenda, 2003). It is the total collection of elements about which the study wishes to make some inferences (Cooper & Schindler, 2008).The study population comprised of the developers in Nairobi city and its environs, as well as planners, local administrators and other local opinion leaders, representatives of the approving authorities and Nairobi City County staff.

The target population for this study was selected based on purposive sampling technique to select Households and key informants who included Developers, planners and other county council staff.

The criteria for selecting different sites for the study was based on the following characteristics;

    i) high concentration of development,

    ii) agricultural activities (Rural areas) and

    iii) known environmental Hazards.

**Table 4.2: Variables hypothesized to be relevant for land Use decision making in Nairobi**

| Unit of analysis | | Variables | Sources |
|---|---|---|---|
| Zone/Land-scape system | land cover changes | Vegetation/Forests | GIS/images |
| | | Urban/built-up areas and Open Lands | GIS/images |
| **Respodents** | | Gender | Questionnaires |
| | | Age | " " " |
| | | Education level | " " " |
| | | Position in Household | " " " |
| | | Size of H/hold | " " " |
| | | Occupation | " " " |
| | | length of time(years) | " " " |
| | | Major attractions | " " " |
| | | Challenges | " " " |
| | | Determinates of land use decisions | " " " |
| | | Land degradation | " " " |
| | Household | Type of land cover highly vulnerable to degradation | " " " |
| | | Name of company | " " " |
| | | Location | " " " |
| | | Position | " " " |
| | | Purpose of the company | " " " |
| | | Major attractions | " " " |
| | | Use of land permit | " " " |
| | | Development challenges | " " " |
| | | Solutions | " " " |
| | Developers | Choice of Development | " " " |
| | | Name of Local Authority | " " " |
| | | Position of respondents | " " " |
| | | Department | " " " |
| | | Major factors during Zoning | " " " |
| | | Effectiveness of Current Zoning | " " " |
| | Planning and Control Authorities | Explanation | " " " |
| | | Level of agreements | " " " |
| | | | |

**Source: Field Survey (2016)**

## 4.6 Sampling Design and Size

A total of 248 households were considered for study which was derived at using the formula outlined below

$n = Z^2pq/d^2$       (Fisher *et al*, 1991)

At 95% confidence level, sample size,

$n = \dfrac{(1.96)^2\,(0.\,77)\,(0.23)}{(0.05)^2} = 272$    adjusted to 248 as a representative of the population

Where: n = the desired sample size, Z = the standard normal deviate, p = the proportion of Nairobi population estimated to have the required characteristics, For this Study P will be estimate at 0.77 (see justification below), q = 1-P, d = the level of statistical significance set.

d=0.05

Total number of households of Nairobi= 985,014 (2009 Census)

P=673591

Taking 761,110 to be the number of households with required characteristics as guided by distribution per constituencies in Table 2.2 in the previous sections, then it follows that:

$$p=\dfrac{761110}{985014}$$
$$=0.77$$
$$q =1-0.77=0.23$$

The total number of households, 248 comprised of 20 households each from the 7 selected Local authorities and 11 households from other areas. Table 4.3 gives the distribution of the samples.

**Table 4.3: Distribution of Households from the study areas in Nairobi City County and other neighbouring Urban areas**

| | Region | Number per households | Percent |
|---|---|---|---|
| Urban areas | Kajiado | 20 | 8.1 |
| | Kiambu | 20 | 8.1 |
| | Kikuyu | 20 | 8.1 |
| | Mavoko | 20 | 8.1 |
| | Nairobi | 20 | 8.1 |
| | Ngong | 20 | 8.1 |
| | Ruiru | 20 | 8.1 |
| | Kabete | 12 | 4.8 |
| | Kahawa | 12 | 4.8 |
| | Kasarani | 12 | 4.8 |
| | Kinoo | 12 | 4.8 |
| | Njiru | 12 | 4.8 |
| | Rongai | 12 | 4.8 |
| | Sykiomau | 12 | 4.8 |
| | Uthiru | 12 | 4.8 |
| | Ruaka | 12 | 4.8 |
| | Total | 248 | 100.0 |

**Source: Field Survey (2016)**

48 developers were also considered where 3 developers were selected from each region. In addition, a total of 7 employees each from the 7 local authorities/county council

In overall, the study relied on a total of 248 households, 48 developers and 7 employees from local authorities.

For accuracy assessment, the random sampling for detecting the land use and land cover was adopted in the study. The reference pixels were selected at random to avoid biasness. A minimum of 1000 pixels was considered per each image and a Kappa index was used to a certain the degree of accuracy per classified image and according to Congalton (1991), an accuracy of 86 percent of the each category of land use and land cover was accepted. The accuracy assessment was cross checked with ground truth aids such as field visits of which the coordinates of particular pixels were located on the ground using GPS. This was further augmented by topographical map of the study area published in 2008 as well as the true colour aerial photograph image of the study area. The maps derived from this analysis were aimed at meeting

the minimum USGS accuracy requirements of at least 85 per cent as stipulated by the Anderson classification scheme (Anderson, *et al*., 1976).

## 4.7 Data collection Techniques

Data collection was conducted through a methodological triangulation which consisted of the use of multiple methods to study a phenomenon or a single problem. Triangulation of data collection involves looking at an object from more than one stand point. In the context of the proposed study, the methods included interpretation of satellite imagery, questionnaire, interviews and field observations. As a strategy, these methods were put in one platform  to gather information and facilitate  the crosschecking of facts

### 4.7.1   Data Sets

Primarily satellite imagery was  used to classify the land cover of the region while   fieldwork was out to acquire first hand data required for the research. Most of the essential data were collected through the fieldwork to improve mapping accuracies of spatial changes. Landscape observations, meetings with experts and structured interviews were conducted in the study areas. The study used cloud-free satellites images of Nairobi as follows; - Landsat 5 Thematic Mapper images at band 2 (Green 0.52 –0.60m), band 3 (Red-0.63- 0.69m) and band 4 (the NIR 0.76 – 0.90m) for the years 1988 and 1995 while Landsat ETM+ images at the same bands were  used for the years 2000, 2005 and 2010. This is because band combination of red, green and NIR allows for delineation of urban built up areas, water bodies and various vegetation categories. The swatch for the Landsat 5 TM and Landsat ETM+ is 185 Km with a spatial resolution of 30m for the bands under consideration. Therefore the procured images were matching in terms of spectral and spatial resolutions. The pre-processing procedures to correct for geometric and radiometric errors as well as calibration of the images to percent reflectance was undertaken on the images. The selected images were geo-referenced in decimal degree coordinate system and rectified to correspond to the Clarke 1880 spheroid and the UTM projection. Topographical maps at scale 1:5000 covering the entire region as well as physical ground truthing was employed as reference data and for accuracy assessment. The Landsat imageries used in this study were obtained from the archives of the European Space Agencies and were procured through the Nairobi based Regional Centre of Surveying and Mapping (RCSM).

### 4.7.2 Data Processing and Image Classification

The image processing procedures for this study included image pre-processing, the design of classification scheme, image classification, accuracy assessment, analysis of the land use and land cover dynamics as well as the comparison of the changes between different years under consideration. As earlier noted, the images were to be rectified corresponding to the Clarke 1880 spheroid and the UTM projection. This entailed the use of eleven Ground Control Points (GCPs) or the tie-points, well distributed across the entire image. These were located in the image and in the 1:50,000 topographical map covering the study area. A digitizing tablet was also used to register the image to the topographical map as well as employment of a second-order polynomial, resulting in a Root Mean Square (RMS) error of less than half a pixel. The images were re-sampled to a pixel size of 30m by 30m using the nearest neighbour method in order to maintain the radiometric properties of the original data.

The study also accommodated a supervised method of image classification of which the first step involved the extraction of the Area of Interest (AoI) or the study area. This was imperative granted that the images which were acquired covered Nairobi (the study area) and its environs. Towards this end, the geographical coordinates of the study area or the Area of Interest was extracted from the vectorised map of the same. The coordinates were then input in the Arcgis 9.3 environment using extract by polygon function in the spatial analysis toolbox. The output of this operation was an extract of the study area fully geo-referenced in the coordinate systems in the three image bands. The extracted image of the study area was then exported to ILWIS Academic 3.4 environment from the Arcgis 9.3 environment in TIFF Format. The exported image had lost the geo-references and another operation to restore the geo-references had to be performed in the ILWIS Academic 3.4 environment. This operation involved the geo-referencing of the imported image using tie-points into geographical coordinate system. This process was repeated for all the images from 1988 to 2010 (Table 4.4).

After doing geo-referencing in the ILWIS Academic 3.4 environment, colour separation operation was undertaken on the imageries. This was followed by building the colour composites of the imageries using combinations of different bands until the combination which is closer to the true colour is achieved. The combination which was closer to the true colour was the combination of the bands 4-3-2. It is worth noting that it was only the colour composite images closer to true colour that was used due to the ease they presented in the visualisation and

identification of the image features. The image classification process after establishment of the true colour composites involved creation of the map list, sample set creation and classification domain creation. These operations assisted in assigning classification schema to the pixels in sample set editor environment.

**Table 4.4: The Tie-Points used for Geo-referencing**

| Points | Coordinates | |
| --- | --- | --- |
| | X (Longitude) | Y (Latitude) |
| A | 36.719 | -1.227 |
| B | 37.045 | -1.181 |
| C | 36.991 | -1.286 |
| D | 36.922 | -1.435 |
| E | 36.657 | -1.325 |
| F | 37.058 | -1.287 |
| G | 36.683 | -1.362 |
| H | 36.931 | -1.158 |
| I | 36.778 | -1.181 |
| J | 36.928 | -1.321 |
| K | 36.891 | -1.364 |

**Source:** Field Survey (2016)

Upon undertaking the above stated steps and having assigned commensurate number of pixels to various land use and land cover classes, the classified images were processed in the ILWIS Academic 3.4 using image processing operation called classification. The accuracy of the images was assessed through crossing the sample sets and the classified images and the level of accuracies established using the confusion matrix operation in the ILWIS Academic 3.4 environment.

The variations in the levels of accuracy are occasioned by seasonal variations at the time of the image acquisitions. As earlier mentioned, to analyze the land use and land cover changes which have taken place in the successive years, the cross matrix function for the classified images were employed. In this regard, the crossing of the images of years 1988 and 1995, years 1995 and

2000, years 2000 and 2005 as well as years 2005 and 2010 were undertaken. The output tables for the operation were generated to reveal the magnitude of changes in tabular format. The tables were also transformed into histograms using statistics operations in the ILWIS Academic 3.4 environment to reveal the percentage changes which has taken place between the successive imageries cross tabulated while the raster image of the operation reveals the spatial distribution of the changes. Upon completion of the operations, the land use and land cover classification outputs and the raster images of the detected changes and exported back to Arcgis 9.3 environment and geo-referenced for polygonisation. This process assisted in creating spatial layouts of the various land use and land cover categories as well for the visualization of the detected changes. The classification process facilitated the calculations of the Land Consumption Rate and Land Absorption Coefficient for the city.

A modified version of the Anderson *et al*. (1976) scheme consisting of five land use and land cover classes were also developed and adopted for this study as illustrated by Table 4.1. Some of the factors considered during the design of the classification scheme included; the major land use and land cover categories found within the study area and the need to consistently discriminate land use and land cover classes irrespective of seasonal differences. Supervised classification approach was adopted since it allowed the spectral clusters to be identified with a high degree of objectivity based on the ground truth derived from the topographical maps, aerial photographs and local knowledge (Yang and Lo, 2002). Towards this end, different spectral reflectance characteristics were assigned to different land use and land covers. The process was carried out using ILWIS Academic 3.4 digital image processing package. The resulting classified images were then exported to Arcgis 9.3 environment for layout design and polygonisation to allow labeling similar to manual image interpretation for the identification of the corresponding land use and land cover for each spectral cluster with the reference information.

It is also important to note that the exportation of the classified images and the change detection raster images to Arcgis 9.3 environment also enhanced or facilitated  operations such as the maintenance and analysis of the spatial and attribute data, integration of spatial and attribute data as well as the output formatting notably the overlaying and recoding operations among others. The digitization was done for sets of land use and land cover layers augmented with such data as major roads, rivers and selected neighborhoods names as derived from the 2008 topographical maps of the study area. The classified images together with the digitized layers were further

manipulated in Arcgis 9.3 environment due to its capability of allowing post-classification quantitative comparisons of land use and land cover changes. Figure 4.5 presents a summary of the main stages involved during the land cover and land use analysis.
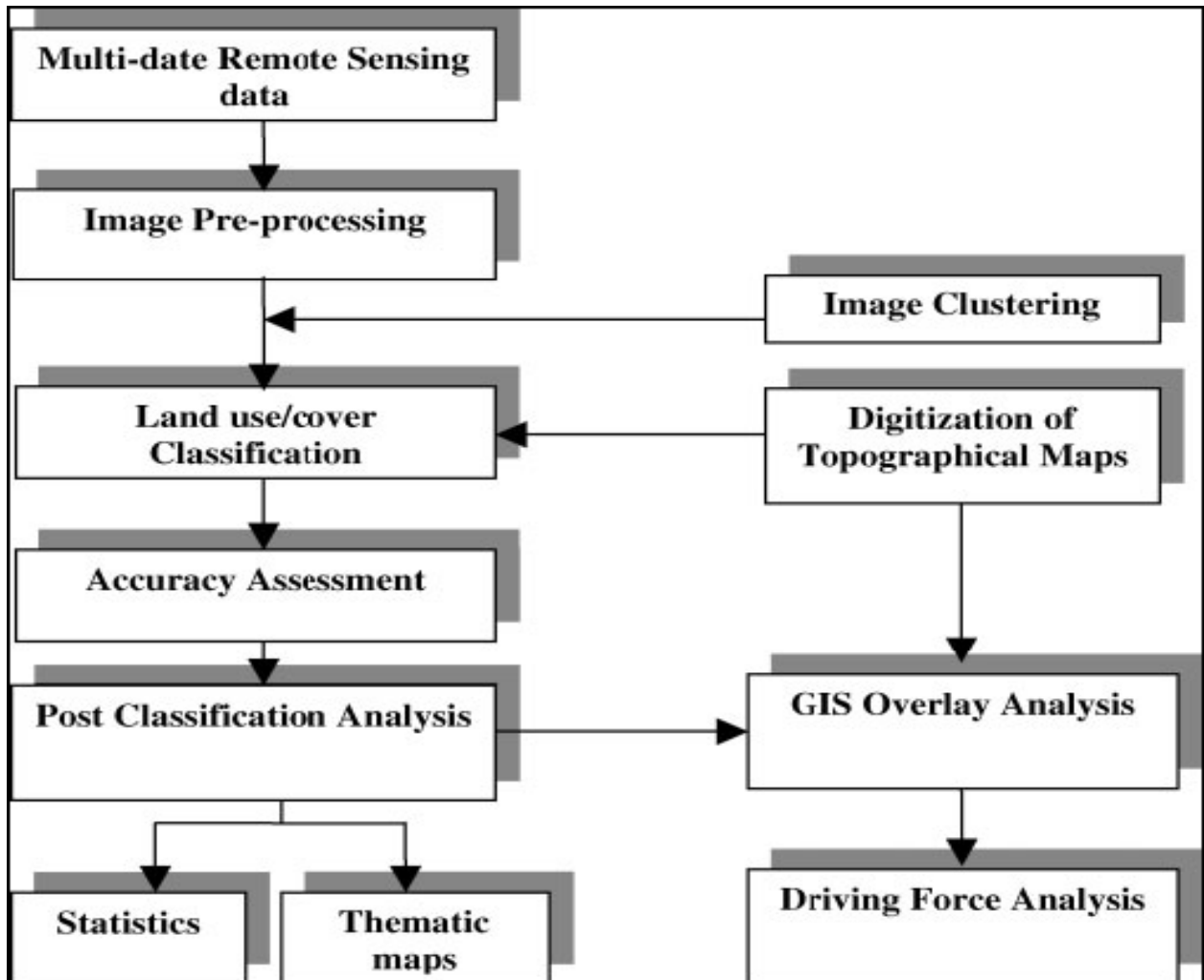


**Figure 4.1: Flowchart for the Analysis of Land Cover and Land Use Dynamics.**
**Source:** Jensen, (1996).

From Figure 4.5, the first part of analysis involved the multi date Remote sensing data. This was followed by image pre-processing and land use cover classification which involved both image clustering and Digitization of topographical maps. The accuracy of the whole process was assessed. The next step was the post classification analysis encompassing both thematic maps and statistics. GIS overlay and driving analysis was also done.

## 4.8 Data Analysis

The primary data gathered through semi-structured questionnaire were analyzed statistically using the computer software (Statistical Package for the Social Sciences (SPSS) version 16.0). Percentages and frequencies were calculated to explain the statistic of respondents' characteristics. Regression analysis was employed to examine the relationship between a dependent variable and a set of independent variables. The independent variables in this case were the various variables linked to respondents discussed in details in the next section. The dependent variables were land Use and land Cover Dynamics. Regression analysis was aimed at determining the joint and relative contributions of each independent variable to the prediction of the dependent variable. Rindfuss *et al*. (2004) also used regression to analyse the factors determining land use patterns in the Netherlands. The method was based on an extensive database, including land use, biophysical, socio-economic, neighbourhood and policy characteristics. In testing hypothesis stated in chapter two, a binomial logit model was compiled for the land use decisions as outlined below:

Logit $P = \alpha + \beta 1 X$policies/regulations$+ \beta 2 X$political $+ \beta 3 X$technological$+ \beta 3 X$economical

Land Consumption Rate and Land Absorption Coefficient for the City was calculated using the following formula:-

The Land Consumption Rate (L.C.R) and Land Absorption Coefficient (L.A.C) functions are stated as: -

**L.C.R = A/P…………………………………………………………………………………(i)**

Where:-

$\qquad$ **A** = Areal extent of the city under a given land use and land cover in hectares.

$\qquad$ **P** = population of the city at a particular date.

**L.A.C = A$_2$ – A$_1$/P$_2$ – P$_1$ …………………………………………………………………(ii)**

Where:-

$\qquad$ **A$_1$** and **A$_2$** are the areal extents of the city under a given land use and land cover in hectares for the early and later years.

$\qquad$ **P$_1$** and **P$_2$** are population figures for the early and later years respectively.

Source: Yeates and Garner (1976)

The Land Consumption Rate (L.C.R) is a measure of compactness which indicates a progressive spatial expansion of a city while Land Absorption Coefficient (LAC) is a measure of change in consumption of new urban land by a given land use and land cover by each unit increase in urban population. The populations herein used for the calculations are estimated using the mean population growth rate of the city estimated at 4.7 percent per annum for the years between 1980 to 1989 while the population growth rate for the years between 1990 to 2010 is estimated at 4.5 percent per annum. Estimation of the population involves the multiplication of the growth rate by the population of the base year while subsequently dividing the same by 100. The result was then multiplied by the number of years being projected. This provided for by the functions: -

$$n = r/100 * P_o \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\text{(iii)}$$

$$P_n = P_o + (n * t)\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\text{(iv)}$$

Where: -

$P_n$ = Estimated population at a given year
$P_o$ = Base year population
$r$ = Growth rate
$n$ = Annual population growth
$t$ = Number of years projecting for

Results from socio-economic data were analyzed with the aid of statistical packages for the Social Sciences (SPSS) software version 16.0 for windows. The data for this analysis was augmented by secondary sources from statistical abstracts of the years 1988 to 2010. The images taken from the 1988 to 2010 were considered because of their clarity and ability to give a clear picture of the changes that have taken place over the specified period. Other sources of data included the Kenya national economic surveys and the Population Census Reports.

**CHAPTER FIVE: ANALYSIS AND DISCUSSION OF RESEARCH FINDINGS**

**5.1     Qualitative Analysis**

**5.1.1   Introduction**

This chapter discusses the results of the analysis and further presents the emerging land use and land cover dynamics of Nairobi City for the periods between 1988 to 2010. The dynamics were viewed from the perspectives of the nature, trend and rate of the change. The chapter further presents quantification of land consumption rate and land absorption coefficient for the City. The above stated aspects of the study allowed for the forecasting of the pattern and trend of land use and land cover dynamics as well as creating valid indicators to the environmental implications of the changes.

**5.1.2   Land Use and land Cover Dynamics of Nairobi City for the Period Between 1988 to 2010 and the Environmental implications of the Changes**

The post-classification comparison approach was employed for the detection of land use and land cover changes; by comparing independently-produced classified land use and land cover maps. The main advantage of this method is its capability of providing descriptive information on the nature of changes that occur. The classified land use and land cover maps of Nairobi for the years 1988, 1995, 2000, 2005 and 2010 are shown in Figures 5.1, 5.2, 5.3, 5.4 and 5.5 respectively. The spatial distributions of each of the classes were vectorised using Arcgis 9.3 computer software as earlier discussed. The quantification of Land Use and Land Cover change is summarized in Table 5.1 while the trend of dynamism from 1988 to 2010 is illustrated by Figure 5.6.

The illustrations by Figure 5.1 through to Figure 5.5 and the analysis of the changes illustrated by Figures 5.7 and 5.8 indicate that major land use and land cover changes having serious implications on the environmental quality of the city have taken place during the study period. The changes correlate positively with the urban sprawl and loss of forests, natural areas and productive agricultural lands. Forests which are environmental stabilizers have declined substantially giving way to built-up areas while natural ecosystems such as rangeland and shrubs have given way to urban developments.
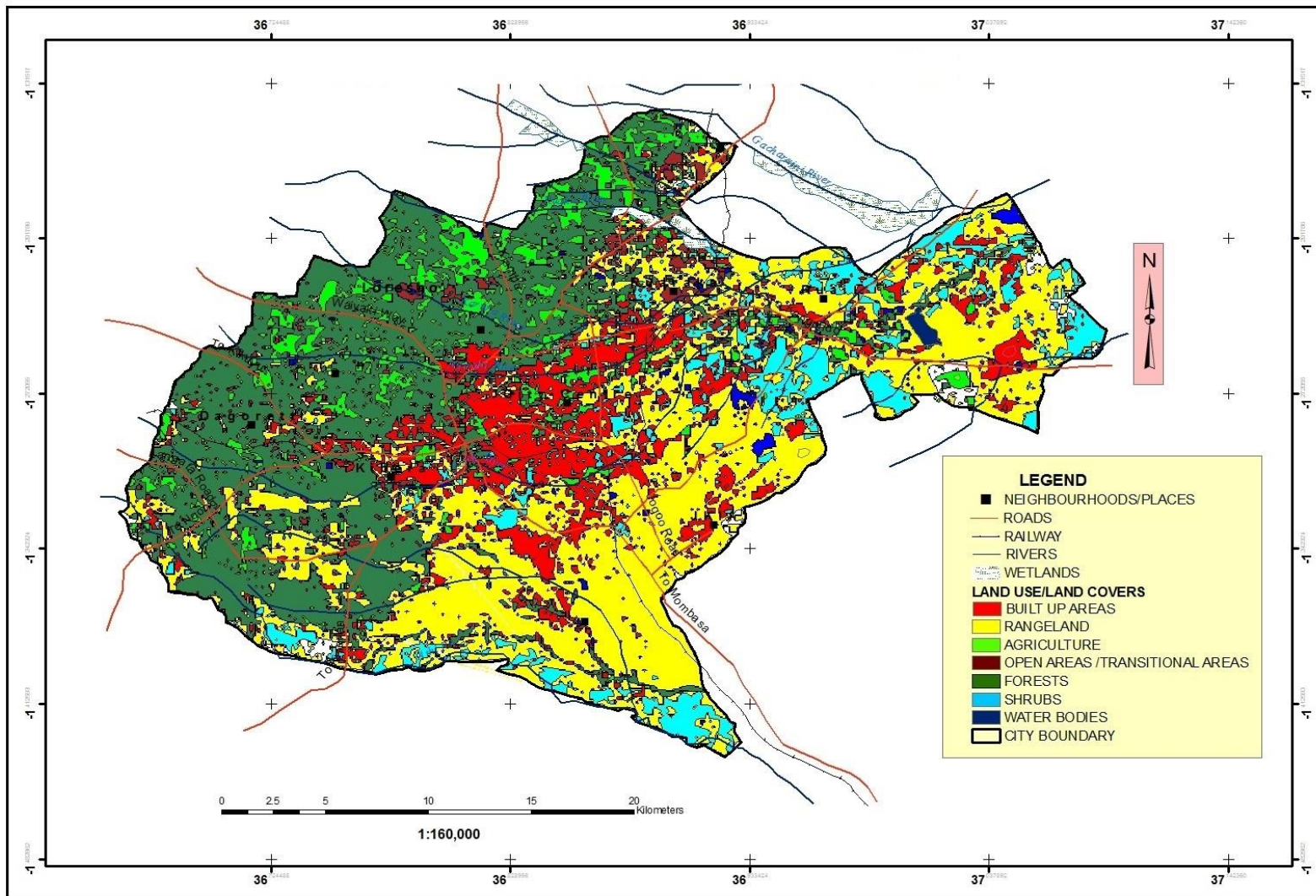
**Figure: 5.1: Classified Land Use/Land Cover Map of Nairobi 1988**
**Source:** Year 1988 images from Regional Centre, Nairobi.
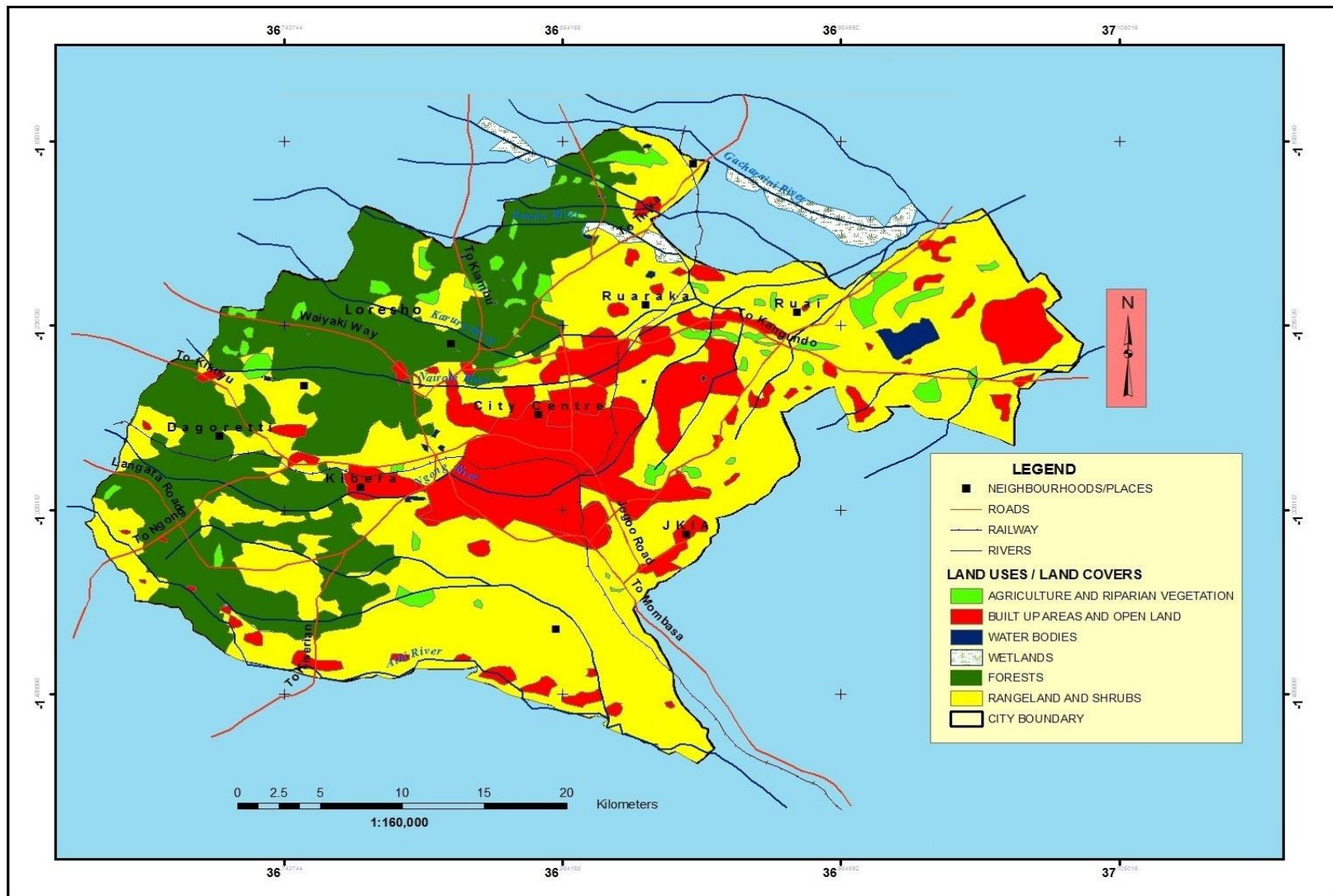
**Figure: 5.2: Classified Land Use and Land Cover Map of Nairobi 1995**
 **Source:** Year 1995 images from Regional Centre, Nairobi.

The urban built-up areas and open land have increased while the agricultural and riparian vegetation occupied in 1988 have decreased. Forest land cover has also decreased substantially while the rangeland and shrubs have shown some increase. The expansion of built up areas are closely related to the decrease in areas previously agricultural and riparian vegetation, rangeland and shrubs and forests have mainly given way to expansion in built up areas and open lands.

The physical setting of Nairobi City has also influenced the expansion directions of the city as illustrated by the land use and land cover change maps presented above. The northeast and westward expansions have tended to follow the flat areas. In the areas to the east where initially the poor road network reduced development and expansion chances; the trend has since reversed since the year 2000 due to the advantages the area presents in terms of availability of building materials and large expanse of land for residential development. In the western part of Nairobi, where the ground is higher with rugged topography, expansion is constrained by the existence of steep slopes and the occurrence of the gazetted forests notably Karura and Ngong forest reserves. The expansion is also experienced in the southern part of the city particularly along the Mombasa road. This expansion is already threatening the existence of the Nairobi National Game Park as anthropogenic activities are already encroaching into the park and the animal migration corridor(s).

The urban sprawl phenomenon is already evident in the city (figure 5.5 ) as manifested through spatio-temporal variations in terms of growth rate and directions. The expansion has not taken place evenly in all directions but has occurred much faster in certain directions. Notably among the most expanding directions are those zones along Thika Road and Kangundo Road. This is attributed to *ad hoc* nature of planning which has characterised the city as corroborated by rapid revisions of land use zoning regulations. This has escalated changes in land use and land cover to exacerbate land speculations. The revision in the zoning policy has encouraged conversion of agricultural land to built-up developments with increased plot ratio, coverage and general development densities. The spatial structure of the city manifests a hybrid of concentric and sector models of urban growth. This has been influenced by the distribution of transportation arteries as the urban development has evolved along the transport arteries emanating from the city centre. The rate of encroachment of built up areas on other land uses and/or land covers has been rapid manifesting discontinuous patches of built-up areas and open lands.
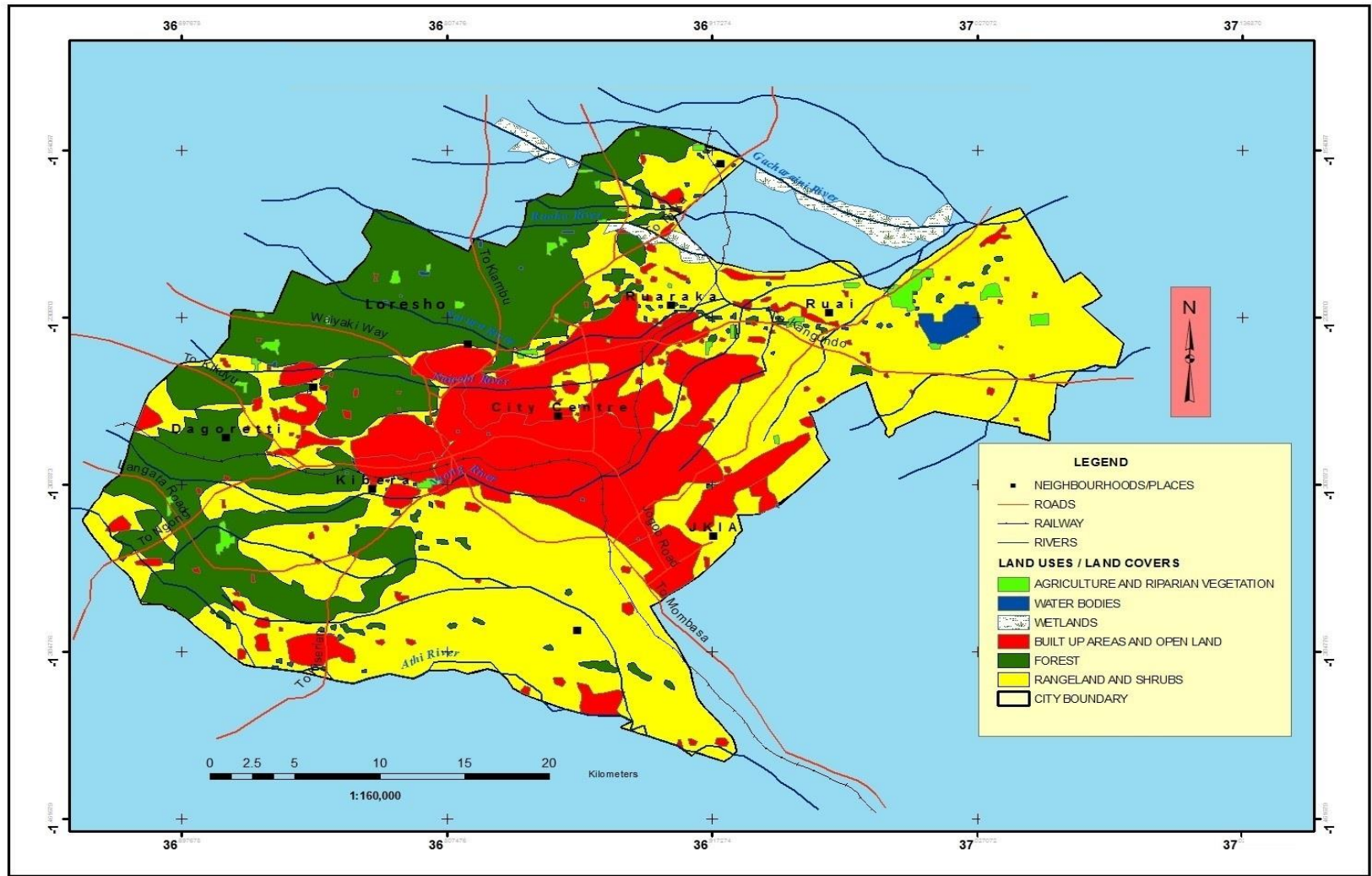
**Figure: 5.3: Classified Land Use/Land Cover Map of Nairobi 2000**
**Source:** Year 2000 images from Regional Centre, Nairobi.
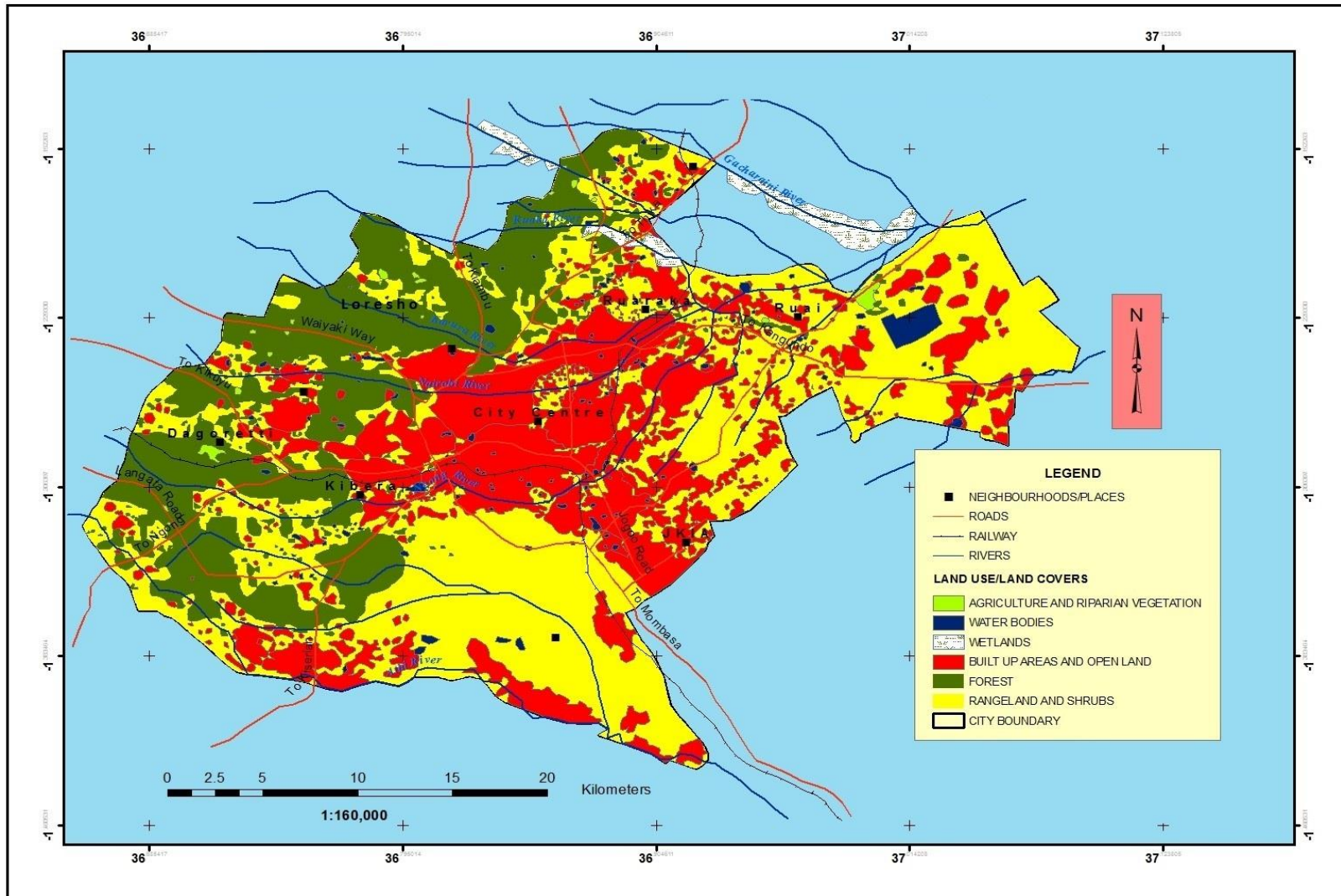
**Figure: 5.4: Classified Land Use/Land Cover Map Of Nairobi 2005**
Source: Year 2005 images from Regional Centre, Nairobi.
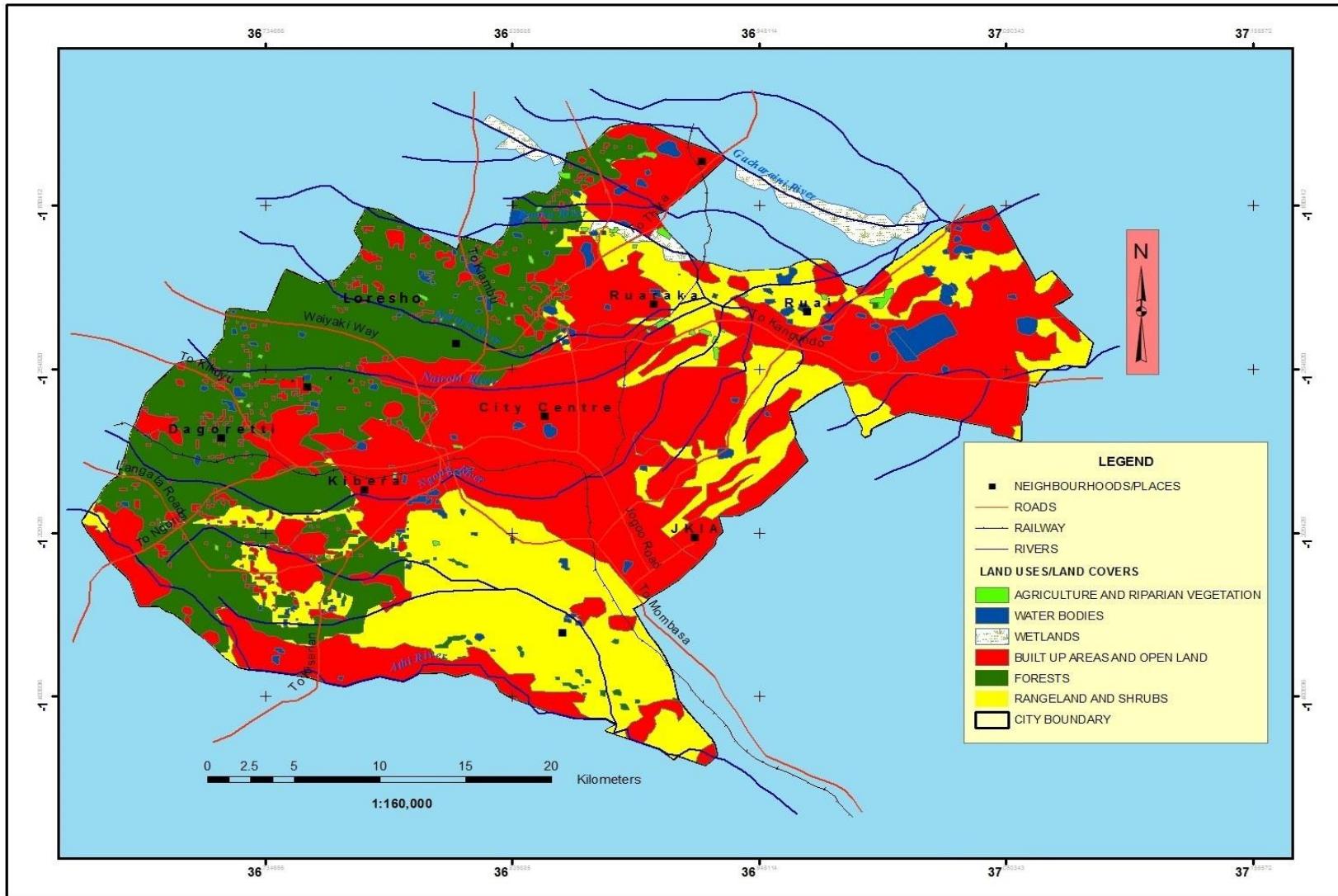
**Figure: 5.5: Classified Land Use and Land Cover Map Of Nairobi 2010**
**Source:** Year 2010 images from Regional Centre, Nairobi.

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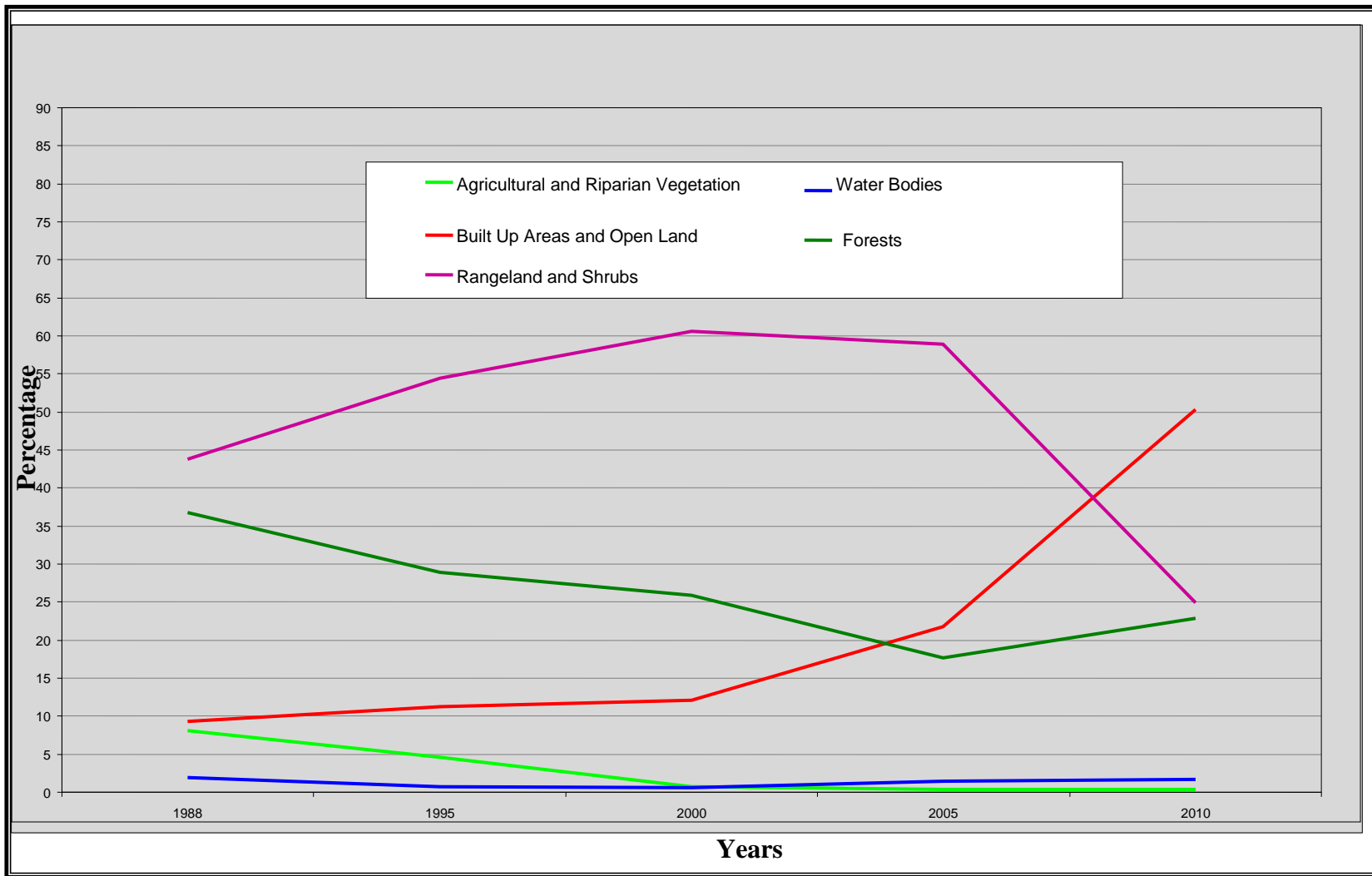
**Figure 5.6: Land Use and Land Cover Change Trends for Nairobi City between 1988 To 2010**
**Source:** Years 1988 to 2010 images from Regional Centre, Nairobi.

Urban agriculture in Nairobi can be categorised as small-scale crop gardens often found near the central part of the city and are located along roadsides, flood plains and in high density or low-income residential areas of the city where there is very limited space. Peri-urban agriculture occurs where the land holdings are large enough to allow commercial cultivation and livestock rearing. Population growth leading to land fragmentation has led to the decline of the percentage of land under agriculture since 1988 to 2010. The land fragmentation has reduced the holding sizes making the current sizes of the land parcels not viable for agricultural development, subsequently leading to change of the land use and land cover from agricultural to urban built up areas in the urban periphery. There has been marked encroachment of urban built up environments into the gazetted and protected areas such as the forests and the Nairobi National Game Park. Other forms of encroachments manifest in terms of anthropogenic activities such as grazing in the forest reserves which reduces the forests to rangeland and shrubs. The anthropogenic encroachment has over the years affected water supply, wildlife habitat availability and overall environmental quality.
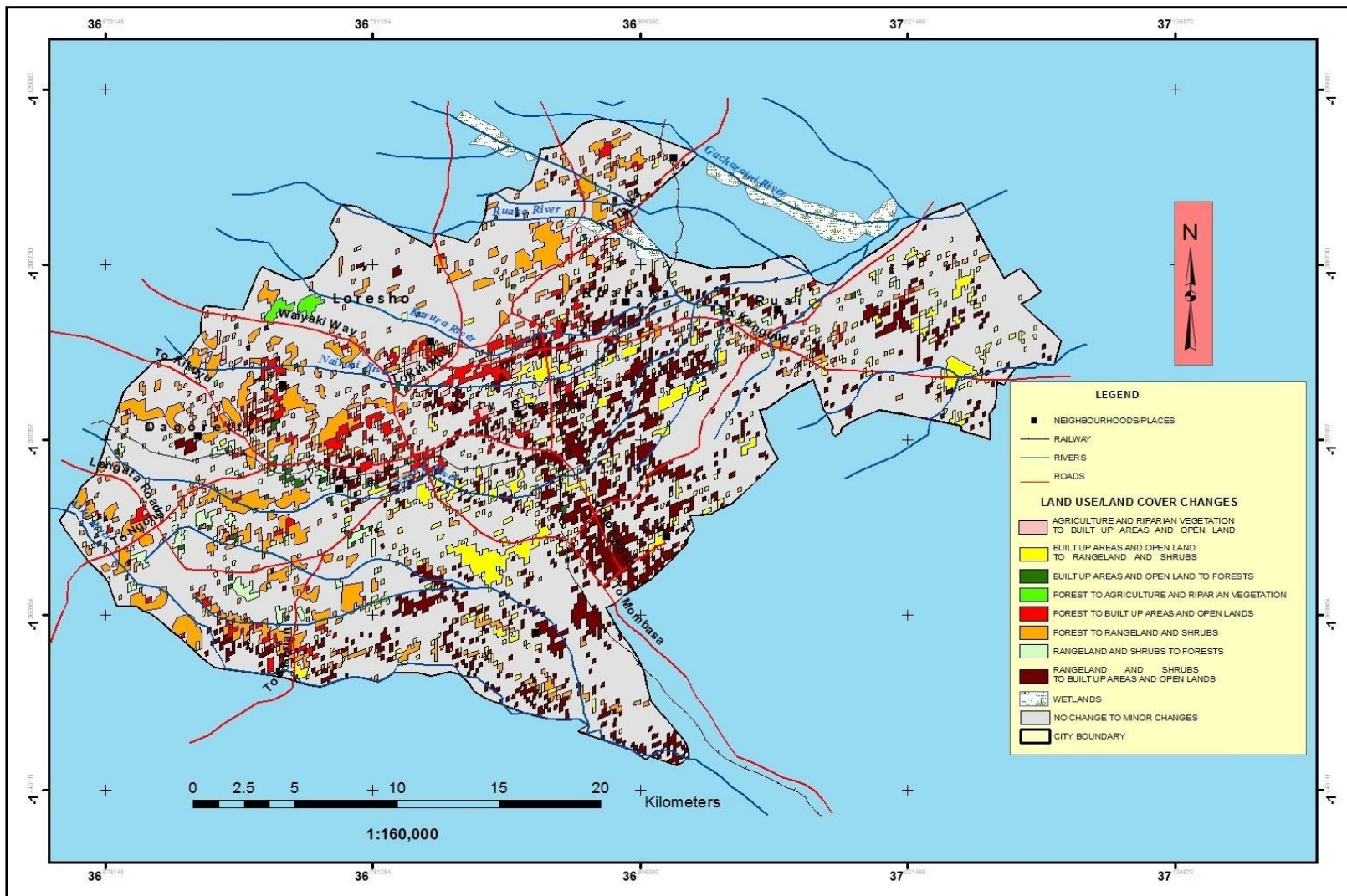
**Figure 5.7: Land Use/Land Cover Changes Between 1988 And 2005**
**Source:** Years 1988 to 2010 images from Regional Centre, Nairobi
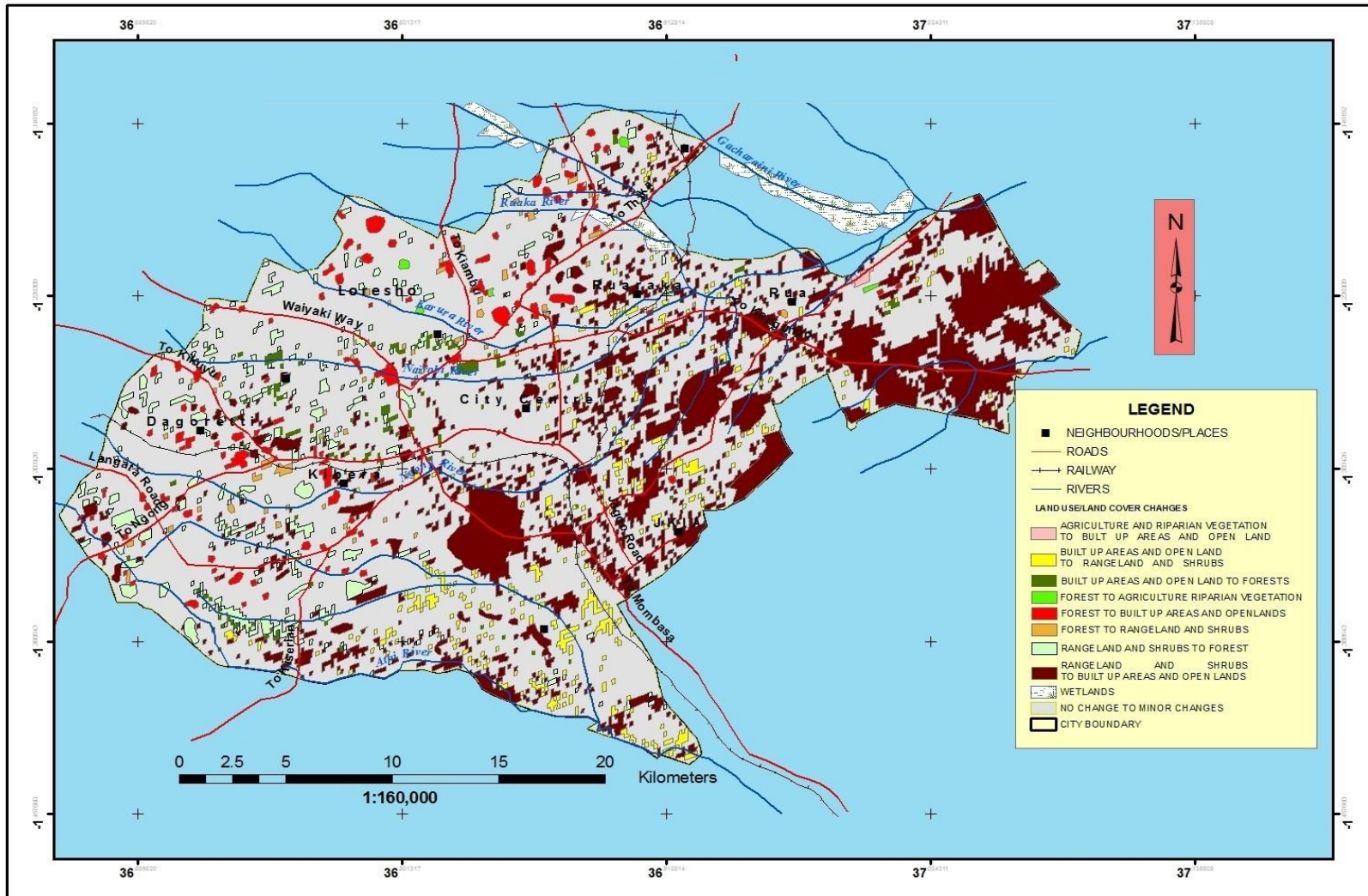
**Figure 5.8: Land Use/Land Cover Changes Between 2005 And 2010**
**Source:** Years 2005 to 2010 images from Regional Centre, Nairobi.

**Table 5.1: Land use and Land Cover Types for Nairobi City Between 1988 To 2010**

| Land Use and Land Cover Classes | Years | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1988 | | 1995 | | 2000 | | 2005 | | 2010 | |
| | Area in Km² | Percentage | Area in Km² | Percentage | Area in Km² | Percentage | Area in Km² | Percentage | Area in Km² | Percentage |
| Agriculture and Riparian Vegetation | 55.541 | 8.120 | 31.464 | 4.600 | 4.603 | 0.673 | 2.086 | 0.305 | 2.196 | 0.321 |
| Water Bodies | 13.447 | 1.966 | 5.062 | 0.740 | 4.268 | 0.624 | 9.672 | 1.414 | 11.190 | 1.636 |
| Built-Up Areas and Open Lands | 63.920 | 9.345 | 77.183 | 11.282 | 82.914 | 12.122 | 148.811 | 21.756 | 344.079 | 50.304 |
| Forests | 251.685 | 36.796 | 197.997 | 28.947 | 177.382 | 25.933 | 120.705 | 17.647 | 156.102 | 22.822 |
| Rangeland and Shrubs | 299.407 | 43.773 | 372.329 | 54.434 | 414.839 | 60.649 | 402.719 | 58.877 | 170.439 | 24.918 |
| **TOTAL** | **684.000** | **100.000** | **684.000** | **100.000** | **684.000** | **100.000** | **684.000** | **100.000** | **684.000** | **100.000** |

**Source:** Field Survey (2016)

The urban built-up areas and open land have increased from 63.920 km$^2$ in 1988 to 344.079 km$^2$ in 2010 (i.e. by 438.29%). The agricultural and riparian vegetation occupied 55.541 km$^2$ in 1988 and have decreased to 2.196 km$^2$ in 2010 (i.e. by 96%). Forest land cover has also decreased substantially from 251.685 km2 in 1988 to 156.102 km$^2$ in 2010 (i.e. by 38%). The rangeland and shrubs have shown increase from the year 1988 when it occupied 299.407 km$^2$ reaching the peak in 2000 when it started declining to 170.439 Km$^2$ in the year 2010. The declines experienced by the agricultural and riparian vegetation, rangeland and shrubs and forests have mainly given way to expansion in built up areas and open lands. The trends in land use/cover changes for various epochs are summarized in Figures 5.9 and 5.10.
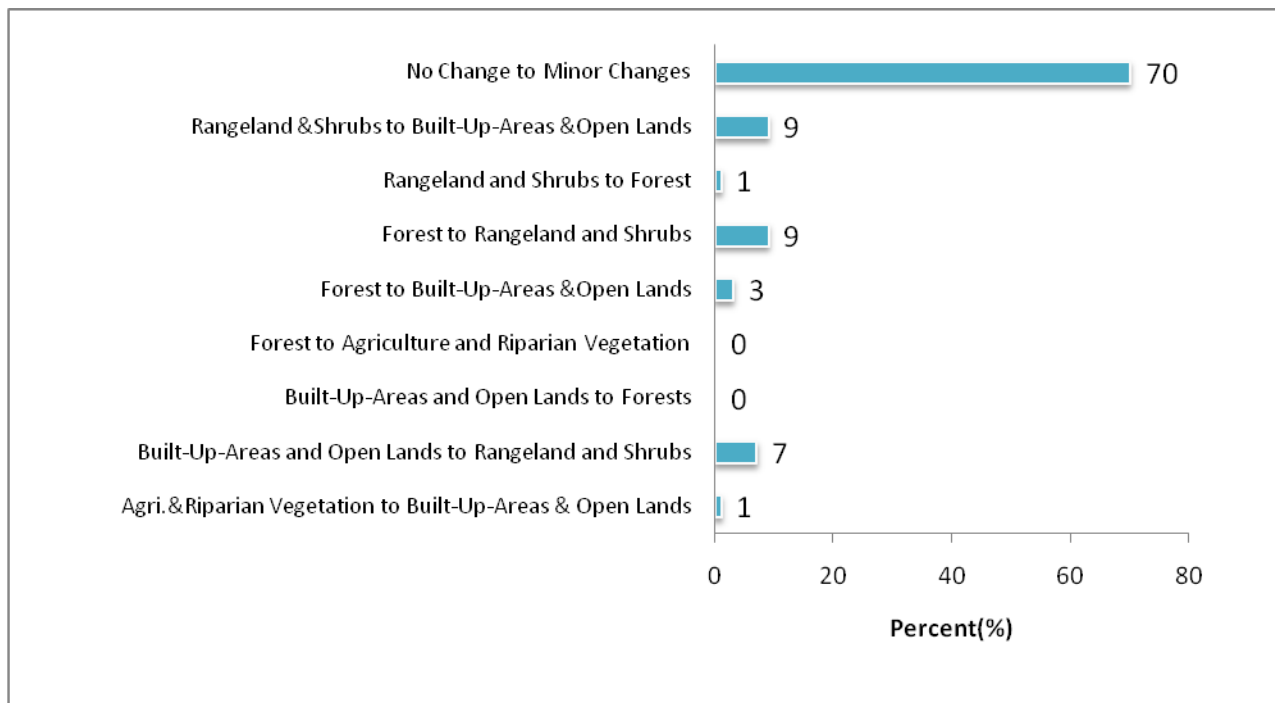


**Figure  5.9: Percentage Land Use and land Cover Changes between 1988 and 2005**
**Source:** Field Survey (2016).

Figure 5.9 gives a comparative analysis of the major land use/cover conversions that have taken place between 1988 to 2010 while the major and important land use/cover conversions that have taken place between 1988 to 2005 as well as between 2005 to 2010 are illustrated in figure 5.10.
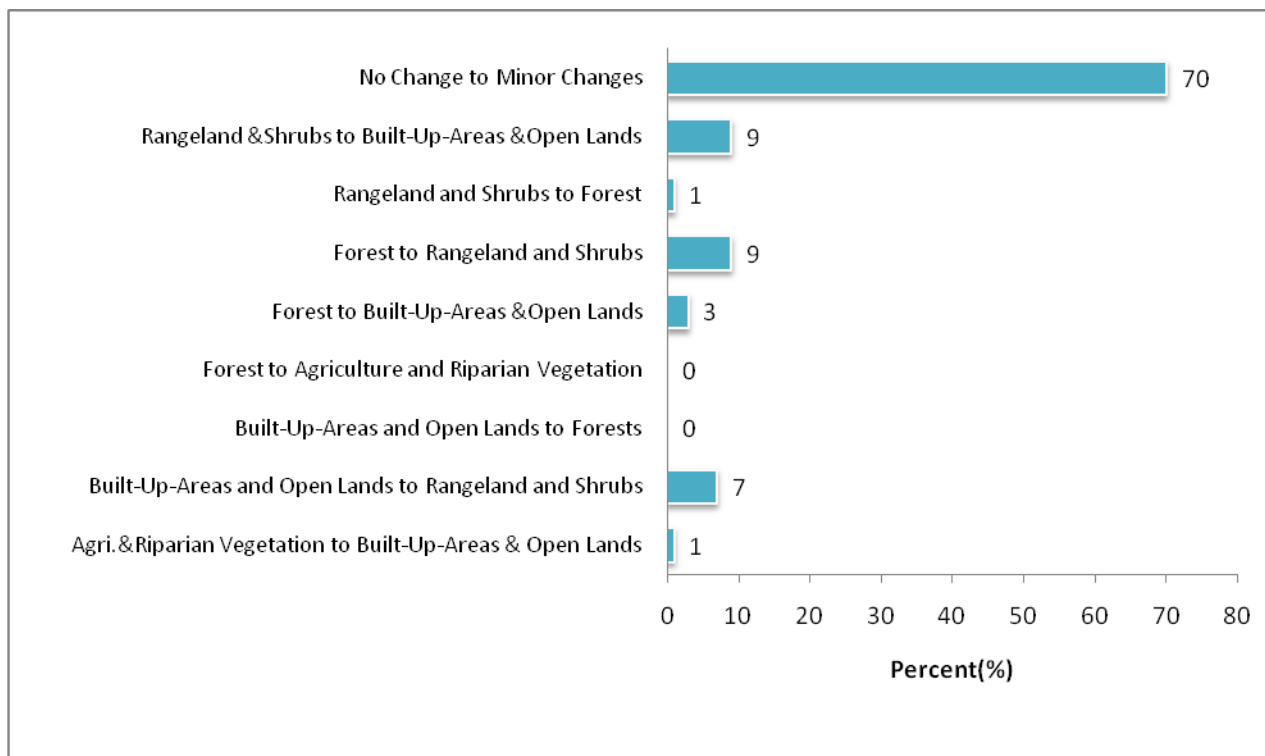
**Figure 5.10: Percentage Land Use and land Cover Changes between 2005 and 2010**
**Source:** Field Survey (2016).

The encroachment into natural ecosystems has not only degraded the natural habitats but has also brought fragmentation and isolation of the remaining natural ecosystems. The wildlife migration corridor towards Kitengela along the Nairobi National Park has been encroached into by the urban built up areas to create human settlements. This corroborates that the urban development policies which have been implemented in Nairobi over the years have been enacted with less regard to the environmental impacts of such developments (Njoroge, Maina & Kariuki, 2011). In some areas such as Kitengela, residential areas are being developed only because of availability of space, with little effort being made in providing the necessary infrastructure such as roads, water supply and sewerage (Hirst and Lamba, 1994). Areas experiencing the most degradation are the informal settlements such as Kibera and the peri-urban areas to the eastern part of the city along Kagundo and Thika roads where the development control are not strongly enforced. Such developments and expansions are accompanied by exploitation of the environmental resources such as the conversion of the rangeland and shrubs to urban built up areas. Towards this end, there is so much pressure on urban land that even areas susceptible to flooding or landslides are often built up for residential accommodation (Lamba, 1994).

Close analysis of land use and land cover changes with help of the available aerial photographs shows that most of the squatter settlements are located on flood plains, in abandoned quarries, on steep banks of river valleys, and on undesirable vacant land such as next to dump sites making such residents susceptible to environmental disaster.  Another important factor to note in the Nairobi's urban development is the role the quarrying activities are playing in altering the urban morphology of the city. The quarries are the major source of building materials for the city and the reserves are scattered on the eastern part of the city. With the changes in demand for residential facilities in the city and the construction boom as occasioned by economic growth between the years 2002 to 2010 (Tibaijuka, 2007), the construction activities have increased in magnitude and the land to the eastern part of the city is alarmingly being converted from the rangeland and shrubs to urban built up areas and open land (quarries) with derelict materials (which constitutes the debris) not being disposed of in an environmental sound manner. The derelict quarries are left open and are often filled with surface runoff. This has serious environmental implications as over the time such quarries become abandoned and the loose soils emanating from them often find their way into the main drainage systems when it rains. From the analysis above, it is evident that the rate at which the land use and land cover has been converting to built-up areas and open land in the eastern side of the city is high, as occasioned by the quarrying activities particularly between the years 2000 to 2010 ( Figure 5.8).

The expansion in the urban built up areas in Nairobi has been occasioned by affordable land and housing construction costs in the periphery as compared to the city centre luring many to settle in these areas (Bose, 2011).  Infrastructural Investment such as roads, water and electricity in the previously urban peripheries has also added benefits to quality of life in such neighborhoods, consequently promoting migration into the neighborhoods. These neighborhoods had low population densities compared to the current situation and there was no traffic congestion (Tibaijuka, 2007). This was  attractive but as the income of an average Kenyan improved the living standards also improved and  owning a car is now affordable for many residents of Nairobi City County, resulting into traffic congestion in these neighbourhoods. According to Prskawetz, Leiwen and O'Neill (2004), socio-economic characteristics of the households such as improved income can produce important effects to the overall demand of the automobiles.

The other factor that have occasioned the spread of the built up areas is the fact that over the years, higher property and business taxes in the city centre have pushed businesses to the commercial centres in the suburbs where taxes are generally low (Bose, 2011). Therefore, even in the absence of policies that would encourage the peripheral urban growth, these centres have proliferated due to the willingness of a growing number of people to live in them and conduct commercial activities.

**5.1.2.1 Associated Impacts of Land Cover Changes**

Figures 5.1 to 5.5 and the analysis of the changes illustrated by Figures 5.7 , 5.8, 5.9 and 5.10 indicate that major land use and land cover changes have occasioned serious implications on the environmental quality of the city have taken place during the study period. The changes correlate positively with the urban sprawl and loss of forests, natural areas and productive agricultural lands. Forests which are environmental stabilizers have declined substantially giving way to built-up areas while natural ecosystems such as rangeland and shrubs have given way to urban developments.

One of the effects of urban paved surfaces is the lowering of percentage of land under the greenery such as the forest cover, grasses, shrubs and the rangeland vegetation in general. The greenery plays a very crucial role in the moderation of the urban temperatures due to its ability to absorb the carbon dioxide gases as well as lowering the concentration of other pollutant gases in the environment. Therefore, with continued depletion of the urban green cover, the city is geared to experience urban heat island effect. The urban temperatures shall increase due to the increase in the amount of asphalt and buildings which emits infra-red (heat) radiations (Bose, 2011).  In some areas, this increase in temperature has been postulated to be as high as $7^0$F (Mahmood *et al.,* 2010). The study is also consistent with that of Tan *et al*. (2010) as reflected in the literature review who concluded that changes in LULC caused significant difference in LST between urban and rural areas land cover. Detailed analysis of environmental implication follows in chapter five.

**5.1.3 Land Consumption Rate and Land Absorption Coefficient for the City**

**Table 5.2: Land Consumption Rate**

| Year | Total Area Under Built Up and Open Lands in Km$^2$ | Total Population | Land Consumption Rate |
|------|------|------|------|
| **1988** | 63. 920 | 1,262,315 | 0.0000506 |
| **1995** | 77.183 | 1,888,240 | 0.0000409 |
| **2000** | 82.914 | 2,181613 | 0.0000380 |
| **2005** | 148.811 | 2,672,476 | 0.0000557 |
| **2010** | 344.079 | 3,273,783 | 0.0001051 |

**Source:** Field Survey (2016).

*Note: Population projections used is based on the rate being 4.7% in the years 1980 to 1989 and 4.5% for years between 1990 and 2010*

The urban built-up areas and open land have increased from 63.920 km$^2$ in 1988 to 344.079 km$^2$ in 2010. The declines experienced by the agricultural and riparian vegetation, rangeland and shrubs and forests have mainly given way to expansion in built up areas and open lands. The Land Absorption Coefficient (L.A.C) is a measure of change in consumption of new urban land by each unit increase in urban population. The results of the LAC for Nairobi using the built up area and open land is presented in Table 5.3

**Table 5.3: Land Absorption Coefficient**

| Year | Total Area Under Built Up and Open Lands in Km$^2$ | Total Population | Land Absorption Coefficient |
|------|------|------|------|
| **1988** | 63.920 | 1,262,315 | - |
| **1995** | 77.183 | 1,888,240 | 0.0000212 |
| **2000** | 82.914 | 2,181613 | 0.0000195 |
| **2005** | 148.811 | 2,672,476 | 0.0001342 |
| **2010** | 344.079 | 3,273,783 | 0.0003247 |

**Source:** Field Survey (2016).

*Note: Population projections used is based on the rate being 4.7% in the years 1980 to 1989 and 4.5% for years between 1990 and 2010*
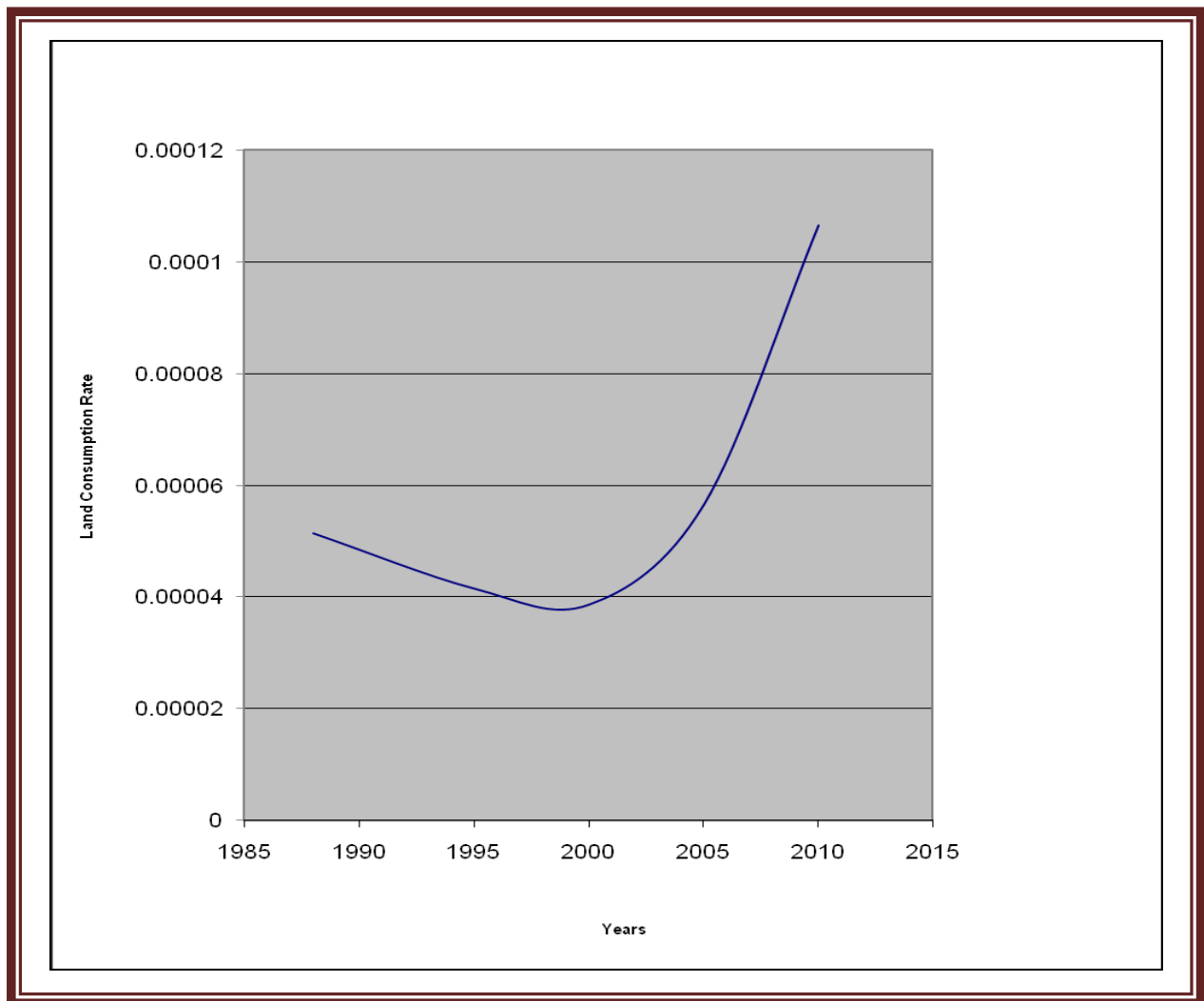
**Figure 5.11: The Dynamic Land Consumption Rate Presentation of Nairobi between 1988 and 2010**
**Source:** Field Survey (2016).

The Land consumption rate for the city reduced between the years 1988 to 2000 (Figure 5.11) due to the fact that most of the population increase in the city were either accommodated within the high rise building already existing within the built up areas or got affordable housing within the periphery of the city where transport cost were affordable. However between the years 2000 and 2010, the Land Absorption Coeffient was high as there was demand for more space to accommodate the increasing commercial and residential functions. The new residential areas for the growing human population made inroads into lands that have been traditionally the migration routes for huge animal herds (McNair *et al.*,  2001).

## 5.2    Quanitative Analysis

### 5.2.1   Introduction

The urbanization rate of Nairobi City has been rapid compared to other major African cities. This is corroborated by the fact that the urbanization rate of Nairobi stood at 4.7 percent between the years 1980 to 1989 and 4.5 percent between the years 1990 to 2010 at a time when the urbanization rate of a number of African cities was projected at 4.0 percent. Some factors that have influenced the rapid urbanization of the city include but not limited to rapid economic development, urban population growth and physical factors (Small, 2008). These factors accounts for 70 percent of the explanatory variables for the rapid rate of land use and land cover dynamics currently being experienced in the city especially  for the conversions of the other land uses and land covers to urban built up areas in the form of residential and commercial developments (Small, 2008).

### 5.2.2   Household Characteristics and Livelihoods

The land use and land cover dynamics for Nairobi City exhibits an interaction between a number of environmental as well as demographic and socio-economic factors. A total of 248 households were considered for the interview. Table 5.4 shows various descriptive statistics for the study population. Table 5.4 also reveals that only 3.6% of survey respondents had no formal education. Nonetheless, 10.5% of respondents had completed primary education with 33.1% having gone up to secondary school. Surprisingly, the vast majority had attained college education with only 10.1% having achieved university education. The table also reveals that more than three quarters (79.8%) of respondents were heads of household as they were the main target. However in households where there were no heads at the time of interview, the next senior member of the family was considered. This comprised of spouse (16.8%), son/daughters (3.8%) and only one respondent representing the category of others which in this case was an uncle. With regards to household's size, on average, there were 5.1 people within each household. More than half (53.2%) of the households comprised of between 5 and 9 members. 40.7% of the households had between 1 and 4 members while 6% of the households had members ranging from 10 to 15. This was a typical household size for many households in the urban areas and further confirms that there is  a  high population in the study area which may be attributed to natural population increase as well as rural-urban migration which are currently estimated at 52 percent and 48 percent respectively. Further breakdown of the above socio-demographic profiles are shown in Table 5.4.

**Table 5.4: Selected Descriptive Statistics of the Study Population**

| Characteristics | Frequency | Percent |
|---|---|---|
| **Gender** | | |
| Male | 190 | 76.6 |
| Female | 58 | 23.4 |
| **Age(years)** | | |
| Less than 19 | 2 | 0.8 |
| 19-29 | 37 | 14.9 |
| 30-39 | 127 | 51.2 |
| 40-49 | 53 | 21.4 |
| 50 and above | 29 | 11.7 |
| **Level of Education** | | |
| No School | 9 | 3.6 |
| Primary | 26 | 10.5 |
| Secondary | 82 | 33.1 |
| College | 106 | 42.7 |
| University | 25 | 10.1 |
| **Size of Households** | | |
| 1-4 | 101 | 40.7 |
| 5-9 | 132 | 53.2 |
| 10-15 | 15 | 6.0 |
| **Position in the Household** | | |
| Head | 198 | 79.8 |
| Spouse | 42 | 16.9 |
| Son/Daughter | 7 | 2.8 |
| Others | 1 | 0.4 |

**Source:** Field Survey (2016).

**Table 5.5: Marital Status of Respondents**

| Marital Status | Frequency | Percent |
|---|---|---|
| Single | 27 | 11.0 |
| Divorsed | 2 | 1.0 |
| Widowed | 5 | 2.0 |
| Married | 213 | 86.0 |
| Total | 248 | 100.0 |

**Source:** Field Survey (2016).

Table 5.5 shows marital status of respondents' interview in the study. Most respondents interviewed were married, represented by 86%. 11 % of respondents were single while 1% and 2% were divorced and widowed respectively.

Single individuals have different kind of outlook of world view compared to the married and with many children. In the latter case, the actual number of decision makers may be more than one and may affect the overall decision on land use. The same case applies to divorced and widowed household heads.

Land use and land cover is also influenced by occupation and income of the individual households. In this study, the main occupation and source of income for households was formal employment, with around 46.0% of households in this category .This was closely followed by those engaged in business (36.3%). Those who practiced Livestock production and Farming were 4.8% and 3.6% respectively while 9.3% of the households comprised of other sources of income not listed in the question. This included casual labourers, *jua kali*, *bodaboda*, mixed farming and watchmen (Figure 5.13).
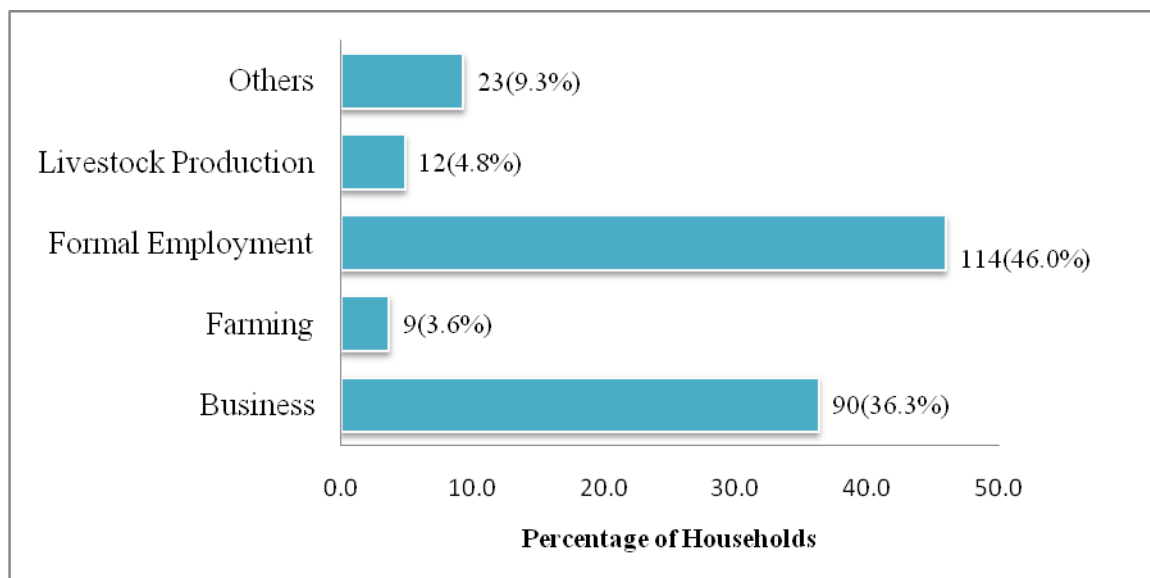
**Figure 5.12:Main sources of Household Income**
**Source:** Field Survey (2016).

Like occupation, average income per month, as shown in Table 5.6, varies between households. Most people, 33.5% get a monthly income of between Ksh.31,000-40,000. This is closely followed by those who earn less than Ksh.10,000. 16.5 % of household heads earn between Ksh.10, 000-20,000 while only 10.1% get a monthly income ranging from Ksh.21, 000 to 30,000.

**Table 5.6: Average Monthly Income**

| Monthly Income(Ksh.) | Frequency | Percent |
|---|---|---|
| Less than KSH.10,000 | 60 | 24.2 |
| 10,000-20,000 | 41 | 16.5 |
| 21,000-30,000 | 25 | 10.1 |
| .31,000-40,000 | 83 | 33.5 |
| More than KSH.40,000 | 34 | 13.5 |
| Total | 243 | 98.0 |
| Not Applicable | 5 | 2.0 |
| Total | 248 | 100 |

**Source:** Field Survey (2016).

This study confirms that the current use and utilization of land is associated with socio-economic traits such as age, gender of household, family size, size of house holds, educational status. The study findings is consistent with that research conducted by Farkas *et al*. (2005) in Central and Eastern European Countries which reiterated the importance of socio-economic profiles of respondents. The same sentiment was shared by Turner (2002). However, this should be taken with a lot of caution in relation to generalization of the findings.

### 5.2.3   People's Perception on Factors Influencing Land Use and Land Cover Changes.

Both questionnaires directed to individual households and developers illustrate the different knowledge levels and attitudes in relation to land use and land cover changes. Figure 5.14 gives a summary on responses from various households interviewed.
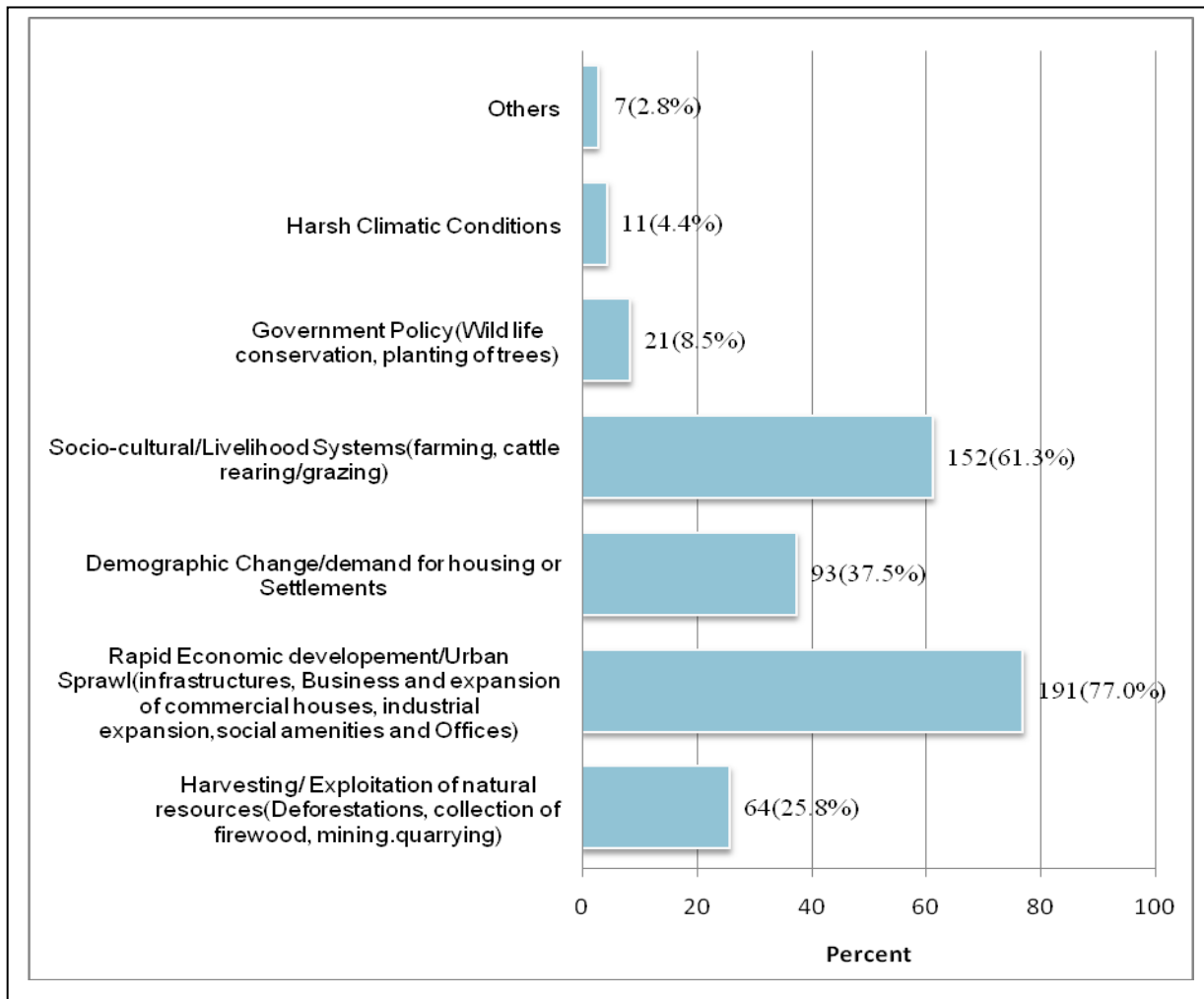


**Figure 5.13: Households' perception on Major Causes of Land Use and land Cover Changes**
**Source:** Field Survey (2016).

NB:  n is 248 and based on multiple response

A higher fraction of households (77.0%) were of the opinion that land use and land cover changes were as a result of rapid Economic Development which entailed urban sprawl, development of infrastructures, business opportunities, construction of commercial units, industrial expansion, social amenities and administrative offices. A relatively high proportion of respondents, 61.3% mentioned socio-cultural/livelihood systems which included agricultural activities like farming and grazing of livestock. Still, other respondents, 37.5% cited demographic changes /demand for housing or settlement. The study findings also revealed that Harvesting/exploitation of natural resources (deforestation, firewood collation, mining etc) constituted 25.8% of the causes of land cover changes. According to 21 (or 8.5%) of respondents, government policies also triggered land cover changes. Some of these included wildlife conservation and the call to plant trees. However, 4.4% of Household head had a strong view that land cover changes were as a result of harsh climatic conditions. The rest, 2.8% of household interviewed mentioned other causes like Landscaping, beautification and poverty.

Similar findings were from the developers where majority of developers, 46 out of 48 representing 95.8% revealed that they choice of development were majorly motivated by economical gain. 91.7% of developers indicated their decision to engage in their choice of development was based on technological capacity. 62.5% said their development option was guided by government policy/regulations. Still others, 60.4% indicated their developmental preference was influenced by political factors. The study findings revealed that socio-cultural influence was negligible at least from the perspective of developers. The breakdown of the findings is summarized in Figure 5.14.
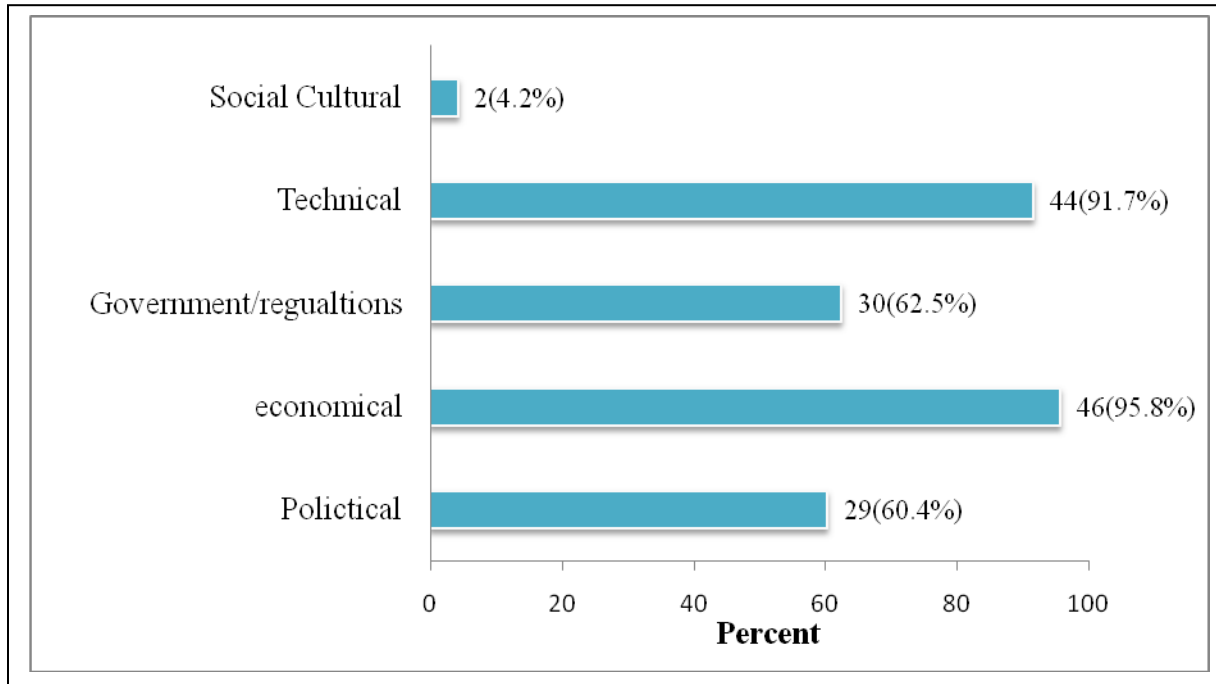
**Figure 5.14: Developers' Perception on Major Causes of Land Use and land Cover Changes**
**Source:** Field Survey (2016).

NB/ n =48 is based on multiple response

### 5.2.3.1.    Economical Factors as triggers of land Use and land cover changes.

The economic development is a significant explanatory variable for the high urbanization rate of Nairobi. This is corroborated by the fact that Nairobi's Gross Domestic Product (GDP) was about £254 million sterling pounds in 1975, £645 million in 1985 and £1.1 billion in 1995 while the national economic survey of the year 2000 put Nairobi's GDP at £1.5 billion (Government of Kenya, 2002). This has led to the establishment of more industries, the boom in real estate development and subsequently the expansion of the built-up areas at a time when the unregulated small-scale businesses have expanded rapidly and the employment in this sector in Nairobi is estimated at 750,000 (Government of Kenya, 2009). Towards this end, the correlation between increased GDP values shows perfect positive correlation coefficient of 0.7 with urban expansion. The high economic growth in the periods between the years 1975 to 1985 (153 per cent growth), led to a higher rate of urban expansion. The period between the years 1988 to 2000 had a lower rate of urban expansion, which can be explained by the slow economic development estimated at 70 per cent growth.

### 5.2.3.2.     Urban Population Growth

The 1969 population census put Nairobi's population at slightly over half a million while the population rose to 1.35 million in the year 1989 against a national total population of 23.0 million (Developments Solutions for Africa, 1992). The current population is estimated at 3,273,783 million (Government of Kenya-Population and Housing Census Surveys, 2009). The substantial population growth in the Nairobi area over the last 40 years (Ngayu, 2011) is responsible for the land use and land cover dynamics as illustrated above. However, the city's economy, public services and infrastructure have not managed to keep pace with the increasing population demands for services. The lag has been occasioned by the urban growth rate outpacing the capacity of local authorities to provide and maintain infrastructure and basic services (Stren and White, 1989). The situation has also been made worse by laxity of the local authority management and lack of clear development policy for the city.

According to one of the city council staff from City council of Nairobi,

> *There has been neglect of urban plan and lack of strategic systems/approach to urban development. In addition, there has been lack of suitable or comprehensive up to date master plan for the Nairobi and failure to implement the Nairobi Metropolitan Master plan.*
> (Respondents, County Council of Nairobi)

The growth in population of Nairobi has been phenomenal, underpinned both by rural–urban migration and a high rate of natural increase. Initial migration was fuelled by rising population, land density in rural areas and a real gap between urban and rural areas in the availability of social services, employment, and wages (Falkingham, Chepngeno-Langat & Evandrou, 2011). The expansion of formal education that facilitated initial migration as the first wave of migrants to the city was mainly young educated people aged between 20 and 29 years old in search of white-collar employment. With significant investment in the education sector after 1963 following independence, the number of migrants continued to grow tremendously (Oucho, 2007). With attempts to stem the migration flow having been unsuccessful, the inability of the city to provide adequate housing for its residents, largely due to the rapid rate of growth, resulted in the mushrooming of the slums and informal settlements reflected in the increased land use and land cover changes. These dynamics have resulted in the urban built up environment taking larger portion of the urban space among the land use and land cover categories. The *ad hoc* planning in

addition to the population increase has made worse the already existing physical, social, economic and environmental problems.

### 5.2.3.3. Socio-cultural/Livelihood Systems

Conversion of cover types to agriculture is considered a land use activity that significantly modifies initial cover types and replaces natural vegetation (Table 5.7). In areas where most cultivation is based on irrigation , there is almost no fallow period that would allow abandoned land to establish pastures and other vegetation hence decline in land cover. However, a combination of increased agricultural activities and high stocking densities can indirectly but severely affect land cover types, especially through overgrazing. In is worth noting that most of the land uses are linked to social or cultural systems and livelihood. A case in point is farming and keeping of livestock as observed in Table 5.7.

**Table 5.7: Distribution of Households and their current land Use**

| Uses | Frequency | Percent |
|---|---|---|
| Residential | 8 | 3.2 |
| Residential Farming | 31 | 12.5 |
| Residential Mixed Agric(farming and Keeping livestock) | 64 | 25.8 |
| Residential Rental Units | 1 | 0.4 |
| Rental houses Only | 11 | 4.4 |
| Farming only | 5 | 2.0 |
| Dwelling/Rental purposes small scale farming | 11 | 4.4 |
| Idle/not in use | 1 | 0.4 |
| Others | 5 | 2.0 |
| Total | 137 | 55.2 |
| N/A | 111 | 44.8 |
| Total | 248 | 100 |

**Source:** Field Survey (2016).

From figure 5.15, it is apparent that apart from residential purposes, most households were involved in mixed agriculture that is farming and keeping livestock. The type of activity is closely tied to  the level of attachments in the area as observed in figure 5.16 where  more permanent practices were determined by ownership of land.
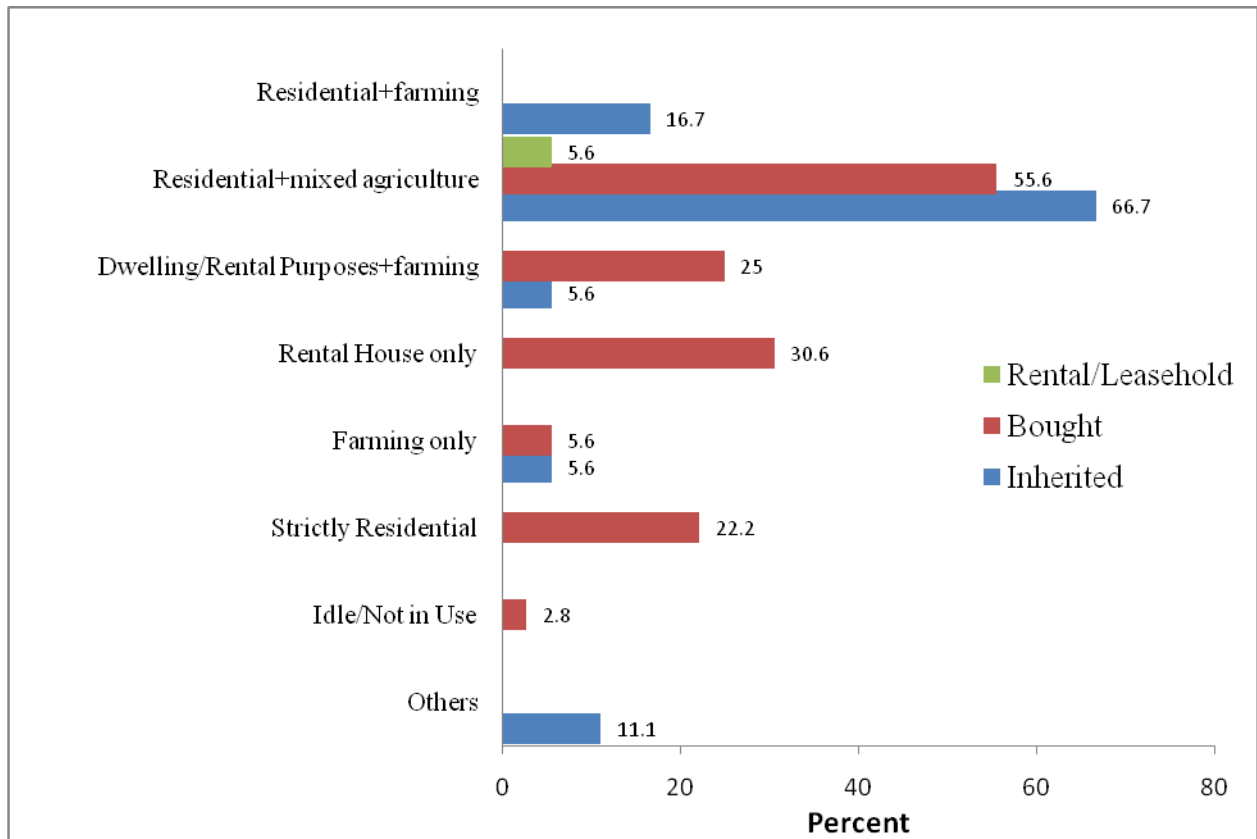
**Figure 5.15: Distribution of households and their response to major uses of land in relation to type of ownership**
**Source:** Field Survey (2016).

### 5.2.3.4. Physical attributes of an Area

The physical factors are more or less related to the economic appeals of that area. This was captured in both household and developers' questionnaires by asking factors responsible for the choice of a specific area. For developers, this was related to aspects like the physical suitability for development like slopes, soils, and hydrology as well as land availability. Other included transport network, availability of the vital infrastructures, market as well as labor. Table 5.8 and Figure 5.16 show the break down of developers and household responses respectively.

**Table 5.8: Developers Responses on Major Attractions of an Area**

| Major Attractions | Frequency | Percent |
|---|---|---|
| Physical suitability for development: slopes, soils, hydrology, land Availability | 20 | 41.7 |
| Transportation and Accessibility, including proximity to interstate highways | 36 | 75.0 |
| Existing land use patterns and location of other residential development | 5 | 10.4 |
| Availability of vital infrastructure (electricity, water and sewer systems) | 43 | 89.6 |
| Availability of labour | 10 | 20.8 |
| Market Demand | 33 | 68.8 |

**Source:** Field Survey (2016).
Results based on multiple responses' from 48 developers

It is clear from Table 5.8, that most developers (89.6%) are attracted by availability of vital infrastructure (electricity, water and sewer systems), followed by Transportation and Accessibility, including proximity to interstate highways (75.0%); Physical suitability for development: slopes, soils, hydrology, land Availability (41.7%), others are attracted by the market demand (68.8%), while the rest, 20.8% are motivated by availability of labour.
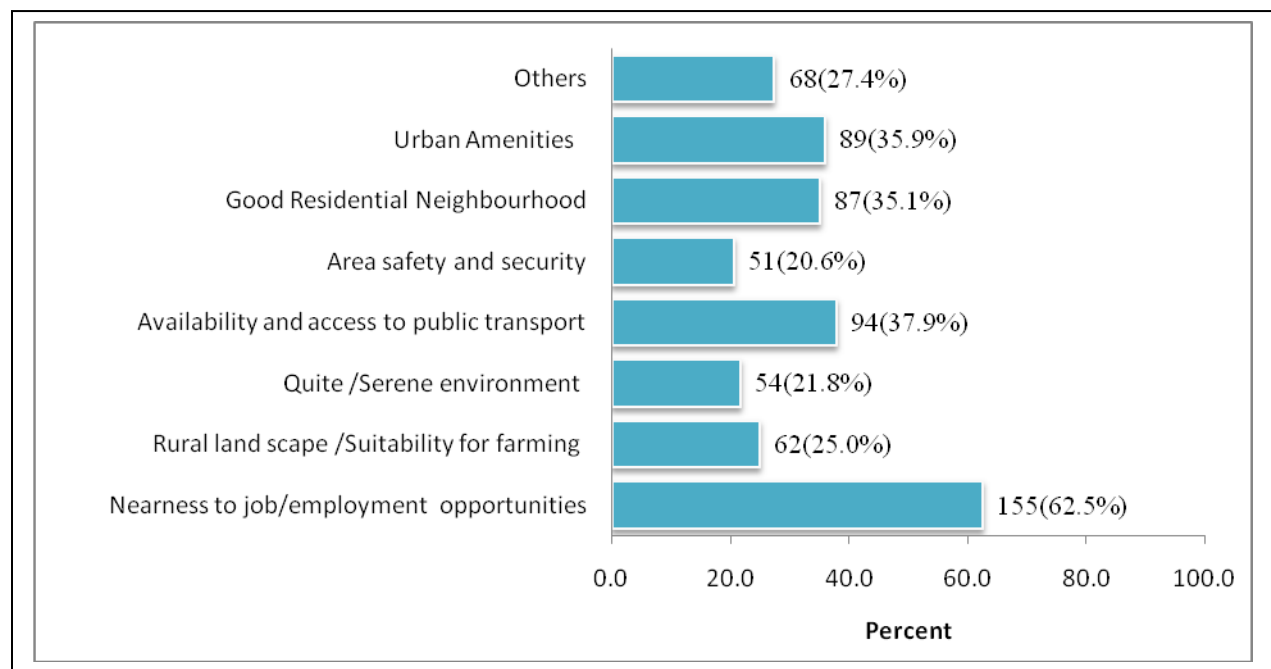


**Figure 5.16: Households' major attrations to current area of residence.**
**Source:** Field Survey (2016).

NB/ n =248 is based on multiple response

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Just like developers, household are also attracted to an area because of availability of transport and access to public transport (37.9%). Other households decision to settled in an area is influenced by potential or perceived job opportunities (62.5%), quite/serene environment (21.8%), urban amenities (35.%) and sometimes rural landscape/suitability for farming played a major role according to 25 % of households interviewed. About a third (27.4%) of respondents indicated other factors like affordable living standards, business opportunities, good climate, proximity to Nairobi town and social amenities.

**Table 5.9: Households and Percentage Distribution of the Length of time In Their Current Residence**

| Period(years) | Frequency | Percent |
|---|---|---|
| Less than 1 | 10 | 4.0 |
| 1-5 | 83 | 33.5 |
| 6-9 | 59 | 23.8 |
| 10-15 | 33 | 13.3 |
| 16-19 | 9 | 3.6 |
| >19 | 54 | 21.8 |
| Total | 248 | 100 |

**Source:** Field Survey (2016).

Generally speaking, more than a third, 33.5% of household in the study area had been in those environments for a period between 1 and 5 years. About 23.8% had been in their place of residence for a period of 6 to 9 years while 21.8% probably those who had been born and brought up in the these areas had lived there for more than 9 years. The main reason for high preference of living in slum areas was the affordable lifestyles, urban amenities, job opportunities among others(Table 5.9)

The presence of the different volcanic rocks such as trachyte, phonolite, tuffs and basanite as presented in Figure 2.3 provides cheap and easily access to building materials consequently leading to the development in real estate and the urban expansion. The tuffs are excellent building stones and are extensively used in Nairobi in the building and construction industry. Major constraints to the expansion of Nairobi City include the national park to the south of the built-up area, and the safety zone and noise corridor around the Jomo Kenyatta International Airport. The National Park, a protected area right next to the built-up area is a unique and valuable resource, not only as a tourist attraction, but also as an ecological counterpoint to noise and traffic pollution. The park therefore

provides a break to stress of the urban environment and provides all the inherent benefits that an unspoiled natural environment provides to its surrounding area. It is therefore a resource that must be preserved and this has checked the southward expansion of the City.

**5.2.3.5.        Government Policy and Regulations**

Land Use preference may also determine the control level vested in the state or government hence controlling land use through various legislations. Almost all the developers interviewed revealed that at one point or another, they have applied for a permit. One of the institutions vested with responsibility of Local Land Administration and land use is the local authority.  Since decision on the use and management of lands are the responsibility of the local authorities, individuals particularly developers need to get permission whenever they want to use the land for whatever reason.

From the study, the various employees of local authorities revealed that some of the major responsibilities of Development and Control Authority were related to:-

*Control of development and land use in relation to interest of proper and orderly development; Regulation and conversion of building and ensuring proper availability of infrastructures (*Respondent from NCC)

*Access the development of infrastructure within the council by enforcing all regulations that govern them and ensure they are strictly followed or adhered to; ensuring sustainability in all development perspective to achieve to vision 2030 requirement(*Respondent Ruiru SC)

*Approval of building plans and sub-division of land proposal for development; coordination of drainage systems and monitoring of private developments* (Respondent from Kiambu SC)

In the same vein, land use and land cover changes is closely linked to use and implementation of various development plans like the physical or land use plans. Local authorities are also responsible for the zoning and revision of development policies which according to the study findings are based on the factors outlined in Table 5.10.

**Table 5.10: The most important factor during zoning**

| Factors | Frequency | Percent |
|---|---|---|
| Density of the population | 4 | 57.1 |
| Fitness of the land for the permitted use | 2 | 28.6 |
| the Site and physical attributes of the land involved traffic and transportation | 1 | 14.3 |
| Others | | 0.0 |
| Total | 7 | 100.0 |

**Source:** Field Survey (2016).

More than half (57.%) of the local Authorities reported that density of the population was the main factor during zoning process while close to a third (28.6%) indicated that fitness of the land for the permitted use was more important. The site and physical attributes of the land involved, traffic and transportation was also quite relevant as revealed by 14.3% of the respondents.

Although local authorities are very important in land control and development, their work has not been subjected to proper evaluation by stakeholders, and this has opened avenues for the employees like the "city askaris" to get involved in various activities of corruption in return for favors from individuals, which may take many forms including failing to take measures pertaining to illegally acquired lands and land grabbing. This situation has led the community to lack trust and confidence in the local authorities. One of the developers interviewed confirmed that they were really frustrated by "city askaris" who demanded bribes. His comments goes as follows:

> "City Askaris are our major problems here. They don't help in any way and most of the time they demand bribes from us."

### 5.2.4. Hypotheses testing on factors Influencing Land Use and land cover changes

Tables 5.11 and 5.12 give the regression results which examined the effect of different factors as determinant of land use and land cover changes with respect to developers and household respectively.

**Table 5.11: Correlation Results of Factors Determining Developers Land Use**

| Independent Variables | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | 6.789701404 | 1.254871 | | 5.410678 | 2.78E-06 |
| Economical | -1.984725724 | 0.976776 | -0.258127861 | -2.03192 | 0.045* |
| Government policy/regulations | -1.994405633 | 0.698784 | -0.358765189 | -2.85411 | 0.006* |
| Technological | -0.937166715 | 0.405435 | -0.295293717 | -2.31151 | 0.026* |
| Social/cultural | 0.803205049 | 0.501042 | 0.212304255 | 1.603071 | 0.116 |

**P=0.002 and df=5**     *Significant at 0.05

**Source:** Field Survey (2016).

In overall, Land Use by developers showed a significant correlation with political, economical, technological, government policy/regulations and socio-cultural factors (P = 0.002, 95% confidence). However, socio/cultural factors had positive but insignificant influence on developer's decision on land use which implies that the more these variables increase, the more the chances that there would be no land utilisation. On the other hand, economic factors, technological and government policy/regulations had negative influence on developer's likelihood to engage in a particular land use.

The negative coefficient of economical factors implies that the higher the economic status of the developer, the less chances of him or her putting a particular land into use. In this case, economical factors was significant with 0.045 likelihood of participation in off-land.

The negative coefficient of government policy/regulations implied that as the rules/regulations increases, there was less likelihood of the developer's participating or engaging in the land use. This contradicts findings of Saint *et al*. (2009) in which technology is viewed as a facilitator for the ease to engage in a particular land use. In other words, knowledge resources that developers posses largely affect land use decisions. For this study, most respondents were hotel managers, transport and logistics agents, manufacturers and were not directly involved in exploitation of land which required some form of technology. Overall, three of the variables in the model showed a significant influence on the land use behaviour of the developers

Like developers, Land Use by households showed a significant correlation with socio-cultural, economical, government policy/regulations, demographic and climate and socio-cultural (P = 0.029, 95% confidence). Unlike developers, household's decisions on land use are majorly influenced by social/cultural, economical and climate factors but exhibit a weak correlation in relation to government policy/regulations or politics and technological advancement. Table 5.10 gives the breakdown of the findings.

**Table 5.12: Correlation Results of Factors Determining Households' Land Use**

| Independent Variables | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | 3.577986419 | 0.461391 | | 7.754783 | 2.42E-12 |
| SocioCul | 1.184036446 | 0.423951 | 0.297779152 | 2.792863 | 0.006* |
| GovPol | 0.347179857 | 0.382025 | 0.078485498 | 0.908787 | 0.365 |
| Clim | -0.989563079 | 0.48907 | -0.179218992 | -2.02335 | 0.045* |
| Others | 0.745120503 | 0.762624 | 0.086042946 | 0.977048 | 0.330 |
| Eco | -1.059438184 | 0.495187 | -0.237119587 | -2.13947 | 0.034* |
| Demo | 0.004947719 | 0.43383 | 0.001129208 | 0.011405 | 0.991 |

**P=0.029 and df=6**   *Significant at 0.05

From the table, government policy had a positive but insignificant influence on the household decision to use land. Instead, land use among households was positively linked to socio-cultural factors, implying the more one was attached to a particular area by virtue of family, ownership of land, livelihood systems, the more the likelihood of using the particular land.

The two analyses are enough illustration and evidence and therefore the study adopts the alternative hypothesis that states "The land use decision making mechanism in the city as embodied by statutory legal and /or urban planning regulations as well as economical, government policy and technological advancement in society determines the land use and land cover dynamism; hence the quality of urban environment".

The above findings are consistent with a number of studies as higlited in the literature. For instance, Bamwerinde and his colleagues while investigating determinants of land use in the densely populated Kigezi highlands of Southwestern Uganda household, assert that economic factors such as access to resource (e.g. labour, land) affect the net returns from the portfolio of plots and affect general land use decision-making especially at the farm level (Bamwerinde *et al*., 2006).

### 5.2.4.1   Political power and Land Use decision-making Mechanisms

Patterns of land use and urban development can "reflect social meanings, institutional values, and political goals within a geographical context" (Lo, 2010, p.529). According to Saint *et al*. (2009), politics of land use revolve around four questions, that is, *who are the stakeholders? Who makes the*

*choices about land use? Who is excluded from use?* lastly, *who benefits from use?* Most land-use decisions are primarily local and individual, however, the regional and national land-management agencies own a considerable amount of authority, thus land is the key to planning and control at broader levels regulated by state and national governments. In this respect, the land-use decision-making process is inherently political (Saint *et al*., 2009). In the same vein, Dafe (2009), asserted that land use/allocation is essentially a political decision linked to the fact that land has a strong spatial aspect and can be used to benefit the people living together in a specific location for instance, residents in ethnic enclaves or high income areas. In addition, land values / goods are highly visible so that their allocation can easily be attributed to political actors by increasing their chances of re-election (Dafe, 2009).

The government has the ability to affect the demand side of the market for land in various ways. For instance, through its use of tax incentives or other types of subsidies, government may increase the demand for certain land-use types beyond a level the market would have achieved otherwise. The Government is itself a demander of land, and so by increasing or decreasing its consumption directly affects the demand-and the expected net rent for land in various use types. Similarly, the government may affect the supply side of the market for land for instance, through rezoning land from one use type to another-in this way, the government would increase the supply of land in the latter use type while decreasing the supply of land in the former use type. In addition, by annexing land into its political boundaries, government increases the supply of land of the relevant use types. Lastly, Government may also impact the expected net return for a particular land-use type through actions that affect conversion costs. Such action could take the form of permits or fees or other requirements that apply disparately to different types of land-use conversions, for instance making it more costly to convert from one land use to another thus reducing the relative number of conversions.

### 5.2.4.2 Technology as a factor in Land Use Decision Making Process

Technological factors conditions land use decisions by influencing the profits accruing to land managers. The availability of new technologies and the ease with which they can be applied to land affect significantly the productivity of labour and capital employed there. It would require intensive labour and heavy capital for construction in mountainous areas, and this constrains the type of lands use-use changes in these areas. The ease and rate of adoption of available technologies by land

managers influence the potential for land use changes. Technological developments like the extension of basic transport infrastructure such as roads, railways, and airports, can open up previously inaccessible resources and lead to their exploitation and degradation .In a broader sense, knowledge resources that land managers posses (as in the case with traditional knowledge) or are able to obtain (eg technical assistance) largely affect land use decisions (Saint *et al*., 2009).

## 5.2.5 Environmental Implications of Land Use and Land Cover Dynamics of Nairobi City County

In the context of this study, environmental quality was restricted to how the land use and land cover dynamics which manifests through spatial and temporal changes in the urban/built-up and open lands, agriculture and riparian vegetation, rangeland and shrubs, forests and water bodies may have future implications on the urban surface runoff (flooding), loss of vegetation cover, water pollution, urban heat islands and a decline in air quality. The current urban sprawl manifesting in the city is detrimental to the environmental quality at a time when the city is already facing an environmental crisis occasioned by loss of green space, farmlands and fragile ecosystems. As the built up areas of the city continue to spread, the environmental problems of the city is postulated to grow exponentially if mitigation measures are not put in place.

### 5.2.5.1 Land Degradation

Land Use and land cover changes are linked to multitude of environmental complications. With this as a background it is not very surprising that land degradation was considered a major problem as reported by most households (Figure 5.17).
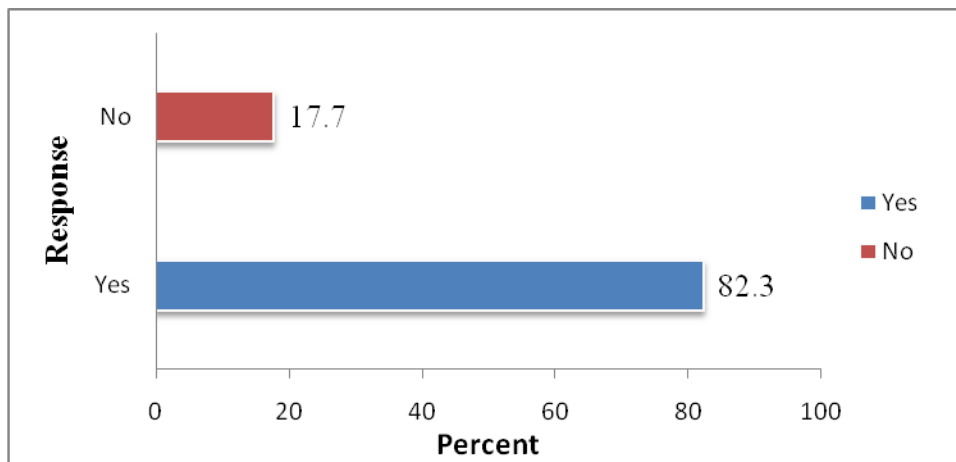


**Figure 5.17: Land Degradation as a problem of land Use and land Cover changes**
**Source:** Field Survey (2016).

From the figure, majority of respondents indicated that land degradation was a major problem as a result of land use and land cover changes. Only 17.7% believed that land degradation is not a major problem. Other studies corroborate the current findings. O'Sullivan (2007) while looking at urban economics reported land degradation as one of the consequence of human based land uses. Unsustainable and improper land use and land cover changes are the major causes of land degradation. Some of these practices include overgrazing of livestock, indiscriminate or excessive clearing of forest or vegetation and other land use and land cover based activities.

### 5.2.5.2 Encroachment of Agricultural land and destruction of Habitat

Generally, contrasting views are reflected by households regarding the current Land-Use/Environmental Challenges as revealed in figure 5.18. Those who were of very strong agreement were as follows: increasing land fragmentation (46%), land grabbing (28.6%), encroachment of agricultural land (17.7%) and habitat destruction/interference (58.9%) . The rest of responses are outlined in Figure 5.19.
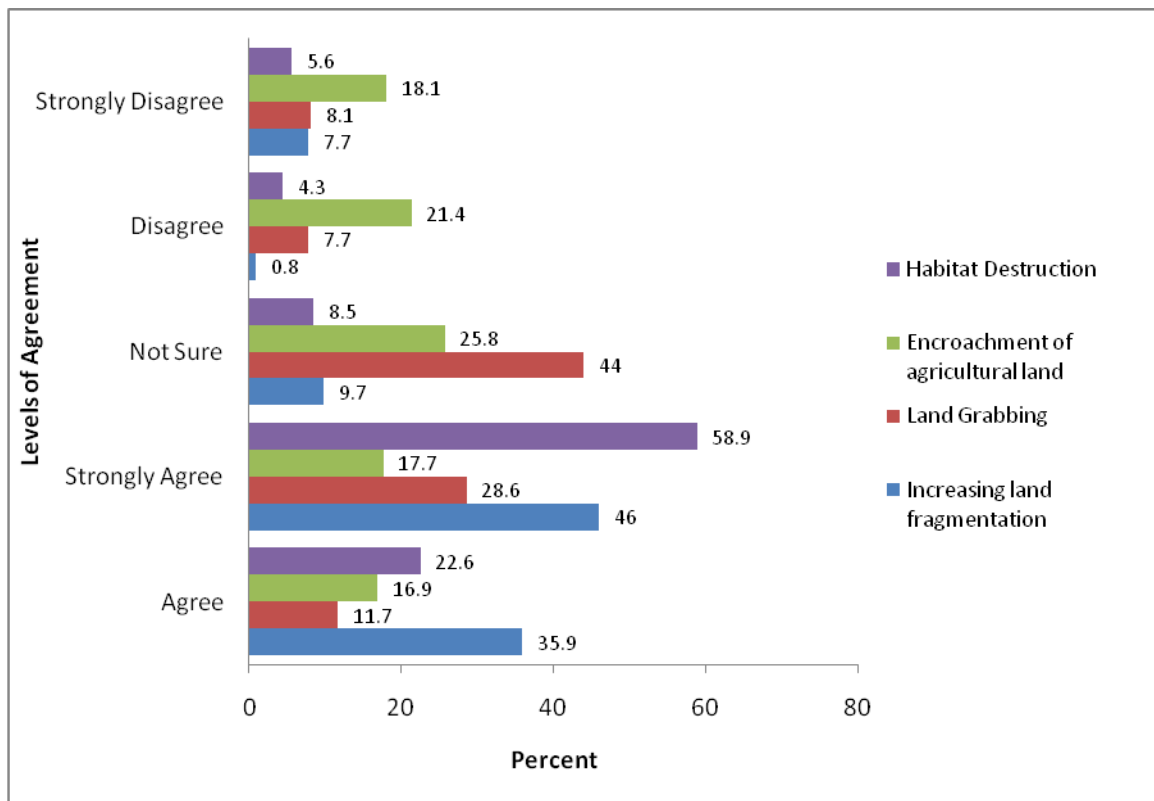


**Figure 5.18: Differerent Levels Of Agreement On Land-Use/Environmental Challenges**
**Source:** Field Survey (2016).

The expansion of the urban built up surfaces shall lead to loss of fertile farmland. This is corroborated by the fact that already Nairobi is exhibiting expansion into the urban peripheries where agriculture is the main economy. The fragmentation of the agricultural land parcels currently taking place is a clear indication that it is no longer viable; instead, people have opted for built-up areas notably to housing and highways developments which are perceived as comparatively more viable. This is likely to occasion loss of wetlands which moderates the flooding incidences by slowing down the rate at which the surface runoff enters the streams. Wetlands also absorb chemicals, organic and suspended solid particles in the surface runoff and without wetlands to act as buffer, the natural drainage systems become contaminated and more areas becomes prone to flooding. The spread of the urban paved surfaces shall also take away the green spaces used for recreation and for the improvement of air quality.

### 5.2.5.3 Erosion and Impacts on Water Bodies

The Table 5.13 gives households' response in relation to perceived effect of land cover change

**Table 5.13: Households' Perceived Environmental Impacts of Land Cover Changes**

| Effects | Frequency | Percent |
|---|---|---|
| Inadequate /lack of water | 81 | 32.7 |
| Surface runoff | 95 | 38.3 |
| Poor Hygiene and sanitation | 110 | 44.4 |
| Erosion | 181 | 73.0 |
| Water body enrichment/lowering of quality | 81 | 32.7 |
| Others | 66 | 26.6 |

n=248 and is based on multiple response

**Source:** Field Survey (2016).

From the study, majority, 73.0% of households believed that land cover changes led to increased erosion, 44.4% of the respondents cited poor hygiene and sanitation as the major effects with 38.3% of respondents indicating surface runoff, 32.7% said that land cover changes led to decline in water while still 32.7% revealed there was water body enrichment /lowering of water quality as a result of land cover changes. The rest of respondents, 26.6% indicated other environmental implications like noise and air or atmospheric pollution, reduced soil fertility and consequently decline in agricultural productivity, reduced grazing fields and others. Many land uses lead to significant disturbance on

land surface thus interfering with natural erosion rate. The higher rate of erosion reported in this study may be attributed to the fact that most land use activities expose land to various erosion agents. In other words, land use is the single most important factor affecting soil erosion strongly enhanced by the human activities mentioned in the previous chapters.  Lowering of water quality may be attributed to both solid and liquid waste both from domestic uses and industries.

The study is consistent with previous studies by Bean *et al*. (2004), Frazer (2005), Carlos (2009) and Gebre and Rooijen (2009).  While studying  Land Cover and Land Use Change and Its Impact on Watershed Services in a Tropical Andean Watershed of Peru,  Carlos (2009) observed that soil erosion was one of the major results. Gebre and Rooijen (2009) reached similar conclusions. However, Bean, *et al.,* (2004) argued that  development of urban built up area was the main cause of  decline in water quality owing to the fact that paved surfaces exacerbates the surface runoff. The surface runoff suspends the organic, oil and chemical compounds as well as providing the media for suspending the solid particles from the paved surfaces (Bean *et al*., 2004).  Another argument for the above environmental challenges may be a result of the fact that the physical development of Nairobi was based largely on the British model of the garden city which has not been able to march its outgrowth (Njoroge, Maina  &  Kariuki, 2011).

### 5.2.5.4 Governance/management of land Use related impact

Poor governance and weak frameworks for environmental regulation as well as implementation coupled with rapid population growth has seen Nairobi and its environs exhibit deteriorating environmental quality over the years. The negative impact of land use can also be attributed to laxity among the county councils/local authorities in administering their duties or responsibilities.

Figure 5.19 gives some of the explanation for the poor management of land use according to the local authorities.
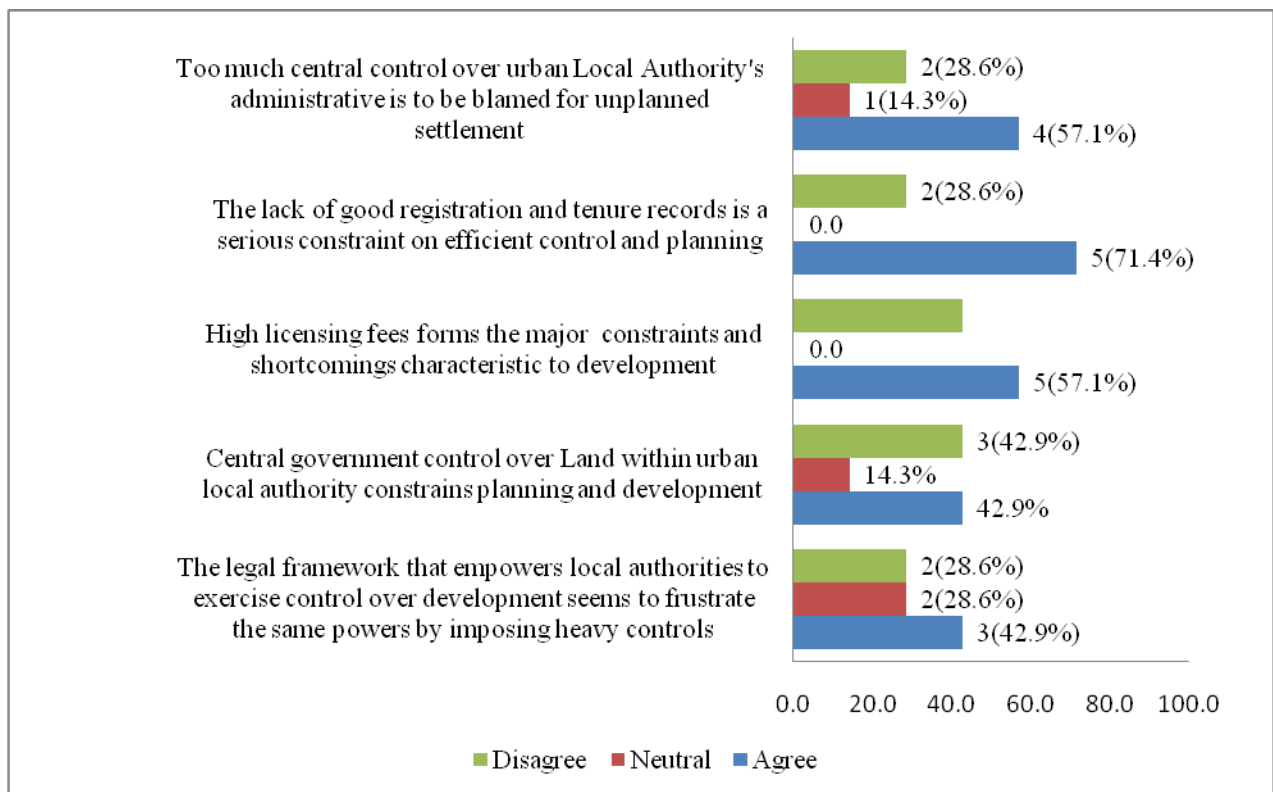
**Figure 5.19: Different Levels of Agreement on Management Challenges**
**Source:** Field Survey (2016).).

As can be seen in Figure 5.19, about 71.4 % of local authorities were in agreement that lack of good registration and tenure records was one of the serious constraints on the efficient control and planning. again, more than a half, that is 5 out of 7 local authority personnel interviewed revealed there was much central control over urban local authority's administration that was to blame for unplanned settlements . The same proportion of local authorities, 57.1%  were in consensus that high licensing fees formed the major challenges and shortcomings to development while 42.9% admitted that the legal framework, which empowered local authorities to excise control over development seemed to frustrate the same powers by imposing heavy control.  This was confirmed by one staff member or employee in NCC during the interviews who stated in his words that:

*The various challenges for NCC range from lack of policy to control development and*

*facilitate private development leading to unfair or illegal practices, neglect of urban plan*

*and lack of strategic systems/approach to regulate development, lack of suitable and up to*

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*date Master plan. This is also linked to the fact that the so-called Nairobi Metropolitan*

*Master Plan has not been implemented* (Respondent from NCC)

He further added that as a result of the various weaknesses sited above, there was lack of regulated urban expansion and development leading to increase of informal development. The same sentiment was shared by respondents from Ruiru and Kiambu County Council who added that highly centralized decision-making at national and local levels heavily affects Nairobi and its capacity to respond to local development needs.

Poor waste management was also reported by the respondents from all the seven local authorities. Again, this could be attributed not only to weaknesses and commitment of local authorities but also their attitude and behaviors. Plate 5.1 illustrates the housing conditions and physical environment in a typical slum within Nairobi City County.



**Plate 5.1 : Housing and drainage in Kosovo Village, Mathare Slum**
Source: Adopted from Oxfam Kenya (2009)

# CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATIONS

## 6.1.    Introduction

This section of the study highlights key study findings and conclusive implications of the findings in line with the study objectives and hypothesis guiding the study and gives recommendations according to what has emerged in the study.

The general focus of this study has been to quantify the land use and land cover dynamics of Nairobi city and the implications of such changes to the sustainable development of the city. The culmination of this work is a recommendation of strategic issues geared towards preserving the desirable aspects of the change while militating against the ravages that may arise due to the undesirable aspects of the change. This Chapter therefore present recommendations for sustainable development of Nairobi city granted that urbanization is inevitable. However, it is noted that having taken consideration of all the emerging development issues in the city arising from the land use and land cover challenges, it is imperative to explore the institutional framework on which these recommendations should be implemented. Therefore, the institutional framework for the implementation of recommendations is also detailed in the succeeding sections alongside areas for further research.

## 6.2.    Summary of Findings

### 6.2.1.  Land use and land cover schema for the city between the years 1988 to 2010.

i.    **Urban built-up areas:** The urban built-up areas and open land have increased while the agricultural and riparian vegetation occupied in 1988 have decreased.  Forest land cover has also decreased substantially while the rangeland and shrubs have shown some increase.  The expansion of built up areas are closely related to the decrease in areas previously agricultural and riparian vegetation, rangeland and shrubs and forests have mainly given way to expansion in built up areas and open lands.

ii.   **Urban sprawl phenomenon:** The urban sprawl phenomenon is already evident in the city as manifested through spatio-temporal variations in terms of growth rate and directions. The

expansion has not taken place evenly in all directions but has occurred much faster in certain directions.

iii. **Spatial Structure of the City:** The spatial structure of the city manifests a hybrid of concentric and sector models of urban growth. This has been influenced by the distribution of transportation arteries as the urban development has evolved along the transport arteries emanating from the city centre.

iv. **Land fragmentation:** Land fragmentation has reduced the holding sizes making the current sizes of the land parcels not viable for agricultural development, subsequently leading to change of the land use and land cover from agricultural to urban built up areas in the urban periphery.

v. **Squatter settlements:** Most of the squatter settlements are located on flood plains, in abandoned quarries, on steep banks of river valleys, and on undesirable vacant land such as next to dump sites making such residents susceptible to environmental disaster.

vi. **Quarrying activities:** Quarrying activities have played a significant role in altering the urban morphology of the city. The quarries are the major source of building materials for the city and its surburbs and these reserves are scattered on the eastern part of the city.

**6.2.2. Factors that influence Land Use and Land Cover dynamics in Nairobi City County**

i. **Encroachment of built up areas**: Encroachment of built up areas on other land uses and or land covers has been rapid manifesting discontinuous patches of built-up areas and open lands. This has been largely due to the **high demand for built up area** as compared to other land uses.

ii. **Population growth** : Population growth  due to natural population growth as well as rural-urban migration has exerted pressure on land, leading to land fragmentation and therefore a reduction of  land under agriculture and forest cover. This has over the years affected water supply, wildlife habitat and overall environment quality.

iii. **Occupation and Income levels:** This study confirms that the current use and utilization of land is associated with socioeconomic traits such as age, gender of household, family size, size of house holds, educational status. This is particularly true for the study area.

iv. **Physical attributes of an Area:** The physical factors are more or less related to the economic appeals of that area. For developers, the physical suitability for development like slopes, soils, and hydrology as well as land availability are critical in their choice of location. Others included transport network, availability of the vital infrastructures, market price of land as well as availability of labour.

v. **Urban development policies and regulations:** Land Use preference also determine the control level vested in the state or government, hence controlling land use through various legislations. The policies and regulations which have been implemented in Nairobi over the years have been enacted with less regard to the environmental impacts of such developments. Urban sprawl phenomenon is attributed to the **ad hoc nature of planning** which has characterised the city as corroborated by rapid revisions of land use zoning regulations. In some areas, residential neighbourhoods are being developed only because of availability of space, with little effort being made to provide the necessary infrastructure such as roads, water supply and sewerage. The revision in the zoning policy has encouraged conversion of agricultural land to built-up developments with increased plot ratio, coverage and general development densities.

vi. **Enforcement of Development Control:** Weak framework of enforcement of development control has led construction of substandard structures as well as overdevelopment of built up areas which affect the overall quality of environment.

vii. **Affordability of land and Construction materials:** Affordability of land and Construction materials has occasioned the expansion in the urban built up areas in Nairobi. Infrastructural investment such as roads, water and electricity in the previously urban peripheries has also added benefits to quality of life in such neighborhoods, consequently promoting migration into the neighborhoods.

viii. **Higher property and business taxes**: Higher property and business taxes in the city centre have pushed businesses to the commercial centres in the suburbs where taxes are generally low. Therefore, even in the absence of policies that would encourage the peripheral urban growth, these centres have proliferated due to the willingness of a growing number of people to live in them and conduct commercial activities.

ix. **Vehicular and pedestrian traffic:** Vehicluar and pedestrian traffic has increased within the city and its surburbs, resulting in congestion degradation of environment quality. This has been occasioned by the increase in of income of an average Kenyan who can now afford to own.

x. **Political power and Land Use decision-making**: Patterns of land use and urban development reflect social meanings, institutional values, and political goals within a geographical context. Regional and national land-management agencies are installed by political key players and own a considerable amount of authority, thus land is the key to planning and control at broader levels regulated by city and national governments.

xi. **Technology**: The availability of new technologies and the ease with which they can be applied to land affect significantly the productivity of labour and capital employed there. The ease and rate of adoption of available technologies by land managers influence the potential for land use changes. Technological developments like the extension of basic transport infrastructure such as roads, railways, and airports, can open up previously inaccessible resources and lead to their exploitation and degradation

xii. **Time Frame for approval of development plans:** Approval of building plans and sub-division of land proposal for development should be reduced since delays in these approvals frustrate land owners.

### 6.2.3. Land Consumption Rate and Land Absorption Coefficient for the City from 1988 to 2010

i. Urban built-up areas and open land have increased from 63.920 km2 in 1988 to 344.079 km2 in 2010. The decline experienced by the agricultural and riparian vegetation, rangeland and shrubs and forests have mainly given way to expansion in built up areas and open lands.

ii. The urban sprawl in Nairobi is corroborated by the increase in Land Consumption Rate and Land Absorption Coefficient for the city. The increase in the two values is occasioned by rapid economic developments, high urbanization rates and the physical base of the city which are the most significant factors influencing rapid land use and land cover dynamics in the city.

### 6.2.4. Environmental Implications of the land use and land cover changes

i.   **Land Degradation**: Unsustainable and improper land use and land cover changes are the major causes of land degradation. Some of these practices include overgrazing of livestock, indiscriminate or excessive clearing of forest or vegetation and other land use and land cover based activities.

ii.  **Encroachment of Agricultural land and destruction of Habitat:** The expansion of the urban built up surfaces has lead to loss of fertile farmland. This is corroborated by the fact that already Nairobi is exhibiting expansion into the urban peripheries where agriculture is the main economic activity. The fragmentation of the agricultural land parcels currently taking place is a clear indication that it is no longer viable; instead, built-up areas have edged out the other land uses as these are perceived as comparatively more viable.

iii. **Erosion and Impacts on Water Bodies:** The higher rate of erosion reported in this study may be attributed to the fact that most land use activities expose land to various erosion agents. In other words, land use is the single most important factor affecting soil erosion strongly enhanced by the human activities. Lowering of water quality may be attributed to both solid and liquid waste from domestic and industrial uses.

iv.  **Governance/management of land Use related impact:** Poor governance and weak frameworks for environmental regulation as well as implementation coupled with rapid population growth has caused the deterioration of environmental quality for Nairobi and its environs.The negative impact on environment can also be attributed to laxity among the former local authorities in administering their duties or responsibilities.

v.   **Urban Heat Island:** With continued depletion of the urban green cover, the city is geared to experience urban heat island effect. The urban temperatures shall increase due to the increase in the amount of asphalt and buildings which emits infra-red (heat) radiations.

vi.  **Natural ecosystems and habitat quality**: The urban built up areas has resulted into reduction of the land under agriculture and other natural vegetation, thereby affecting the natural ecosystems and habitat quality which has consequently led to environmental degradation. This has also been exuberated and compounded by the proliferation of the informal settlements in the urban periphery.

### 6.2.5. Study hypothesis results

The findings on the quantification of land use and land cover dynamics of Nairobi city and the implications of such changes on the city's environment, together with the hypothesis testing, have clearly supported the alternative hypothesis that "The land use decision making mechanism in the city as embodied by statutory legal and /or urban planning regulations as well as economical, government policy and technological advancement in society determines the land use and land cover dynamism; hence the quality of urban environment".

### 6.3.    Conclusion

Rapid urban growth and the accompanying land use and land cover changes have prompted concerns over the environmental degradation and ecological alteration in the city. It is noted that the greatest contributor to this is the encroachment of the urban built up areas into the fragile ecologies. The category of the built up dichotomy responsible for this is the informal settlements whose inhabitants keeps on migrating from one settlement to another. The migration is occasioned by the fact that the lands where they establish the settlements are not legally owned by themselves and in most cases they are government land reserves of which, soon as need arises for government to develop the land, the illegal occupants are often evicted. This makes the establishment of such settlements a crucial issue to urban development in Nairobi.

The post-classification analysis of the land use and land cover dynamics using satellite data together with GIS indicates increased land use and land cover changes in the city. This has been occasioned by rapid urban growth and concentration of people between the years 1988 to 2010. The analysis reveals that urban areas have expanded significantly leading to degradation of the natural vegetation such as the forests, riparian vegetation, shrubs and rangelands resulting in ecological disruptions. This study has shown that lack of relevant spatial information, crucial for planning, may be alleviated with remote sensing data that can provide opportunities for periodical survey of land use and land cover changes and their spatial distribution. Spatial patterns of urban sprawl over different time periods in particular can be systematically mapped, monitored and accurately assessed from satellite data as integrated with Geographic Information Systems along with conventional ground data to give accurate input to the development of sustainable urban structure plan which significantly rely on the spatio-temporal data.

It is further imperative to note that sustainable urban development detailing appropriate standards for human development should be pursued as a national goal. This shall remain achieved at the altar of sound environmental conservation policies and programmes geared towards promoting practices and consumption patterns that conserve and protect environment, such as sustainable human settlement development. As such, programmes such as relocating and upgrading informal settlements from marginal urban locations to appropriate land suitable for shelter development should achieve minimum displacement, cost effectiveness and effective community participation. In this regard, interplay between Physical Planning Act (Cap 286 of the Kenyan Laws) and the Environmental Management and Co-ordination Act (1999) should in this case manifest through the enforcement of the Acts in the implementation of the Comprehensive Urban Structure Plans and Part Development Plans clearly marking open spaces as well as spelling out development procedures for urban development. This will conserve fragile ecosystems and at the same time meet the people's aspirations.

## 6.4.    The Study Recommendations

From the study findings and conclusions, the following recommendations are made:

i. ***Enhancing Development Control:*** The greatest hindrance to sustainable city development in Nairobi is noted to be lack of comprehensive development plan on which the development authority should be drawing the legitimacy for the development control. In a situation where there is lack of a comprehensive development plan to regulate the development, there is the likelihood of illegal developments taking place which manifest in the form of rapid urban land use and land cover dynamics with undesirable repercussions. Towards this end, the City Authority should develop a comprehensive development plan for the city and strive towards enforcing the development control standards emanating from the plan.  Within this framework, the land use and land cover zoning should strive at creating balanced land use and land cover as well as creating land use functionality. Further, the zoning requirements such as floor index, plot coverage, sky limit and plot size should strictly be adhered to in lieu of infrastructure expansion. This should go aal the way to include elimination of time period in plan approval process which tends to promote illegal developments.

ii. ***Expansion and Maintenance of the Infrastructure:*** The development rate in the city has surpassed the capacity of the existing infrastructure. This has manifested in higher frequency

of sewer blockages and bursts. It is therefore proposed that for the city to continue supporting the current population without the built-up areas spreading into ecological fragile zones there is need for expansion and proper maintenance of the existing infrastructure. The infrastructure envisaged here for expansion includes water reticulation, sewer and road network.

iii. *Environmental Impact Assessment:* It is recomended that all the proposed major developments which are likely to have environmental implications be subjected to Environmental Impact Assessment (EIA), in accordance with the provisions of Environmental Impact Assessment regulations of 2003. This proposal should be enforced by National Environment Management Authority (NEMA) in conjunction with the City Authority. However, the evolution of the Physical Development Plan as proposed above should also be based on land suitability analysis in evolving development zones. This is imperative in protecting the fragile ecologies like the riparian vegetation and forests covers against encroachment by other anthropogenic activities. The land use suitability analysis is also imperative in protecting human life and the property. Loss of life and property may arise due to disaster as occasioned by poor location of land uses such as the residential developments along the riparian reserves which are prone to occasional flooding disaster.

iv. *Multi-Sector Partnership Approach to Urban Development:* The current urban development paradigm operational in the city is not people driven and various development agents feel left out in the urban development arena. Therefore in the evolution of a new development plan for the city, the people and various development agents should be brought on board for them to feel part and parcel of the plan that shall emanate from the consultative process. This makes it easy for people to understand the issues entailed in the plan and take charge in implementing and undertaking self driven development control.

v. *Policy Issues:* In Kenya, the declining social housing development and the construction industry have become oriented towards satisfying the demands of groups with higher purchasing power. This is synonymous with privatization and restitution concepts which have found niche in the management of public affairs, radically altering the urban housing market. This has brought significant changes in the types of dwellings being constructed as private construction companies have become more oriented towards the provision of housing for the high-income groups. This has consequently driven the urban poor to the urban periphery and/or open lands as they may not afford the housing rates thus they move

to the peripheral land to establish low income residential developments. This has consequently culminated in environmental degradation and rapid land use and land cover dynamics arising from land use and land cover invasion and/or successions. In this regard, the government should have a well clearly stated and implementation phased policy for urban low income housing development if the environmental degradation and encroachments into the fragile ecosystems has to be controlled within the city and its surburbs.

## 6.5.    Areas for Further Research

In conclusion,this study proposes further research to be undertaken in the following fields:-

i.    Land use and Land cover dynamics in the city on similar basis but using higher resolution satellite imageries such as IKONOS, Quickbird and/or multi-spectral SPOT imageries. In particular, the research should focus on enquiry on the  land use and land cover of Nairobi by the year 2030 if the current factors remain constant in line with the Vision 2030 which is the National development model currently being implemented.

ii.     The use and control of motorised transport in urban areas; their effects on urbanization pollution and environmental quality.

iii.    The identification and definition of strategies for enforcement of urban development control legislative and policy instruments and institutions.

iv.    Control and regulation and of all professionals in the areas of urban  and spatial planning highlighting vertical and horizontal lines of authority and responsibility.

v.    Public engagement framework in generation of urban areas master planning that define the mix of activity and their spatial location. This should be supported by legislation and regulatory framework that are enforcemable.

The above stated recommendations strengthen the imperative role spatial planning regulatory framework shall continued to play in achieving sustainable urban development.

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Questionnaire N0……………….

Area/Location………………………

**Appendix 1: Questionnaire for Consumer/Household**

**Preamble**

This questionnaire is prepared to collect data about land use and land cover Changes and environmental implications. It is expected to generate and provide helpful information for policy makers and development practitioner's .Therefore, your inputs as a stakeholder to fill this questionnaire is highly appreciated and information provided will stay confidential and your right to involve or not is also respected.

**A.)  DEMOGRAPHIC INFORMATION (DRIVERS TO LAND USE AND LAND COVER DYNAMICS)**

[Please Tick where appropriate]

Q.1.  Gender of Respondents   1.  ☐Male          2. ☐Female

Q.2.  Age of respondent (years)

1. ☐ Less than 19          2. ☐ 19-29          3. ☐ 30-39          4. ☐40-49

5   ☐ 50+

Q.3.  What is the highest level of education achieved?

1.☐ None          2. ☐ Primary          3. ☐ Secondary          4.☐ College

5. ☐ University

Q.4.  Marital Status    1.☐ Married          2. ☐ Single    3. ☐ Divorced  4. ☐ Widower/widow

Q.5.  What is your position in the household?

1.☐ Head          2. ☐ Spouse          3. ☐ Son/daughter

4.  ☐ Others (Specify)……………………………………………………….

Q.6.  How many people are in your household…..........................................................................?

Q.7.  Respondents' main occupation (economic Activities).

1.☐ Formal employment   2. ☐ Farming  3. ☐ Livestock Production  4.☐ Business

5. ☐ Others (Specify)……………………………………………………………

Q.8.  What is your monthly income?

1.☐ Less than Kshs 10,000        2. ☐ Kshs (10,000 - 20,000)    3. ☐ Kshs (21,000 - 30,000)

4.☐ Kshs (31,000 -40,000)        2. ☐ Kshs (40,000 and above)

## B.) Land Use and Environmental Implications

Q.9. For long have you been living in your current residence?

1.☐ Less than one year      2. ☐ (1-5) years    3. ☐ (6-9) years    4. ☐ (10-15) years

5.☐ (16-19) years        6. ☐ >20 and above years

Q.10. What factors were important in your decision to live in this area?
[Multiple responses]

1 ☐ Nearness to job/employment opportunities    2. ☐ Rural land scape /Suitability for farming
3 ☐ Quite /Serene Environment           4. ☐ Availability and access to public transport
5 ☐ Area safety and security            6. ☐ Good Residential Neighbourhood
7.☐Urban Amenities                   8. ☐ Others, specify……………………..........

Q.11. What major challenges have you faced since moving to this place?
[Multiple responses]

1   ☐ None                          2. ☐ Deteriorating housing conditions
3   ☐ Inadequate waste disposal/ Sewage system    4. ☐ In adequate water
5. ☐ Others, specify……………………..........

Q.12. Do you have land of your own in this urban centre? 1☐Yes        2. ☐No

Q.13. If yes, what was the means of acquisition?

1. ☐ Inherited      2. ☐ Bought        3. ☐ Rental/leasehold

4. ☐ Others, specify……………………..........

Q.14. How is being used?

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Q.15. Do you have any future plans of the land usage? 1☐Yes       2. ☐No

Q.16. If yes in Q15, specify......................................................................................................................
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Q.17. If your answer in Q15 No, give reason

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Q.18.What is your level of agreement the following statement in relation to land use?

| Land Use-Environment Challenge | Agree | Strongly Agree | Not Sure | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| Increased rate of land fragmentation/division | | | | | |
| There is high rate of Land grabbing | | | | | |
| There has been high rate of land Encroachment for agricultural purposes | | | | | |
| There is a lot of Habitat destruction | | | | | |

Q.19.Is land Degradation a problem in your area? 1□Yes                2. □No

Q.20.What are the main causes of land cover change?

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Q.21.What are the major problems associated with the above land cover change?

[Multiple responses]

1 □ Inadequate/lack of water                2. □ Surface Runoff

3 □ Poor Hygiene and Sanitation                4. □ Erosion

5 □ Water body enrichment/lowering of quality

6.□ Others, specify…………………........................................................................

THE END
THANK YOU VERY MUCH FOR YOUR CO-OPERATION!

**Appendix II: Questionnaire for Developers**

**Preamble**

This questionnaire is prepared to collect data about land use and land cover Changes and environmental implications. It is geared towards generating and providing useful information for policy makers and development practitioner's .Therefore, your inputs is highly appreciated and information provided will stay confidential and your right to involve or not is also respected

Q.1.    What is the Name of your Company?………………………………………………………

Q.2.    Site Location……………………………………………………………………………….

Q.3.    Position in the Company……………………………………………………………………

Q.4.    Which of the following Development Purpose applies to your company?

1.□ Real Estate             2. □ Light/Commercial          3. □ Hotel Industries

4.□ Transport and logistics

5. □ Others Specify………………………………………………………………

Q.5.    What key factors determined your choice of the above development

[Multiple responses]

1.□ Political       2. □ Economical          3. □ Government Policy/ Regulations

4 .□ Technological

5. □ Others Specify…………………………………………………………………

Q.6.    What attracted you most to this place?

[Multiple responses]

1.    □Physical suitability for development: slopes, soils, hydrology, land Availability

2.    □Transportation and Accessibility, including proximity to interstate highways

3.    □Existing land use patterns and location of other residential development

4.    □Availability of vital infrastructure (electricity, water and sewer systems)

5.    □Availability of labour

6.    □Market demand

7.    □Others, Specify……………………………………………….................................

Q.7.    Initially, when your company/organisation made the decision to develop the land, what were the organisation's expectations from it?

1 ☐ capitalize a market opportunity        2. ☐ Maximum business growth

3 ☐ Extend business                        4.  ☐ Increase income

5. ☐ Others, specify………………….........

Q.8.    Have you ever applied for land Use permit? 1. ☐    Yes    2. ☐    No

Q.9.    If yes in Q6, please specify

………………………………………………………………………………………………

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Q.10.   What development challenges have you faced so far?

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Q.11.   In your opinion, in what ways can the above challenges be addressed?

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………………………………………………………………………………………………

………………………………………………………………………………………….

The remainder of this Questionnaire is observation only. Please fill in this section while inspecting interviewing the respondents

Number of rooms
Size of the house/room
Wall-mud, block
Floor

**Appendix III: Questionnaire for Development and Control Authorities**
(Tick where appropriate)

**Preamble**
This questionnaire is prepared to collect data about land use and land cover Changes and environmental implications. It is geared towards generating and providing useful information for policy makers and development practitioner's .Therefore, your inputs is highly appreciated and information provided will stay confidential and you're right to involve or not is also respected

Q.1.    Name of Local Authority
   1.☐ Nairobi County Council    2. ☐ Kiambu        3. ☐ Kajiado   4. ☐ Ngong'
   5.☐ Ruiru            6. ☐ Mavoko        7. ☐ Kikuyu

Q.2.    Your position……………………………………………………………………………

Q.3.    Department …………………………………………………………………………...

Q.4.    What are the major responsibilities of Development and Control Authority?
   ………………………………………………………………………………………………
   ………………………………………………………………………………………………
   ………………………………………………………………………………......................
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Q.5.    Is the local authority having an approved development planning Policy? 1. ☐Yes   2.☐No

Q.6.    If no, how is development control undertaken within the local authority?
   ………………………………………………………………………………………………
   ………………………………………………………………………………......................
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Q.7.    Give the current structure of development control?

| Human Resources | | Machinery/Equipment | |
|---|---|---|---|
| Levels of Skills | No. | Type | No. |
| Planners | | 1 | |
| Development control Officers | | 2 | |
| Administration officers | | 3 | |
| Others | | | |

Q.8.   Which the following is the most important factor considered during the zoning process and development policy revision?
1.☐ The density of the population   2. ☐ The fitness of the land for the permitted use
3 ☐ The site and physical attributes of the land involved traffic and transportation
4 ☐Others, Specify………………………………………………………………………

Q.9.   How would you rate effectiveness of the current zoning process/development policy?
1.☐ Satisfactory     2.☐ Not Satisfactory
Q.10.  Explain your answer
…………………………………………………………………………………………………
…………………………………………………………………………………...............................
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Q.11.   What is your level of agree on the following statement?

| Statement | Agree | Neutral | Disagree |
|---|---|---|---|
| The legal framework that empowers local authorities to exercise control over development seems to frustrate the same powers by imposing heavy controls | | | |
| Central government control over Land within urban local authority constrains planning and development | | | |
| High licensing fees forms the major  constraints and shortcomings characteristic to development | | | |
| The lack of good registration and tenure records is a serious constraint on efficient control and planning | | | |
| Too much central control over urban Local Authority's administrative is to be blamed for unplanned settlement | | | |

Q.12.   In your opinion, what has been the general pattern of development in the local authority?
…………………………………………………………………………………………………
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Q.13.   What factors are responsible for the above?
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Q.14.   What are the implications of the above development?
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<div align="center">

THE END
THANK YOU VERY MUCH FOR YOUR CO-OPERATION!

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