UNIVERSITY OF NAIROBI

SCHOOL OF ENGINEERING

MAPPING URBAN SPRAWL AND ITS IMPACTS - A CASE STUDY OF RUIRU SUB-COUNTY, KIAMBU COUNTY.

BY:-

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F56/68360/2013.

A Project Submitted in Partial Fulfilment for the Degree of Master of Science in Geographic Information Systems in the Department of Geospatial and Space Technology of the University of Nairobi.

JUNE, 2015.

Declaration

I, (Mbuta K. Shadrack), hereby declare that this research project is my original work. To the best of my knowledge, the work presented here has not been presented in any other university.

Signature: …… …….……..….

MBUTA K. SHADRACK Date

This research project has been submitted for review with our approval as university supervisor(s).

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DR. F.N KARANJA Date

Signature: …… ……..……

MR. SAMUEL NTHUNI Date

Acknowledgement

I am deeply grateful for the experience that has been the Department of Geospatial and Space Technology. It has been a great opportunity especially because of all the wonderful people I have met and interacted with: my fellow classmates, my lecturers, the university staff and friends. You have all in one way or the other enriched my knowledge at this master's level.

I would like to express my sincere gratitude to Dr. F. N. Karanja; my thesis supervisor as well as Mr. Samuel Nthuni. Thank you for the invaluable guidance and for the patience you have shown to read through the messy drafts I sent you.

My special thanks to staff at Ruiru Sub County who made time to avail information and advice for my research work.

Finally to my beloved ones, Carol and Gift, my thesis is dedicated to you. You are my inspiration and my rock. To all my other family members, I am thankful of your support, your prayers, encouragement and your love.

To my fellow Masters students, it has been an incredible journey these past few years. I will never forget you guys.

Dedication

I wish to dedicate this thesis to my family; to my beloved wife Caroline Mukii and my dear son Gift Muuo. Thank you for your love, care and prayers that have seen me accomplish my studies in peace. May the Almighty God bless you abundantly and keep you. To my son Gift, I dedicate this work to you in hope for your bright future and excellence in the academic world. May you fly even higher and fulfil more in your generation.

Abstract

Rapid urbanization is a trend seen across the developing world, with the fastest rates of growth seen in Sub-Saharan Africa. Much of this is due to rural urban migration of people in search of higher education, jobs and or higher standards of living. This is the case of Ruiru town and its surrounding. The trends of urban sprawl appear to be haphazard in Ruiru town with the increase population and better road network. A lot has happened within the last ten years and the impact is hugely felt on land and natural resources. With the population of Ruiru town expected to grow even further, there is need to assess the extent of urban sprawl. The underlying problem in this research was based on the fact that a lot of land in Ruiru town has seen major changes in use and a lot of urbanization activities are witnessed especially along the major roads without development control measures.

The main objective of this research was to examine how the application of GIS technology and remote sensing can be used in spatial urban sprawl mapping. Other objectives of the study included; to determine the spatial extent of urban sprawl in Ruiru between 2003 and 2009, 2009 and 2013 and a combined overlay analysis of the ten year impact, to examine the causes and impacts/effects of urban sprawl in Ruiru Sub County with key interest on environment, natural resources and economic indicators and to predict the patterns of future extent of urban sprawl in Ruiru Sub County and give the possible direction of any sprawl chances.

To achieve these objectives, a joint approach of non-spatial and spatial techniques was used in the methodology of the study. The pattern of urban sprawl was identified and modelled using remotely sensed data. The analysis in this study included land cover and land use, spatial and temporal changes and urbanization growth pattern recognition as well as non-spatial analysis such as environment and economic indicators. The remote sensing data was then classified for land use, based on themes - built up areas, water bodies, agricultural land and vacant/other land. Change detection was then carried out to determine the spatial extent of the urban sprawl if any. The results showed significant occurrences of urban sprawl specifically 16% urban growth for the period of ten years. Land has been converted to urban use in an increasing rate with future urban growth pointing towards Gatongora Ward where land is available for development.

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Acronyms

GIS: Geographical Information System

KES: Kenya Shillings.

IEBC: Independent Electoral and Boundaries Commission.

KNBS: Kenya National Bureau of Statistics

RLPDP: Ruiru Local Physical Development Plan

CBD: Commercial Business District

UN: United Nations

ICLEI: International Council for Local Environmental Initiatives

UNEP: United Nations Environmental Programme

CHAPTER 1: INTRODUCTION

1.1 Background to the Study

Urbanization and the growth of cities are a symbol of man's progress and what he is able to achieve. Population increases in Kenya's urban centres and the consequences of unplanned urbanization are directly related to growth management practices that seek to influence the way in which built-up land can proliferate. The pattern, density, and rate at which built-up land develops are the basis for one contemporary debate: urban sprawl versus urban growth. As a contemporary planning issue, the debate over sprawl is framed by different disciplines and their understanding of how and why urban areas grow. Although urban sprawl is a type of urban growth, sprawl is dependent on the way in which development occurs (Almeida, 2005). Cities and towns are not only centres of power, but are also indicators of history, culture, and industry. As Ling (2005) points out cities are engines of rapid economic growth.

However the process of urbanization and expansion of cities has certain implications on the environment and socio-economic aspects of life. Urban sprawl has been one of the burgeoning issues of study in the present development situation where increasing population and migration for better livelihood opportunities have paved way for rapid expansion of the urban centres.
According to figures from international organizations like UNEP (United Nations Environmental Programme) and ICLEI (International Council for Local Environmental Initiatives), Africa has the fastest rates of urbanization worldwide and it is projected that unprecedented urban growth will take place in the developing countries in the coming years (UNEP, 2007).

Whereas the rate of urbanization has been rapid and tremendous, it is crucial to note that the growth of urban areas is not uniform worldwide. According to the United Nations figures: in the Americas, Europe and Oceania about 70% of the population live in urban areas whereas in Asia and Africa it is estimated to be about 39% and 37% respectively (Tryzna, 2007). In actual fact most of the developed countries are already urbanized while the developing countries are in the process of becoming urbanized. The unprecedented population growth coupled with unplanned developmental activities has resulted in rapid but skewed urbanization. As population increases, so does the need for new housing, schools, and transportation networks. In the urban world today, industrial, commercial, and residential districts are markedly different from years past.

Decentralization is a trend indicative of urban sprawl and present day industrial, commercial, and residential areas are no longer necessarily a part of the urban core (Nechyba et al 2004). Rather, these types of development are often found in low-density areas that are separated from the major urban area by large tracts of homogeneous land. Hence, the need for larger transportation networks and in turns a greater dependency on automobiles, which produce more air pollution. As new roads are put in place, precious farmland is often left unprotected from commercial or residential developers (Hathout 2002). The greater the imperviousness of an area the more water runoff one can expect, which is the catapult for water pollution (Wilson et al 2003). Without regulations on urban growth, consequences of urban sprawl are likely to continue. The problems created by the haphazard and unrestricted growth of city aggravates irregular and chaotic development of residential, industrial and commercial areas resulting in traffic bottle necks, slums, polluted environment and others all known and felt by the residents of a city.

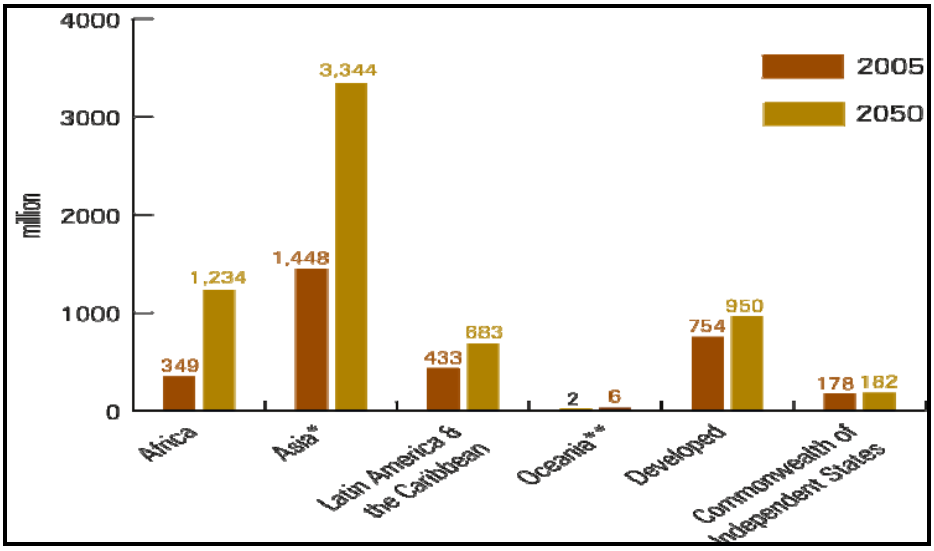

Figure 1.1: Urban Population 2005 and 2050 Source: UN-Habitat, 2007

In Kenya, the unprecedented population growth coupled with unplanned developmental activities has resulted in urbanization, which lack basic infrastructure facilities and utilities. This also has posed serious implications on the resource base of the country. The hitherto rich agricultural lands and forests have been converted into concrete jungles.

In most urban centres in Kenya, urbanization takes place either in radial direction around a well-established town or linearly along the highways. This dispersed development along highways, or

surrounding the city and in rural countryside is often referred as sprawl. Some of the causes of the sprawl include - population growth, economic growth and proximity to resources and basic amenities. Patterns of infrastructure initiatives like the construction of roads and service facilities (such as shopping malls, markets, hotels/shops, etc.) also often encourage the regional development, which eventually lead to urbanization. Identification and analyses of the patterns of sprawl in advance would help in effective infrastructure planning in urban areas. In order to estimate and understand the behaviour of such urban sprawls, which is crucial for sound environmental planning and resource management, the current study was undertaken in Ruiru Sub County, within the larger Kiambu County. Ruiru is located within 3 kilometres of Nairobi's city boundary. Ruiru, like many other towns around Nairobi is a dormitory town for the nation's capital, and is connected by both rail and road. The Ruiru town covers an area of 292 km2 and was originally surrounded by numerous coffee plantations a majority of which have so far been cleared to pave way for more urban land uses such as commercial cum residential use.

Urban sprawl is responsible for eliminating agricultural lands, spoiling water quality, and causing air pollution (Allen et al 2003). The timely understanding of the causes and problems of urban sprawl and ways of solving such problems would help ensure sound environmental planning and proper resource management.

Mapping Urban Sprawl

Without the advent of technological advancement which saw the introduction of Geographic Information Systems, mapping any phenomenon took an extremely long time. Maps produced through manual cartography for comparison were to be planned well in advance of a due date. Computer aided maps without GIS were very rudimentary and were not very aesthetically pleasing to say the least. The availability of different types of spatial data allows a GIS user to map virtually any phenomena with a geographic dimension applied to it. In addition, large amounts of data are processed before the creation of a map with much less work than with manual cartographic techniques. With GIS, maps can be compared in a fraction of the time and can be done at variable scales with ease.

The use of Geographic Information Systems modeling has become quite prevalent within the field of urban sprawl research. Some research on urban sprawl uses GIS as a tool in understanding the effects of urban sprawl on the natural environment. GIS reveals spatial

patterns of urban sprawl by measuring distances of new urban growth areas from town centres and roads for example (Gar-On Yeh et al 2001). Because urban development is irreversible, GIS simulates future land development (Lee et al 1998). A Geographic Information System is a decision support system that can facilitate urban planning.

Because there is a lack of a universal definition of urban sprawl, a map of urban or built-up land is an adequate starting point in studying urbanization. A map provides the visual aspect from which studies on urban sprawl can begin in relation to urban growth. A Geographic Information System is useful for mapping the spatial distribution of urban areas. Unlike traditional cartographic methods, GIS allows for the manipulation of different types of data in one map frame. Mapping urban phenomena is a crucial part of quantifying urban sprawl. While many layers of data are used to create a map of urban growth, ultimately it is the map that tells the story about the level of urban sprawl over a given landscape. This type of mapping involves a temporal signature in which two or more time periods are used for comparing amounts of urbanization. One base map shows urban or built-up land in a starting year and another map shows the developed land from the end year. Therefore, mapping the extent of urbanization over a given period of time is an essential part of understanding urban sprawl.

1.2 Problem Statement

Urban sprawl presents a big threat to areas adjacent to city boundaries; if unaddressed, the consequences are not only environmental, but also social, economic, emotional and aesthetic. Below is a table that shows the consequences of sprawl on the economic, natural and aesthetic aspects of an area/region. According to UN- Habitat report 2009, it is projected that 60% of the world population will be living in the urban areas. This indicates the challenges the increasing urbanization trends have on various sectors of the economy in any given country. In Kenya, the trend is not far different, given the increasing trend of urban development which is now fuelled by the devolved system of governance. Kiambu County leads with 60% of its population already living in urban areas. According to census report by open data source 2015, Kiambu County has a total population of 1,673,785 and out of this, 1,017,376 are living in urban areas (Kenya open data, 2015).

Ruiru town is at the heart of Kiambu town connecting the entire county with all major roads almost passing through this town and to some extend the sub county. A lot of developments have occurred in the recent past that has fuelled investment in the town. No doubt, this advancement

comes with a lot of challenges and cost. With these trends, it is important to establish a reliable study and documentation to help in controlling and monitoring urbanization and sprawl effects in Ruiru Sub County in order to concentrate resources to sustainable activities. As noted in various studies, urban sprawl has associated cost and externalities that are harmful to natural resources and human life, making this study an urgent undertaking to establish connection between urban sprawl and development.

Table 0:1 Cost of Sprawling on Various Aspects of life

Aspect	Consequences of Sprawl
Economic	Increased cost of infrastructure
	Loss of farm and forest
	Urban decay
	Greater fiscal disparities among localities
	Adverse impact on environmental resources
	Higher tax burden
	Higher land prices
Physical	Congested roads and heavy traffic
	Overcrowded market and lanes
Social	Decreased social interaction
	Limited meaningful consumer choice
Emotional	Loss of community spirit
	Loss of sense of ownership and land
Aesthetic	Decreased leisure time
	Monotonous landscape

Source: Jain, 2008

Whereas urban sprawl is a global problem, most current studies have focussed on developed countries, especially North America and Europe. This has created a gap in the study of urbanization and urban sprawl in developing countries. Accordingly, this study focused on studying the problem in the context of a developing country: a case study of Ruiru Sub County in Kiambu County, to study the impacts of urban sprawl. Nairobi's physical expansion has come at the expense of the natural environment. Urban sprawl and the construction of roads and other

city infrastructure has led to the loss of forests and other natural areas, such as mixed rangeland and bush lands (Tibaijuka 2007).

Figure 0:1 The Reality of Urban Sprawl Source: Hetma & Dete, 2011

As population increases, so does the need for new housing, schools, and transportation networks. There is a distinct difference between the urban world today; industrial, commercial, and residential districts from years past. Decentralized administrative units is a trend indicative of urban sprawl and the present day industrial, commercial, and residential areas are no longer necessarily a part of the urban core (Nechyba et al 2004). Rather, these types of developments are often found in low-density areas that are separated from the major urban area by large tracts of homogeneous land. Hence, the needs for larger transportation networks and in turn a greater dependency on automobiles, which produce more air pollution. As new roads are put in place, precious farmland is often left unprotected from commercial or residential developers (Hathout 2002). The greater the imperviousness of an area the more water runoff one can expect, which is the catapult for water pollution (Wilson et al 2003). Without regulations on urban growth, consequences of urban sprawl are likely to continue.

1.3 Objectives

Main objective

1. To demonstrate how GIS and remote sensing can be used to effectively study and monitor urban sprawl

Specific objectives

1. To determine the spatial extent of urban sprawl in Ruiru between 2003 - 2013.
2. To examine the causes and impacts/effects of urban sprawl in Ruiru Sub County
3. Predict the patterns of future extent of urban sprawl in Ruiru Sub County.

1.4 Scope of work

This study addresses itself to the use of GIS to study and monitor urban sprawl and its impacts on areas adjoining the edge of a city. A case study of Ruiru sub county; one of Kenya's fastest growing regions is undertaken to give a realistic and practical picture of the problem. The skyline of Ruiru, once a small centre seems to be changing more. The rapid growth of this area has seen reduction in once rich agricultural lands and food baskets of Nairobi City. The study solely focused on Ruiru Sub County and restricted itself to the administrative boundaries of the same.

The purpose of this study is to use spatial and non-spatial approaches in measuring urban sprawl in the Ruiru sub county, between three different time periods: 2003, 2009 and 2013. The time epochs selected (2003 – 2013) because of the availability of data. A spatial modeling approach is one that employs GIS analysis techniques such as buffering and reclassification of data. Buffering refers to creating a zone wherein urbanization may occur along highways. Reclassification of Data entails aggregating or eliminating the different classes of land cover/land use into only those classes that represent urban or built-land as detailed elsewhere.

A non-spatial modeling approach involves analysis of land use regulations, master plans, local land use policies and practices, and interviews with developers, land owners, and local planners. Four administrative wards make up the study area: Gitothua ward, Biashara ward, Gatongora ward and Kahawa Sukari ward. These four jurisdictions constitute a contiguous "border" around Ruiru town and manifest a broad range of land uses and land cover as well as differences in land use policies and practices.

1.5 Justification for the Study

Predicting urban land use change is important if city planners are to provide, even at a minimum standard, necessary infrastructure and services to their residents. Forecasting where and how urban change will manifest itself, however, is a challenge for any city and its planners. Thus, it is envisaged that if the growth process of urban and informal settlements is better understood it can be modelled and applied in real situations for the prediction of growth under likely future scenarios. Spatially explicit modelling can be used to conduct experiments that test our understanding of key processes and for describing them in quantitative terms. As a simplification of reality, a model can allow the user to structure data collected from real world in a manner that is easily interpreted and understood by the scientific world as well as the general public. The result of the study helped identify the spatial growth pattern of Ruiru settlement in order to make adequate future planning for proper provision of social and infrastructural facilities in the area. In addition, this study is relevant to the county government of Kiambu and to be specific the sub county of Ruiru in planning and controlling development. The results of this study therefore would provide relevant background for urban planners, developers and administrators in the event of future development and policy formulation to ensure sustainability within Ruiru.

Cities around the world symbolize man's progress in terms of growth and development. They symbolize power, history, culture, and industry, as (Ling 2005) points out cities are engines of rapid economic growth. Sudhira et al. (2004) state that understanding the patterns of urban sprawl can help with natural resource planning, natural resource utilization, and the provision of infrastructure facilities. Urban sprawl creates inefficient use of land, land resources, and large-scale encroachment on agricultural land (Gar-On Yeh et al 2001). By and large, urban populations exert tremendous and ever increasing pressure on the surrounding environment (Ling, 2005).

The most pressing problem is the substantial loss of fertile agricultural land in many parts surrounding our main cities/urban areas. This is a serious threat to our economy bearing in mind that Kenya is predominantly an agro-economy. Ewing (1997) argues that suburbanization as we know it is not the issue, but rather the wasteful form of development known as sprawl with which many critics have a problem. Nechyba et al (2004, 186) list a plethora of ills related to sprawl: the loss of open space, urban decay, unsightly strip mall developments, the loss of a sense of community, patchwork housing developments in the midst of agricultural land,

increasing reliance on the automobile, the separation of residential and work locations, and the spreading of urbanized developments across the landscape.

Haphazard and unplanned expansion of our urban areas has resulted to urban sprawl whose consequences has been loss of open space, increased cost of infrastructure, loss of farm and forest lands, fragmentation of farms and crop land area, urban decay and increase in energy consumption, habitat fragmentation and biodiversity loss. Timely understanding of the causes and problems of urban sprawl and ways of solving such problems would help ensure sound environmental planning and proper resource management. This will present city planners and mangers with tools necessary to plan for and avail necessary services to areas hence supporting health expansion of our urban areas. “Indeed; Sprawl has become the metaphor of choice for the shortcomings of the suburbs and the frustrations of central cities (Galster et al., 2001, 681)."

1.6 Organization of the Report

This research thesis addresses the problem of urban sprawl with an interdisciplinary perspective. In the first chapter, a background of the whole concept is introduced with clear objectives and validation of the study in terms of its significance. In the second chapter, a theoretical framework is presented. This incorporates discussion of the urban setting of Ruiru town and its surroundings and provides an overview of the urban structure, discussing various causes of urban sprawl and how they are related. In addition, this chapter focuses on the global trend of urban sprawl, urbanizations and several models that explain how urban sprawl emerges. In the third chapter, methodology used in the study is discussed in details with focus on the study area information, the research design, maps and imagery validation and interpretation of data collected. It gives details on how supervised classification can be used in analysing land use /land cover change in thematic study of built-up areas, agricultural land and undeveloped land parcels. In the fourth chapter, a discussion and presentation of the findings is discussed in line with the objectives of the study. The fifth chapter outlines conclusions and recommendations based on the study findings and how several stakeholders would implement the stated recommendations.

CHAPTER 2: LITERATURE REVIEW

2.0 Urban sprawl

Although accurate definition of urban sprawl is debatable, a general consensus is that urban sprawl is characterized by unplanned and uneven pattern of growth, driven by multitude of processes and leading to inefficient resource utilization. The direct implication of such sprawl is change in land-use and land-cover of the region as sprawl induces the increase in built-up and paved area (Sudhira and Ramachandra 2007). It is worth mentioning that opinions on sprawl held by researchers, policy makers, activists, and the public differ sharply, and the lack of agreement over how to define sprawl certainly complicates the efforts to characterize and restrict this type of land development.

Urban sprawl is initially detected by gauging urban growth in many ways. One way is by using remote sensing and GIS to measure rates of urbanization (Masek et al 2000). Other studies have measured sprawl in terms of data layers within a GIS to detect patterns of urban sprawl (Clarke et al 1998). Wilson et al. (2003) not only measure change of an individual pixel, but also changes within a framework of a neighbourhood of pixels. This technique is known as neighbourhood statistics and is extremely useful in visualizing densities of new growth areas.

In modeling the complex nature of urbanization, it is often necessary to apply more than one technique to understand how to measure an increase in urban growth or urban sprawl. While quantification of urban growth often involves a direct measurement of new built-up or urban land, it is also important to include qualitative information. A study done in the Chicago metropolitan region by Zhang (2001) found that social-economic factors were most important in attracting residents to a new development, potentially leading to urban sprawl.

Clearly, there have been many ways to measure urban dynamics indicating that there are numerous avenues to reach a similar destination. Population growth can be a driving force behind urban sprawl. A study done by Sprawl City, a non-profit organization that researches urbanization issues shows that there is a correlation between the amount of population growth and the consumption of land in what the United States Bureau of the Census calls urbanized areas (Sprawl City, 2005). Urbanized areas are comprised of the contiguous developed land of the central city and its suburbs (Sprawl City, 2005). In order to understand urban sprawl it is

important to contemplate many different urban growth dynamics including population growth, land conversion practices, and market forces.

Urban sprawl is characterized by haphazard land use patterns; leapfrog land use patterns, strip commercial development along highways, and high-density mixed use developments, all of which occur over a relatively short period of time (Ewing 1997). It has also been defined in terms of associated causes: urban sprawl is generally believed to result from poorly planned, large-scale new residential, commercial and industrial developments in areas not previously used for urban purposes (Zhang 2001). However, there is one overriding theme in the recognition of urban sprawl: a spatial-temporal signature unique to the phenomenon.

The result of this development process is commonly called 'urban sprawl.' In this form, urbanization spreads outward in a haphazard pattern, consuming more land than is necessary and creating excessive public costs for community facilities and services (Lee et al., 1998, 865). Sprawl is urbanization that takes place in either a radial direction around a well-established city or linearly along the highways over a given period of time (Sudhira et al 2004). Clearly, radial and linear are just two types of map patterns that sprawl can take. Sudhira et al. (2004) state that to understand the complexity of urban sprawl, land use change analyses and urban growth pattern recognition must be determined.

2.1 Urban Sprawl Trends

2.1.1 Global Trends in Urban Sprawl

As population increases, urban sprawl on a global scale is becoming more apparent than ever. Increases in population often lead to increases in development, which has a direct influence on agricultural land conversion. Moeser (2000) states that urban growth is inevitable over the next two decades and that most of this growth will take place in less developed countries. In China, rapid land use change has occurred since economic reform (Gar-On Yeh et al 1998). A study done there measures urban sprawl in terms of land suitability and the favourability that land has for being converted to an urban use (Gar-On Yeh et al 1998). The authors were interested in developing a model that could be used for sustainability purposes in an attempt to control urban sprawl under rapid rural urbanization (Gar-On Yeh et al 1998).

"This is most severe in southern China and the coastal areas where the economy is developing very rapidly and the conflict between the environment and economic development is most severe (Gar-On Yeh et al., 1998, p. 169-170)."

In other developing countries like India, where the population is over one billion, one-sixth of the world's population, urban sprawl is taking its toll on natural resources (Sudhira et al 2004). The study area of Mangalore, India is a national leader in banking, private entrepreneurship, insurance and other financial institutions (Sudhira et al 2004). Mangalore, India has also seen an increase in the amount of industrialization in the form of Iron Ore Palletisation Units, Fertilizer, Refinery, and Petro-chemicals with the economy also fortified by agricultural processing and port related activities (Sudhira et al 2004). Over 25% of India's population lives in urban centres and it is projected that about 33% of the population will be living in urban centres in the next 15 years (Sudhira et al 2004). "This indicates the alarming rate of urbanization and the extent of sprawl that could take place. In order to understand this increasing rate of urban sprawl, an attempt is made to understand the sprawl dynamics and evolve appropriate management strategies that could aid in the region's sustainable development (Sudhira et al., 2004, 29)."
The approach to the Sudhira (2004) study is to use change at the landscape level within a Geographic Information System to calculate the fragmentation and patch density of new growth areas and classify those areas as sprawl. While many models seek to achieve this goal, they do not relate urban sprawl to anything more than urban growth.
"The inadequacy in some of these is that the models fail to interact with the causal factors driving the sprawl such as population growth, availability of land and proximity to city centres and highways (Sudhira et al., 2004, 30)."

Sudhira et al (2004) use GIS, remote sensing, and landscape metric techniques to quantify urban sprawl by measuring densities and spatial distributions of built-up land. Using landscape metrics that show densities of urban land and connectivity of that land, the authors are able to justifiably classify different types of urban sprawl: cluster, leapfrog, and linear (Sudhira et al 2004). More dense and compact areas of built-up land are classified as cluster, while medium density areas with low connectivity areas are indicative of leapfrog patterns. The linear pattern of sprawl is classified as high and medium density built-up areas of development located along the highways (Sudhira et al 2004). This technique for quantifying urban sprawl is extremely adequate based on

the assumption that it is the pattern and spatial distribution of urbanization that is the key component to urban sprawl.

2.1.2 National Trends in Urban Sprawl

Urban sprawl is an issue that many cities across the developing world are facing as urban areas continue to grow. A case in point is Kenya where several satellite towns around Nairobi have come up. These are towns like Athi River, Ongata Rongai, Kitengela, Juja, Ruai etc. which are acting as dormitory towns for Nairobi City County.

Summing up, the various definitions of sprawl indicate that the term is most often used as a noun (Galster et al 2001). Sprawl describes conditions and patterns of development characteristic of an urban area or part of that urban area over a period of time (Galster et al 2001). The given definitions suggest that there can be different levels and types of sprawl and that sprawl can be viewed as a process because of the inclusion of time (Galster et al 2001). The advantage that GIS offers to sprawl research is the capability to visually assess and quantify defined sprawl patterns. The research discussed thus far used techniques such as landscape metrics and neighbourhood statistics, both of which are extremely affective in measuring the density and connectivity of new patches of urban growth over a given time period. I have shown that while these approaches are extremely adequate in understanding sprawl, they are often more complex than they need to be. In the methodology it will be shown how the use of neighbourhood statistics within the GIS can be an extremely effective way to visually assess and quantify sprawl.

The patterns of urban sprawl in Kenya are not far different from those of other major cities across the world. Many towns are experiencing this phenomenon due to market failure. For instances, Kitengela town has seen many people working in the town preferring this peri urban town. This is because of enhanced transportation system with the construction of Athi River – Namanga international highway. Furthermore, the increased demand for better housing and space has moved many families to acquire own houses in this area which initially was rural agricultural land. The result has been scattered development in the town sprinkling from the town centre to the nearby towns such as Isinya. The same phenomenon s witnessed in Ruiru town and some parts of Kiambu County where many people are capitalising on the recent infrastructure development. The construction of the northern and eastern by passes and the Thika superhighway has fuelled many commuters to acquire residence in outcast of Nairobi even as far

as 40Km away. On the other hand, urban sprawl in other towns is propagated by demand for land and holding land for speculation. This is common in towns with anticipation for future cities and shopping malls. While many developers will own a land and develop it within the short run, many however will hold the land for long time until speculated developments are initiated. Due to institutional failures and lack of strong policy, there are no strong legal frameworks to compel development thus development in such lands will occur in uncontrolled and unpleasant manner (Skilla, 2013).

2.2 Factors Contributing to Urban Sprawl

The spatial configuration and the dynamics of urban growth are important topics of analysis in the contemporary urban studies. Several studies have addressed these issues which have dealt with diverse range of themes (e.g., Acioly and Davidson 1996; Wang et al. 2003; Páez and Scott 2004; Zhu et al. 2006; Hedblom and Soderstrom 2008; Geymen and Baz 2008). Urban sprawl, as a concept, suffers from difficulties in definition (Johnson 2001; Barnes et al. 2001; Wilson et al. 2003; Roca et al. 2004; Sudhira and Ramachandra 2007; Angel et al. 2007; Bhatta 2010). Galster et al. (2001) critiqued the conceptual ambiguity of sprawl observing that much of the existing literature is 'lost in a semantic wilderness.' Their review of the literature found that sprawl can alternatively or simultaneously refer to: (1) certain patterns of land use, (2) processes of land development, (3) causes of particular land-use behaviours, and (4) consequences of land-use behaviours.

A widely accepted concept of urban sprawl has to do with its negative and unpleasant results it has on the land surface. As implied by its name, urban sprawl is an inherent spatial occurrence that is characterised by low density, disperse and auto dependent affecting environment and social setting. The association of urban sprawl and urban growth is correlated in that as towns develop, urban sprawl is fuelled up by such growth forces. Hasse and Lathrop (2003) highlighted that 12 million hectares in USA was converted to developed land with a third of this coming from agricultural and forest. In their study they concluded that, the increased urban development has underlying forces that attracts urban sprawl in an event of weak policy and enforcement of development regulations (Hasse & Lathrop, 2003).

However, in another study, Brueckner pointed out that the critique of urban sprawl may not apply in every setting. He drew the differences between the demerits of urban sprawl and its

merit in a free market. Although many studies have victimised the whole concept of urban sprawl, it is important also to note the opposite is true in a free market setting. The market forces determine the value and worthiness of the land. This doesn't warrant dominance of the primary agricultural over and secondary mechanised development (Brueckner, 2000) allocation of land is determined by demand for that land for specific use. Mieszkowski and Mills in 1993 summarised the key forces of land demand in the current generation in any country as population pressure, transportation improvement and increased household income. He concluded that as these forces continue to influence how people utilised their land, the phenomenon of urban sprawl is inevitable especially in urban and peri urban areas. Increased population has resulted to increased demand for houses and given the increased household income, many families have disposable amount of money to command the space they want and area. Proper transportation networks mean easy accessibility, mobility and connectivity of places. Many people in urban areas find themselves moving from the CBD to far outcasts of the towns. Urban sprawl results in these scenarios due to the desire of convenience and satisfaction (Brueckner, 2000).

Economists have a different approach in criticizing urban sprawl and growth. Economists have used the term market failure to bring out the concept of urban sprawl. Market failure refers to incidences where the authorities fail to allocate resources in the desired approach in order to achieve maximum economic aggregate. Market failure is associated with unbalanced economic incentives due to institutional dysfunction that results to harmful economic effects to society in terms of sustainability. This does not happen only in space planning but also in all natural resources allocation and utilization. Economists have identified three market failures in the process of urban growth that results to urban sprawl. The first failure emerges from a failure to plan for the social value of open space when land is converted to urban use. The second arises from a failure on the part of individual commuters to understand the social costs of congestion created by their use of the road network, which leads to excessive commuting and cities that are too large. The third market failure develops from the failure of real estate investors to plan for all of the public infrastructure costs generated by their project (Brueckner, 2000).

Much of the quantitative research on urban sprawl begins with measurements of urban growth over a given time period. Gar-OnYeh et al. (2001) measure the urban form of an area to examine a change in shape, size, and configuration of the built-up environment. They use measure dispersion of a geographic variable, coupled with a GIS and remote sensing technology which

measures the degree of spatial concentration to calculate sprawl. This type of research keys in on aspects of sprawl such as density, connectivity, and location of new urbanization. There is also the variable of time that must be incorporated into these studies to account for rates of growth, which is a key component of sprawl. Other aspects of interest are social processes and transportation conditions. Thus in an holistic approach to address the emerging issues associated with urban sprawl, all urban stakeholders need to be brought on board and formulation of solution based on sustainable approaches.

2.3 Role of GIS and Remote Sensing in Mapping Urban Sprawl

The complexity of urban systems makes it difficult to adequately address their changes using a model based on a single approach (Allen et al., 2003, 1). Therefore, it is ideal to use tools such as GIS and remote sensing as part of research on urban sprawl because of their capacity to handle many different types of spatial data. In South Carolina, a GIS-based integrated approach to modeling and prediction of urban growth in terms of land use change was employed to meet the challenge of studying urban sprawl (Allen et al 2003). The researchers used satellite imagery incorporated into a GIS to map predictions of urban growth in the study area. The predictions were based on variables such as road density, forest, slope of the land, and population density. Each variable was entered into the system as a data layer and multiplied by a coefficient to determine how likely it was that a given parcel of land would be converted to urban land use (Allen et al 2003).

In East and West St. Paul, Winnipeg, Manitoba, Canada, most urban sprawl was occurring on prime agricultural land (Hathout 2002). In that study, a GIS was used to predict future growth patterns and the impacts that such growth would have on agricultural land (Hathout 2002). Hathout (2002) used the data base analysis capabilities found in a GIS to analyse aerial photographs of the study area from 1960 and 1989 to determine impacts on agricultural land. For that study, land use derived from the aerial photographs in the GIS was placed in one of three main categories: urban, agricultural, and other (Hathout 2002). GIS will not only allow for powerful visualization of urban sprawl within the study area by providing maps, but it will also allow for an in depth analysis of the data by providing the capability to examine all of the data in one system therefore facilitating the measurement of urban sprawl. We can use the GIS to produce maps of different growth scenarios, which allow visualization of the results.

GIS is also an extremely powerful tool for creating new data from existing data and is often referred to as a decision support system (Burrough et al 1998). In China, GIS was used as a decision support system to test different development scenarios and land consumption parameters for use by planners and local government officials (Gar-On Yeh et al 1998). Using the neighbourhood function in the GIS, Gar-On Yeh et al. (1998) were able to test development scenarios that would reduce the fragmentation of new growth, a component of urban sprawl (Gar-On Yeh et al 1998). In another study by the same authors, it was concluded that Landsat TM images coupled with an entropy integrated GIS was successful in measuring and monitoring urban sprawl patterns when the area is large and land use changes quickly (Gar-On Yeh et al 2001).

The methods used to quantify urban sprawl throughout the literature are dependent on the intended purpose and the individual aim of each piece of research. The objective of the research conducted on the Washington-Baltimore CMSA was to relate observed changes in land cover to economic and demographic drivers of that change (Masek et al., 2000, 3474). They used historic and present-day satellite imagery to measure land use change, but it was unclear how the researchers were going to link those changes to economic and demographic data. The purpose of the study was to quantify and map urban growth thereby determining the geographic extent, pattern, and class of such growth over time. As Wilson et al. (2003, 275) show, urban sprawl has been cited for its negative impacts on the environment, but with no clear definition of urban sprawl, it is difficult to measure.

2.4 Physical Patterns and Forms of Urban Growth and Sprawl

Wilson et al. (2003) identified three categories of urban growth: infill, expansion, and outlying; with outlying urban growth further separated into isolated, linear branch, and clustered branch growth. The relation (or distance) to existing developed areas is important when determining what kind of urban growth has occurred. Indeed all types of urban growth are not considered as sprawl; one development that can be considered as sprawl by someone may not be considered by others (Roca et al. 2004). Furthermore, urban sprawl has a negative connotation, and not all urban growth is necessarily unhealthy. In fact, some types of urban growth (e.g., infill growth) are generally considered as remedies to sprawl. Therefore, sprawl cannot be characterized by the simple quantification of 'the amount of land that has changed to urban uses.' Sprawl phenomenon should be treated separately than the general urban growth. Ewing (1994) reviewed

several patterns of urban sprawl, and argued that the pattern of sprawl is ‘like obscenity’, the experts may know sprawl when they see it.

2.5 Estimating Urban Sprawl

Urban sprawl is often difficult to gauge because it can occur slowly over time. Wilson et al (2003) argues that without a universal definition of sprawl it is extremely difficult to model. Not all urban growth is considered sprawl because what is sprawl to some may not be to others. "Creating an urban growth model instead of an urban sprawl model allows us to quantify the amount of land that has changed to urban uses, and lets the user decide what he or she considers to be urban sprawl" (Wilson et al., 2003, 276). Many studies indicate that it is the pattern, density, and rate of new urban growth that creates the appearance of sprawl. Population dynamics are often cited as a driving force behind urban sprawl. This thesis uses Geographic Information Systems (GIS) mapping and land cover change analysis, neighbourhood statistics, community surveying, key-informant interviews with planners and developers, and planning documents to measure sprawl. Some of the urban growth models that were used in this study are discussed below.

2.5.1 The Monocentric City Model

The monocentric city model is a descriptive model of urban resource allocation in a city that was designed to explain accurately the phenomenon that there is one dominant place to work: the central business district, another place to live which are mainly outside the city and are referred to as suburbs. This model was generated by joint effort of William Alonso, Edwin Mills, and Richard Muth in 1960s and it’s one of the concepts that help to understand the concept of urban growth.

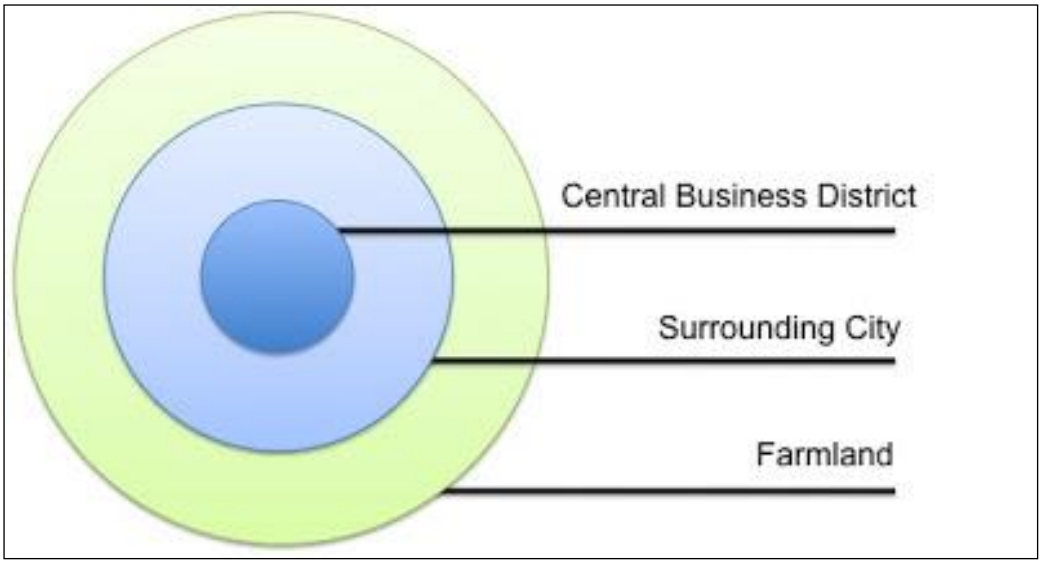

Figure 0:1 Monocentric Model **Source: Friedrichs, 2012**

Monocentric model assumes that people are working in the central business district (CBD). The CBD is regarded as the bull eye point in the town where every person tries to access almost daily for specific hours either for work or access services. The greater the radial distance from the center at which an individual resides, the greater is the cost of this commute. This model further goes to explain that rent is highest closest to the central business district, decreasing as distance increases and the commute to the central business district gets longer. Consumers tend to pay higher rents per square foot closer to the central business district and lower rates farther away; that's why the line for city rent is curved. It further assumes that lot sizes increase and population density falls with increase in distance from CBD. When the amount of rent a central-business-district commuter is willing to pay is the same as the rent farmers are willing to pay for an acre of cropland, the city ends. This is called the "urban fringe." All individuals are, no matter where they live, must commuting to the CBD to earn income and can migrate in and out of the city.

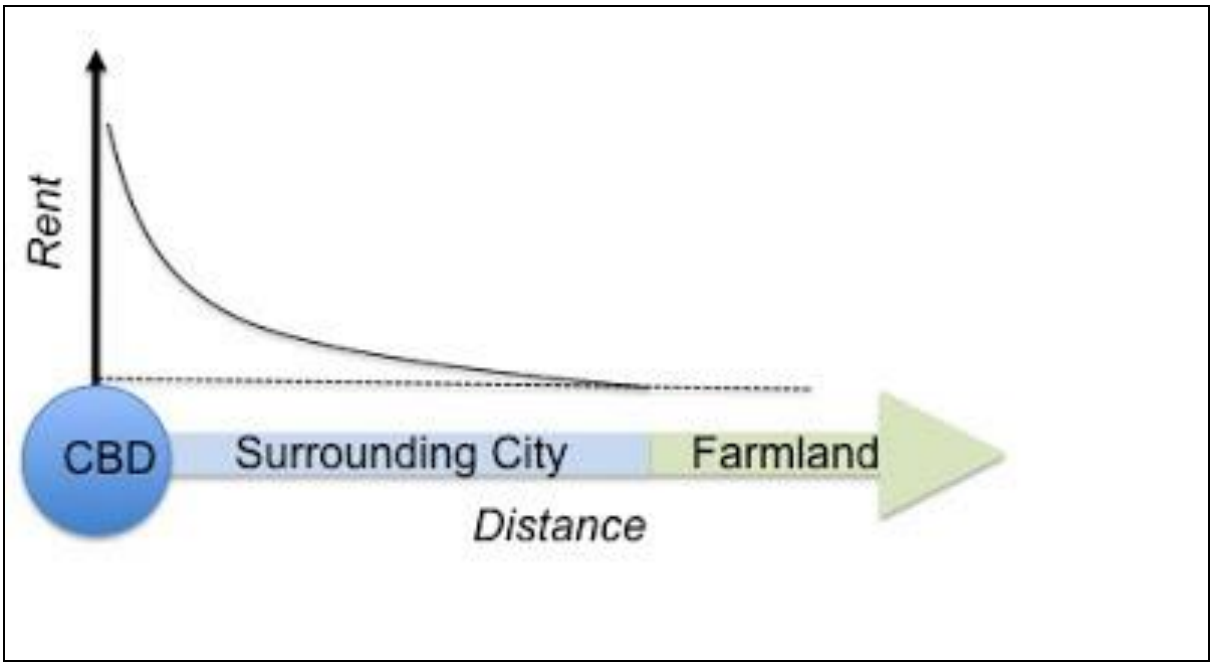

Figure 0:2 Relationship between Rent and Distance Source: Friedrichs, 2012

The monocentric model is a little out of date, however, as many cities have multiple centers and the technology makes centralization of employment less important. In as much as the work distances and rent from the CBD may still be applicable, the density may vary depending on the economic group certain investors are targeting as they construct houses for rentals in the urban periphery. But there are important lessons to be drawn from this model: Cities are denser at the center and; Transportation increases sprawl. Or, rather, faster transportation increases the convenience of commuting, increasing rent that central-business-district commuters are willing to pay, and thus increasing the area of developed land without a corresponding increase in population.

2.5.2 The Polycentric Model

As a development of the monocentric model due to its criticism, McMillen (2001) explains that "as metropolitan areas have become increasingly decentralized, traditional CBDs have come to account for a much smaller proportion of jobs than in the past. Large employment districts have arisen outside of central cities that rival the traditional city center as places of work. When these districts are large enough to have significant effects on urban spatial structure, they are referred to in the urban economics literature as employment sub center" or polycentric urban structure.

The polycentric structure of urban areas has become more evident over time. Economic centers attracting employment from city dwellers have multiplied. Raising the number of centers amounts to raising the surface available at a given commuting distance in the city -or equivalently to reducing transport costs- and to reducing as a consequence the competition for housing. People have greater housing surfaces, smaller commuting distances and a higher utility. The mean density while housing surfaces increase. These effects are more pronounced when the centers are further away from one another as indicated in the models below. Individuals thus work at the center which is the closest to their housing, and as a consequence, can change jobs as they move.

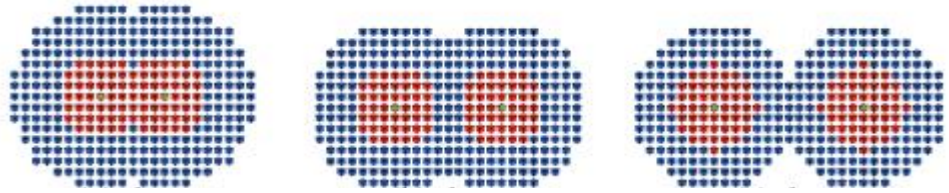

Figure 0:3 Polycentric Model A

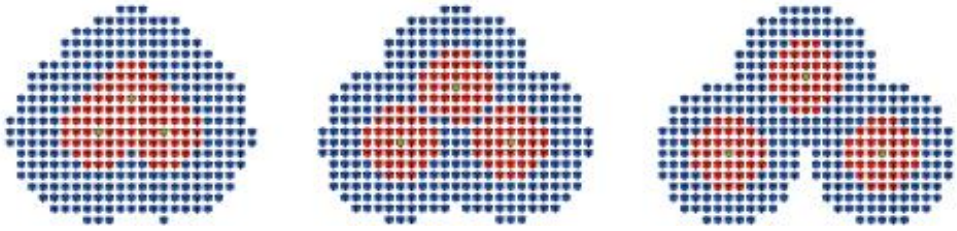

Figure 0:4 Polycentric Model B

Source:Lemoy, Raux & Jensen, 2011

CHAPTER 3: METHODOLOGY

3.1 Study Area

Introduction

This particular study was undertaken in Ruiru Sub County; one of Kenya's fastest growing satellite towns. Located along the Thika superhighway between Kenyatta University and Juja, Ruiru town is one of the fastest growing towns in the county. It is a busy commercial hub hosting several industries. It is well connected by road and rail to neighbouring towns. Ruiru town links to the northern Kenya through international roads and railway connection. Ruiru Sub County is located in Kiambu County, one of the forty seven counties in Kenya. Ruiru town is headquarter of Ruiru Sub County and centre for several companies.

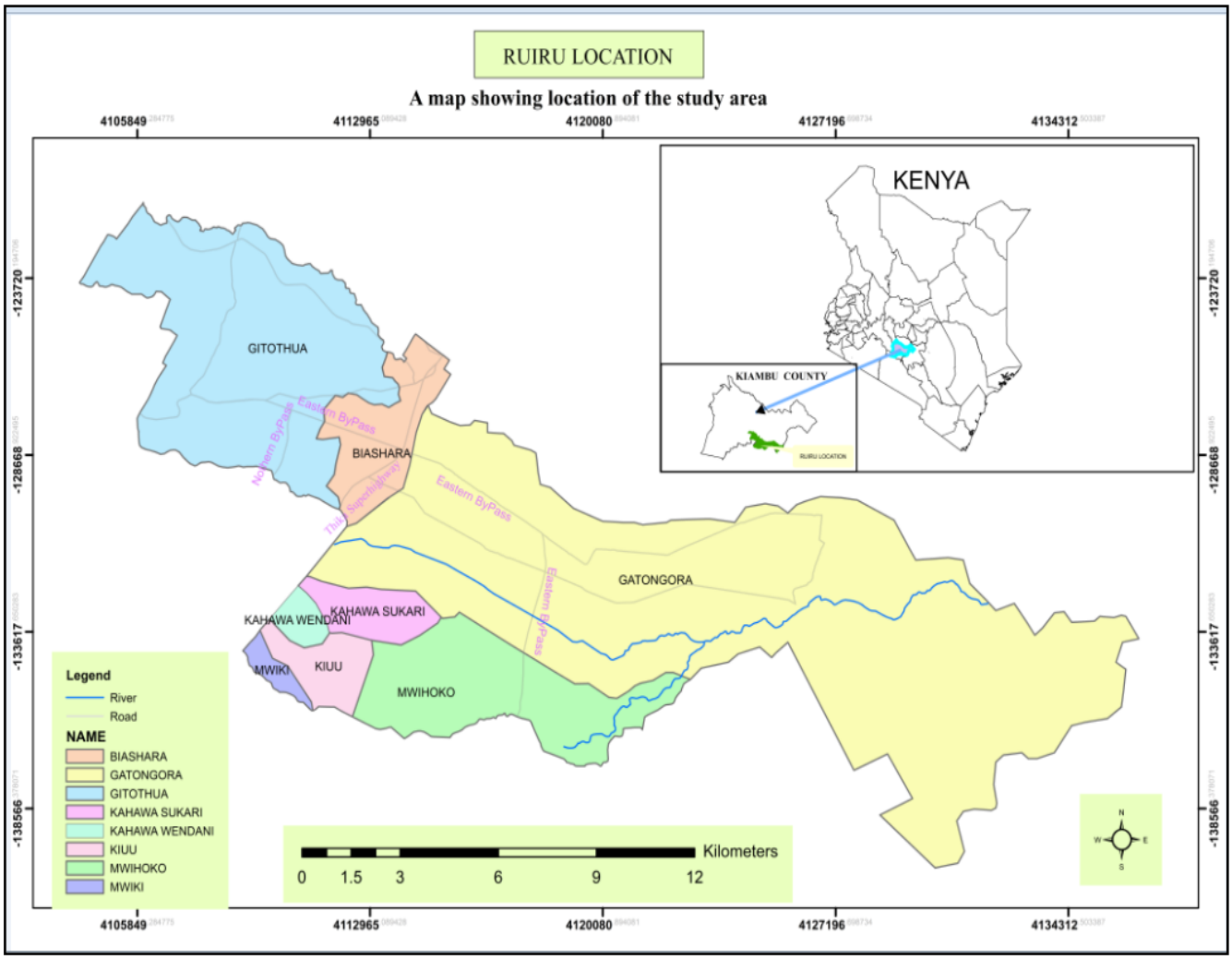

Figure 0:1 Ruiru Sub-County

Geographic Position and Administrative Units

The Ruiru sub county is situated 22 kilometres from Nairobi City. Ruiru's geographical coordinates are 1° 9' 0" South, 36° 58' 0" East**;** and is between Latitude -1,1500 (18'60.000"S) Longitude 36,9667 (3658'0.120"E). The Altitude of Ruiru is 1 570 m above sea level.

Table 3.1: Ruiru Constituency Information

County:	Kiambu
Population:	201,986 (Census 2009)
Area:	179.90 Sq. Km
No. of County Assembly Wards:	8

Source: IEBC, 2009

The sub county of Ruiru is administratively divided into four sub-locations namely; Kiuu, Theta, Mugutha and Ruiru. The sub county is further divided into eight wards according to IEBC, 2009 report namely Biashara, Gitothua, Gatongora, Kahawa Wendani, Kahawa Sukari, Mwihoko, Kiuu and Mwiki.

Land ownership in Ruiru town can be classified into four major ownership categories namely; freehold, leasehold, government land and trust land. Although this is made to change with the new constitution, freehold land ownership is the leading land ownership in Ruiru town, followed by leased land. The government land and Trust land or in other words, the Public and community land respectively as outlined in the current constitution comprises of about 5% of the land in Ruiru Town.

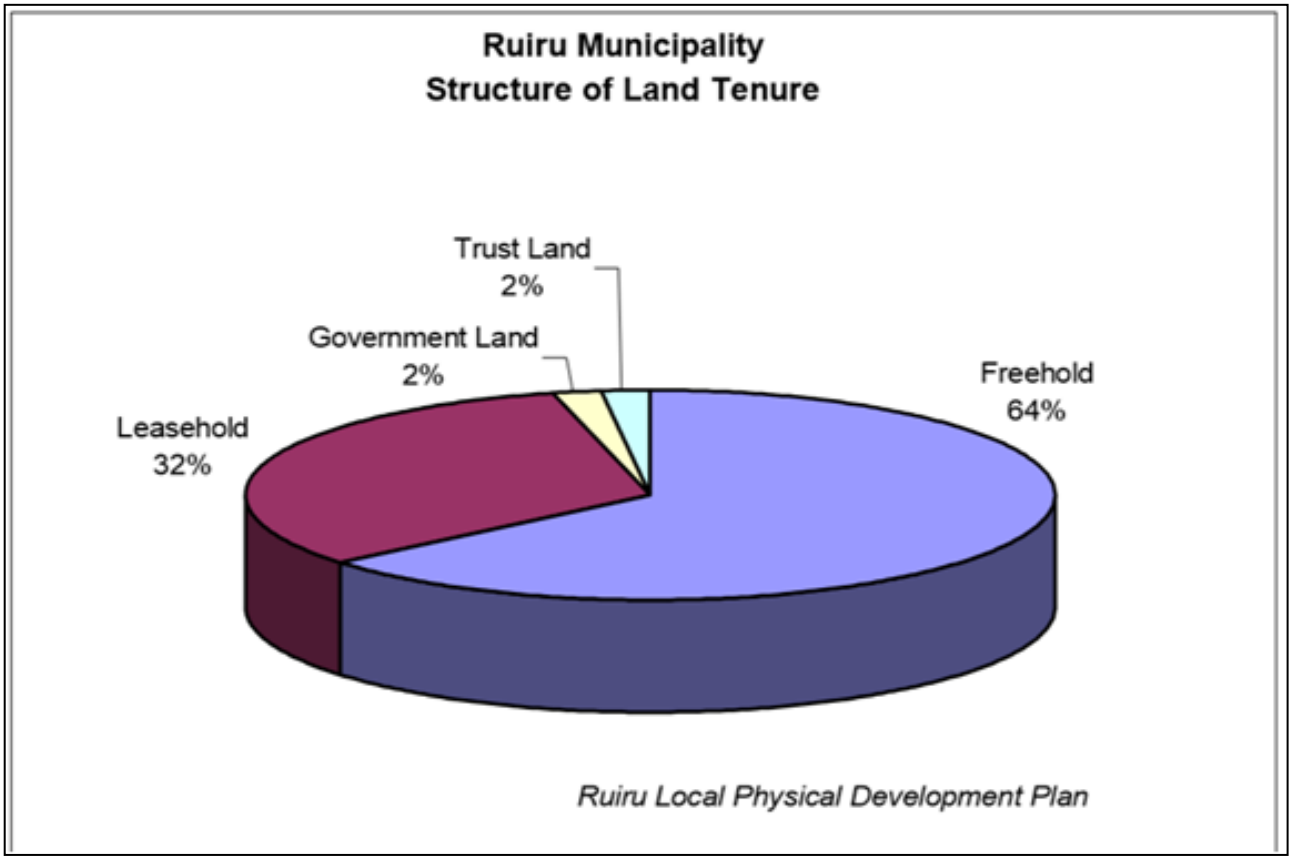

Figure 0:3 Land Ownership in Ruiru Town (2009) Source: RLPDP, 2009

Rainfall is bimodal in Ruiru, with Long rains occurring from March to May while the short rainy period occurs from October to December. The type of rainfall found in Ruiru town is generally characteristic of the climate of Nairobi-Thika region. Rainfall averages between 850mm – 1000mm. The temperature is generally high, the mean maximum temperature being 26 degrees Celsius while the mean minimum temperature being around 14 degrees Celsius. The average annual temperature is about 21 degrees Celsius. Ruiru also experience winds that blow from the north to southern end with varying speed.

Topography and Slope Analysis

Ruiru town is located on the transitional zone of the upper Athi basin and the Kikuyu dissected plateau. The area rises from the north western end of the municipality to the south western end. Ruiru River divides the township into two parts. Town lies approximately 1550m above sea level. The area generally slopes from the northwest to southeast. The topography offers good environment for farming and also housing development. To the North-West the town's

topography is generally steep and dissected by Makuyu and Ruiru rivers. The area between the CBD and Majengo estate is trough shaped and liable to floods during heavy rains. The areas south of Nairobi-Thika road are generally flat and offer good location for industrial development.

Geology and Soils

The geology of study area comprises of tertiary volcanic rocks, the most important being Nairobi stone. The Nairobi stone is a tertiary volcanic rock which is used mainly for construction. Its appearance is underlain dark ashes and tuffs and is underlain by aggrometric tuffs, some of them welded.

The soils in Ruiru originate from volcanic rocks that gradually occur on levels between 1200 to 2000 m above the sea level. The common appearance of the soils ranges from shallow yellow/brown to red friable clays. These are young soils also known as cambisols that result from erosion activities. . However there are patches of black cotton soils. The tertiary volcanic rocks mainly make up the soils on the hilly area and are developed on undifferentiated tertiary volcanic rocks (basalts, andesite, olivine and rhyolites). Soils resulting from these rocks are dark reddish brown, well drained, friable and very calcareous. They are stony forming loam to clay loam, and in many places saline. There are also lithosols with calcic, xerosols boulding and saline phase and rock outcrops. The industries and coffee farms in Ruiru are located on the hilly areas of the town, which have the dark reddish soils.

Hydrology and Drainage Systems

Ruiru area is part of the larger eastern slopes of the Aberdare's Mountains. The land is generally undulating with a general drainage pattern towards the Athi river basin Though the area is generally undulating, these characteristics are seen in the main drainage channels in the municipality i.e. Ruiru, Theta, Gatharaini and Kamiti rivers which drain into the Athi basin. However, some areas are poorly drained e.g. parts of the CBD like the municipal stadium, flood during the rainy season and are actually inaccessible for months after the rains

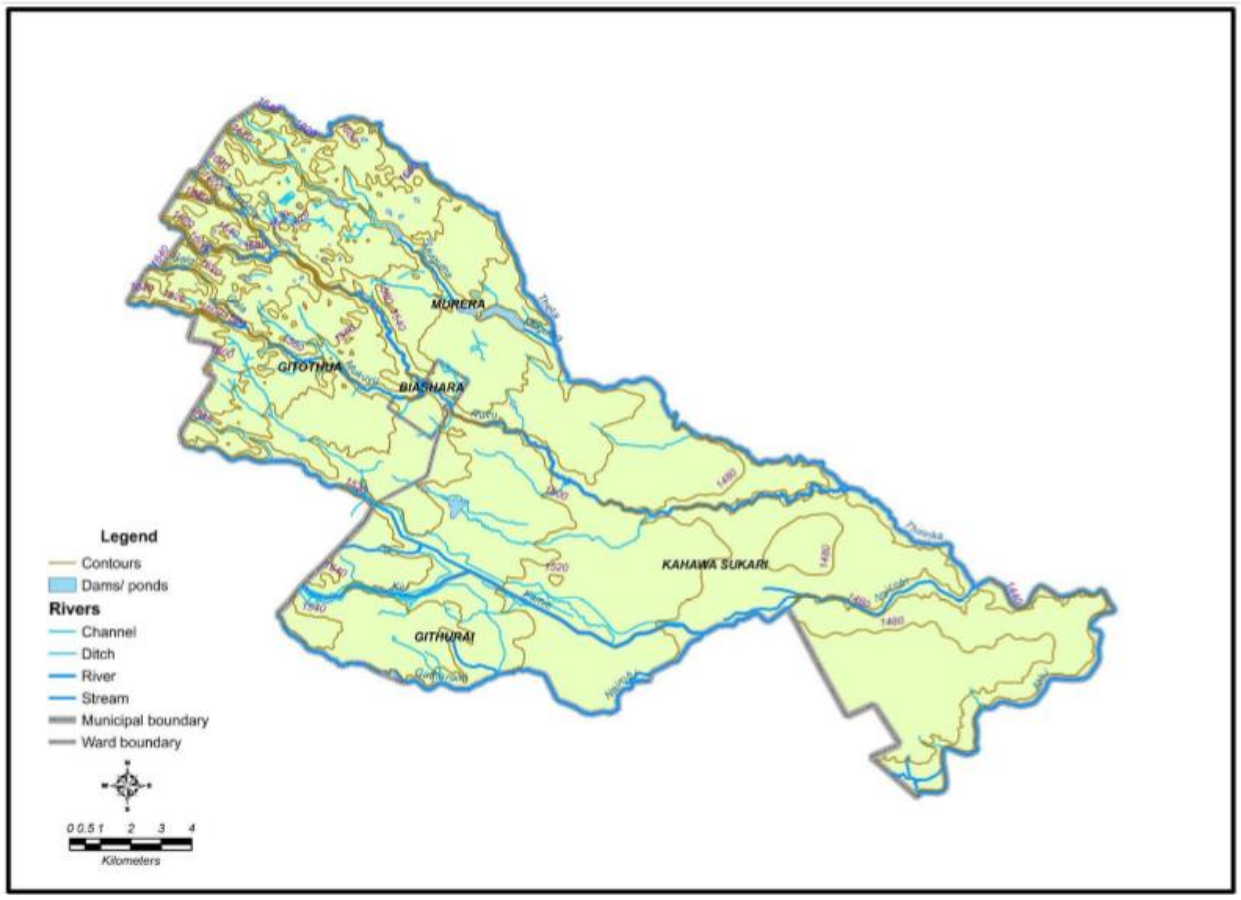

Figure 0:4 Hydrology Drainage in Ruiru Source: RLPDP, 2009

Population Size and Demographic Characteristics

Ruiru town has experienced a tremendous population growth rate since the development of the urban centre in 1913. Its role, location and functions as a service centre and recently a satellite town of Nairobi city has had a significant influence in the growth of the population.

From 1969, the municipality has shown tremendous population increase as from approximately 10,000 to 109,574 as in 1999.

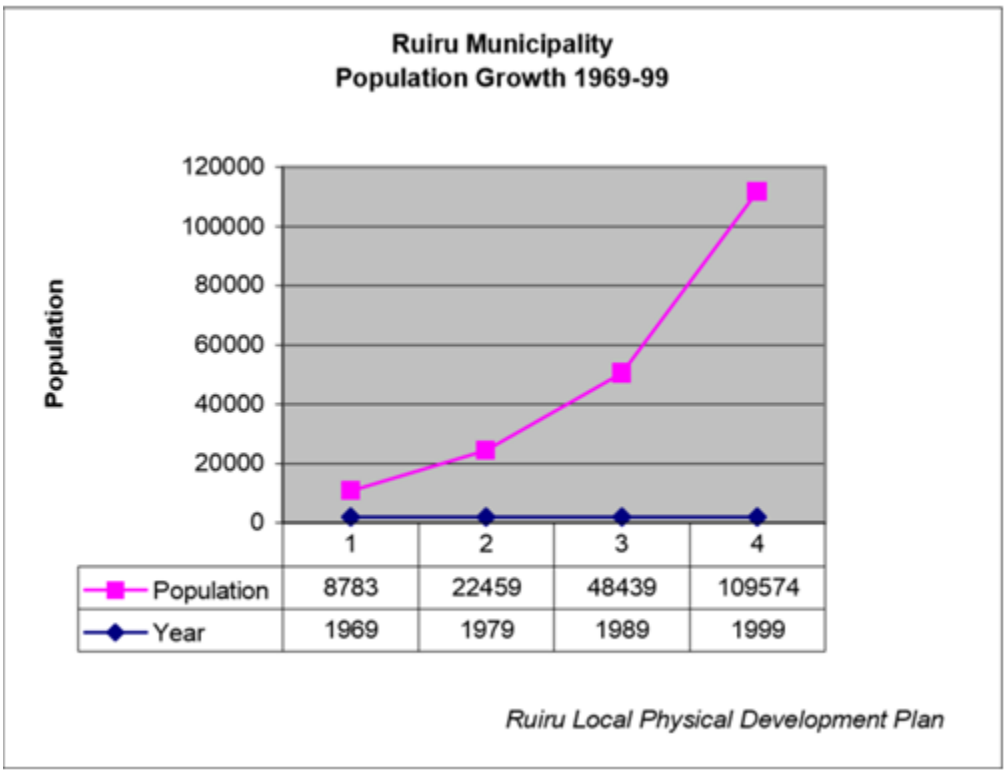

Figure 0:5 Ruiru Population Growth Graph Source: RLPDP, 2009

According to a KNBS 2009 report, the population was found to be approximately, 238,855 thus a growth rate of about 1.29%. This shows that the town has grown at a rate of 8.1%. Ruiru has a household average ratio of 3:1, typical characteristic of urban areas.

3.2 Research Design

In this research, two basic research methods where used: quantitative and qualitative. The quantitative methods involve the use of Geographic Information Systems data to produce maps of urbanization within the study area. Neighbourhood statistic measurements were also used to quantify and display the density and connectivity of patches of new built-up land. The Geographic Information System was applied in this study because it easily allowed reclassification of land cover data into categories appropriate for the purposes of this study. The GIS also allows for the usage of different types of data such as jurisdictional boundaries and roads that lie within those boundaries. The neighbourhood statistic calculations were important in justifying the classification of new growth areas into one of two types of sprawl: linear and or cluster.

The qualitative aspects of this study consisted of interviews with local land developers, town administrators, planners and analysis of jurisdictional comprehensive plans. With a qualitative approach, it opens a chance for researchers to acquire more knowledge and better understanding of multivariate phenomenon such as urban sprawl and further be able to account for development based on land value and zoning ordinances. It is not practical to assume that a strictly quantitative or qualitative approach alone would be adequate enough to make any conclusions about sprawl and its effects trends in a given area. While maps primarily provided visualization of the spatial distribution of built-up land, they cannot explain why one parcel is more attractive to a developer or investor than another parcel of land. Conversely, Scheduled interviews with developers, planners, engineer and financial officer was done to help in quantification and classification of growth areas into meaningful classes of urban sprawl. It is vital in this kind of research, to incorporate aspects of both qualitative and quantitative analysis techniques in order to be able to reasonably describe and understand whether and to what extent urban sprawl trends exist in Ruiru town.

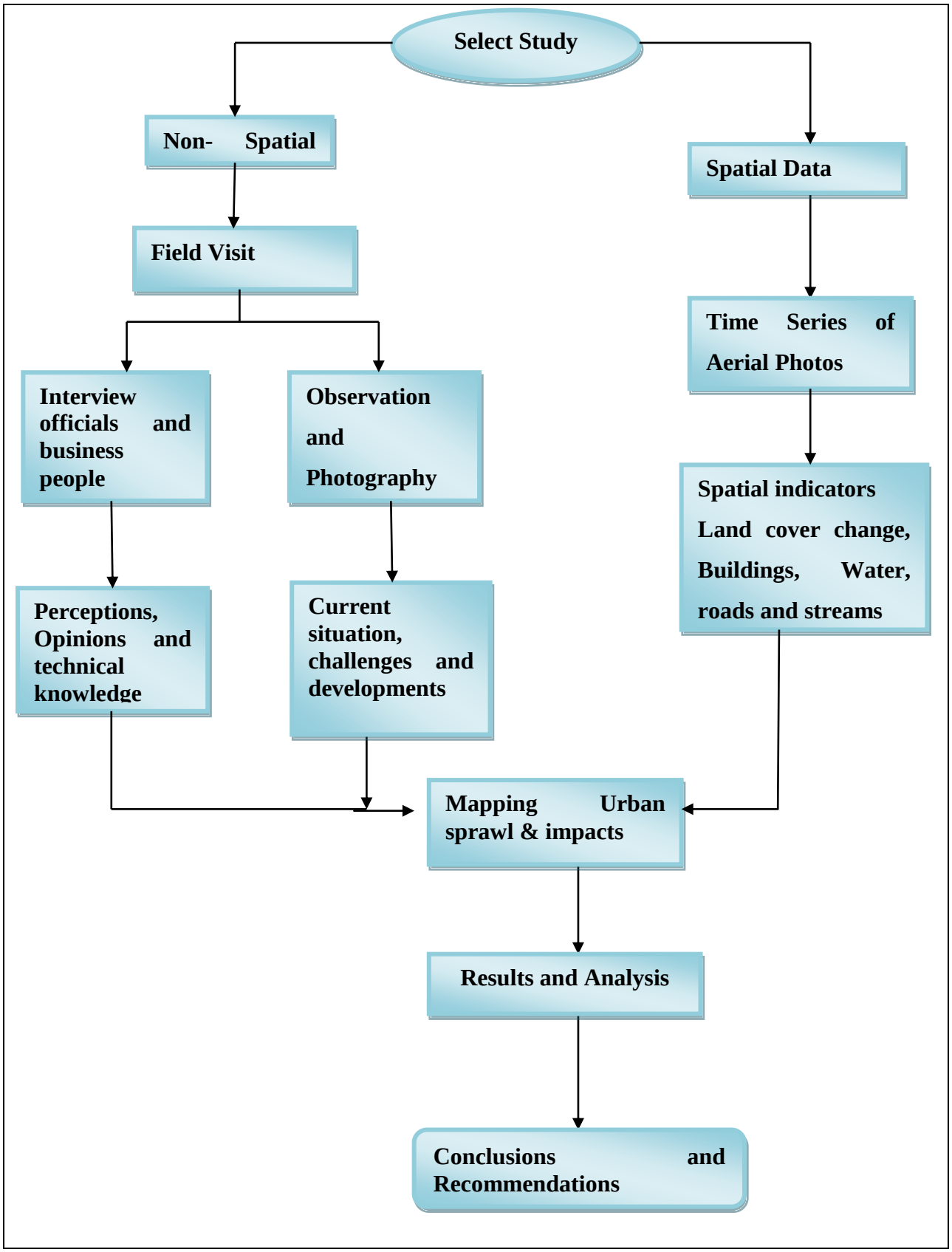
Select Study
Non- Spatial
Spatial Data
Field Visit
Time Series of Aerial Photos
Interview officials and business people
Observation and Photography
Spatial indicators Land cover change, Buildings, Water, roads and streams
Perceptions, Opinions and technical knowledge
Current situation, challenges and developments
Mapping Urban sprawl & impacts
Results and Analysis
Conclusions and Recommendations

Figure 0:6: Research Methodology Flowchart

3.3 Data Sources and Tools

As said elsewhere, both quantitative and qualitative data sampling strategies were used and merged into one approach. For the purposes of this research, built-up land was defined as any land cover that is synonymous with urban land cover, which includes paved, industrial, commercial and residential areas. This was followed by taking one sample of each kind of assumed sprawl based on the neighbourhood statistic calculations to use in interviewing developers and to analyse jurisdictional master plans. In order to gauge sprawl trends, samples were taken only from the study area. This will give an indicator of the extent to which growth had taken place in the study area.

In order to obtain sample sites, a combination of the map of new urban growth and the map of new urban growth density was used. For the spatial data, visual/supervised classification approach was used in this study.

3.3.1 Data Sources

1. National and Regional administrative boundaries (county and sub county boundary files showing the border of each jurisdiction within the study area). This was obtained from the Ruiru physical planning department, from Kenya national bureau of statistic (KNBS) and independent electoral and boundaries commission (IEBC).
2. Land use data, satellite imagery, and infrastructural data showing the trend of development activities in the study area for the previous 10 years. This was obtained from Ruiru Sub County and KNBS.
3. Data on the economic activities in the study area and the revenue from urban related activities and the trend for the last 10 years. This was obtained from Finance department of the sub county of Ruiru.
4. Data on urban development activities occurring in the study area and the trend of activities in the last 10 years. This was obtained from the physical planning, engineering and the public works departments in Ruiru Sub County.

3.3.2 Data Collection

Primary data used in this research was collected by means of structured interviews, observation and photography. Types of activities in the area, topography, infrastructure, services and the authentic environment was observed and noted. Interviews were scheduled with the sub county

administrators, planners and engineer in order to get their opinion regarding urban sprawl. In addition, some outstanding developers, business people and investors in the study area were interviewed in order to determine their perception of urban sprawl and ideas regarding urban development challenges.

Secondary data used in this study included information on urban sprawl, infrastructure and urban services by accredited scholars and researchers, both published and unpublished. Data from the internet was also used. This kind of information was incorporated to give a strong background to the study and also information on urban sprawl, its definition, causes and consequences, urban mobility forms and challenges, urban infrastructural services and the challenges on service delivery. Secondary data about the study area including existing land use trends and patterns, Infrastructure, and environmental profile and its states was collected especially from State administrative organs within the study area's jurisdiction.

Interview Schedule

Scheduled interview was conducted with various officers and decision makers in the management and administration of the town. This included the Sub- County engineer, sub - County planner; sub county finance officer, business people and other stakeholders.

Observation Guides

This approach was useful for the assessment of the situation on ground. Observation was mainly focused on the current development and urban sprawl conditions in the sub-county of Ruiru. Observation also focused on the current land uses, major changes in land use and land cover changes, urban activities such as waste management, infrastructure, drainage and mobility.

Photographs

Photographs were used to capture information which was to be referred to during the analysis of data. This serves as evidence of the situations and conditions in the area of study.

Maps and Satellite Imagery

Topographic maps are effective in giving immediate data on the land uses and various activities distribution over the area. It's an effective tool of collecting spatial data especially where research is limited in time. Maps showing administrative boundaries, spatial population distribution and infrastructural services in the town were obtained and used as base map for the data analysis (Matthew, 2008).

In this study, an Othophoto (Othorectified imagery) for the classification that has a resolution of 0.25m and a projection of WGS 1984 was used. This was preferred due to better visualization and produced more accurate results and easy to identify the different classes within the area.

3.4 Data Pre - Processing

Data pre-processing was done using various approaches depending on the nature of the data. Secondary data obtained from different departments was analysed statistically. Statistical Softwares e.g. Microsoft Excel was used in data analysis and generation of Graphs, charts and indices. ArcGIS software was used to generate maps showing changes in urban development and occurrences of urban sprawl in Ruiru town and the entire sub county. The spatial data was analysed using the supervised and visual classification and post analysis done using ArcGIS tools.

3.5 Mapping Urban Sprawl

3.5.1 Land Use Mapping

To understand the changing elements of land use, this study focused on three main land covers and how there percentages have changed within the study scope time. The methods of Data Analysis included Calculation of the area in square km of the resulting land use land cover types for each study year to see the rate of change and subsequently comparing the results, The Markov Chain and Cellular Automata Analysis for predicting change, Overlay operations, Maximum likelihood classification and Land consumption rate and absorption coefficient were utilized.

The comparison of the land use/ land cover statistics assisted in identifying the percentage change, trend and rate of change between 2003 and 2009, and 2013.

Trend Percentage Change = (Observed Change/Sum of Change) x 100.

The Markov Chain Analysis and Cellular Automata Analysis method was used to analyze the spatial extend of each land use/land cover. This identifies the actual location and magnitude of change although this was limited to the built-up land, the Land Consumption Rate (LCR) and Land Absorption Coefficient (LAC) formula. Pixels were chosen throughout the study area (image) after which ground truth was done and compared with the classified map, which matched. Enough random pixels were checked and the percentage of accurate pixel gave a fairly

good estimate of accuracy of whole map. The growth dynamics of Ruiru Town from 2003 to 2013 was polygonised.

3.5.2 Land Use/Change Mapping

In supervised classification, spectral signatures were developed from specified locations in the image. These specified locations were given the generic name 'training sites' and were defined by the user. Generally a vector layer was digitized over the raster scene. The vector layer consists of various polygons overlaying different land use types.

Supervised classification was much more accurate for mapping classes. The strategy was simple: recognized conventional classes (real and familiar) or meaningful (but somewhat artificial) classes in a scene from prior knowledge with what's present in the scene, or more generally, the region it's located in, by experience with thematic maps, or by on-site visits. This familiarity allowed for making the classification to choose and set up discrete classes (thus supervising the selection) and then, assign them category names.

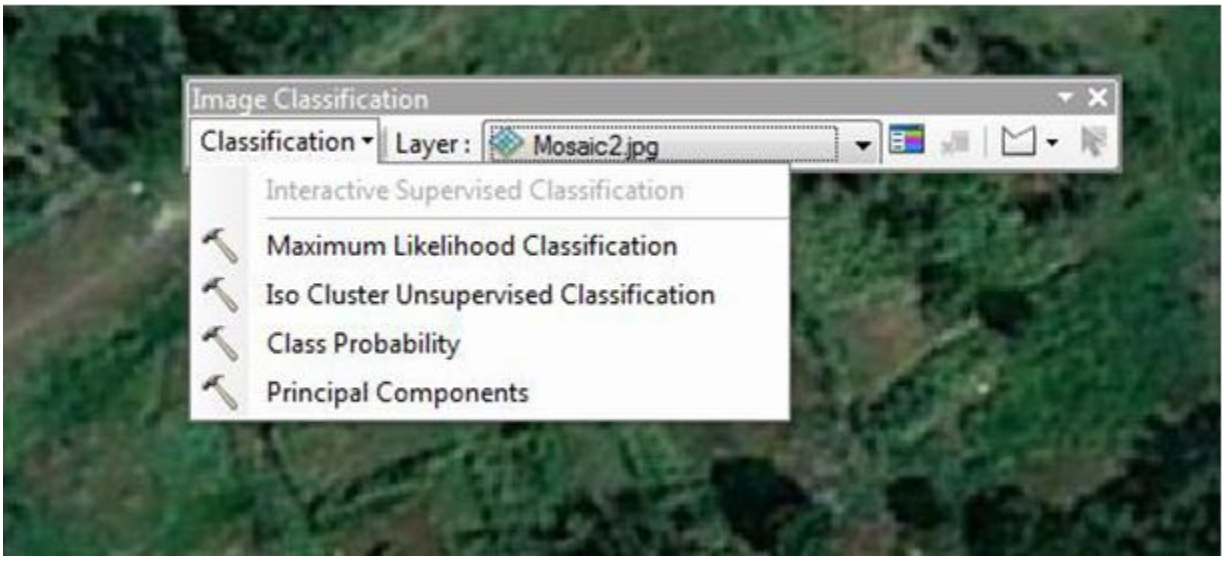

Figure 0:7 Image Classification under Supervised Classification

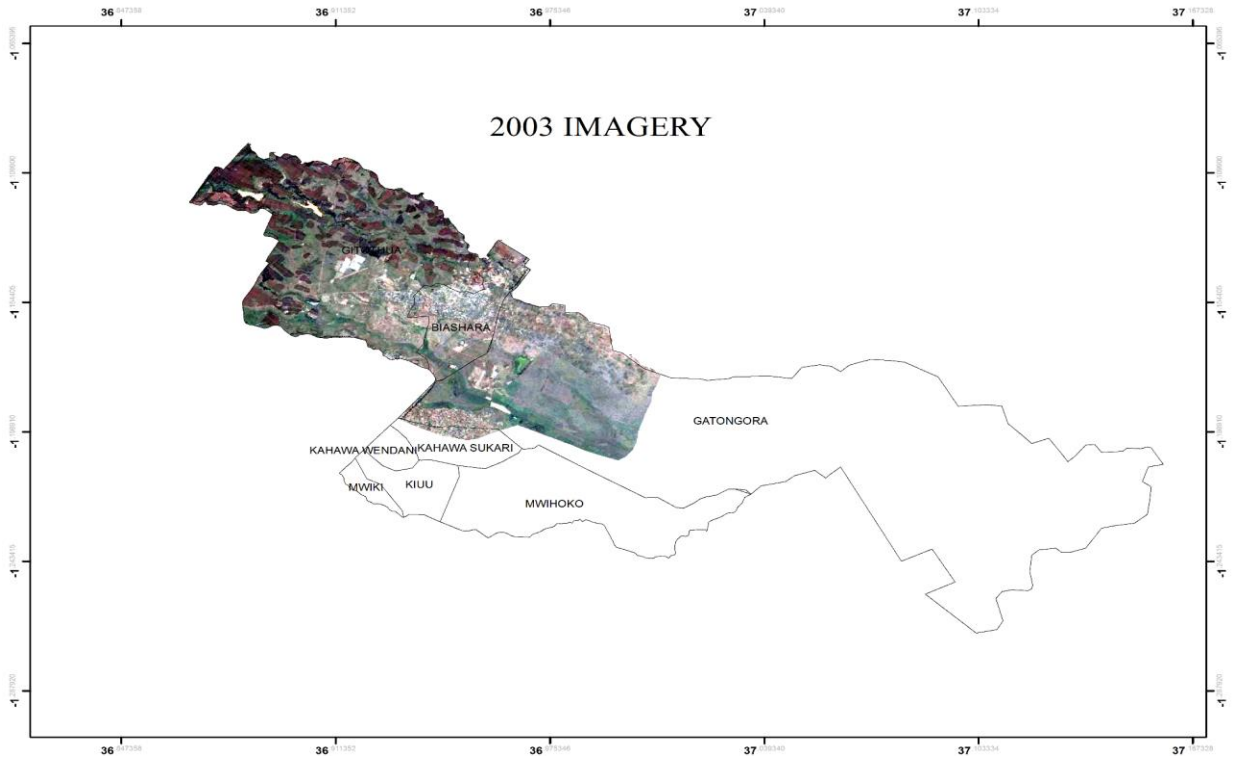

Figure 0:8 Imagery of the Study Area (2003)

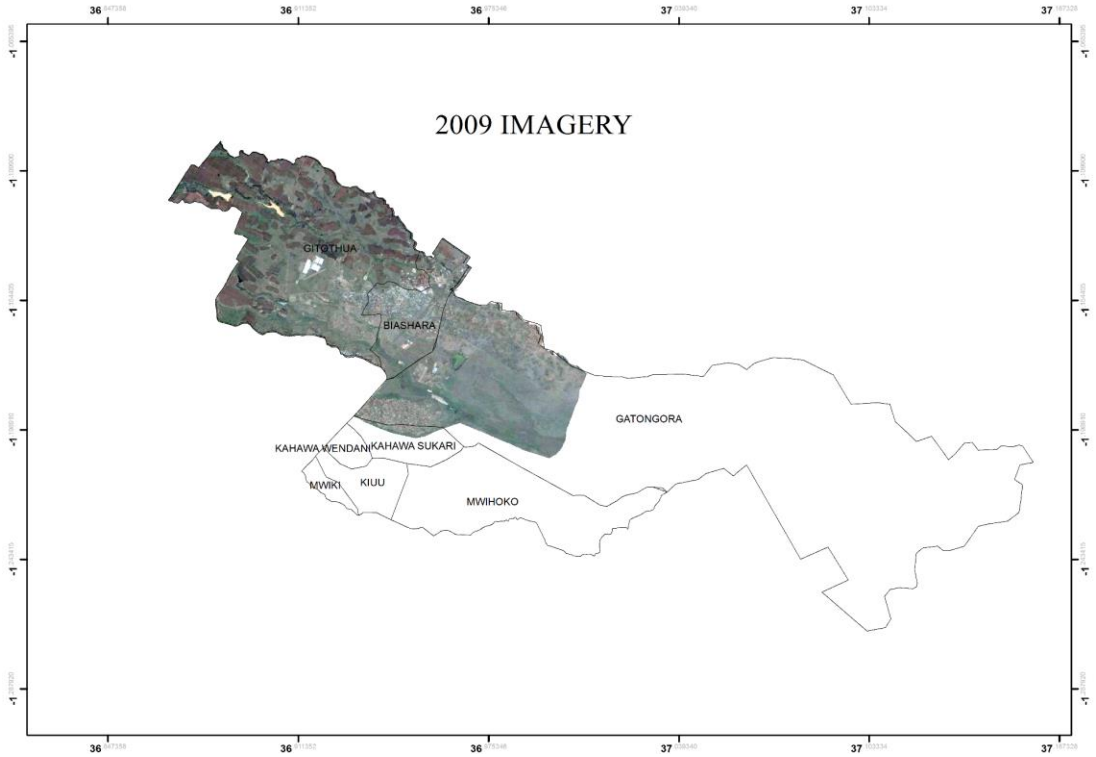

Figure 0:9 Imagery of the Study Area (2009)

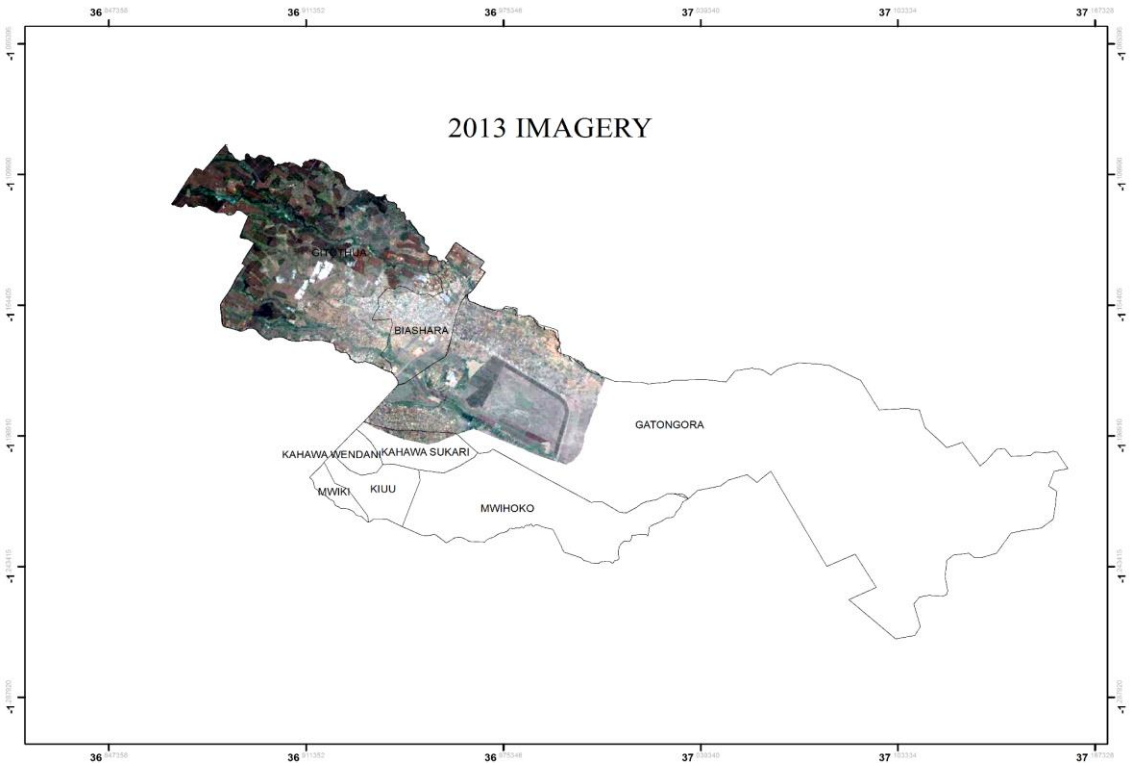

Figure 0:10 Imagery of the Study Area (2013)

The plates above are satellite images of the study area showing the condition of the area as at 2003 (Figure 3.8), 2009 showed by Figure 3.9 and 2013 showed by Figure 3.10. Different colours shows different land covers as detected by the satellite.

The resulting training sites were areas representing each known land cover category that appeared fairly homogeneous on the image (as determined by similarity in tone or colour within shapes delineating the category). In the computer display these sites were located and circumscribed with polygonal boundaries drawn. For each class thus outlined, mean values and variances of the Digital Numbers (DNs) for each band used to classify them are calculated from all the pixels enclosed in each site. More than one polygon was drawn for any class. The classification program then acts to cluster the data representing each class. When the DNs for a class are plotted as a function of the band sequence (increasing with wavelength), the result is a spectral signature or spectral response curve for that class.

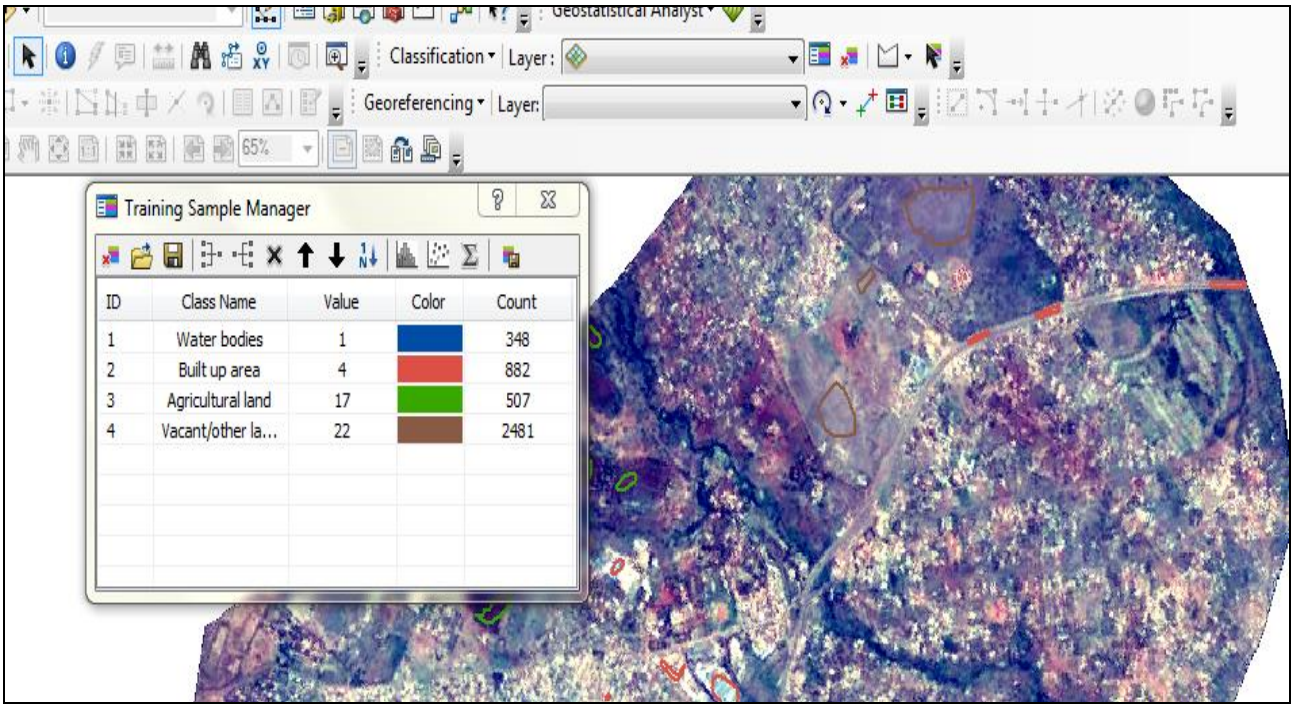

Figure 0:11 Signature Collections on a Satellite Image

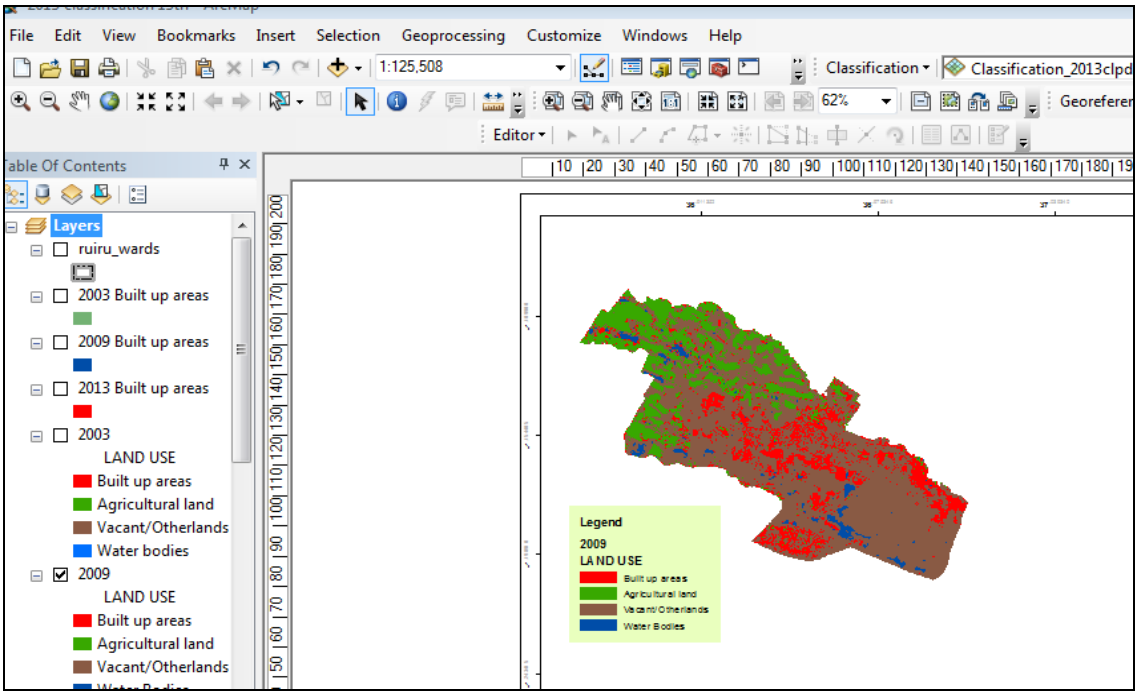

Figure 0:12 Supervised Classification on a Satellite Image

In proposing the town development control mechanism based on the effect of urban sprawl, a spatial plan matrix showing the objectives of planning approach, strategy, timeframe for implementation and the necessary actors was designed.

3.5.3 Accuracy Assessment

The increased usage of remote sensing data and techniques has made geospatial analysis faster and more powerful, but the increased complexity also creates increased possibilities for error. In the past, accuracy assessment was not a priority in image classification studies. Because of the increased chances for error presented by digital imagery, however, accuracy assessment has become more important than ever. A common tool to assess accuracy is the error matrix. Error matrices compare pixels or polygons in a classified image against ground reference data. These matrices can measure accuracy in several ways. The overall accuracy of the classified image compares how each of the pixels is classified versus the actual land cover conditions obtained from their corresponding ground truth data. Producer's accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User's accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location Error matrices have been used in many land classification studies and they were an essential component of this research.

Pixels were chosen throughout the study area (image) after which ground truth was done and compared with the classified map, which matched. Enough random pixels were checked and the percentage of accurate pixel gave a fairly good estimate of accuracy of whole map. By increasing the sample size for the area I was able to have a more precise class for classification. Using the ground truth point I converted them from point to raster since each of them represented the different land cover types in ArcGIS software. After converting the ground truth point to raster I was able to now compare them with the classified image and do the accuracy assessment using the combine tool between the classification raster and the ground truth raster. I made sure all the cell size were the equal with the raster cells. ArcGIS allowed for automated accuracy assessment for each supervised classification, but due some technical restrictions all accuracy assessment was completed in Microsoft Excel.

The validation analyses were performed separately for 2003, 2009 and 2013. The classified images were compared with the ground truth data and the resultant pixel agreements

A measure for the overall classification accuracy can be derived from this table by counting how many pixels were classified the same in the satellite image and on the ground and dividing this by the total number of pixels:

The tables below represent the confusion matrix of the estimated total number of pixels for the years 2003, 2009 and 2013;

Table 0:1 Confusion Matrix of the Estimated Total Number of Pixels for the Years 2003

	2003	**Ground truth**				**No. Classified Pixels**
		Built Up Areas	Agricultural Land	Vacant Land	Water Bodies	
Classified In Image As	Built Up Areas	46	2	1	1	50
	Agricultural Land	1	47	1	1	50
	Vacant Land	2	3	44	1	50
	Water Bodies	1	1	1	47	50
	No Of Ground Truth Pixels	50	53	47	50	200

Overall Accuracy 2003: 92%

Table 0:2 Confusion Matrix of the Estimated Total Number of Pixels for the Years 2009

	2009	**Ground truth**				**No. Classified Pixels**
		Built Up Areas	Agricultural Land	Vacant Land	Water Bodies	
Classified In Image As	Built Up Areas	43	2	3	2	50
	Agricultural Land	2	45	2	1	50
	Vacant Land	2	2	45	1	50
	Water Bodies	1	1	3	45	50
	No Of Ground Truth Pixels	48	50	53	49	200

Overall Accuracy 2009: 89%

Table 0:3 Confusion Matrix of the Estimated Total Number of Pixels for the Years 2013

	2013	Ground truth				No. Classified Pixels
		Built Up Areas	Agricultural Land	Vacant Land	Water Bodies	
Classified In Image As	Built Up Areas	44	3	2	1	50
	Agricultural Land	3	45	1	1	50
	Vacant Land	2	2	45	1	50
	Water Bodies	1	2	1	46	50
	No Of Ground Truth Pixels	50	52	49	49	200

Overall Accuracy 2013: 90%

The overall accuracies of 2003, 2009 and 2013 were above 85%. There were substantial and almost perfect agreements between the classified image and the ground truth data for 2003, 2009 and 2013.

3.5.4 Impacts of Urban Sprawl

Impacts of urban sprawl were then tabulated with the assessment of changes in the four key land use categories namely; Built up area, Water bodies, Agricultural land and Vacant/other lands. Each timeline was analyzed statistically, accounting the percentage land occupied by each use and comparing this to the total. Correlation analysis of the previous timeline percentage helped in understanding the spatial impact of urban sprawl and how each land use was varying over the time. For the non-spatial data, impact of urban sprawl was analyzed based on form of data collected. The data collected from financial department was tabulated and analyzed to project the positive impact of urban growth which is directly related to urban sprawl. Also, Environmental study was analyzed to examine the impact of urban sprawl with key observation to wetlands and water bodies.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.0 Introduction

Urban sprawl as highlighted in this study is concerned with the uncontrolled development occurring in land causing major effects on the land and the environment. The activities arising from urban development may have positive or negative impact to the nearby environment and the people. In an urban setting, there is a direct relationship between increase in population and chances of urban sprawl. This chapter highlights the factual findings and the analysis of the data in order to drive out a scientific reasoning in approaching urban sprawl.

4.1 Results

4.1.1 Land Use / Land Cover

In mapping the impacts of urban sprawl on natural land and the land cover, this study focused on the changes that have occurred over land e.g. built up area within Ruiru town and its surroundings. Aerial maps showing extend of spatial land use and land cover change were generated to qualify the fact that there is sprawl and to what extent. Ruiru Sub County originally had its entire land except in Biashara ward being agricultural land characterised by farming and undeveloped land. Water bodies in the region include Galana and Ruiru rivers, man-made dams and Wetlands. The growth of Ruiru town and the neighbouring towns has seen expansion of Built-up areas, taking up a huge chunk of the land in the area that was initially agricultural r undeveloped. This can be seen in the sequence of aerial maps showing how these changes have occurred in different years since 2003 to 2013. The growth of Built-up areas around Ruiru town depicted by aerial imagery shows different types of growth. There is pronounced growth mainly along the roads. This is the common trend of urbanization in Kenya where many people tend to move to settle along the transportation channels. According to the sub county Authorities, this scenario is expected to manifest even in the undeveloped land in Gatongora ward, where major developments of infrastructures and utilities are currently underway.

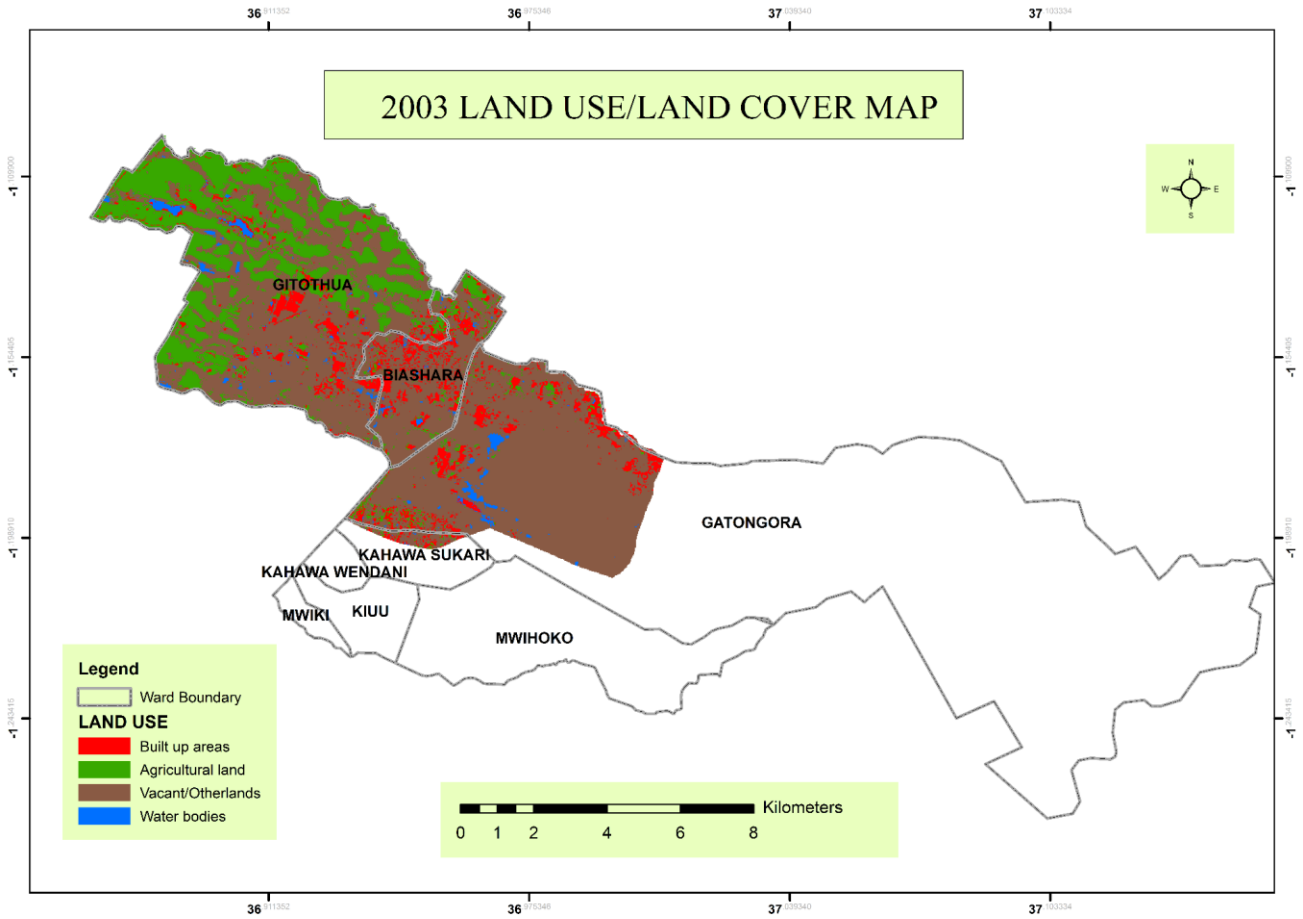

Figure 0:1 Land Use/Land Cover Map (2003)

A map showing spatial coverage of the four land use parameters namely Built up area, agriculture and hinterland and water bodies as it was in 2003. This is done with respect to Ruiru Sub County and within new Sub county Administration Boundaries. There is significant Built up areas emerging along the roads taking a linear shape and also scattered within the sub county.

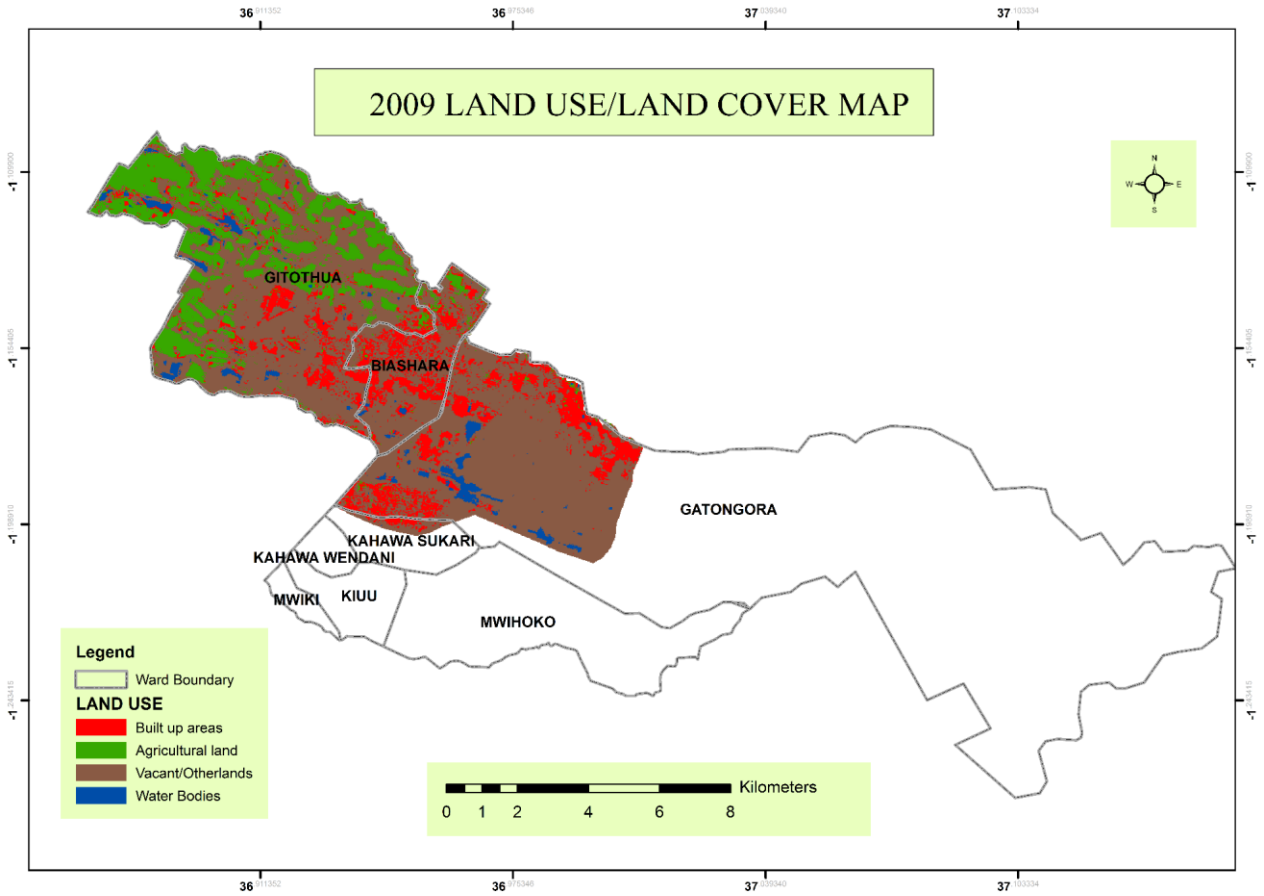

Figure 0:2 Land Use/Land Cover Map (2009)

A map showing the extent of the four land use parameters as at 2009. It is clear from the map how the Built-Up area has grown in size as compared to 2003 map in Map 4.1. The map shows a more concentered linear and scattered settlement in various points in the Sub County. In places where Built up area has increased, there is also reduction of agricultural land as it the case around Gatongora ward.

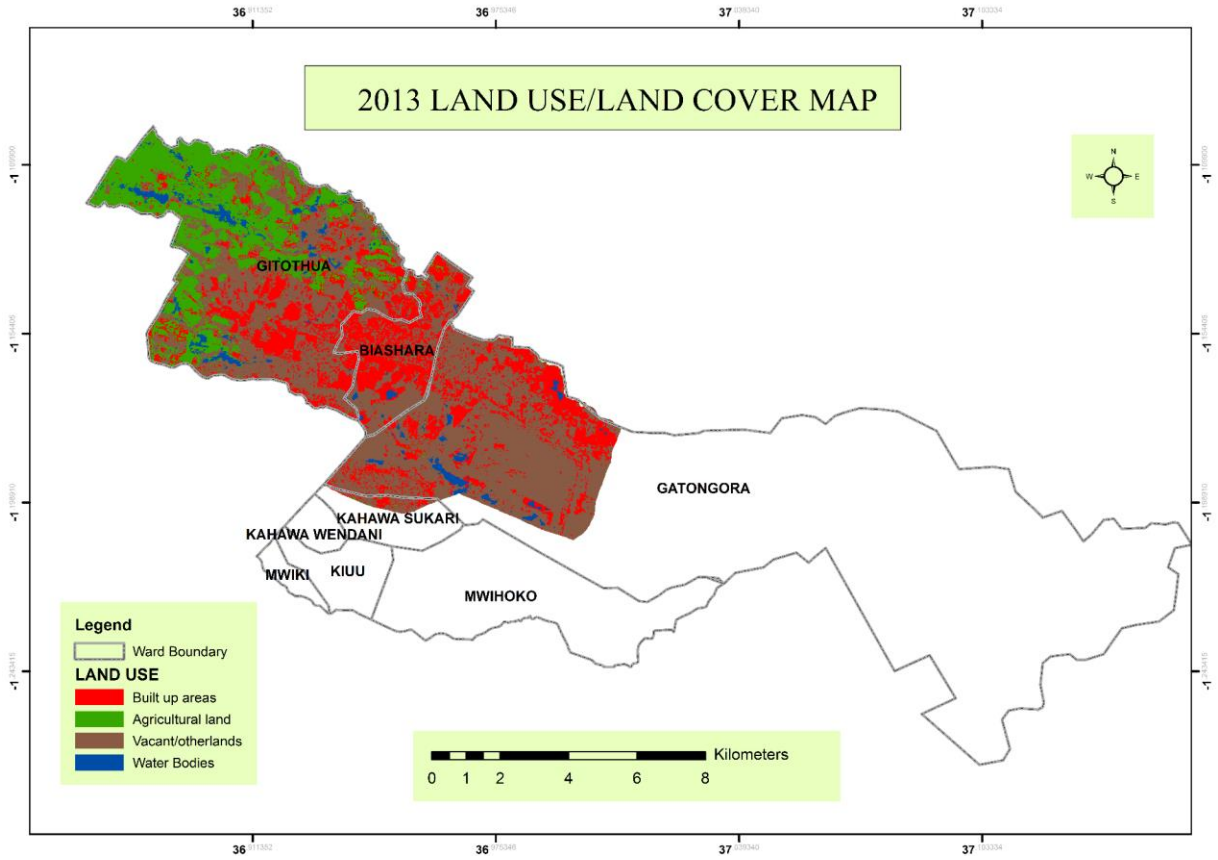

Figure 0:3 Land Use/Land Cover Map (2013)

Map 4.3 shows the urban sprawl extent as at 2013. Urban growth has occurred so significantly that many of the clustered settlements are almost joining. In addition, there is massive linear settlement in all direction around Ruiru town. A keen study on the map shows that there is an inward expansion of linear growth where many houses are coming up in a one kilometer radius of the main roads.

The area under development or what is classified as Built-up land in 2003 portrays a scattered shape and a linear growth. As seen above, much of the initial development around the town can be associated with the main roads network and the railway transportation. The clustered shape of Built-up regions can be associated with the growth of companies and industries especially around the Ruiru town. However, the larger part of the land was not development by 2003, in other words, no permanent changes had occurred on the land.

4.1.2 Land Use/Land Cover Change Analysis

Table 0:1 Change Trend

Year Of Study / Area	2003(Area in Km2)	% of Total	2009(Area in Km2)	% of Total	2013(Area in Km2)	% of Total
Built up area	7.10	8.5	12.39	14.9	21.20	25.5
Water bodies	1.44	1.7	2.18	2.6	2.89	3.8
Agricultural land	18.40	22.1	15.59	18.7	16.41	19.7
Vacant/other lands	56.31	67.7	53.09	63.8	42.75	51.0
Total Area	**83.25**	**100**	**83.25**	**100**	**83.25**	**100**

Table 0:2 Rate and Magnitude of Change

Year Of Study / Area	Change Between 2003 And 2009	Change Between 2009 And 2013	Change Between 2003 and 2013
Built up area	7.8	8.81	16.61
Water bodies	0.74	0.71	1.45
Agricultural land	-2.81	0.82	-1.99
Vacant/other lands	-3.22	-10.34	-13.57

Table 0:3 Trend Percentage Change

Year Of Study / Area	Built Up
Change between 2003 and 2009	7.8
Observed change/ Sum of change × 100	7.8/33.22 * 100 = 23.48%
Change between 2009 and 2013	8.81
Observed change/ Sum of change × 100	8.81/33.22 * 100 = 26.52%
Change between 2003 and 2013	16.61
Observed change/ Sum of change × 100	16.61/33.22 * 100 = 50%

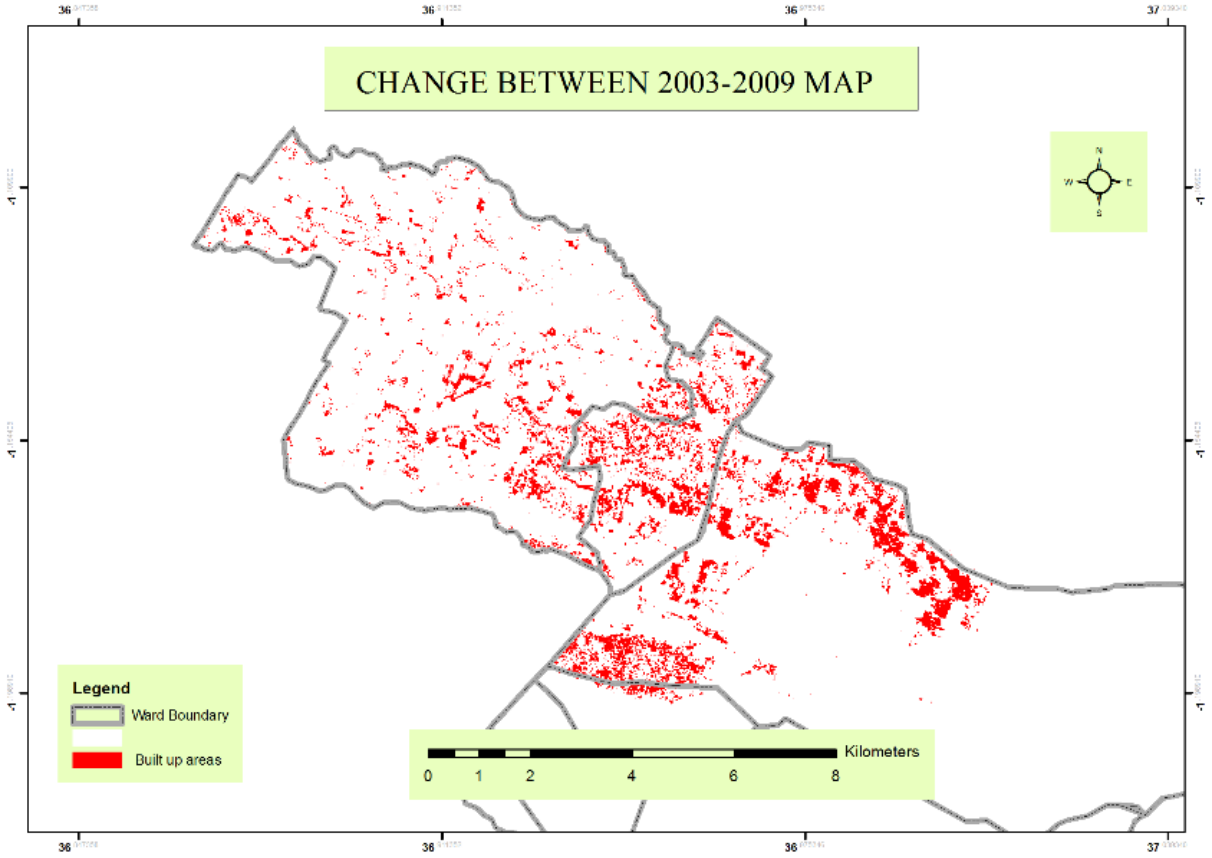

Figure 0:4 Built – Up Change between 2003 -2009

The above figure show extend of urban sprawl indicated by urban built up area for the period 2003 – 2009. There is witnessed scattered and clustered settlement in various locations majorly in towns like Ruiru, Kahawa, Githurai, and some parts of Gitothua Ward.

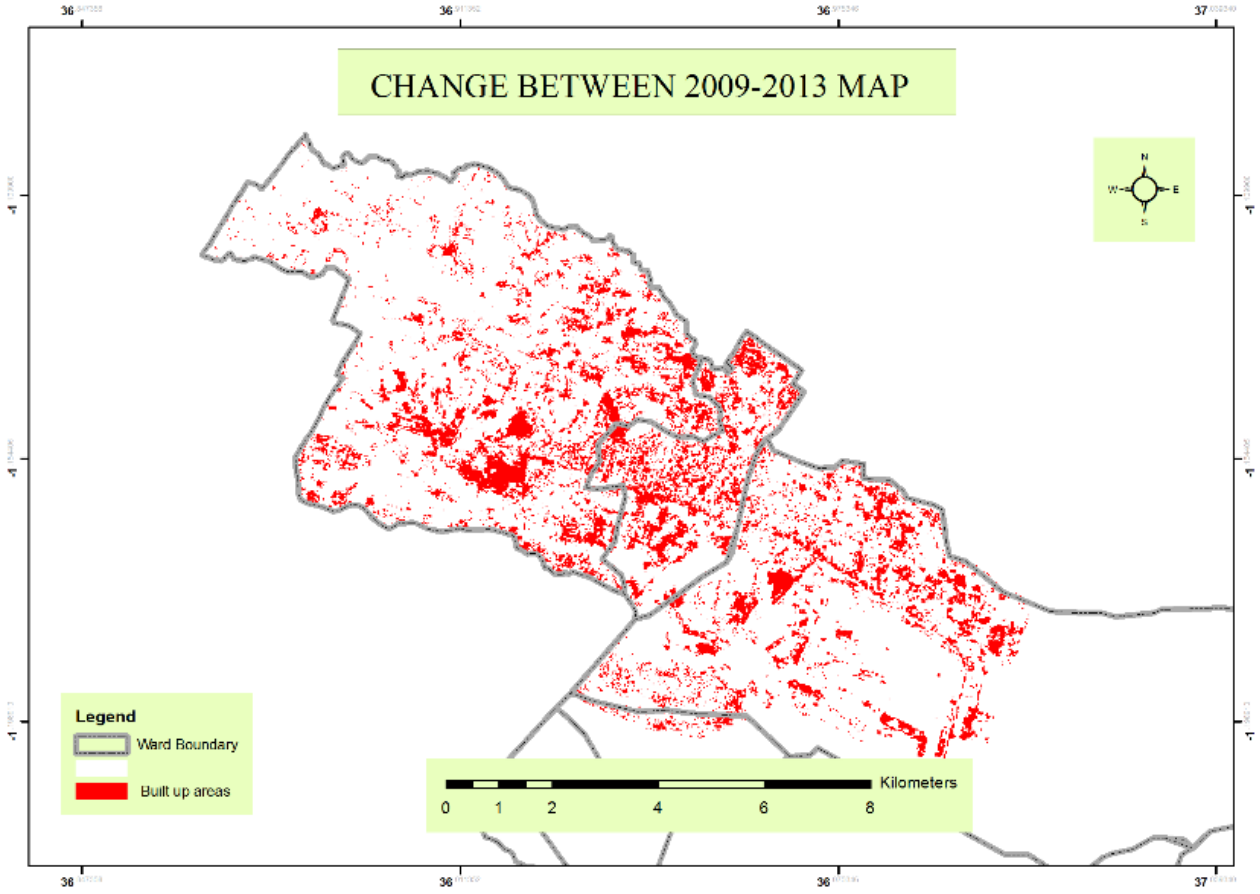

Figure 0:5 Built – Up Change between 2009 -2013

There is intense built up area in the period 2009 – 2013 as compared to the previous time scale. Outstanding in this case is the emerging linear settlements along major road routes. The clustered zones in the previous time scale (2003-2009) appear more concentrated and highly built up.

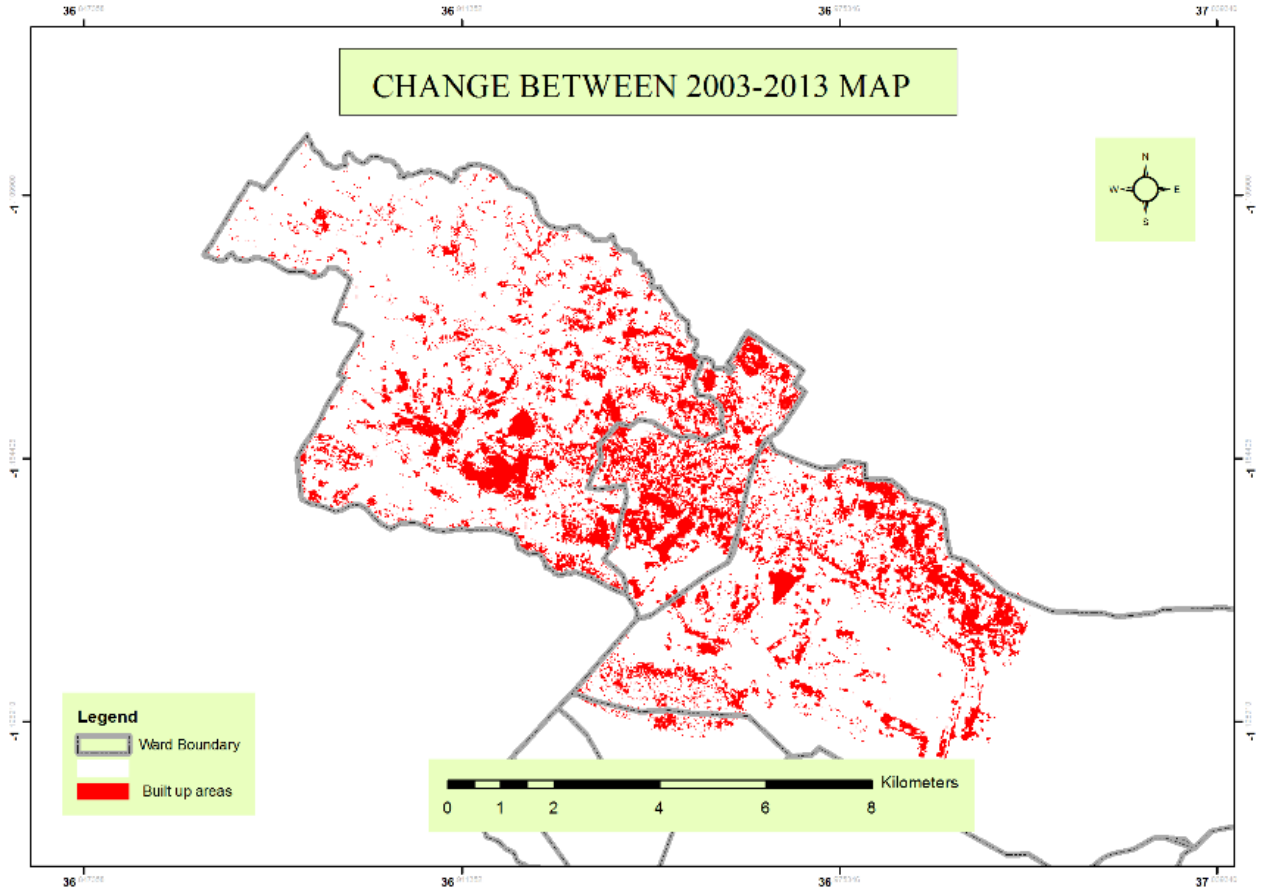

Figure 0:6 Overall Change between 2003 - 2013

This figure shows the overall urban growth in Ruiru Sub County for the entire study time (2003-2013). Detailed analysis is given in the subsequent sections below.

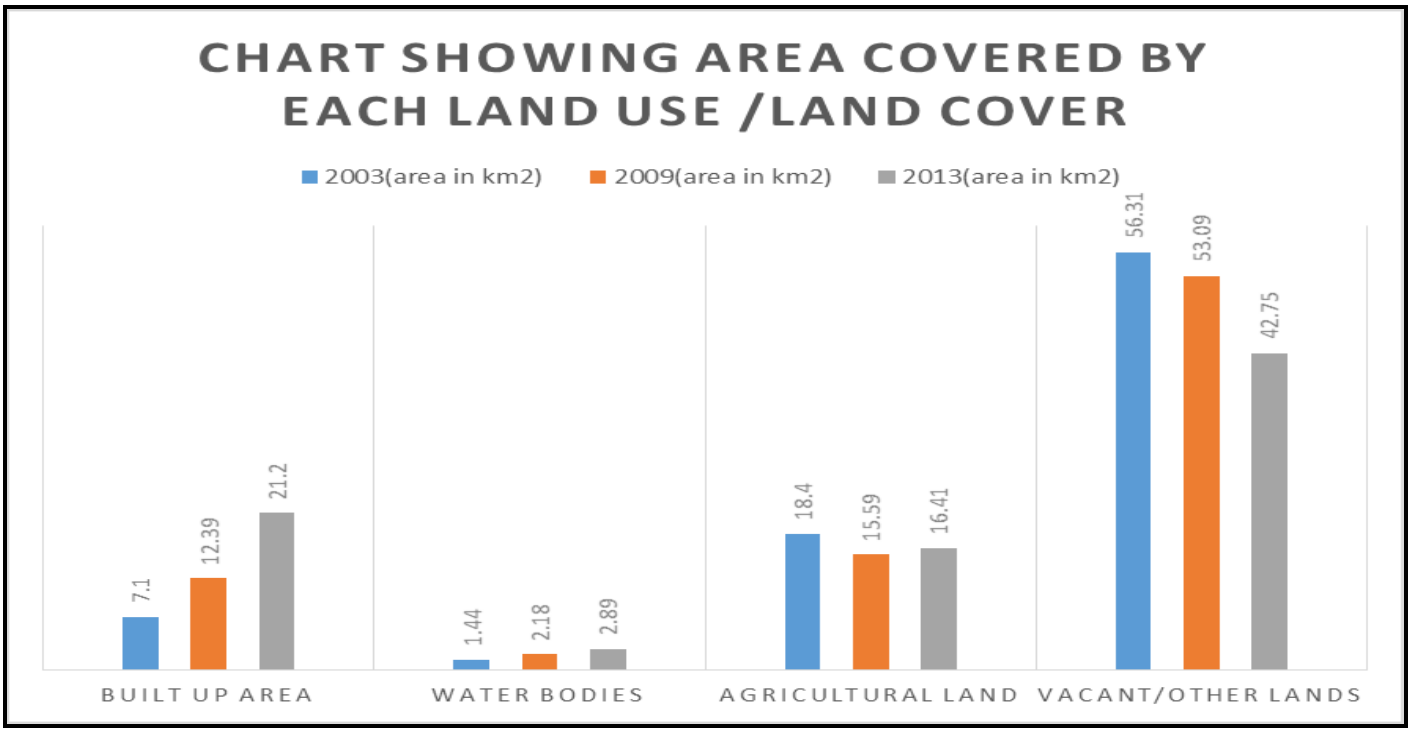

Figure 0:7Area Covered by Each Land Use/Land Cover

A chart showing area covered by each of land use/land cover over the ten years timeline. Built up area has grown from 7.1 % to 21.2 % over the ten years while vacant land reduces from 56.3% to 42.7 %. Water bodies have increased from 1.4% to 2.9% due to creation of artificial dams in the region.

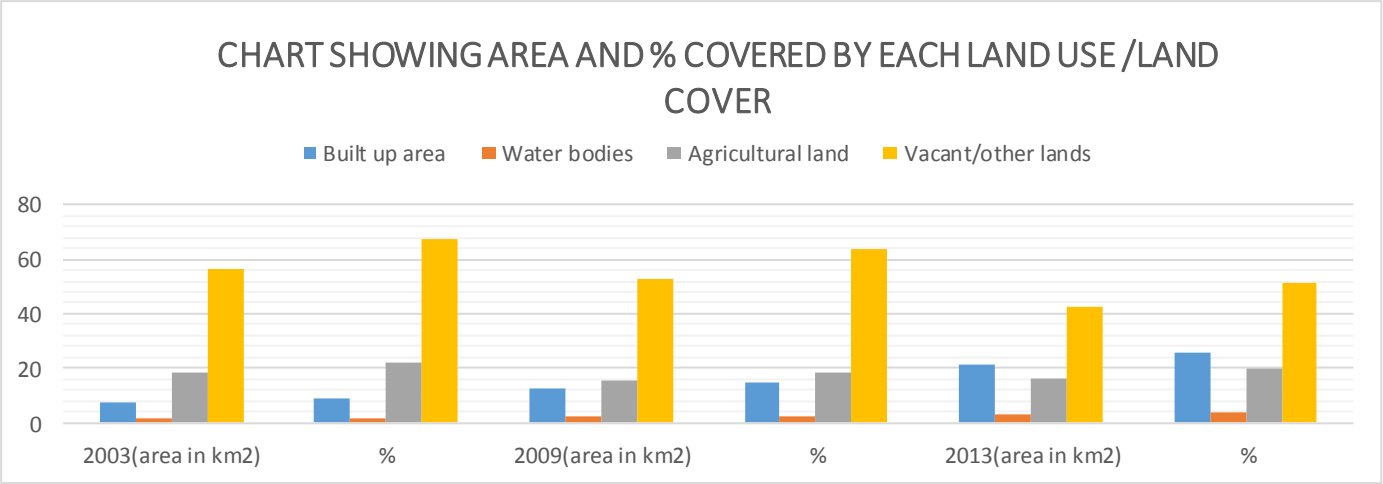

Figure 0:8 Area and Percentage Covered by Each Land Use/Land Cover

A graph showing total area occupied by each of the four parameters land use/land cover for the period 2003 to 2013.

4.1.3 Urban Sprawl

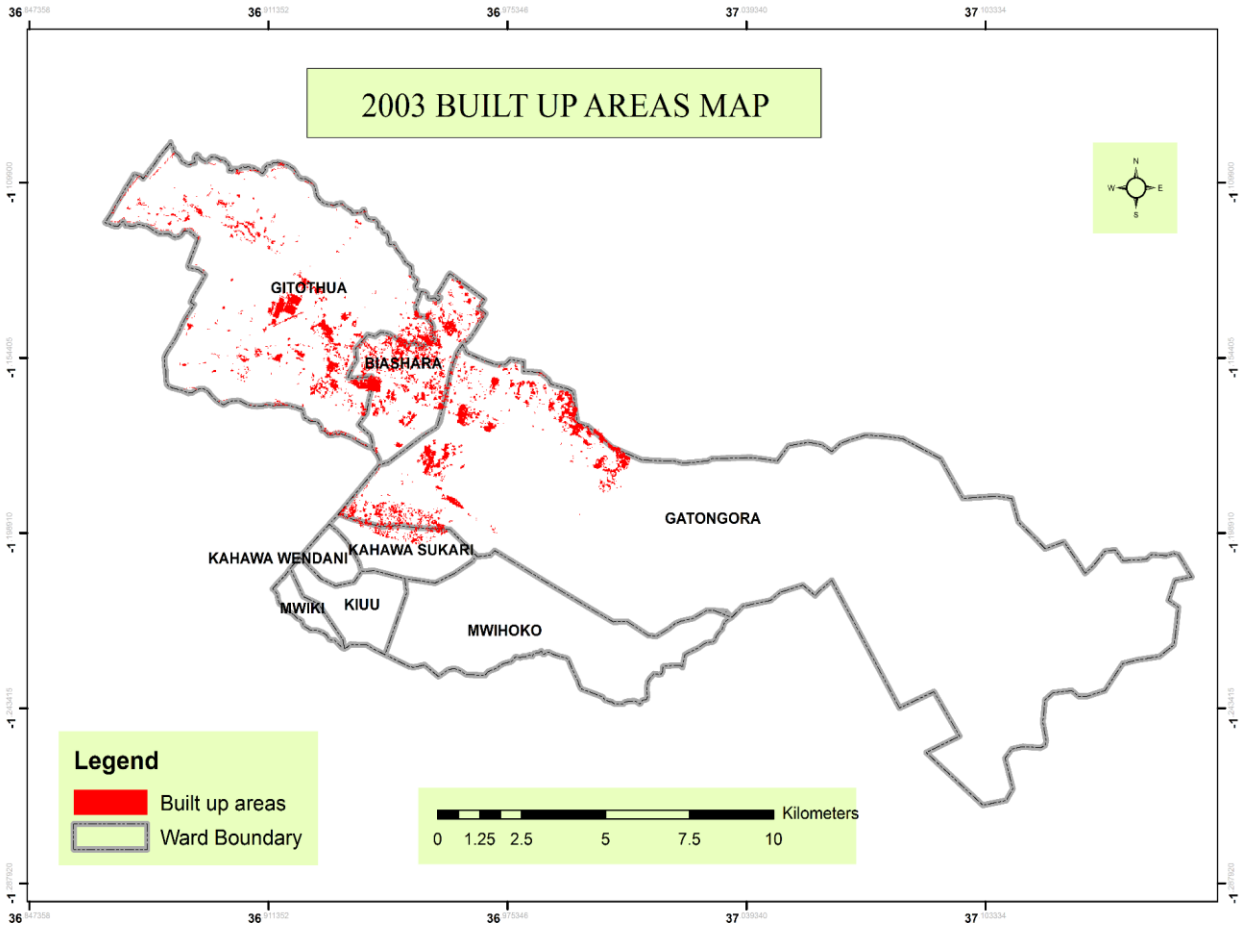

Figure 0:9 Built-Up Areas in Ruiru Town -2003

Urban sprawl was assessed by taking closer look on the changes of Built up area in the region and the form of growth it takes.

As single use map showing spatial extent of buildup area in Ruiru town by 2003. This development shows both clustered and linear forms of sprawl.

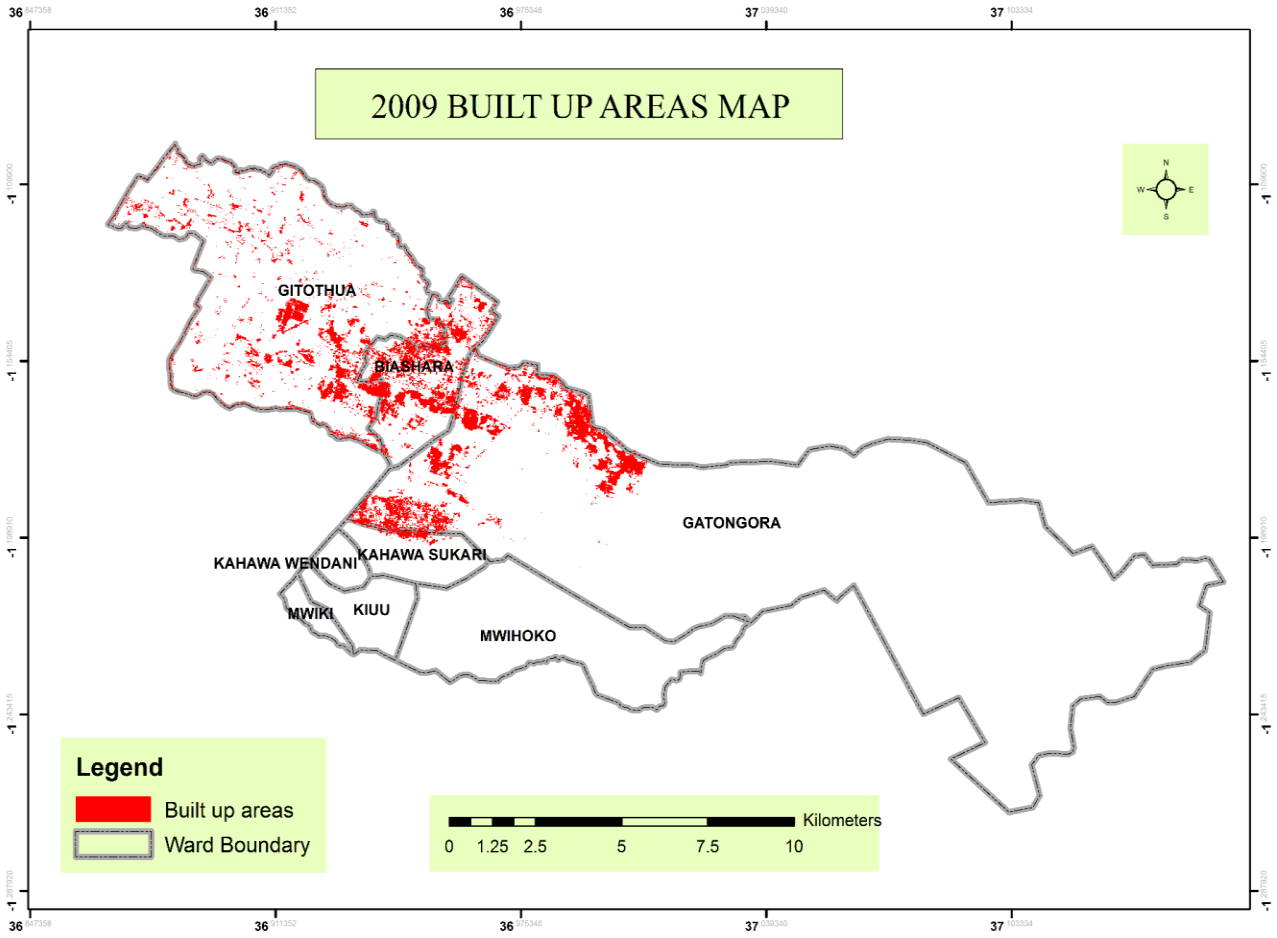

Figure 0:10 Built-Up Area in Ruiru Town -2009

A single use map showing the spatial growth of Built-up area by the year 2009. Compared to the previous years, this map shows more concentrated linear and scattered settlement in Ruiru town.

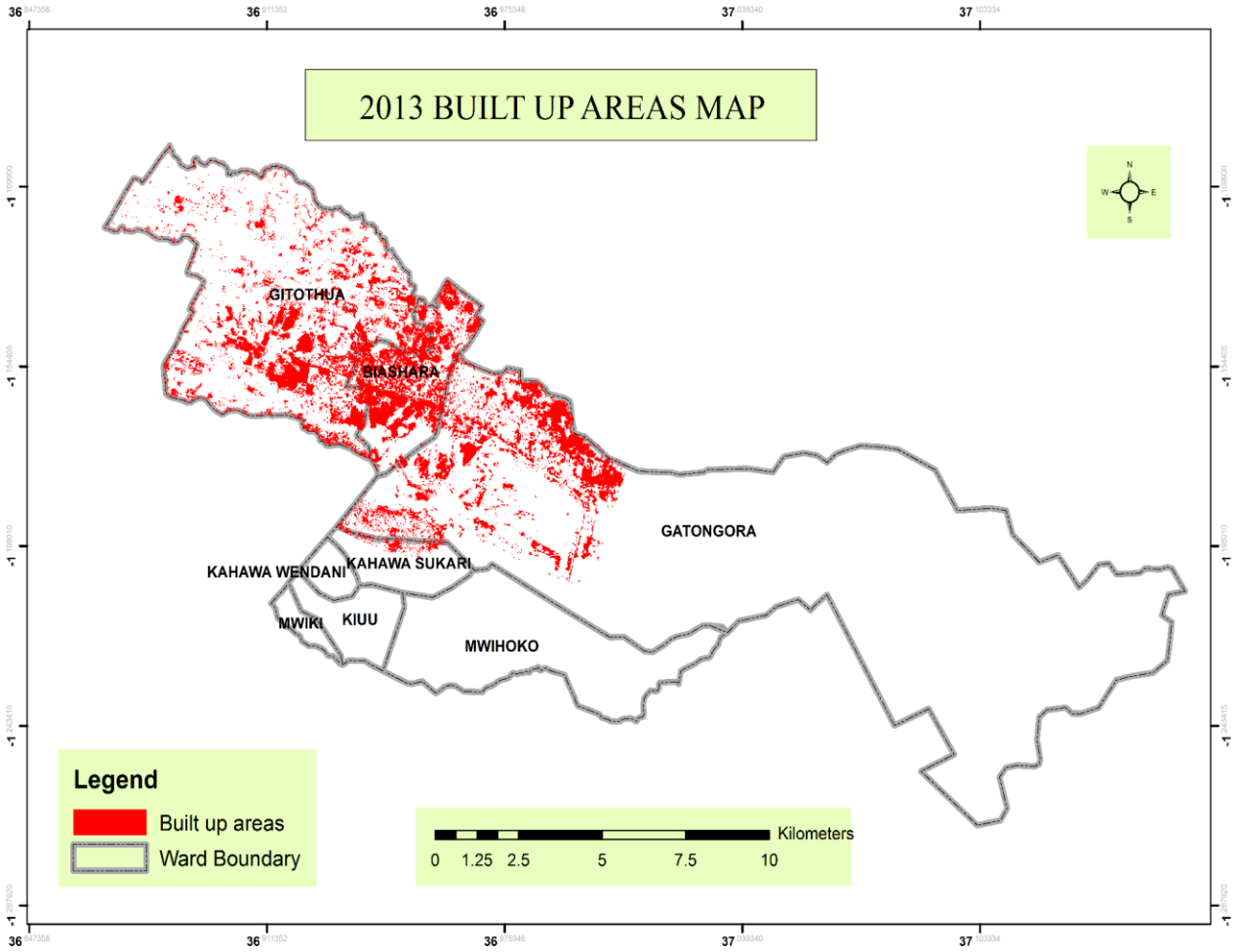

Figure 0:11 Built-Up Area in Ruiru Town -2013

A map showing detailed patterns of spatial growth of urban sprawl indicated by Built-up area in 2013. As seen in the map, there is concentrated settlement in clustered form and also in linear form. The growth has spilled over even to the nearby wards by this time which can be associated to population increase and good infrastructure e.g. roads.

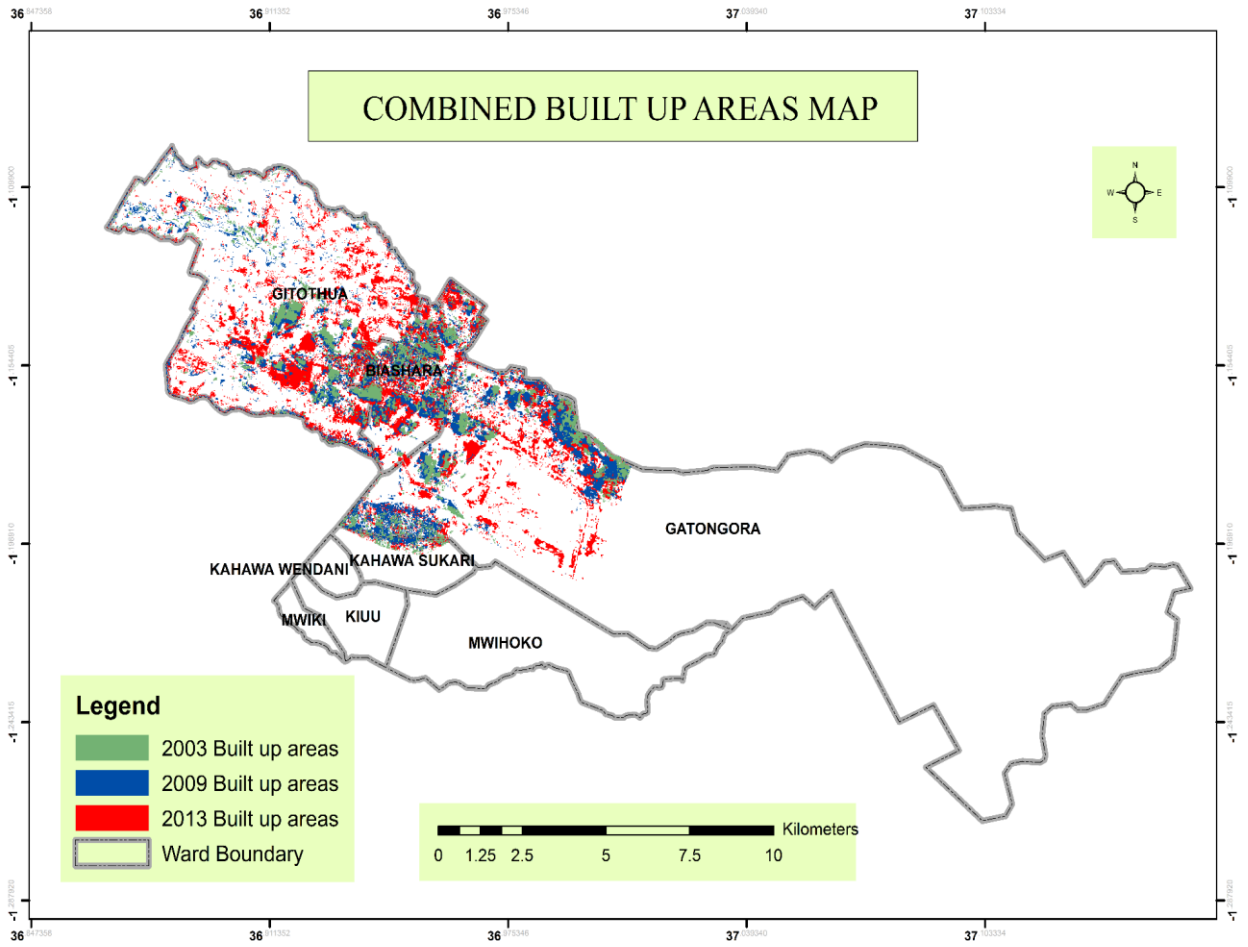

Figure 0:12 Combined Built- Up Area Map (2003-2013)

This combined overlay analysis map shows the combined Built up area for the year 2003 -2013. The green part shows the area that was Built-Up in 2003, the blue regions show the Built-Up area by 2009 and the red region shows the area that was built up by the year 2013. There is concentrated settlement by 2013 in Kahawa, Gitothua, Biashara and Gatongora wards. A clear sprawl taking a leaf frog pattern can be seen in Gatongora ward and this can be attributed to land ownership and availability.

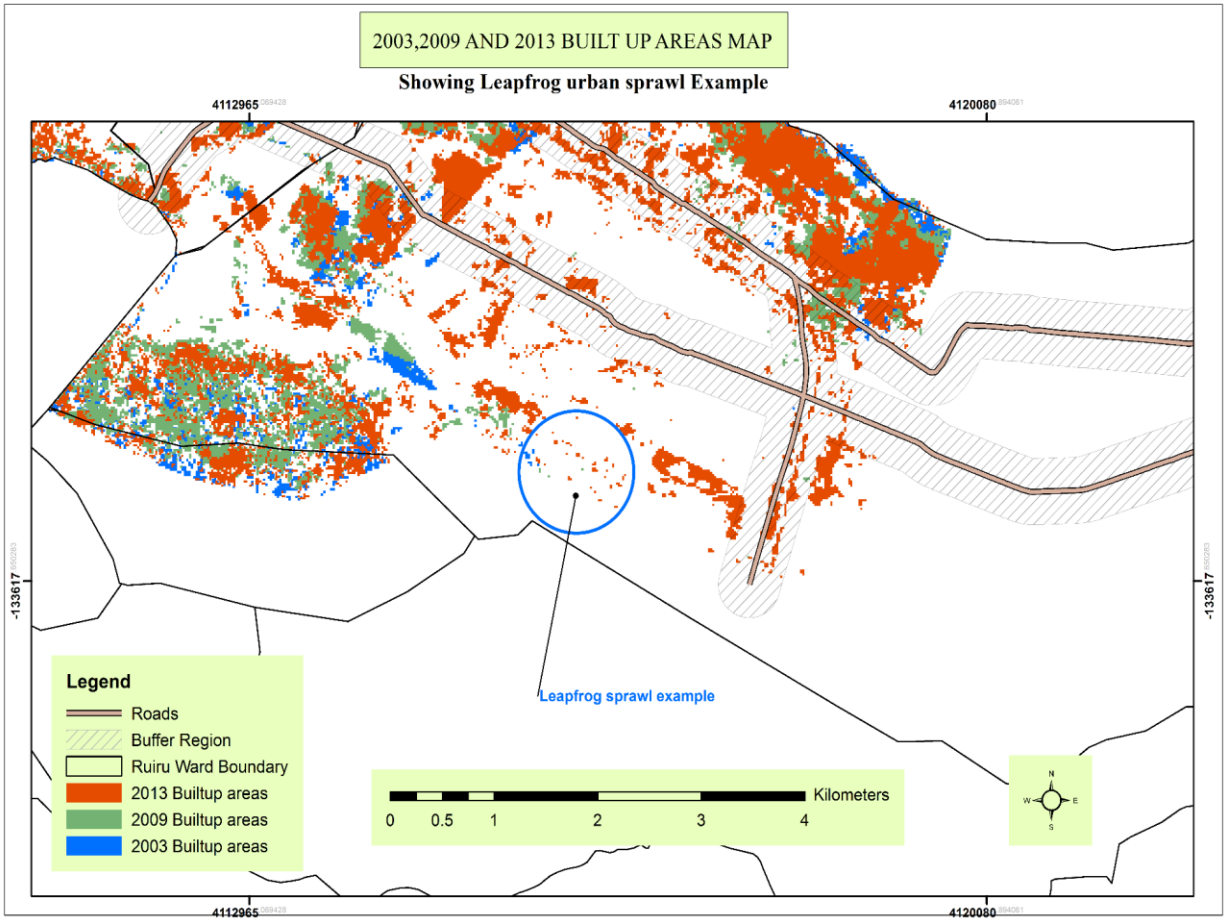

Figure 0:13 Leapfrog Urban Sprawls in Ruiru Ward

A map showing leaf frog urban sprawl in Ruiru Sub County. This is hugely witnessed in Gatongora ward as a result of the eastern by pass and land availability.

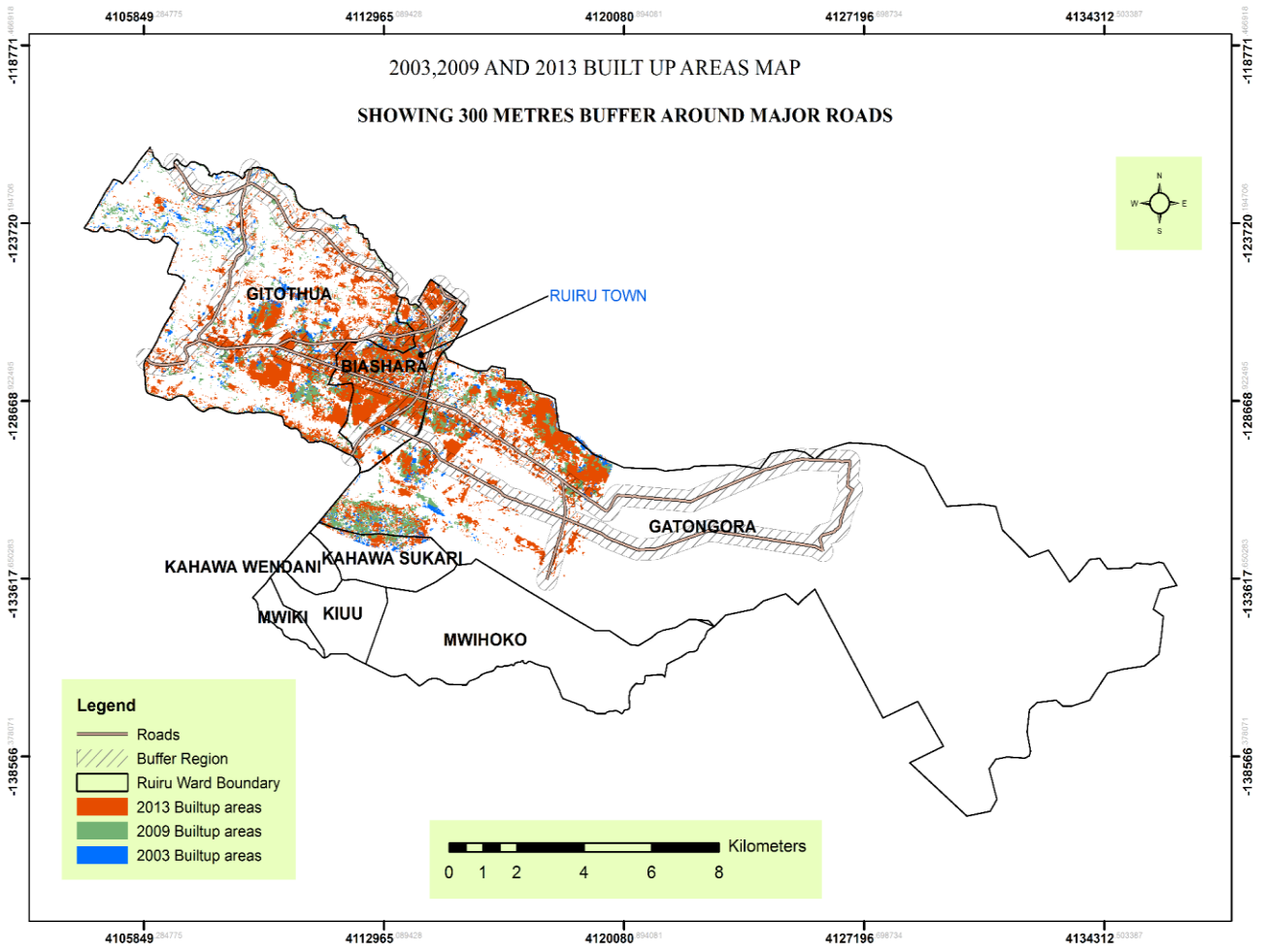

Figure 0:14 Built - Up Area in Ruiru Town within 300M Buffer Zone

Manipulation of GIS data revealed basic spatial patterns of urbanization over the time period between 2003 and 2013. A buffer zone of 300M was created to study the linear sprawl along major roads and around Ruiru town.

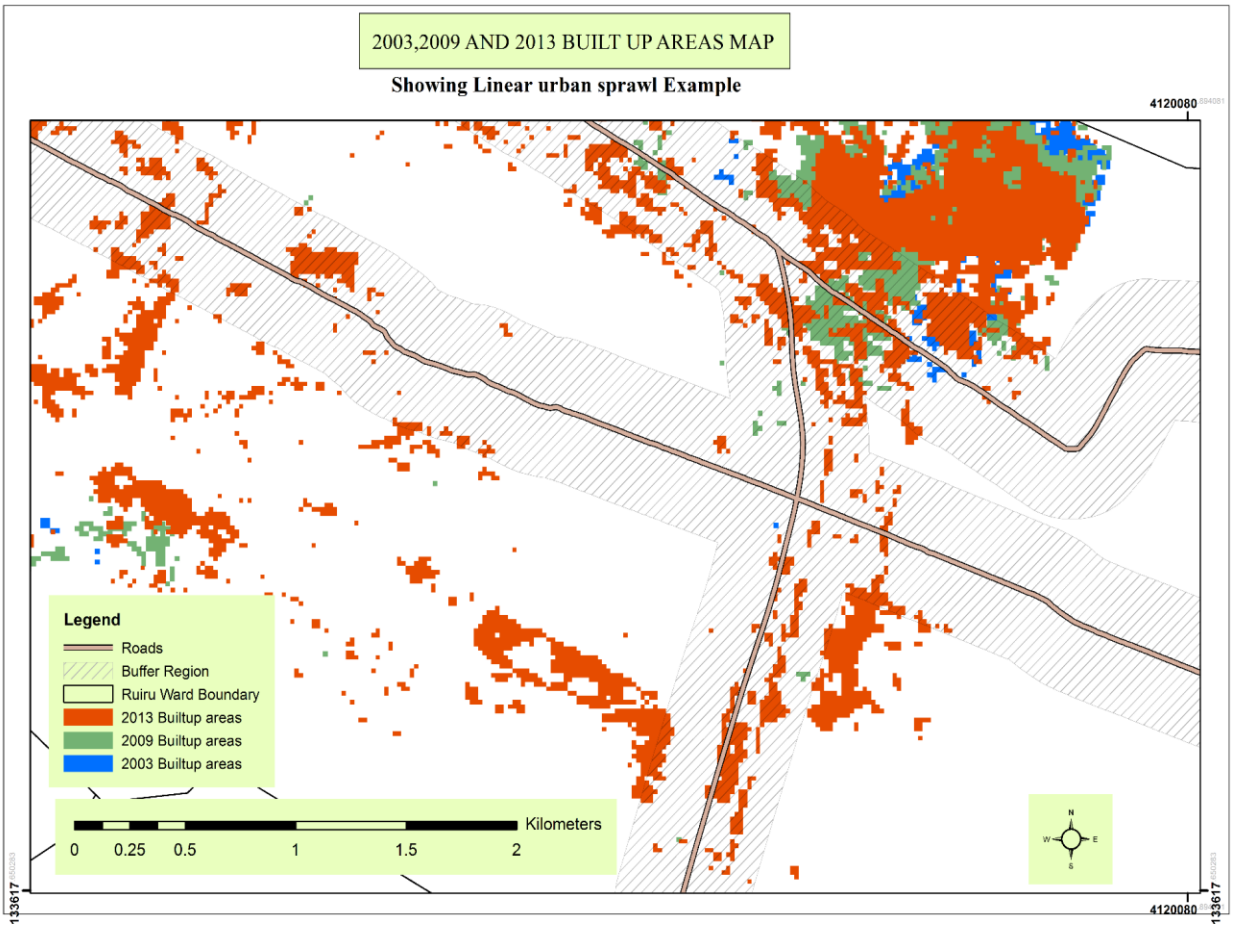

Figure 0:15 Linear Urban Sprawl along Eastern and Northern by-pass

A zoomed view of linear settlement in the ten years period as it majorly occurred along the main roads. This is clearly seen along the northern and eastern by passes and also along Thika superhighway. Much of these developments have occurred within 2009-2013 period, which has seen major infrastructural improvement in the region.

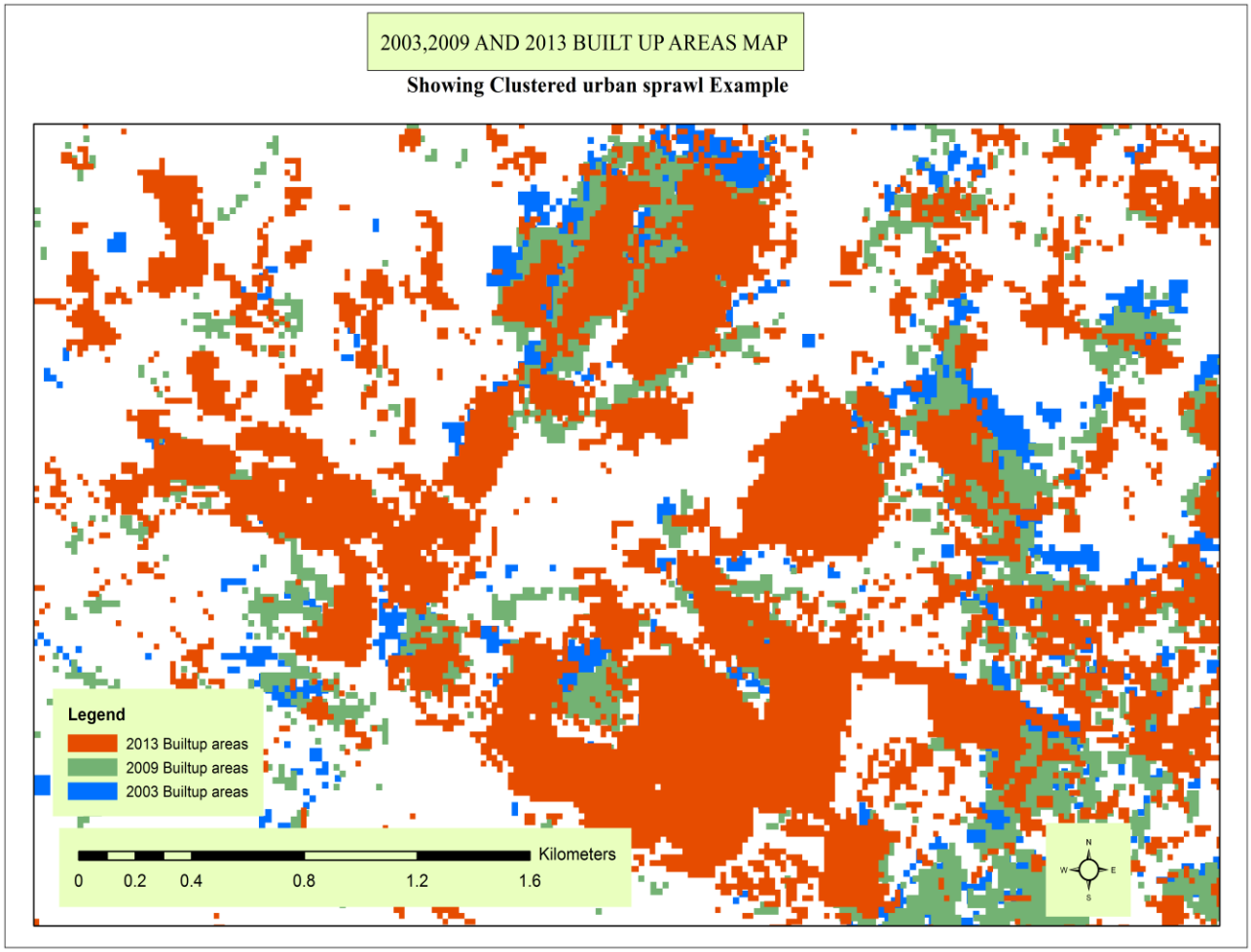

Figure 0:16 Clustered Sprawl pattern in Biashara Ward

A zoomed view of Ruiru town within the ten years shows some significant clustered settlement forms that are mainly found within the Biashara ward. This is because of increased population and growth of the original town and the industries around Ruiru town. With increased population within the period 2009-2013, there is increased population density per square kilometer in the area around Ruiru town.

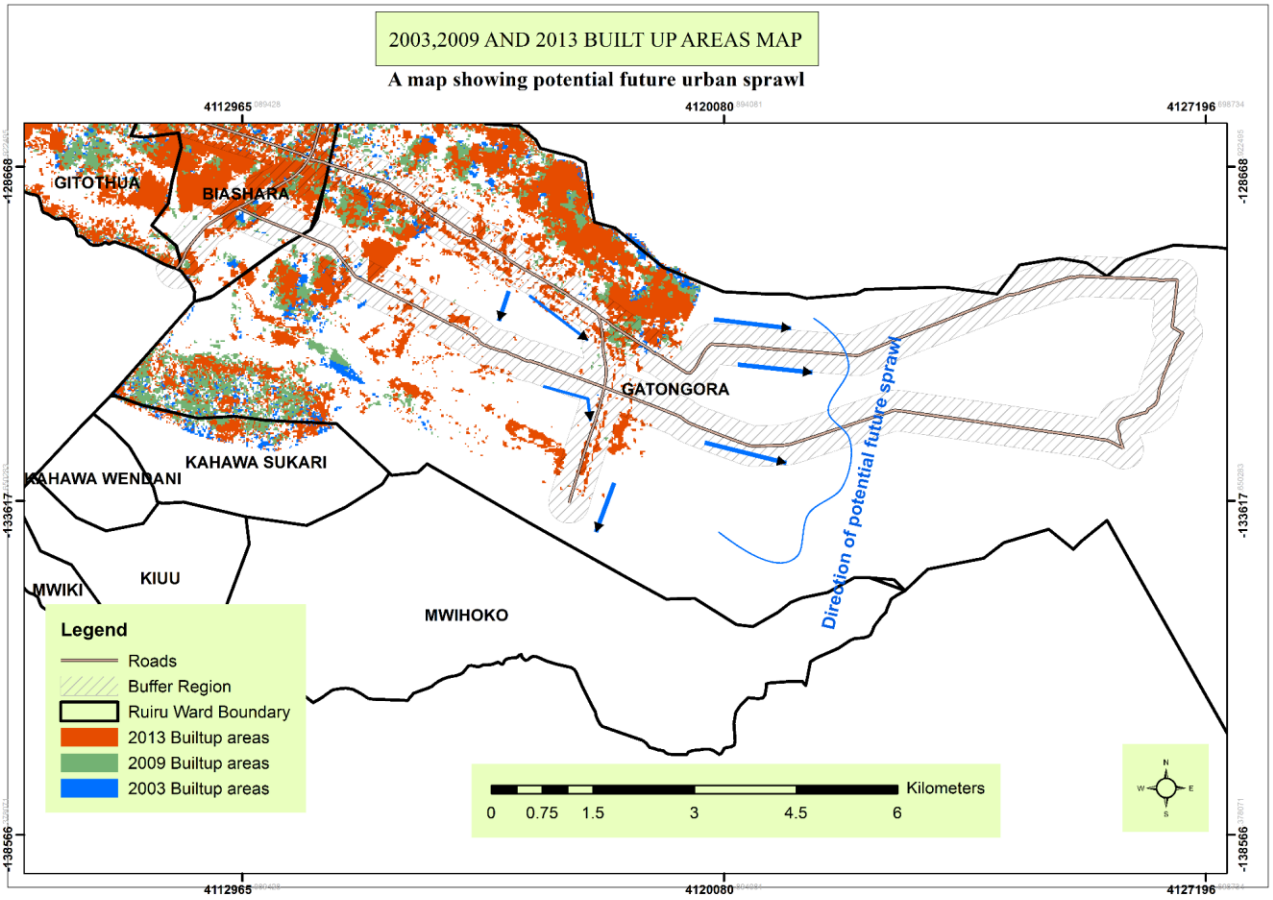

Figure 0:17 Potential Future Urban Sprawl

The maps of urban or built-up land cover show that new urban growth has occurred significantly within the study area. The percentage of undeveloped land to urban ground-cover change over the period between 2003 -2013 time period increased by almost 15%, a great deal of change that provides a strong chance that a substantial amount of urbanization in Ruiru town occurred over the period . By including road data, it is easy to visualize clearly where patterns of linear sprawl were taking place. Leapfrog patterns of sprawl appeared to be somewhat disconnected from other areas of existing or new urban growth areas. Cluster patterns of sprawl appeared to be part of existing built up land around Ruiru town. Cluster patterns also appeared to grow out of what was once a leapfrog pattern of development in some areas.

However, the patterns of sprawl represented in this research are not exclusive of built - up area changes, that give measurements of the density of new growth areas and display the connectivity and fragmentation of those new growth areas such as Gatongora. The maps on population

density are important in showing where urban land density increased over the period. There is a clear increase in the density of urban land to the east west part of Ruiru town, Kiambu County. However, increases in urban land density are apparent throughout the study area. The population is highest in Kahawa Ward and lowest in Gatongora ward.

4.2 Impacts of Urban Sprawl

4.2.1 Demography

According to the census report of 2009, Ruiru town had a population of 238,858. This is the most populous town in the entire Kiambu county and it's projected that about 299,067 people will be living in the town by the year 2017. The availability of good transport system opening Ruiru to nearby towns and the capital city, Nairobi puts this town and its environs in a better position for demographic spill in the near future. The adoption of the new constitution in the year 2010 in Kenya has seen many services getting devolved to the county governments and the implication of these is a lot of services are available to the people.

There is a close relationship between urban growth and demographic changes. Ruiru town has attracted high population due to its urban development capacity. The town is the home of some leading industries in the country which include Devki limited, Spinners and Spinners, Maisha Mabati among others. Availability of these companies serves as the tie note connecting other activities to emerge in the town and its environs. Other contributing factors to population increase include availability of good institutions such as Kenyatta university main campus and Ruiru campus, other tertiary Colleges, government institutions among others. These new populations come with new needs and new preferences hence the form of urban sprawl will take the nature and the desire of the age group. With the new system of governance, Ruiru Sub County is headed by a Sub County administrator who is based in Ruiru town. In an interview with the Sub county head, he revealed the potential of the sub county to grow and achieve its population projection by 2017. Among the 12 sub counties in Kiambu County, Ruiru Sub County has the highest population followed by the neighbouring Thika Sub County. According to the Sub County Planner, this is due to the strategic location of the town and availability of viable economy activities.

Table 0:4 Population Projections by Sub County (2009-2017)

POPULATION PROJECTION BY SUB COUNTY (2009-2017)				
SUB COUNTY	**2009 (CENSUS)**	**2012 (PROJECTION)**	**2015 (PROJECTION)**	**2017 (PROJECTION)**
GATUNDU SOUTH	114,180	124,223	135,149	142,962
GATUNDU NORTH	100,611	109,460	119,088	125,972
JUJA	118,793	129,241	140,609	148,737
THIKA	165,342	179,885	195,706	207,020
RUIRU	**201,986**	**219,752**	**239,080**	**252,901**
GITHUNGURI	147,763	160,760	174,899	185,010
KIAMBAA	145,053	157,811	171,691	181,617
KIAMBU	108,698	118,259	128,660	136,098
KABETE	140,427	152,778	166,216	175,825
KIKUYU	125,402	136,432	148,432	157,012
LIMURU	131,132	142,666	155,432	164,187
LARI	123,895	134,792	146,648	155,125

Source: Kenya National Bureau of Statistic (KNBS)

During the field research and data collection exercise it emerged out that, Devolution of services has enhanced more and more development to take place with a lot of ease in the sub counties. The Sub County planner highlighted the confidence of many developers in the administration and how application for developments has improved with time. The underlying problem of population growth, improved lifestyle and a large population of young people is the need for better housing.

Ruiru Sub County has witnessed urban sprawl in its Wards at an alarming rate. Indeed, Biashara Ward in Ruiru Sub County is among the most populated town in the Country with about 4837 people per square kilometre. This can easily be seen in the population density per each ward according to its size as shown below.

Table 0:5 Ruiru Sub County Wards Population Information (2009)

RUIRU SUB COUNTY -WARDS INFORMATION				
WARD NAME	**WARD POPULATIION**	**WARD AREA (sq.KM)**	**POPULATION DENSITY(P/sq.KM)**	**POPULATION PERCENTAGE**
GITOTHUA	18,083	20.70	873.57	8.953
BIASHARA	41,596	8.60	4836.74	20.594
GATONGORA	13,807	112.90	122.29	6.836
K/SUKARI	8,744	4.40	1987.27	4.329
K/ WENDANI	16,711	1.10	15191.82	8.273
KIUU	46,351	4.90	9459.39	22.948
MWIKI	44,760	1.50	29840.00	22.160
MWIHOKO	11,934	25.80	462.56	5.908

Source: Independent Electoral and Boundary Commission (IEBC)

Urbanisation continues to take place in the entire Sub County and more and more people continue to move in to the towns within Ruiru Sub County to fight necessary services. Therefore, there is no doubt that the rate of urban sprawl in Ruiru Sub County is proportion to the rate of population change. Gatongora is the largest ward in Ruiru Sub County with a total area of about 113 square kilometres representing 63% total land of the Ruiru Sub County. The larger part of the ward was undeveloped land until recent when major development activities started emerging in the area. Indeed the Planner to the Sub County highlighted that, about 40% of the development application either to construct residential or commercial properties are mainly from Gatongora Ward. Increased population continues to exert pressure on the land. This has led to increased cost of development in the sub county. Many places that where zoned for single dwelling developments have been converted to multi user residence. As witnessed near the town many apartments are coming up to accommodate many people within the small available land.

Plate 0:1Upcoming Developments in Gatongora Ward

As witnessed in many parts of the Sub County, population pressure has led to increased development in the undeveloped land which is largely found in Gatongora Ward. The effect is not only felt on land, but also in the environment and natural resources. One outstanding problem was the increased hardpans due to compaction effect of anthropogenic activities. In addition there is increased production of refuse and other waste that has resulted to greater harm to the environment. As witnessed in various regions, many developments are happening without necessary infrastructures such as roads, sewers and drainage systems. This has resulted to negative impact event to the residents.

Plate 0:2 Urban Sprawl Effects on Land

There is an urgent need to formulate development control mechanisms in the sub county in order to accommodate the emerging challenges. In addition it is necessary to develop local monitoring system to account for changes in demographics and advice accordingly on how to address the challenges.

4.2.2 Economic

Urban growth has both positive and negative impacts on the economic aspect of a place. The same applies in Ruiru Sub County where heavy industrial activities are found and a lot of urban related activities. To figure out the impact of urbanization on the economy, this study focused on the income generation from the sub county residents and the opinion of the experts interviewed.

Table 0:6 Ruiru sub County Revenue (Urban Development only)

REVENUE PROJECTION FINANCIAL YEAR 2014/15			
SOURCE	**DEPARTMENT**	**ACTUAL 2013/14**	**TARGET 2014/2015**
Ground rent-other years	Planning	70,745.00	90,000.00
Sub-letting	Planning	106,500.00	120,000.00
Property certification	Planning	209,620.00	220,000.00
Bus park Toilet Fee -Ruiru	Planning	87,940.00	120,000.00
Land rates -current year	Planning	1,001,940.00	1,500,000.00
Land rates penalties	Planning	120,933.00	200,000.00
Land amalgamation fee	Planning	25,640.00	30,000.00
Land rate other years	Planning	6,402,892.00	9,500,000.00
Charge of ownership	Planning	10,100.00	15,000.00
Application fee for way leave	Planning	350,000.00	400,000.00
Plot sub division fee	Planning	2,636,115.00	3,000,000.00
Ground rent other years	Planning	45,625.00	50,000.00
Ground rent current year	Planning	25,290.00	30,000.00
Other property charges	Planning	10,595.00	12,000,000.00
Plot transfer fee	Planning	3,569,500.00	5,000,000.00
Application forms	Planning	1,579,045.00	2,000,000.00
Business subletting fee	Planning	380,000.00	400,000.00
construction of residential	Planning	1,677,170.00	2,000,000.00
PPA 1 & 2	Planning	476,000.00	500,000.00
Structural approval fees	Planning	2,232,000.00	2,500,000.00
Building plan approval fee	Planning	16,264,056.00	19,000,000.00
Building inspection fee	Planning	11,274,600.00	13,000,000.00
Land amalgamation fee	Planning	25,640.00	20,000.00
TOTAL		**48,581,946.00**	**71,695,000.00**

Source: Finance Department: Ruiru Town, 2015

Several models have been deduced in the history to explain how various forces underlying urban growth contribute to urban sprawl. Given the increasing population, the increasing income and falling commuting rate, there is inevitable expansion of towns and urban centres. This is the case witnessed in Ruiru town where major economic activities are shifting from primarily agricultural activities to secondary activities such as commercial, industrial and Built up residential estates. As shown in the tale above, there is major income to the county government coming from such development activities within the urban centres. In addition, there is increased income per household given that the high population in Ruiru Sub County is a middle class group. The amount received from planning related sources accounted for more than a third of the total revenue collected in 2013/2014.

According to the sub county financial officer, the sub county has already achieved its financial income projection budget of about 200 million shillings. He associated this achievement to better services the people are receiving from the County government in an event where people are motivated to pay their taxes and arrears in exchange for better services. Although majorly the income comes from five leading wards out of the eight, the information clearly indicate s the growth of the towns and the potential the town has towards expansion with a lot of wealth in circulation.

The town expansion has followed the indication of economic viability. During an interview with the Sub county planner, it emerged that land value had appreciated significantly in Ruiru town and generally in the entire sub county. This is due to better services and infrastructures such as the Thika Superhighway, Northern and Eastern by passes among other services. Many developers have put a lot of massive development projects in Gitothua ward due to its location and economic viability. This includes potential Tatu city that has provoked many land owners to change their land from agricultural land into residential cam commercial land use. However in order to prevent market failure and conserve agricultural land, the Sub County and the entire County Government has put in place development measures to control the extend of land sue change. The planning department has adopted a 10% rule that limits development to only 10 % of the total land from the original use. This move has controlled development in Gitothua area hence helping in minimising sprawl menace.

Plate 0:3 Controlled Developments in Membley Region

4.2.3 Environmental

Solid waste management is another challenge that is directly related to urbanization and urban sprawl. While many cities across Africa struggle with the problem associated with waste management, both solid and liquid, Ruiru town is not any better. According to the Sub County planner, a lot of solid waste is generated from the towns. The greatest challenge is that the sub county doesn't have any solid waste landfill thus; all solid waste is transported daily to the nearby dubbing site at Thika. As the population continues to increase, there is significant increase in total mass waste per household, posing a greater challenge to the town management. To address this problem, the county government is planning to set up a waste recycling centre around a suitable place in Gatongora area.

Another problem is associated with liquid waste management. Allot of liquid waste is generated by industries, institutions and households in the Ruiru suburbs. The county authorities have responded to this challenge through improved drainage channels and collection system. In the national level, the government has set up a multibillion project to collect, recycle and clean liquid waste from the county and the neighbouring towns. This project set out in Gatongora area will serve as one of its kind in solving liquid waste challenges in Ruiru town. This is an added advantage to developers and many land owners who have an advantage on how to channel their

waste. According to the county engineer, this project will help in reducing environmental degradation especially non- point pollutants emitted by companies and farms.

Plate 0:4: Section of the Ruiru Sewerage Works under Construction

Ruiru Sub County enjoys a great network of infrastructural connection that opens the towns in the locality to other parts of the country. There are greater achievements in terms of transport infrastructure that have promoted the growth of town, though much of it is not planned. The construction of northern bypass and eastern bypass which traverses Ruiru Sub County has promoted a lot of linear sprawl development. High-rise buildings are emerging along these roads with major investment in commercial and residential activities. One of the greatest impacts of urban sprawl resulting from improved transportation in the Sub County is uncontrolled development especially along the bypass. Since 2010, the area along Eastern bypass has attracted major investment of commercial buildings. A closer observation on the Google earth images since 2010 up to date shows a great land cover change along the major road routes.

Plate 0:5: The Junction of Eastern and Northern Bypass. Source: Google Earth

This sprawl has affected both the land and the environment. A closer study on Gitothua area revealed that, development has occurred even in to wetlands and river beds.

Plate 0:6 Human Activities encroaching into Riparian Reserve in Gitothua Ward

According to some developers engaged in Gitothua ward, there is currently huge conflict of land use in the area due to increased demand for land. It emerged during this study that, land has appreciated significantly in the region and many people are willing to dispose their huge tracts of land for other uses other than agricultural. Subsequently, there is increased encroachment of reserved riparian areas along the rivers and even wetlands. Some construction have extended even beyond the required reserve perimeter posing a great danger to environmental degradation and loss of biodiversity.

Plate 0:7 An Upcoming Mall and Farming Activities Near a Stream (KU Unicity)

4.3 Discussion of the Results

There is a clear increase in the amount of urban land from 2003 to 2013. The increase in built-up land use was visible with a cursory analysis of reclassified maps of the Ruiru Sub County and confirmed through further calculations showing increases in the percentage of urban land. In 2003 urban land constituted approximately 8 % of the study area. In 2009 urban land accounted for approximately 9 % of the study area and in 2013 it constituted about 17% of the land in the study area. The initial review of land use / land cover maps and the fact that urban land increased by approximately 16% over the ten year time period, facilitated the idea that urban sprawl patterns would be detected within the study area because without any new urban growth, it is not possible to have any urban sprawl. The 2003 Land Cover Data set is based on the impervious

cover of the land, which indicated urban or built-up land for the purposes of this research. The classification in 2003 is based more on a traditional classification of satellite imagery, where the 2009 data are based on imperviousness of the land. This study used four classes from each year to determine the extent of sprawl within the study area. From 2003 to 2013, the differences in land cover / land use classifications did not justify discarding this data. I was comfortable using these classes to represent urban land because they could only represent a built-up or developed landscape. Maps generated from the data collected clearly shows a leapfrog growth in some areas of the study area especially in the industrial zone. There is however, more cases of linear growth and sprawl incidences especially along the main transportation links.

In conclusion it was successful in this research to use GIS and Remote Sensing techniques to map extend of urban sprawl in Ruiru Town over the ten years.

Analyzing urban sprawl patterns in this study made it clear to assess the causes and effects of urban sprawl in Ruiru town. A quantitative survey analysis revealed that a major cause of urban sprawl is the increasing population in the town. In addition, the improved transportation routes connecting Ruiru town to its neighbourhood has played a key role in increased patters of linear sprawl.

The impact of urban sprawl is direct related to urban growth problems in the sub county. As witnessed in the study area through the observation and photography interpretation, it's possible to conclude that urban sprawl has resulted to increased pressure on the natural land. Also, urban sprawl has negatively impacted agricultural land, resulting to conflict of interest in land uses between agricultural uses and Built up urban uses.

Urban sprawl as noted has a detrimental effect of natural resources. Human activities occurring in a limited land area leads to stress on that land parcel. This was noted on the populous regions where land surface is high compacted and hardpans forms. In events of shallow rains, there are incidences of poor infiltration and drainage. Also, human activities encroaching the riparian reserve near the main water bodies' results to water population and contamination of aquatic ecosystem. In conclusion, urban sprawl is inevitable in the course of urban growth. There is need to put mechanism in place to control development and settlement in urban areas in order to protect other interest that may be not factored in by developers. The county government has adopted a sustainable method in term of providing technical knowledge in all matters related to urbanism. The government of Kiambu has employed professionals in all fields to help in

planning and providing service right from the grass root. This move has helped build trust to citizen and ensure developments are monitored even up to ward level. A sub county planner is in charge of development approval in the Sub County thus, monitoring development at this level will be easy and effective.

This study used population density analysis and current pattern of development to show potential areas of future sprawl and the direction. A map was then generated to show the spatial truth of this phenomenon and how it may occur in the future. This is clearly shown in the maps in the previous chapter where a lot of current development are been witnessed in Gitothua and Gatongora wards.

Future developments will take place in areas that have land to support the population and urbanization. No doubt this phenomenon has started to occur in Gatongora ward and much more is expected. The vastness of these developments may merge the Built-up areas in other words the towns with the rural hinterlands. Many owners of land in the area have sub divided their lands already into plots ready to dispose them for cash. This calls for multiple ownership of land parcels and in the event of lack of development control, unwanted Neighbourhood will start to emerge in the vast land.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The analysed results show that urban land use in Ruiru Sub County is fast growing with disordered spatial configuration taking place indicating a typical sprawling tendency. Urban growth has both positive and negative impacts to a town. The following specific sprawl features are identified: obvious land fragmentation and irregularity of land use, unsuccessful enforcement of land use planning; unadvisable pattern of land use growth with typical discontinuous development, strip development and leapfrog development; high densities of land use, high population density; and other negative impacts on agriculture, environment and city life. The increased land fragmentation and conversion is as a result of anticipated higher returns over a short period of time once commercial and other urban land use activities are undertaken. This has come at a cost as most of the agricultural land is now converted to urban land use, meaning less agricultural productivity.

The high population densities have meant poor services and with un-matched infrastructure development. Waste management both solid and liquid waste; is a big problem in the Sub County with no designated waste disposal site. The lack of a conventional sewer line to manage waste water means a lot of reliance on septic tank and pit latrines/toilets. This in turn has led to environmental pollution and contamination of both surface and underground water sources leading to waterborne diseases. There is also encroachment on riparian reserves and other water catchment areas as well as clearing land for development leading to low water table and eventual water shortages and increased dry periods. The increased urbanization has led to more developments meaning less infiltration of water and increased surface runoff. This has led to erosion and thus silting of rivers as well as creation of heat islands.

5.2 Recommendations

It is important to evaluate land use changes in order to assist in anticipating the impacts associated with change and contribute to an understanding of productive environmental sustainability. It is necessary to understand the agents of change; beneficiaries of change as useful indicators in planning. However, for effective and functional urban growth management, data is required on changes taking place in our urban areas. Such data is vital to urban development and prevention of uncontrolled expansion and its consequences. For instance,

land use changes require continuous updating of lands and their analysis so as to determine the rates and direction of city growth; such is the case in Ruiru sub county.

It is worth noting at this point that there are varied policies existing in Ruiru Sub County for managing urban growth and most of the policies are centered on urban renewal, protecting open spaces and redevelopment etc. Therefore, armed with the knowledge and findings from projects and research such as this, the development control and the necessary planning authorities should aggressively swing into action to bring orderly and planned development.

There is also need for political will to implement development control measures. Strict adherence to development control/land use policies, urban renewal, improved coordination between land use planning and decision on urban growth and changes, Local development and public regulation of urban sprawl are some of the recommendations of this work. Poor policies are the sole or dominant cause of urban sprawl; new policies designed to arrest or mitigate sprawl are therefore needed.

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APPENDICES

Appendix 1: Definition of Terms

Urban Sprawl: in the context of this research work, urban sprawl refers to any uncontrolled development on the urban land that involves change of the current land use. It is a phenomenon that is indicated by several factors among them; loss of agricultural land to Built up areas, loss of natural resources, loss of wetlands and ecosystems, increased dense urbanization and increased impervious surfaces. It is an occurrence mostly referred to as undesirable due to its negative implication on economy, environment, social and aesthetic of a place.

Urban Growth: refers to increased development and expansion of urban areas signified by increased Built up areas, increased population and major changes in the land use and land cover. Urban growth can be measured by several factor and indicators. These include population index, percentage of Built-up area and imagery land use and land cover change (L.U.C.C).

Urbanization: this the process of growth and development of urban areas replacing the natural land uses and the agricultural land practices. Urbanization is characterised by increased shift of lifestyle from the rural practices such as agriculture and forests to secondary land uses such as Building, high density residential, infrastructures and improved utility services.

GIS: is an acronym geographical Information system. It refers to the use of geo referenced data to visualize, question, analyze, and interpret cases in order to understand relationships, patterns, and trends on the land.

Remote Sensing: refers to the science and art of acquiring earth information without necessary being in conduct with the earth. This is done by receiving satellite images, recording them and then analysing them to generate information of a specific earth surface.

Appendix 2: Structured Interview

Issues to be addressed:

- Mandate/activities
- Performance: successes, measures and problems
- Objectives (pattern of growth, infrastructure & services, environmental management possible interventions)

No.	Area	Information
1	Town residents: Ruiru town	Income, land ownership, Employment, perception of urbanization and challenges of urban growth.
2.	Enterprises supermarkets shops hotels traders clubs Retail & wholesale, Open air market	Income, employment/labour force, customers, services and utility supply, urbanization challenges
3.	Environment Planning Revenue and Finance Office Enforcement	Sub- County expenditure, municipal services, disposal of municipal solid wastes, dump sites, hazardous waste facilities, and hazardous waste policies being implemented. Water and sanitation: water resources and supply, drainage network coverage, sewage treatment and sewage disposal, sources of sea water pollution, water quality monitoring and policies being implemented.
4.	County government Physical planning Energy and Infrastructure	Mandate, role and challenges. Service delivery and resources allocation Planning problems. Sources of energy, distribution and challenge Development projects, infrastructures and associated challenges

Appendix 3: Recommendation and Implementation Plan

OBJECTIVE	ISSUES	STRATEGY	ACTIVITIES	TIME FRAME			BUDGET	ACTORS
				ST	MT	LT		
1. **Use of GIS and Remote Sensing in Mapping Urban Sprawl**	Lack of Sub County Database	• Mapping of Resources • Land uses/Land cover Maps • Investment in basic GIS resources	• Survey • Prepare baseline maps • Purchase GIS tools and equipments • Training and recruitment of qualified personnel	✓ ✓ ✓	✓		10M	Sub county Administrator Sub County Planner Sub County Engineer
	Inadequate IT resources	• Invest in IT	• Digitize all Administrative units • Devolve services to ward levels	✓ ✓			50M	
	Poor resource management	• Put in place resource management mechanisms	• Mapping and documentation of resources	✓			20M	
2. Spatial Extend of Urban Sprawl in Ruiru Sub county	Uncontrolled Growth along in the sub county	Regulate Development. Impose development control mechanisms Land use Change Control	• Enact By- Laws • Enforce Physical Planning Act • Minimize Land use changes • Empower community on need for controlled development • Design and construct sanitary landfill		✓ ✓	✓	10M	Planner NEMA Private Sector Chief Engineer NGOs CBOs
	Scattered	• Control	• Zone land uses	✓			10M	Planning

	development occurring in Ruiru area	development/settlement in all Wards	• Control development standards					Department Engineering Department
	Linear sprawl along major transport lines	• provide guideline on development • Encourage public participation in implementing building laws • Control and discourage settlement on the road reserves	• Zoning regulation • Public participation • Settlement monitoring and control. • partnership with private developers		✓		20M	Planning Department Sub County building engineer Private investors
3. The Causes And Impacts/Effects Of Urban Sprawl In Ruiru Sub County	Increased population in Ruiru Sub County	Encourage decentralization	• control Taxation margins • Improve housing facilities outside the town centers • Devolve some services to ward levels	✓ ✓	✓		10M	Housing Department Planning Administration
	Economic growth and Service Delivery	Categorize revenue sources Monitor Financial channels and setbacks\ Public participation in Budgeting and Decision making Encourage Computerized Bookkeeping	• Sub County Revenue policy • Sub County Accounting system • Sub County Public forum • Promotion of social unity	✓ ✓			5M	Finance department Sub County administrator
	Infrastructural Problems within the	Improve access roads within the town	• apply Murram on all access roads within Ruiru town	✓	✓	✓	50M	Sub county Engineer Transport

	town	Improve sewerage system and drainage systems Parking space for motorists Walking footpaths and cycling lanes	• Expand the capacity of sewer lines and drainage channels • expand access roads to have space for pedestrians and cyclists					Department
	Loss of Water bodies and wetlands	Protection of riparian reserve	• On site buffer signs • Create strong enforcement units to protect ecosystems • empower people on the need to protect water bodies • Employ professionals in water related fields. • Planting buffer vegetation	✓ ✓	 ✓	✓	15M	Environment Department NEMA Private Sector\ CBOs •
	Loss of agricultural land to Build up land use	• To enhance urban agriculture • • To control Built up areas development	• Plan riverine agriculture • Impose development charges • Enforce development control regulations • Minimize land size convertible to secondary uses	✓	 ✓		50M 10M	• Agriculture department • Planning department
	Waste management problems	• Develop waste collections foci points Privatize the solid waste collection sector	• Map solid waste collection centers • Develop a Solid waste Disposal site • Create alternatives of handling waste e.g. recycling	✓	 ✓	✓	30M 15M	• Sub County Authorities • Private sector

Policy Framework	Poor planning regulation	• development of sub county development plan (to control development)	• Monitor all planning projects • Control land use change • Control all developments	✓	✓		20M	• Planning Department
	Enforcement of laws and policies	Strengthen institutions through capacity building and implementing laws	• Workers performance evaluation • separation of powers and independence in duty discharge	✓	✓		5M	Sub County Government