UNIVERSITY OF NAIROBI
SCHOOL OF THE BUILT ENVIRONMENT
DEPARTMENT OF ARCHITECTURE AND BUILDING SCIENCE

MANAGEMENT OF THE EFFECTS OF LAND USE CHANGES ON URBAN INFRASTRUCTURE CAPACITY: A CASE STUDY OF RUAKA TOWN, KIAMBU COUNTY, KENYA.

BY

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A Project Report submitted in partial fulfillment of the requirements for the Award of the Degree of Master of Urban Management in the Department of Architecture and Building Science, University of Nairobi.

2020

Declaration

This project report is my original work and has not been presented for the award of a degree in any other University or any institution of higher learning. No part or whole of this work may be reproduced or transmitted in any other form without the prior permission of the author and/or the University of Nairobi.

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Dedication

I dedicate this work to my parents for their endless love and for encouraging me to undertake the master's course and walking me throughout the journey. I extend my special feeling of profound gratitude to my loving wife Annette Kerubo whose words of encouragement and immense support that went all the way in motivating me to complete the work. I also owe a great deal to my sons Andrew and Allen for allowing me to utilize family time to conduct the research and giving me a hearty smile however late I got home.

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Abbreviations and Acronyms

BRT	Bus Rapid Transit
CBD	Central Business District
CSP	County Spatial Plan
e-DAMS	Electronic Development Application Management System
ETM+	Enhanced Thematic Mapper Plus
FCC	False Colour Composite
GIS	Geographical Information System
GoK	Government of Kenya
Ha	Hectares
ISUDP	Integrated Strategic Urban Development Plan
KeNha	Kenya National Highways Authority
Kerra	Kenya Rural Roads Authority
KM^2	Square Kilometres
KURA	Kenya Urban Roads Authority
LRT	Light Rail Transit
LUC	Land Use Changes
LULC	Land Use/Land Cover
NCA	National Construction Authority
NEMA	National Environment Management Authority
NMT	Non-Motorized Transport
OLI	Operational Land Imager
RCMRD	Regional Centre for Mapping of Resources for Development
RS	Remote Sensing
TIRS	Thematic Infrared Sensor
TM	Thematic Mapper

TOD	Transit Oriented Development
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USGS	United States Geological Survey's
WGS	World Geodetic System
WHO	World Health Organization
WRA	Water Resource Authority

Operational Definition of Terms Used in the Report

County Government: Refers to the administrative body charged with the responsibility of development control which in this case unless specified means County Government of Kiambu.

Development: Pursuant to Section 2 of the Physical and Land Use Planning Act (No. 13 of 2019 of Laws of Kenya), development refers to carrying out works on land or any material change in the use of any structures on land.

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

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

Land: Land is the surface of the earth and the subsurface rock, any body of water on or under the surface; marine waters in the territorial sea and exclusive economic zone, natural resources completely contained on or under the surface and the airspace above the surface (Constitution of Kenya, 2010).

Sustainable Development: World Commission on Environment and Development (Brundtland Commission, 1987) defines sustainable development as development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs.

Urban Infrastructure: The fundamental utilities and amenities supporting urban development. They include roads, water supply, wastewater reticulation, stormwater drainage and energy among others.

Urban Sprawl: Denotes outward expansion of the core urban areas to peripheral areas leading to consumption of agricultural land and vegetation by urban developments (Galster *et al*, 2001).

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Abstract

Land-use change is a major driver to the effects of climate change and other socio-economic and environmental challenges, major challenge policymakers, planners and urban managers grapple with. Ruaka town is no exception as it faces high rapid land-use change with myriad challenges on the management of the effects on urban infrastructure and aggravated by inadequate inter-agencies, coordination and collaboration.

The study is an investigation of the effects of land-use changes on urban infrastructure (roads, water supply, and wastewater infrastructure). It seeks to answer the drivers of land-use changes and document the spatial-temporal land-use changes between the years 1988 to 2019, establish their effects on infrastructure. The study establishes a decline in vegetation and agriculture and rises in built-up areas which is partially contributed by urbanization and population growth in the area with major land fragmentations and land-use conversions. The findings reveal encroachment of development to vegetation and riparian reserves which expose the human population to disasters and calamities in cases of climate change. Lack of approved planning policy has encouraged massive land-use changes due to the ad hoc nature of planning using the development control tools which are not approved. The key drivers of land use changes deduced were good accessibility of the area, high population growth, land speculation for investments, high returns from investments, demand for housing and accommodation. The adverse effects on urban infrastructure include pollution and contamination of water sources, traffic congestion, use of unconventional onsite waste management practices such as pit latrines and septic tanks for waste-water management.

The study concluded by evolving a management strategy to unravel the challenges through the promotion of a sustainable and resilient urban infrastructure. The strategies emphasize the technical, social, economic, environmental and jurisdictional dimensions.

CHAPTER ONE: INTRODUCTION

1.1Background Information

Urbanization has been revealed as a global phenomenon and as a key factor to land-use change which has emerged as a key sustainability concern. This has been mainly through the transformative effects of such urbanization on rural regions into urban built-up regions (Lambin et al, 2001). The world has rapidly urbanized through such land-use changes and land-use conversions over the last 50 years making the urban areas as the major areas of urban development which require attention. Cities and urban areas are vital areas that contribute to about 80% of the World's GDP and as such, they require much attention to manage the effects of urbanization on LULC (Land use/land cover changes).

Urbanization has been well manifested from the estimates indicating that more that than half (55 %) of the world population lived in urban areas in the year 2018. As such, it is also projected that 60% of the world population will live in urban areas by the year 2030 while 70% of the projected world population to be live in urban areas by the year 2050 but with a high concentration of such urban population in Asia and Africa (UN, 2018). The massive rapid pace of urbanization has often brought about rapid land-use change and land cover conversions in Africa and Asia. This has been occasioned by the fact that most parts of Africa and Asia are still predominantly rural as opposed to developed countries. Based on the current trends and projections of the same, the urban land cover will be expected to increase by 1.2 million Km^2 by the year 2030 (UNDP, 2016). As urban areas continue to experience unprecedented land-use changes and the problems that emanate from such land-use change and land-use conversions, it's evident that the mainstream centers in Kenya are ill-prepared for urban growth and ill-equipped to manage the subsequent effects of land-use changes, the pressure of an endlessly growing population which has become a burden to the available urban infrastructure that has haunted the functionality of these towns.

The rapid urbanization and land-use changes strain have exacerbated problems especially on the safety of urban infrastructure and distribution systems creating a capacity concern as evidenced by the inadequate design of such urban infrastructure; construction and inadequacy in its urban management. Policymakers have equally faced key challenges of handling such unprecedented urban growth because of the inadequate capacity of infrastructure, lack of guiding policy and institutional framework to guide in the administration and development control that has impacts on urban infrastructure. Similarly, the weak capacity of the county governments to enforce development control has exacerbated the situation.

In Kenya, Kiambu County is one of the 47 counties highly ranked with the highest number of urban centres of which Ruaka Town is the fastest growing town within the County. Ruaka Town which was formerly a predominantly rural agricultural center has over the decades expanded extensively leading to massive land subdivisions and conversions from agricultural to residential, commercial and other diverse mixes of users without a guiding policy framework for such rapid transformation. Such rapid land-use change and land conversations have attracted a high population and urban settlements consequently leading to traffic congestion, intermittent water supply, poor liquid and solid waste management, high cases of insecurity and high disease prevalence due to high underground water contamination from the unmanaged onsite septic tanks among others. Solutions to these limitations and challenges have always seemed to be ad hoc and reactionary rather than proactive measures being established. Over the past decade, there have been planning attempts and efforts to have all urban centres within Kiambu County have local physical development plans prepared but this has not yielded any fruits of having the proposals being implemented. This has mainly been occasioned by inadequate coordination between institutions, lack of technical, financial capacity and political goodwill. Negative reactions of local communities have also being experienced occasioned by previous negative experiences with local authorities and numerous unmet promises which has

often led to mistrust in such government operations (Kenawy *et al*. 2017). These limitations and challenges have led to the haphazard urban growth which has raised questions on the capacity and management strategies these institutions mandated with such hefty responsibilities use in containing these catastrophes.

The County Government of Kiambu has not lived up to the expectations of controlling urban developments. This has led to uncontrolled developments and land use changes which has resulted in negative effects on urban infrastructure. Due to the nature of densification without commensurate urban infrastructure expansion, there has been a strain on the access roads which were footpaths to agricultural farms and single dwelling units, contamination of water from sunk boreholes adjacent to neighboring sanitation facilities such as pit latrines and leakages from septic tanks as the area does not have a conventional sewerage system. This has been attributed to a lack of effective management policy in place, inadequate financial support and technical capacity of the County Government to deal with the uncontrolled urban developments. This study, therefore, sought to establish the effects that stem from the land-use changes on the urban infrastructure notably roads, water, and water-wastewater infrastructure towards evolving a lasting solution of a management strategy to handle the effects of the same.

1.2 Problem Statement

Studies have revealed that the urbanization process is one of the key factors that has led to global land use and land cover changes. This is mainly due to the lack of proactive planning policy guidelines in the majority of the areas, particularly in developing countries. Having a proper planning policy is not enough but rather its successful plan implementation, development control and enforcement which is more important. Land-use changes present a threat to urban infrastructure, which if unaddressed, the consequences are severe and are not

only environmental but also social and economic. The effects of such land-use changes have impacts on roads, water and wastewater infrastructure among other urban infrastructure.

Ruaka Town has over the decade's experienced land-use changes mainly as a result of the high urbanization rate of Kiambu County due to its proximity to Nairobi City County. The town lacks an approved development and land use policy to guide and manage urban developments. This has led to adverse and unregulated land use conversions which have consequently impacted the urban infrastructure. Against this backdrop, it has been established that large knowledge gaps exist in containing the effects of land-use changes (LUC) on urban infrastructure. As a result, the evaluation brings forward the limitations of the County Government to manage and regulate the effects of urban LUC on urban infrastructure yet this is imperative for sustainable urban development. Despite previous similar studies and research were undertaken, a gap has been identified as previous studies never opted for urban management strategies that would contain the effects of LUC on urban infrastructure coupled with land use change-resilient urban infrastructure systems measures. The study, therefore, fills this gap and culminates into providing possible solutions, answers and recommendations on the management strategies to promote land use change-resilient urban infrastructure to enhance sustainable growth.

1.3 Goal of the Study

The goal of this study was to investigate the effects of land-use changes on urban infrastructure to promote land use change-resilient urban infrastructure with sustainable urban development.

1.4 Objectives of the Study

The following objectives guided the study;

a. To document the land-use changes and establish their drivers in Ruaka Town, Kiambu.

b. To establish the effects of land-use changes on existing roads, water, and wastewater infrastructure capacity in Ruaka Town, Kiambu.
c. To evolve a management strategy to unravel the effects of land-use changes on roads, water and waste-water infrastructure capacity.

1.5 Research Questions

The study seeks to answer the following questions;

a. What land-use changes can be documented and what are the drivers of such land-use changes in Ruaka Town, Kiambu County?
b. What are the effects of land-use changes on the existing roads, water and wastewater infrastructure in Ruaka Town, Kiambu County?
c. What management strategy can be evolved to unravel the effects of land-use changes on roads, water and waste-water infrastructure capacity?

1.6 Research Assumptions

To undertake this study, the following assumptions were put in place;

a) The continued urbanization of Ruaka town will be accommodated through increased development densities and land-use conversions to built-up environments.
b) Infrastructure in the town is not expected to be expanded in the near future to all properties.
c) Developers and investors are driven by the concept of a (rational) economic man which assumes profit maximization as the main motive for the development or investment.

1.7 Significance of the Study

Land use conversions emanating from urban growth is a challenge to sustainable urban development. This necessitates the need for a management strategy to ameliorate the effects of the same urban infrastructure. Ruaka town has attracted a high population due to its strategic location within Kiambu County and its proximity to Nairobi City. The advantages offered by

the town have translated into an increased rate of estate developments as accentuated by the increased demand for housing facilities. This has resulted in an increased strain on existing urban infrastructure which requires management strategies to ameliorate the adverse impacts. Ruaka is within the jurisdiction of the recently formed Municipalities which require management of its urban infrastructure.

1.8 Scope of the Study

This study sought to examine the effects of LUC on urban infrastructure in Ruaka Town, Kiambu County, Kenya. In this regard, the study area covers Ruaka town and the entire Ndenderu Ward in Kiambaa Sub-County with an area of approximately 15.8 Km^2 (Map 2-2) The study area lies between Longitude 36° 31' 0" and 37° 15' 0" East and latitudes 10° 25' 0" and 1° 12' 0" South of the Equator. The study considers land use developments and how they affect urban infrastructure capacity notably roads, water and wastewater.

1.9 Limitations of the Study

There were no policies or development guidelines approved by the county government that would be referred to guide the study thus the research relied on the knowledge of the study area. Further to the above, data used in the study such as the Landsat imageries have discrepancies in terms of accuracy. This was due to different seasons of harvesting and planting which depicted different greenery or vegetation and agriculture. Getting views of the developers was a challenge since most of the developers do not reside in the area and the management of the premises is left to caretakers. It was also difficult to categorize different land uses from the imageries under the built environment category and therefore they were clustered together as a built environment as opposed to specific land uses such as residential, commercial, educational or industrial land uses among others.

1.10 Organization of the Study

The study comprises of six chapters. The chapter on the introduction of the study comprises of background information, problem statement, the goal of the study, objectives of the study, research question, research assumptions, significance of the study, the scope of the study, limitations of the study and organization of the study. Chapter two on the study area comprises the location and size of the study area, the background of the study area, physiographic factors, demographic features, land use, land tenure systems and urban infrastructure. Chapter three is a literature review while chapter four presents study methods that comprise of the research design, target population, sampling design, research instruments, data collection process, data analysis, data presentation and ethical considerations followed, while chapter five is the analysis and discussion on the field findings. Chapter six is the study's conclusions and recommendations.

CHAPTER TWO: THE STUDY AREA

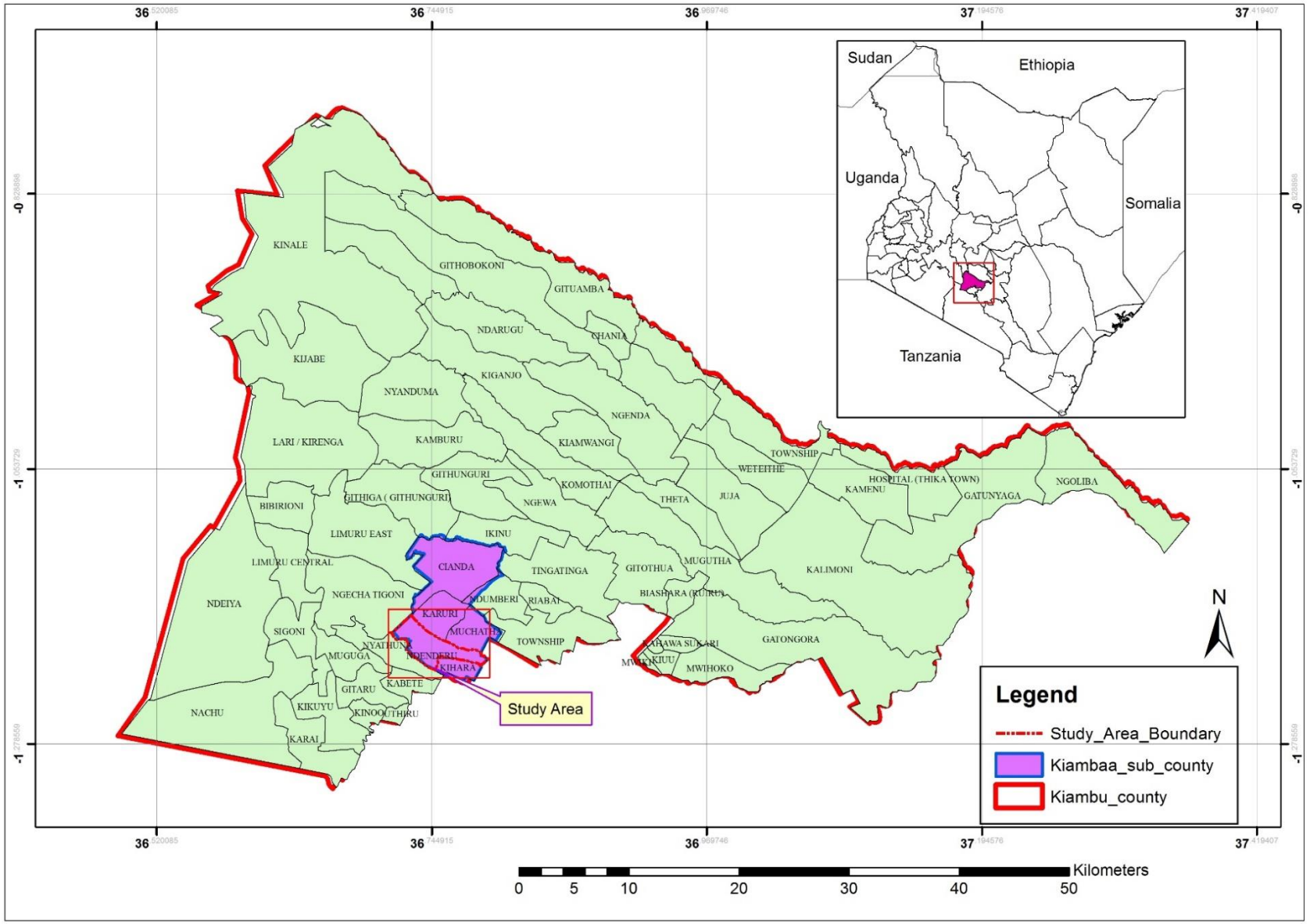
2.1 Introduction

This chapter highlights the location of Ruaka Town, Kiambu County of Kenya and the salient factor that has influenced LUC. This is in recognition that the management of LUC in any town is widely determined by social, economic, physiographic and political factors in operation in the town. It's therefore significant to assess and get a clear understanding of these factors.

2.2 Location and Size

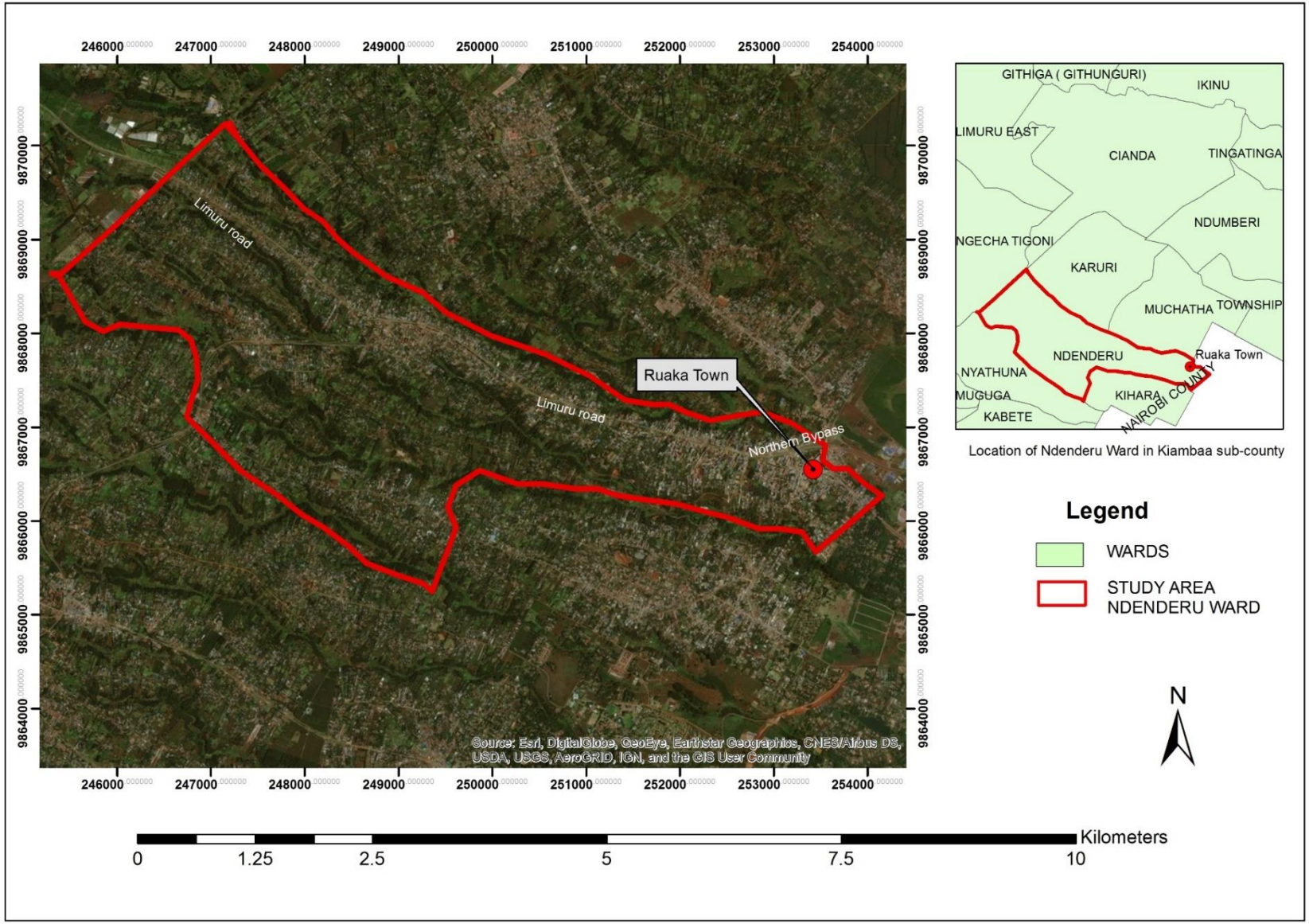
Ruaka town is situated within Ndenderu Ward, Kiambaa Sub-County, Kiambu County. The town is located North West of Nairobi City and is easily accessed by the Northern Bypass and Limuru Road. Ruaka is part of the larger Nairobi Metropolitan with easy access to Kiambu, Limuru, Nairobi, Thika, Kajiado, Machakos and Muranga Towns. The study area is situated between Longitude 36° 31' 0" and 37° 15' 0" East and latitudes 10° 25' 0" and 1° 12' 0" South of the Equator.

Map 2-1: Location of Ruaka in Kenya and Kiambu County Context



Source: (Survey of Kenya, 2018).

Map 2-2: Location of Ruaka Town (Ndenderu Ward) in Kiambaa Sub-County



Source: (Google Maps, 2018).

2.3 Historical Background of Ruaka Town

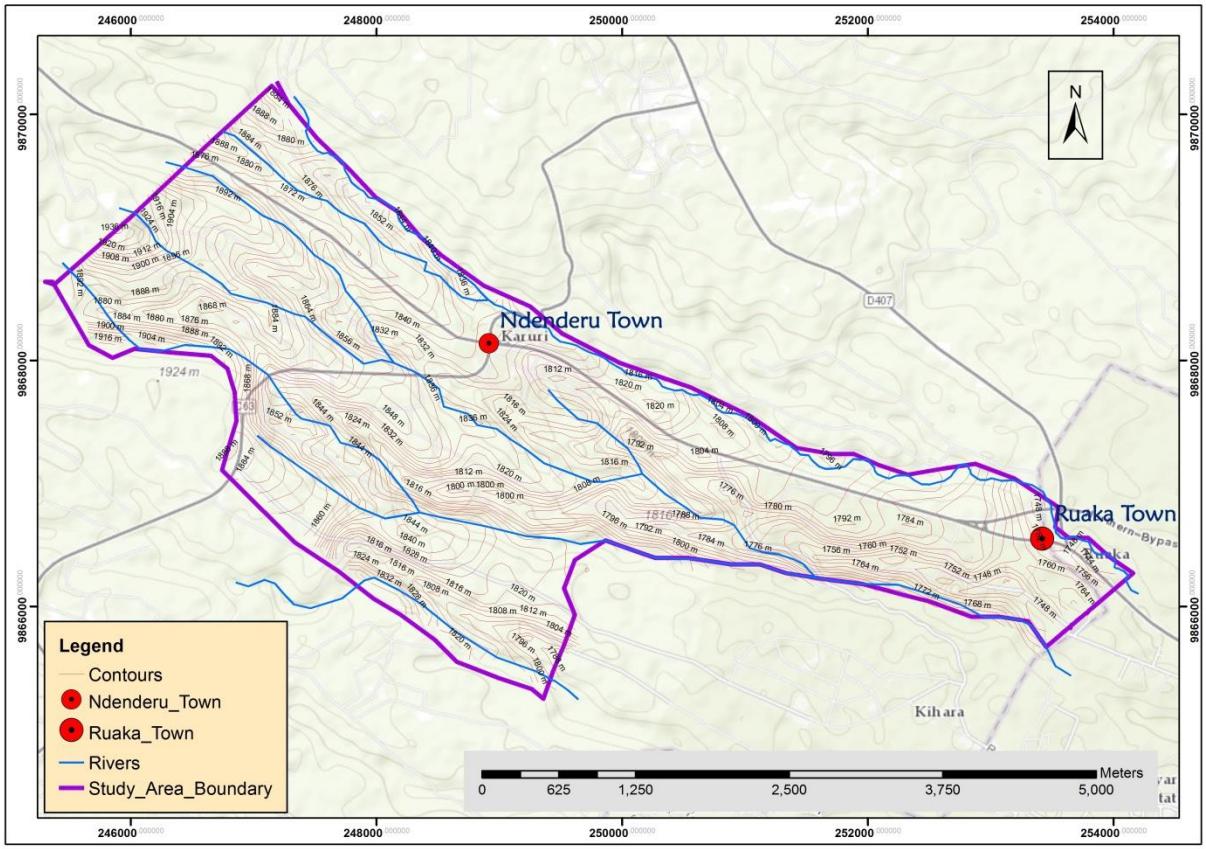
Ruaka town is situated within Kiambaa Sub-County and was formally known as the Town Council of Karuri. The town was established as a meeting centre in the pre-colonial era where paramount chiefs used to meet. The origin of the word Karuri was derived from one of the chiefs- Karuri was Gakure who used to have meetings under one large "Mugumo" tree located in the area. Initially, Karuri was classified as an urban council until 1997 when it was renamed as Karuri and upgrades as a town council status increasing the area coverage from 44.8Km^2 to the current 46 Km^2.

Ruaka Town was named after River Ruaka that flows across it. Initially, land on which the town currently stands was communally owned. At the onset of colonization, locals were regrouped into villages with the first village being in Ruaka shopping centre for people who worked in the white settler's coffee farms. There was an emergence of shops built at the current Ruaka shopping centre to provide basic needs to these workers. The land was later subdivided into private plots with agriculture being the main user. Due to urban growth, the large agricultural plots were further subdivided and converted to residential and commercial users subsequently leading to the densification of developments. Currently, Ruaka lies within Kiambaa Sub-County which was later conferred as Karuri Municipality, Kiambu County with five wards namely; Ndenderu where the study area lies, Cianda, Muchatha, Karuri and Kihara Wards.

2.4 Physiographic and Climatological Factors

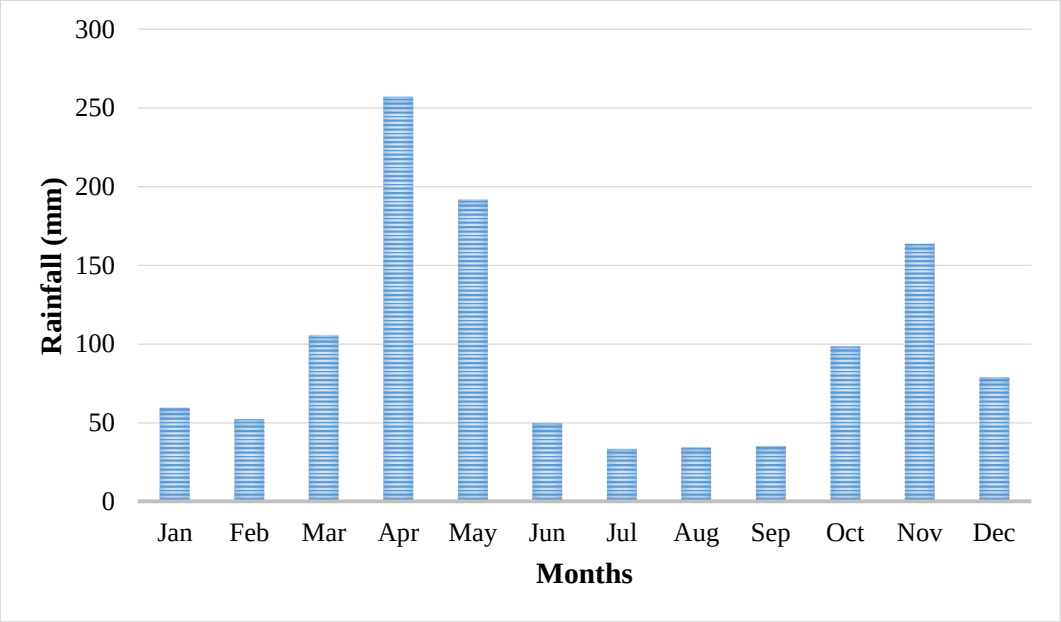
Ruaka Town and Ndenderu ward lie between 1,748 metres to 1,936 metres above the sea level with soils being red volcanic. The town generally gently slopes eastwards towards Nairobi city with a rugged and deeply incised landscape towards the Ruaka River, a major hydrological feature in the area.

Map 2-1: Contour map of Ruaka in Ndenderu ward



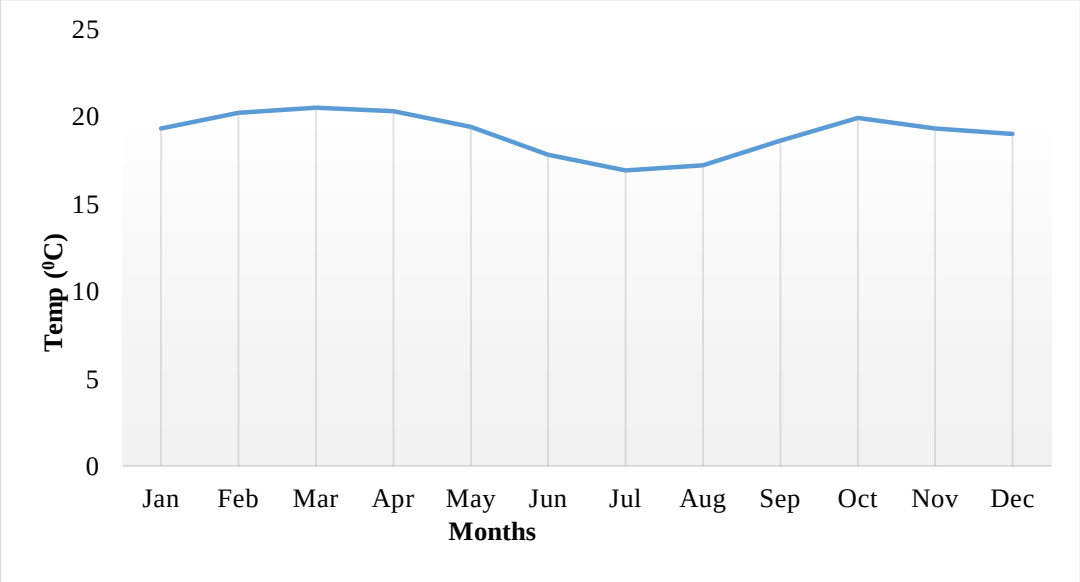
Precipitation in Kiambu County is bi-modal with long rains in March to May and short rains in October to November. Ruaka Town receives an average annual rainfall of 900mm, with a mean monthly temperature of 22^0C and a maximum of 27^0C. December to March are the hottest months while July to August experiences the lowest temperatures. The average relative humidity ranges between 54% in the dry months and 300% in the wet months of March to August. Prevalent winds in Ruaka town are generally weak with the strongest occurrence in August to October (5-10m/s) blowing from all directions. Rainfall and temperature dictate the type of crops cultivated and livestock reared as well as the typologies and nature of building materials used in development. Temperatures and Rainfall patterns in the area are favorable for different housing typologies and developments in the area which thus increased land-use changes from agricultural to built-up developments (Kenya Meteorological Department, 2018).

Figure 2-1: Monthly Rainfall in mm



Source: (National Irrigation Board, 2018).

Figure 2-2: Mean Monthly Temperature in ^{0}C



Source: (Farm Management Handbook of Kenya, 2009).

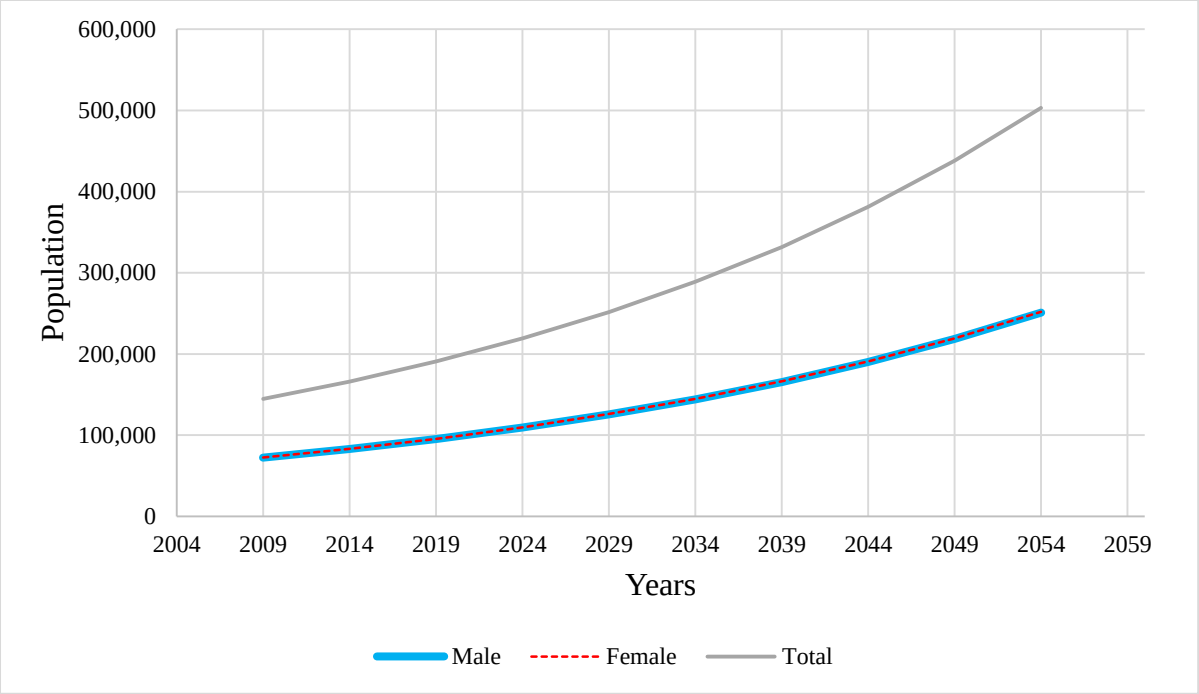
The main hydrological features in the area are River Ruaka which drains into Nairobi River. Boreholes and wells are the alternative sources of water. The area is not well served with piped water from the county's main water supply. There is the potential of harnessing underground

water to serve the increasing population, however the challenge has been the sinking of boreholes closer to the sanitation facilities such as pit latrines and septic tanks which leads to pollution of ground and underground water sources *(*Water Resource Authority, 2018*).* Besides, most of the riparian reserves have been encroached upon due to high urbanization devoid of development control measures in the area. This has resulted in pollution, contamination and loss of biodiversity.

2.5 Demographic Features

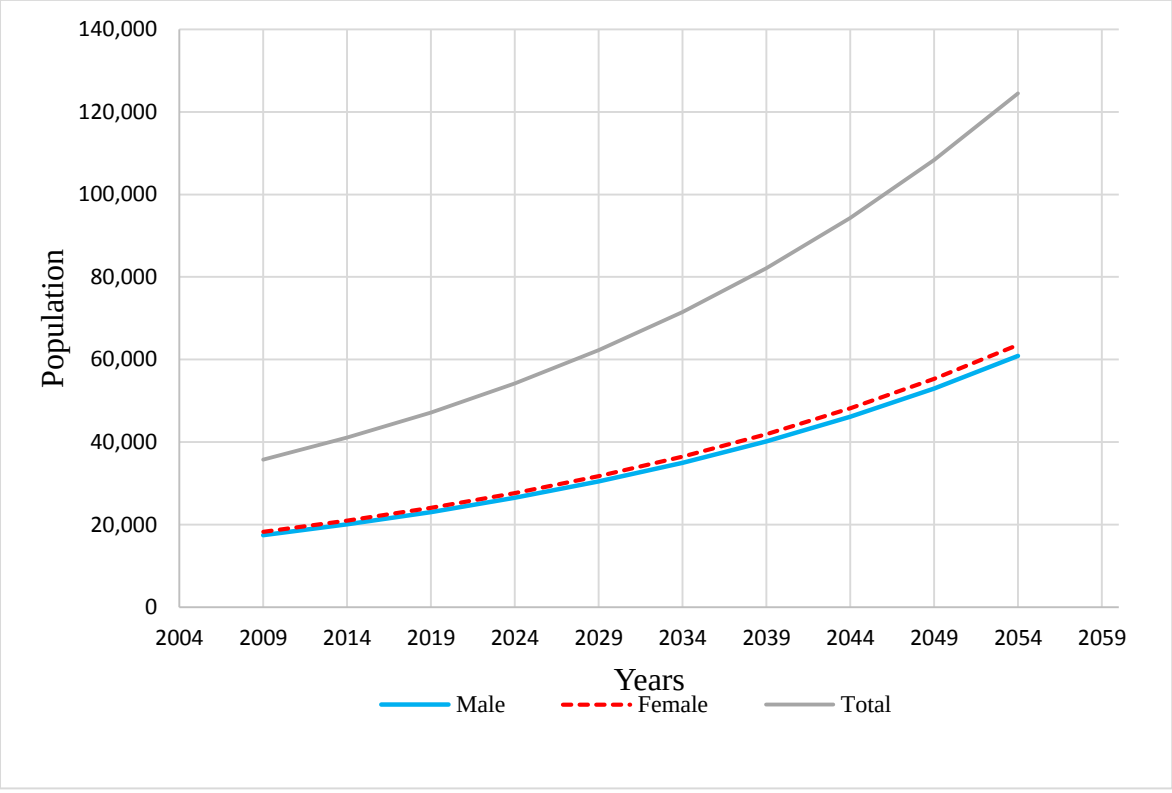
According to the 2009 Kenya Population and Housing Census, it placed Kiambaa Sub-County's population was 144,582 with a gender distribution of 72,173 males and 72,409 females and a population density of 1,979 persons/Km^2. In 2019 Kenya Population and Housing Census, Kiambaa Sub-County had a total population of 236,400 persons comprising 115,690 male, 120, 695 female and 15 intersex. The population of the Sub-County is expected to reach 503,158 by the year 2054. The Census placed the population of Ndenderu Ward at 35,750 with a gender distribution of 17,491 males and 18,269 females. The demographic change was influenced by Kiambu County's population growth rate which stands at 2.81 percent due to the influx of people working in Nairobi city and availability of infrastructure providing easy access. Population growth has been on the rise over the years and is expected to increase in the future. This led to a demand for housing, commercial facilities and employment opportunities resulting in land-use changes to accommodate these demands. Currently, in the year 2019, it is estimated from the projects there are 47, 178 people in Ndenderu ward, 23, 076 males and 24, 102 females. The population of Ndenderu Ward is projected to be at 124, 447 people by the year 2054.

Figure 2-3: Population Projections for Kiambaa Sub-County



Source: (KNBS, 2009).

Figure 2-4: Population Projections for Ndenderu Ward

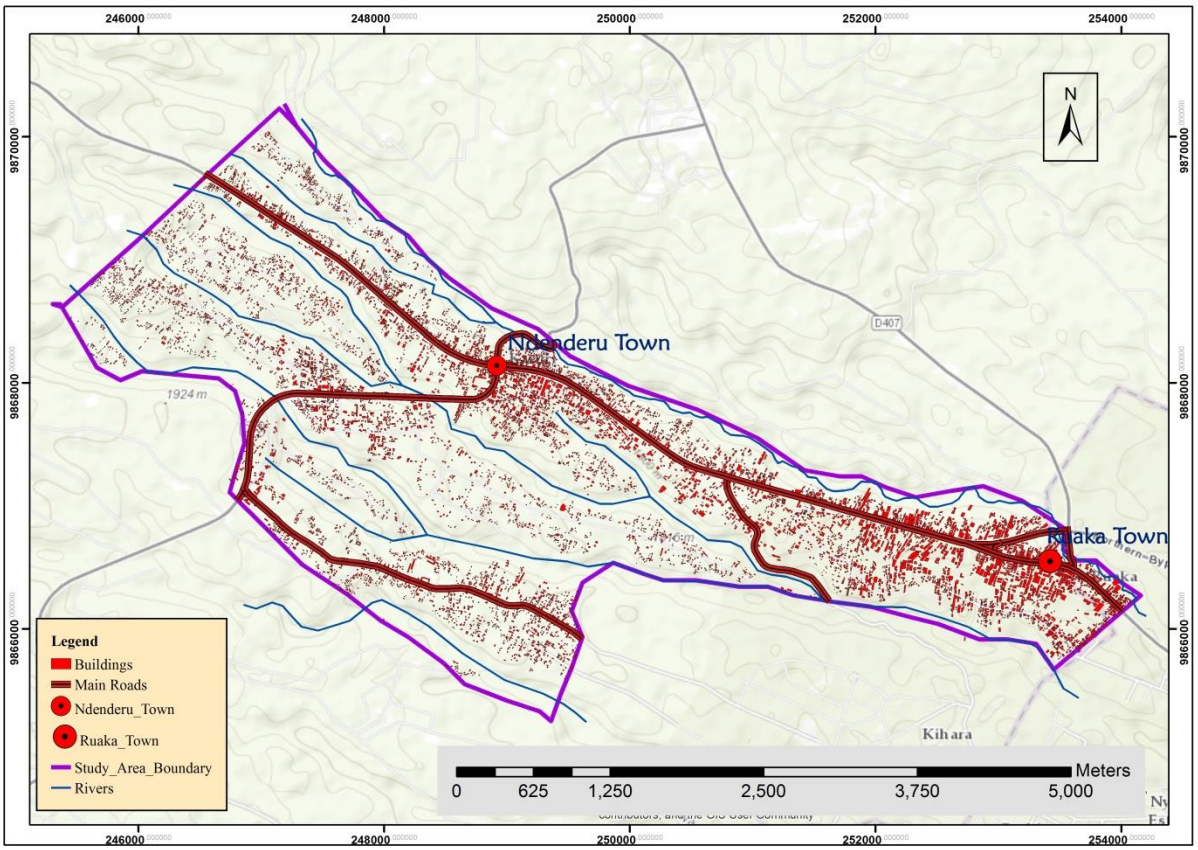


Source: (KNBS, 2009).

2.6 Land Uses and Land Tenure Systems

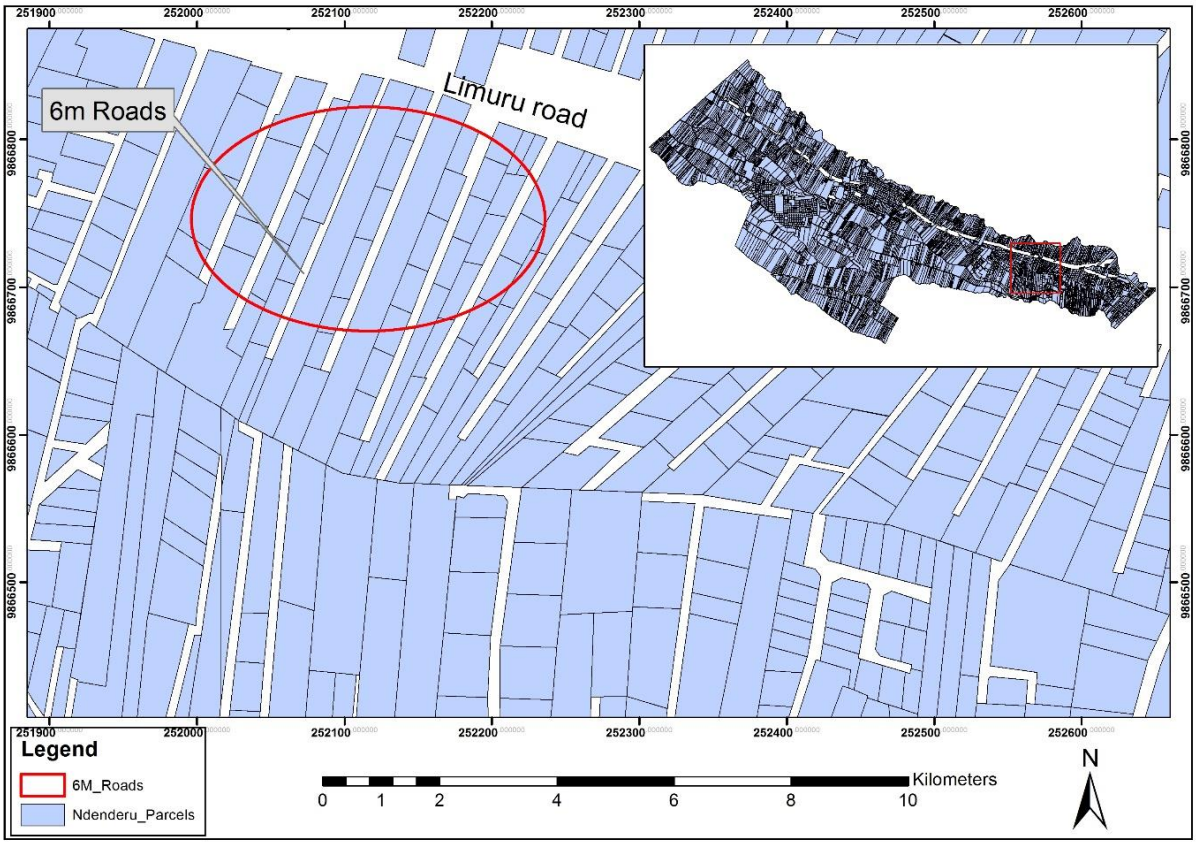
Land in Ruaka was predominantly under agriculture land use on the freehold tenure system, but in the recent past, there has been a significant shift from agricultural to urban developments. The proximity of Ruaka town to Nairobi city has seen land conversions from agricultural to built-up developments. The existence of all weathered roads has given the people working in working in Nairobi an opportunity to reside within Ruaka town. This attracted major real estate developments in the area and subsequently land-use changes. The conversions started from the agricultural farms to single dwelling units which later changed to multiple dwelling units and commercial flats. The developments have implications on domestic and wastewater, roads, energy and other allied infrastructure in the town.

Map 2-2: Built-Up Developments Trend 2019.



Most of the developments are along Limuru Road and the Northern/Western Bypass which encourage corridor development. The rugged terrain restrains developments along the major road where land is relatively flat while the steep areas towards the river are left under vegetation cover. Within the Ruaka CBD and the road to Banana, there are major developments that have encroached into the riparian reserves. There are some leasehold land properties whereby land-use changes have been taken place and endorsed on ownership documents. Irregular land a subdivision characterizing the town has led to the emergence of small irregular plots not developable if subjected to statutory building lines and setbacks. This has been a source of conflict between developers and the County Government of Kiambu.

Map 2-3: Level of Land Subdivisions



Source: (Survey of Kenya, 2018).

2.7 Urban Infrastructure

Ruaka town is accessible through a series of roads consisting of Limuru road, Ruaka-Banana road, Northern Bypass and Western Bypass making the town attractive to real estate investors. Due to informal land subdivisions characterizing the town, the majority of the town plots are of small sizes with narrow access roads ranging from 3 metres to 6 metres in width. This has been a source of conflict between the property owners and the county government when seeking development approvals for the roads are narrow and not meeting the stipulated standards for the roads adopted by the county government.

The town's CBD is served by Karuri Water and Sanitation Company Ltd water supply which the rest of the town relies on boreholes. Due to increased subdivisions of which an average size is 0.045Ha, there is a tendency of sinking boreholes on one plot together with a pit latrine or septic tank. This has led to pollution and contamination of such underground water resources. Since the town is not under sewer reticulation, the residents dominantly use pit latrines and septic tanks which if not managed well have always led to pollution through spillovers and contamination of underground water leading to waterborne diseases.

It is evident from the discussion above that Ruaka is situated in a strategic location and proximity to Nairobi city. Physiographic factors and its strategic location favor the high concentration of population and rapid growth of the area which has seen rapid land user changes. The existence of bypasses and major urban infrastructure has facilitated the rapid growth and development of the area.

CHAPTER THREE: LITERATURE REVIEW

3.1 Introduction

This chapter discusses the imperative literature on urban development and the implications of the same on infrastructure quality and capacity. It also highlights the theoretical and methodological approaches and related studies on urban land-use changes.

3.2 Theoretical and Methodological Approaches to Urban Land Use Differentiation

Mapping land-use changes are critical in determining the socio-economic patterns of changes. Past studies on urban land-use change have been undertaken using Geographical Information System (GIS) and remote sensing tools (Screenivasulu *et al*, 2013). Therefore, GIS has greatly assisted in the collection, storage, display, detection and analyzing of the land-use changes. Classification is used in analyzing Landsat imageries acquired over time to correlate the changes that have taken place over time. Satellite imageries are used in analyzing the nature of changes for the built environment and vegetation cover. Landsat Multispectral Scanner (MSS), Enhanced Thematic Mapper Plus (ETM+) and Thematic Mapper (TM) have been widely used in several studies in the determining land use changes over time because of their high spectral resolution (Reis, 2008). Remote sensing and GIS have been used to collect data in past studies to fill a gap in knowledge on land-use changes such as the case of Chhatarpur District in India when satellite imageries were used to prepare land use maps which were then used for developing sustainability strategies. (Mishra *et al*, 2012). Towards this end, it is evident that Remote Sensing and Geographical Information System (GIS) are imperative in land use planning and policy development more so in monitoring land use patterns and changes. Many studies in North America and West Europe have demonstrated that high-resolution satellite imageries are vital in collecting information on land-use changes. Therefore, areas experiencing rapid urban sprawl can be monitored using satellite imageries to assist Planners

and policymakers in resource allocation and policy decisions on areas for development and other strategic interventions (Billah and Rahman, 2004).

The first of these theories is the bid rent theory consisting of the postulations of Alonzo and Weber among others. The theory explains land use competitions in a city by stating that land uses to compete with one another for land close to the city center which is more accessible and has an agglomeration of economies (high concentration of activities and people) thus higher chances of making a profit (Sullivan, 2012). As a result, the prices of land in the inner cities are higher compared to other locations. The Bid Rent Theory explains why land in Ruaka at the outer ring of the Nairobi city attracts more residential and commercial developments with developers and tenants ready to pay higher rent to establish their businesses as it's more accessible to a wider population.

Alonzo (1964) advanced a model based on land values based on the location and size of land. The model assumed a city of uniform employment and shopping centres and equidistant travel distances. It also assumes that each household or firm has equal opportunity and access to market information on the cost of land and commuting costs. In this case, many household choices are based on cost and location (distance) of commuting. The theory partially explains differentials in land prices towards Ruaka town. Weber (1929) viewed a city's spatial structure as a culmination of human socio-economic interaction as aided by the transportation network. Suburbanization theory postulates the expansion of the city to the periphery. According to Adefioye (2016), due to demographic and economic factors cities expand to the periphery forming adjacent territorial centres. This is attributed to the high cost of land within the city and the need for large spaces for urban activities which have often resulted in a shift of residential and commercial land uses from the city center to suburban areas that are within city limits. The theory of suburbanization explains how Ruaka Town emerged as a result of its

proximity to Nairobi city. Labour Aristocracy thesis has been used in Africa to explain the rural-urban migration. The theory is an amalgamation of two theories notably labour mechanism and urban bias theory. Labour mechanism states that owing to labour differentials between rural and urban areas, labor moves from rural to urban areas. Urban bias theory contributed by Lipton (1977) states that governments tend to centralize investments and activities in urban areas compared to rural areas thus good life accentuated by electricity, piped water, good housing, and telephony. This attracts the rural counterparts to migrate to the urban areas to enjoy the privileges hence abandoning the rural areas only to find out that it's not all that good as expected thus urbanization of poverty. Labour Aristocracy theory tends to demonstrate how people move from rural areas to Nairobi city with an expectation of high wages as opposed to actual wages. This forces them to look for alternative places outside the city which in this case is Ruaka town thus accentuating the demand for housing and commercial services. This has seen rapid land-use changes from agricultural to residential and commercial users.

Hoyt (1939) developed sector model to explain the internal structure of cities. The model posits that cities grow around a series of sectors radiating from the CBD and centered along major transportation corridors with similar business enterprises clustering and locating along the major roads. Rent then graduate downwards from the CBD towards the peripheral areas. In this regard, residential areas along the major thoroughfares tend to attract commercial activities as is witnessed in Ruaka town with the emergence of banks, supermarkets, and offices among others. Burges (1925) advanced the concentric model to explain the internal structure of the North American cities. The model explains how a city's social groups are spatially arranged in a series of rings notably the Central Business District (CBD), Zone of Transition, Zoning of working men's home and commuter zone. This model demonstrates that due to urban growth, each zone gets invaded by the adjacent zone as the city expands outwards. This explains the

outward expansion of Nairobi city to Ruaka town hence leading to the land-use changes. Arising from the weaknesses of sectoral and concentric models it explains the urban internal structure. Harris and Ullman (1945) developed a multi-nuclei model to explain the urban internal structure. The model postulates a city's growth from several CBD patterning the land use from which other land uses gravitate.

A study by Mwathi (2016) on effects of land use and land cover dynamics on the environmental quality of Nairobi and its environments evaluated the trends, rate and nature of land uses and land cover initially from 1988 to 2010. The study indicates that the city has continued to expand, marked by a decrease in the agricultural and riparian vegetation. This has led to environmental degradation corroborated by land degradation, degradation, and destruction of habitat, air, and water pollution as well as urban heat island. The study concludes that this is occasioned by the weak institutional framework for development control and the proliferation of informal settlements in the urban periphery. The study recommends that for sustainable development of the city, there is a need for enhancement of development control, expansion and maintenance of the infrastructure, formulation of current and relevant policies as well as embracing a multi-sector partnership approach to urban development. Asoka *et al* (2013) studied the effects of population growth on urban infrastructure and services in Eastleigh Neighborhood, Nairobi and observed that solutions to urban problems depend heavily on effective urban planning, infrastructure development, and management. The study reveals that rapid and unplanned growth has led to a strain on the capacity of infrastructure and environmental degradation.

Museleku (2013) carried out an investigation into causes and effects of agricultural land use conversions in the urban fringes of Nairobi-Kiambu interface and found out that there was the prevalence of conversion of agricultural land whose effects were both positive and adverse.

The study reveals that land conversions are a result of low returns from agriculture, high demand for housing facilities, urban population growth, weak and ineffective development control institutions and proximity to Nairobi city. To ameliorate the ravages of land conversions, the study recommends the adoption of proactive development policy (legal and institutional frameworks) to control developments. Although the study analyzed how the land conversions exert pressure on existing infrastructure, the study never recommended a framework for the management of the same.

Kirigwi (2008) researched on the effects of rapid urbanization on land use in the Nairobi urban fringe a case of Ruaka town. The study aimed at making an inventory of developments in an attempt to find how they conform to local development policies. The study revealed that there were increased subdivisions of agricultural land and changes of the user from agricultural to built-up ones consequently leading to the destruction of natural vegetation. The study established that the defunct local authority didn't have the technical and economic capacity to resolve the rapid land-use changes and development to the riparian reserves. The study recommended the need for preparation of a physical development plan alongside with the reduction of bureaucratic procedures on the plan approval process and developments. It also noted the key challenges of bureaucracy in the harmonization of policies for the management of urban sprawl. The drawback of this study is its failure to analyze how the developments impact on the infrastructure and how this can be managed. Mundia and Aniya (2005) posit that urban expansion as accentuated by economic growth and expansion of transport corridors often leads to urban sprawl and loss of land cover. Maina (2010) posits that increased demand for housing facilities in Ruaka town has led to conversions of land from agriculture users to the built-up environment and subsequent land subdivisions to smaller plots, leading to high plot coverage. According to Kumar and Sangwan (2013), urban sprawl and land-use changes are occasioned by urbanization, population, and economic growth. This necessitates land use

planning and administration with long term monitoring and management. Olujimi (2009) argues that despite many attempts by national and international agencies containing urban sprawl, not much has been achieved. This necessitates a re-evaluation of the strategies used to contain the sprawl. Olujimi (2009) suggests a people-oriented strategy in managing sprawl with facilitation by government officials as it is essential to plan with the people rather than to plan for the people.

3.3 Drivers of Land Use Changes

Landsat images have been used in previous studies to analyze drivers of urban land-use changes. The main causes of land-use change established from such studies demographic, climatic, geographic and socio-economic factors with others being proximity to highways (Lo and Yang, 2002). Drivers of land-use changes are essential to aid in making recommendations and decisions on future land use patterns (Samie, *et al*, 2017). Previous studies indicate that remote sensing imageries are essential in mapping land-use changes, investigating the nexus between land-use changes and the key drivers as well as assessing the impacts of the same within a period of time for purposes of rational urban management. Outcomes from the case of Wuhan city in China indicates that over a period of time, there were substantial land-use changes on the arable land to built-up environment occasioned by socio-economic (population increase and industrial developments, physical, cultural and climatic factors as well as policy considerations) (Xiangmei *et al*, 2016).

Population growth is a key driver to land-use changes which has often led to urban sprawl. This would be through a natural increase in population or migration to urban areas as a result of pull and push factors such as proximity to workplace, availability of land, perceived better facilities and services, economic opportunities, conducive climate and environment among other reasons. The increased population strains the capacity of existing urban infrastructure and

services. Independent decision made by the government or private sector especially in areas that lack development guidelines often leads to land-use changes and in most cases uncontrolled and uncoordinated urban developments. The economic growth of regions has seen land use transformation with massive urban developments and land conversions from agricultural to built-up areas. Other key drivers to land-use changes include industrialization, land speculations (expectations in land appreciation), changes in development and property tax, high living cost a property cost in the city as compared to the peri-urban areas, lack of affordable housing within the precincts of the city, demand for more living spaces due to limited land size within the city, government regulation that concentrates regulation within the core city as opposed to peripheral areas, effects of new development corridors attracting urban developments and failure in enforcement of planning policies and regulations (Bhatta, 2010).

In the epoch of global urbanization, cities of the south are facing rapid urbanization with land-use changes challenges that are detrimental to urban sustainability. Such unprecedented population booms and variant economic trends pose stress on finite urban land resources and infrastructure. Urban sprawl has been witnessed with its challenges of vegetation destruction and environmental degradation manifesting through decreased air quality, increased surface water runoff, flooding, deterioration of water quality and increased urban surface temperatures among others if not well managed (Subramani and Vishnumanoj, 2014). Other studies reveal that land-use changes mainly brought by urbanization have resulted in floods which can be predicted although not successful through the type of land uses which are mainly commercial, residential and industrial. Other sources of floods include aging drainage infrastructure, increased urban developments, increased paving and climate change. In other instances, floods have been caused by lack of drainage especially in an urban area mainly because most of the drainage networks are dilapidated and therefore cannot handle the increased volumes of water (Saberifar and Shokri, 2017).

3.4 Policy, Legal and Institutional Framework

Policies, laws and institutional arrangements guide the urban growth and development in various ways as defined out below: -

3.4.1 Policy Framework

Kenya Vision 2030 (GoK, 2007) is a long-term development blueprint with economic, social and political pillars. The blueprint aims to transform Kenya into a newly industrializing middle-income country providing a high quality of life by 2030. The blueprint anticipates that 60% of Kenyans will live in urban areas by the year 2030. This requires an effective management strategy to enhance the achievement of the economic, social and political gains in urban development, more so for highly urbanizing towns such as Ruaka. Kenya Vision 2030 (GoK, 2007) is also complemented by the National Spatial Plan whose aim is to achieve sustainable population and human activity distribution on national space to attain socio-economic development, sustainable use of land and controlled urban developments.

Kenya's urbanization agenda is also geared towards the fulfillment of the Sustainable Development Goals (SDGs) agenda which includes the promotion of urban resilience in infrastructure and making cities inclusive, safe and sustainable. The broader promotion of sustainable urbanization as anchored in the SDGs is operationalized by the National Land Policy (GoK, 2009), National Housing Policy of Kenya (GoK, 2004) and the National Urban Development Policy (GoK, 2011). The National Land Policy (GoK, 2009) established under Sessional Paper No. 3 of 2009 aims at guiding on efficient, equitable and sustainable use of land to address socio-economic, environmental and political concerns. In the urban arena, the objective of the policy is to promote the management of urban land uses within a planned framework ensuring that they are undertaken to meet order and urban sustainability. While the National Housing Policy for Kenya (GoK, 2004) aims at providing adequate, decent and affordable housing for all citizens, Draft National Urban Development Policy (GoK, 2013)

creates a framework for sustainable urbanization through infrastructure, housing, land, environment, and climate change management. It also recognizes that walking and cycling has been given less attention despite being the key mode of transport and calls for strategies and standards that emphasize on safe pedestrian and cycling facilities, efficient, reliable and high-quality mass transport systems and well-designed public spaces in towns and urban areas.

3.4.2 Legal Framework

The supreme law of Kenya being the constitution of 2010 in its Article 1 (2) stipulates that sovereign power is vested to the people of Kenya. This power can be expressed through direct participation or indirectly through elected representatives. It places the citizens at the centre of decision making and promotes the public participation and involvement of citizens in decision making, which forms the basis of involving all stakeholder in a consultation process in plan making or any decision that affects them notably; access to adequate and decent housing with reasonable standards of sanitation, access to clean and safe water in adequate quantities. It establishes a devolved system of governance and formation of County Governments with departments of roads and transport, water and sanitation that are responsible for planning and management of County roads, traffic, parking, street lighting, water supply and wastewater management. The constitution gives its citizens the right to freedom of movement, right to clean and healthy environment and mandates all public officers to respond to the needs of vulnerable members of the society including children, women, elderly, persons with disabilities, minority/marginalized groups. The same is reinforced by the Physical and Land Use Planning Act (No. 13 of 2019) which grants powers for the county governments to control the use and development of land, buildings in an orderly way and to consider approval of development applications. It also provides for the preparation of plans for purposes of improving land and securing provisions for infrastructure facilities and services including giving provisions for new roads and their hierarchies to serve major different classes of

developments, streets, subject to provisions of the Street Adoption Act (Cap 406) and Public Roads and Roads Access Act (Cap 399).

Other legislation that reinforces the need for sustainable urban development are the County Government Act (2012), Urban Areas and Cities Act (2011), Environmental Management and Coordination Act (1999), National Land Commission Act (2012), Land Act (2012), Water Act (2012) and Building Code (Adoptive By-laws (1968) among others. The County Government Act (2012) provides for the preparation of planning and management frameworks under Section 104 thus granting powers to the county government powers to plan and manage its areas within its jurisdiction. The Urban Areas and Cities Act (2011) provides for the classification, management, and governance of urban areas; the criteria of establishing urban areas, principles of governance and public participation of residents. Parking, public transport, sanitation, water supply and street lighting are enlisted as requirements of classifying an area like a town or municipality. While Environmental Management and Coordination Act (1999) provides for the management of the environment, sustainable use of land its natural resources and requires all urban infrastructure projects to undergo environmental impact assessment and social impact assessment before construction. National Land Commission Act (2012) provides for administration and management of public land in an efficient, sustainable and equitable manner. The act also mandates the National Land Commission with the responsibility of monitoring and providing oversight over land use planning and alienation of public land to private entities, monitoring registration of rights and interests in the land. The need to equitably and efficiently utilize land and natural resources as further reinforced by Land Act (2012) and Water Act (2012) which collectively provides the legal foundation to consolidation and rationalization of the management of land and the management, conservation, use and control of water resources. The Building Code (Adoptive by-laws) of 1968 provides for the

development control processes and procedures of erecting developments and penalties for defiance.

3.5 Effects of Land Use Changes

Land changes have taken place in various parts of the world with a greater decline in land cover and an increase in the built-up areas resulting in economic, social and environmental impacts. The decline in farmlands has an impact on the decline in food production and the rise in the cost of purchasing food products. Densification and built-up areas increase water and air pollution as well as the rise of thermal temperatures of the areas (Wu, 2008). Other impacts of land-use changes include impacts on wildlife and ecosystem, loss of farmland, increase in impervious surfaces, the decline in air quality as a result of car-dependent lifestyle, the decline in water quality and quantity since the aquifers are not replenished due to increased impervious urban surfaces (Bhatta, 2010).

Urbanization and land-use changes have often resulted in disturbances of land and its hydrological systems pose a serious risk to the provision of urban water services, drainage capacity, increases pressure on urban water systems and affects their water quality, quantity and aquatic ecology depending on where and how they occur (Huggett *et al*, 2004). Urban areas with massive developments located in flood-prone areas are usually prone to flood hazards as a result of increased impervious urban surfaces such as roads (Du, 2010). Changes in land use through urban development often have impacts on transportation (roads) such as traffic congestion, changes in travel demand and mobility. Land-use changes, therefore, lead to road expansion and the creation of new roads as a result of urban growth that requires wider roads to enhance mobility and safety. This often attracts more urban developments to provide urban facilities for the larger population which increases in pressure on urban ecosystems, aggravates urban congestion and threatens biodiversity conservation, noise and air pollution

(Marimoto, 2012). Studies in the United States and Europe reveal urban form as a key driver to travel behaviors. Policies advocating for the transformation of this trend have been formulated to reduce transport emissions, reduce traffic congestion, improve safety and enhance security on roads. Studies on the impact of urban form variables such as urban density, city size, land-use mix, spatial clustering, and polycentrism were analyzed with time and distance. It was deduced that spatial clustering and city size are determinants of commuting and therefore cities that lack the clustering and limits in city size have problems with commuting. Therefore, city limits and clusters, especially for the high density, enhances limit in the commuter distance and travel time (Engelfriet and Koomen, 2018).

Floods brought by land-use changes/urban developments have led to the destruction of property and loss of life and therefore if not controlled the situation can worsen with the increased level of land-use conversions which has seen a rise in flash floods in urban areas. The floods have been accentuated by the impervious services as a result of urban developments which does not allow a substantial amount of surface runoff water percolation to the ground. The surface runoff water is also obstructed by non-biodegradable materials which often clog the drainage systems and as a result end up into sewerage drainage and water supply systems leading to spillovers, pollution, and contaminations endangering the life of people and the ecosystem. The impacts of such floods are experienced on roads especially where the drainages are not maintained or do not have the adequate capacity to contain the stormwater which makes the roads impassable (Mukherjee *et al*, 2016). Land-use changes and urban development have led to the expansion of paved surfaces and as a result, has led to encroachment of riparian reserves. The immediate effect of such encroachments has posed flood risks to such areas and disrupted ecosystem services of such riparian reserves (Orewole *et al*, 2015). Water shortages have been a growing concern throughout the world with ongoing droughts, water rationing, climate change, and global warming. This has been attributed to the high population growth rate due to urbanization

and the high rate of land-use changes that exert pressure on already limited existing water supply (Tamara *et al*, 2016).

3.6 Concepts, Strategies, Standards and Principles in Management of Infrastructure

3.6.1 Management Concepts and Strategies for Roads and Transport Systems

Management of the transport system and roads require sustainable management strategies and solutions. Smart and intelligent infrastructure requires design principles, concepts and strategies. They include people-centered and inclusive infrastructure, resilient and sustainable infrastructure, interoperability and flexibility, managing risks and ensuring safety. The triple bottom line framework is to integrate the social, economic and environmental elements. Economic elements in the management of roads and transport will support the economic vitality in the development of urban infrastructure in a cost-efficient manner. The cost of transport and general management should be affordable to the households which they are willing to pay. The transport and road management should address the social needs by making transportation and road networks accessible, safe and secure and should be carried out equitably to accommodate the disadvantaged groups. Management of roads and transport infrastructure should create solutions that enhance environmental conservation, reduce emissions and pollutions such as the use of non-motorized transport and pedestrianization of some of the streets. Management of transport and road infrastructure should be in line with the current County Urban and Municipal Plans, County Integrated Development Plans, County Spatial Plans and County Sectoral Plans.

Best practice paradigms have advocated for sustainable management strategies that enhance an effective and efficient transport system which includes avoid strategies, shift strategies and improve strategies. Avoid strategies that focus on system efficiency to reduce or avoid the need for travel. This can be achieved through advocating for compact and mixed-use developments

as well as pricing and regulatory mechanisms through the introduction of levies for those who use private means of transport during the peak hours. Shift strategies are aimed at improving trip efficiency includes the shift from energy-intensive to walking cycling and public transport. This can be achieved by making cycling safer and attractive, promotion of public transport, provision of adequate and safe public spaces, improvement of street designs, seamless link between walking/cycling with Public Transport systems, Park and Ride facilities, Pricing and regulatory mechanisms to discourage private car ownership vehicles to the CBD area especially during peak hours and promoting alternative options such as carpooling, bicycle sharing. Improve strategies enhances vehicle efficiency through pricing and regulatory mechanisms with alternative means of transport such as ropeways technology, electric trains, cable cars, battery cars among others.

3.6.1.1 Management Principles for Roads and Transport Systems

Streets ensure the mobility of residents from one location to another as well as become joints of meeting and interaction, business and recreation activities making towns livable. Decisions made on such streets and roads have a great impact on the quality of life in such areas. It is essential to enhance the safety and security of all road users and more especially pedestrians, cyclists and any other form of non-motorized means of transport.

The principle of complete street designs enhances safety, efficiency and modal hierarchy. In designing for safety, the design of streets dictates the speed limit along such streets or roads. Streets that regulate and encourage low-speed limits encourage the non-motorized means of transport and pedestrian use hence enhancing the safety of such road users. All roads should have safe streets and roads with street lighting dedicated lanes for Non-Motorized Transport (NMT) users and Cyclists and secure pedestrian crossings. Mobility should enhance efficiency, convenience and safety of road users from their origin to their designation. This can be achieved

through high capacity and high-quality public transport systems. Road widening at the initial stages increases the efficiency or road users and encourages more people to own private cars but in the long run, the transport routes become congested and therefore road widening has never been a long-term solution to traffic problems. Therefore, the only long-term solution is by the use of high capacity and high-quality mass transport facilities and systems such as the Bus Rapid Transport as well as the non-motorized transport (NMT). Other solutions to reduce traffic congestion by reducing the number of vehicles on roads rather than by widening roads to accommodate the ever-rising number of vehicles is by increasing parking fees, congestion pricing and other measures.

In designing the modal hierarchy in the provision of infrastructure and facilities, more attention should be given to pedestrians, non-motorized transport/cycling and public transport with the least attention given to motorized transport especially private car ownership. The design of roads should ensure more space is allocated to pedestrian and cyclist lanes as opposed to the roads. Therefore, the priority networks should be the pedestrian networks, cycling networks and public transport networks. Pedestrian networks must be complete, have the shortest and direct connecting route, publicly accessible and safeguarded from vehicular traffic to enhance the safety of pedestrians. In areas with large blocks, redevelopment of such areas should correct such anomaly where such an opportunity arises to correct it. Areas with frequent pedestrian users should have pedestrian crossings where there are slow speeds and fewer volumes of traffic. Traffic control and traffic calming measures should be used in areas with faster speeds with high traffic volumes. Efforts should be made to revitalize open spaces for relaxation and recreation especially in routes designed for NMT users. Public transport systems should be connected seamlessly with the Non-Motorized Transport (NMT) for ease of transition from one mode to another.

Cycling networks require dedicated lanes with physical separation to ensure the safety and comfort of cyclists in areas with high traffic volumes. Short routes should be designed for cyclist lanes to key destinations more especially to facilities within residential areas and to workplaces with signage located at strategic locations for easy navigation. Public transport being a non-profit entity should be affordable and reliable to allow passengers to travel wherever and whenever they want. Management of roads and transport systems should ensure that such systems and facilities are accessible, affordable, reliable and acceptable. The availability of such public transport system should be in terms of route possibilities, timings and high frequencies. Management of public transport should ensure that such systems are acceptable by the users in terms of their personal safety, security, comfort and cleanliness. Public transport systems move large volumes of people faster and efficiently while occupying smaller space as compared to the private car as a means of transport. The efficient public transport system must offer the dedicated right of ways such as BRT lanes on high traffic transport corridors. Motorist networks should be restricted to ensure the efficiency and safety of pedestrians, cyclists and public transport systems. Effective regulatory measures must be put in place to regulate private transport systems and motorist lanes especially those near schools or public facilities to observe low traffic speeds. Ancillary amenities and sanitation facilities installations should be mandatory at destinations and considerations made for people with disabilities, children, elderly, expectant mothers, sick and women.

Street elements including raised footpaths for the pedestrian zone, frontage zone and furniture zone, wide cycle tracks, raised, direct with universal access crossings at areas of concentration of people, carriageways which are not too wide, bus stops with weather protection, landscaping, sufficient vending space, street lighting, aligned street furniture, stormwater, appropriately sized and calmed service lanes, utilities, on-street parking, safe, universal access, and direct

footbridges and subways must be planned and managed in a better way to create efficiency, easy accessibility and maneuverability, safety, security, comfort and unconstrained movement.

3.6.2 Level of Service and Standards in Management of Water Supply Systems

Management of water supply infrastructure requires its improved accessibility, equity in distribution, reliability, safety and quality, adequate quantities and acceptability in taste, smell and colour. Implementation of water infrastructure management must be done in an integrated approach to achieve an adaptable and resilient infrastructure that gives access to safe water and sanitation all groups including the disadvantaged groups. All stakeholders must be involved in the coordination and management of water supply systems. Wastewater should be recycled and reused in agriculture and open spaces management. The infrastructure must adapt to upgradability and modification in the case of urban expansion and population growth. Management of water management should be decentralized to enhance high efficiency and effectiveness in its management. The level of service provision and quantity of water collected is vital to promote its hygiene and therefore the recommended basic access to water within 1km distance and 30 minutes should be an average of 20 litres collected per capita per day. The optimal access and consumption of water are estimated at an average of 100 to 200 litres per capita per day and supply of piped water being through multiple taps within the house (Howard and Bartram; WHO 2003).

3.7 Case Studies of Best Practices on Management of Urban Infrastructure Systems

Sustainable urban infrastructure systems in the best practices ensure that the transportation and urban infrastructure systems support the economic vitality of the region in a cost-efficient and affordable manner meets the social needs of the people in terms of their accessibility, safety, security, inclusive of the disadvantaged and disabled groups as wells as creating solution which reduces environmental pollution and degradation. Managed urban growth and land-use

changes often have numerous core benefits such as minimized cost of growing and operating an urban area, reduction of effects on transportation systems, reduction in depletion of agriculture land, making land scarce and affordable, reduction in pressure on the environment, enhance urban design and aesthetics of undesirable features, enhance efficiency in the provision of social needs and enhance economic balance through local economic development. Besides, financial muscles and political will is vital in the implementation process of urban infrastructure and should be highly emphasized to ensure smooth execution of project proposals. Best case studies indicate how effective management of its urban infrastructure systems has been successful.

3.7.1 Case of Zurich's Transport Management Systems

Zurich is one of the most densely public transport networks in the world but it has the easiest access which is quick and reliable making it one of the best transport systems in the world. It is estimated that 44% of its residents or commuters use public transport to the workplace and that just 28% of all journeys are taken by car. The system works well due to its urban management systems which are integrated with multi-modal passes. The coordination is done by one agency with several transport lines which exhibits its technical dimension in the management of its urban infrastructure. The management ensures high-frequency departures that run day and night with regularly targeted fare reductions. The management has also ensured that future developments are built around the public transport lines or within walking distances to public amenities and shopping areas such as schools, shopping malls and workplaces. Zurich has traffic monitoring systems, quality of service with high operating frequencies of trams and integrated networks which led to the success of its public transport system. The benefits gained from such efficient and integrated transport system has attracted businesses and growth in the economy of the city, high reduction of greenhouse gas emission

making Zurich the lowest in emissions in Europe at 5 tonnes per person and boosted the social life of the city as it is ranked amongst the top cities in the world with high quality of life.

3.7.2 Case of Toronto's Transport Management Systems

The main challenge in transportation in most cities such as New York has been the ability to meet traffic congestion and developing transportation networks due to the growing population. The ability to the said challenges has been due to financial constraints and limited space. In the process of building new infrastructure and coordinating the systems can improve and increase the transportation capacity in the short-term period. Toronto has created overlapping networks of various transportation modes such as buses, subways, streetcars, bike shares and car shares which are integrated and linked by easily accessible real-time information systems. The integrated mobility has improved the transportation system and increased its capacity which should be replicated in other cities and towns such as Ruaka town through integrated mobility strategies that focus on coordination of existing transport systems to increase their connectivity and capacity.

3.7.3 Case of Singapore's Water Resource and Waste Water Management Systems

3.7.3.1 Water Resource Management Systems

Singapore is a small populated city that is considered a water-scarce country due to its limited land area available to tap water, lack of groundwater resources and the increasing population although there is plentiful rainwater. It has managed to get out of this situation through urban management strategies, institutional reforms and sound urban governance which has transformed it to the most reliable and model for successful water resource management in terms of its accessibility, reliability and sanitation standards to its population. It has emphasized on the adaptability and management of water supply and demand to ensure high water quality standards, reliability, service quality, sustainability, finance and efficiency. This has been made

possible through integrated water resource management with the diversification of water supply, expanding and building water reservoirs, management of water demand through pricing, enforcement of water conservation measures, importation of water and desalination of water. Singapore has integrated innovative approaches to water management which has intervened on problems of water supply and attained sustainable and cost-effective water management solutions. It has established long-term water supply strategies known as Four National Taps for collecting water from local catchments, NEWater-reclamation of water, desalination of water and importation of water. NEWater is a Singapore success story that exemplifies the determination of managers to turn challenges into opportunities from dirty to ultra-clean, high grade reclaimed water is a key innovation that Singapore invented that is a weather-resilient solution that cushions water supply against dry water. Political and government commitment to the realization of sustainable urban water management has promoted its success by giving the water a top priority (Chiplunkar *et al*, 2012). Singapore uses a progressive water tariff structure that penalizes the inefficient use of water for domestic water consumption that exceeds $40m^3$ per month (Tortajada, 2006). Lessons from Singapore can assist urban managers to adopt resilient urban infrastructure management systems that maintain infrastructure as opposed to building more or expanding the infrastructure. Rehabilitation and promotion of flexible development of new infrastructure services promote the sustainability of developments. There is a need to identify assets likely to suffer in case of future urban expansions and other vulnerabilities and provide solutions to curb such menaces. It is essential to identify the aging infrastructure or approaching the end of the design life and retrofit it or build a new resilient urban infrastructure. In addition to the technical dimensions, there is a need to involve the public in the implementation of such projects for public acceptance and confidence for the project to succeed as demonstrated in Singapore. This is through a public engagement campaign to educate the public on the stringent process of water production and

how to maintain the safety of water for drinking. This can be achieved through public media and community engagement programs that ensure community understanding and support. The governance of Singapore has led to a remarkable transformation and success stories of water infrastructure management. If infrastructure managers implemented the same formula, they will equally succeed through meritocracy which means the best people to be selected to run the infrastructure, pragmatism which means whatever ideology and policies work should be used and honesty in management of infrastructure through non-corrupt, transparent and accountable practices.

3.7.3.2 Wastewater Management Systems

Singapore has a holistic water management system that integrates both water and wastewater in providing clean water and proper sanitation to its citizens. In the management of wastewater, they have ensured high service coverage of waste management systems to serve urban areas. Their systems have a high rate of monitoring to increase detection in rates and areas of blockages to ensure that they are accurately registered. Singapore has laid concurrent emphasis on supply and management of wastewater, equity, efficiency, institutional effectiveness, an enabling environment with strong political will and effective regulatory and legislative frameworks. It has also ensured that there are collaboration and sensitization of its stakeholders (Tortajada, 2006). Singapore has substantially invested in wastewater infrastructure and ensured all industrial estates and residential areas are served with the public sewerage system and the management ensures that all wastewater is discharged into the public sewerage system. The wastewater systems are separated from stormwater drains whereby wastewater systems are directed to wastewater treatment plants and recycled while the stormwater and surface runoff is collected and drained to rivers and reservoirs. The separation prevents wastewater from polluting reservoirs and rivers and also stops stormwater from draining to wastewater infrastructure causing overflows. Singapore has ensured strict enforcement of the legislation to

ensure proper management of wastewater and minimize pollution and contamination. All developers must connect to the available sewerage system. Proposals of developments are scrutinized to prevent any damage to the existing wastewater infrastructure systems (Chiplunkar *et al*, 2012).

3.7.4 Case of South Africa's Water Resource Management Systems

South Africa has used water pressure management technology in the management of its water resource through Public-Private partnerships to the water supply system of Sebokeng and Evaton which are two of the high to medium density residential areas. The technology ensures minimization of water loss by controlling the pressure in the water supply and distribution networks as well as lowering the tariffs through the reduction of energy used for pumping water. Assessment done in these areas indicated that excessive high pressure in the water supply networks particularly during the off-peak hours caused damage to the pipes and fixtures leading too excessive water loss through leakages and wastages. High costs for repair, replacement, maintenance and management of the water supply systems were incurred. The advanced water pressure reduction installation plant reduced the water pressure during the off-peak hours and allows to a reduction in pressure at night which also reduces leakages. This reduced the amount of water wastage significantly.

3.8 Conceptual Framework

Land-use changes entail the drivers and effects of land-use changes as highlighted from the previous studies and theories on land use differentiation. This forms the basis of the conceptual framework. The land-use changes are the independent variables, urban infrastructure capacity being the dependent variable, intervening variables being natural growth, urbanization, population pressure, socio-economic and political factors which lead to the subdivision of land, conversion of land, densification, high private car ownership leading to traffic congestion and

having impacts on existing infrastructure. The effects of land-use changes on urban infrastructure capacity include low capacity and poor condition of roads, low capacity and unreliable water supply systems and poor wastewater infrastructures management systems such as septic tanks which leads to pollution and contamination. Interventions on infrastructure management would be through the technical, economic, social, environmental and political dimensions which can aide in evolving a management strategy to unravel the adverse effects on urban infrastructure.

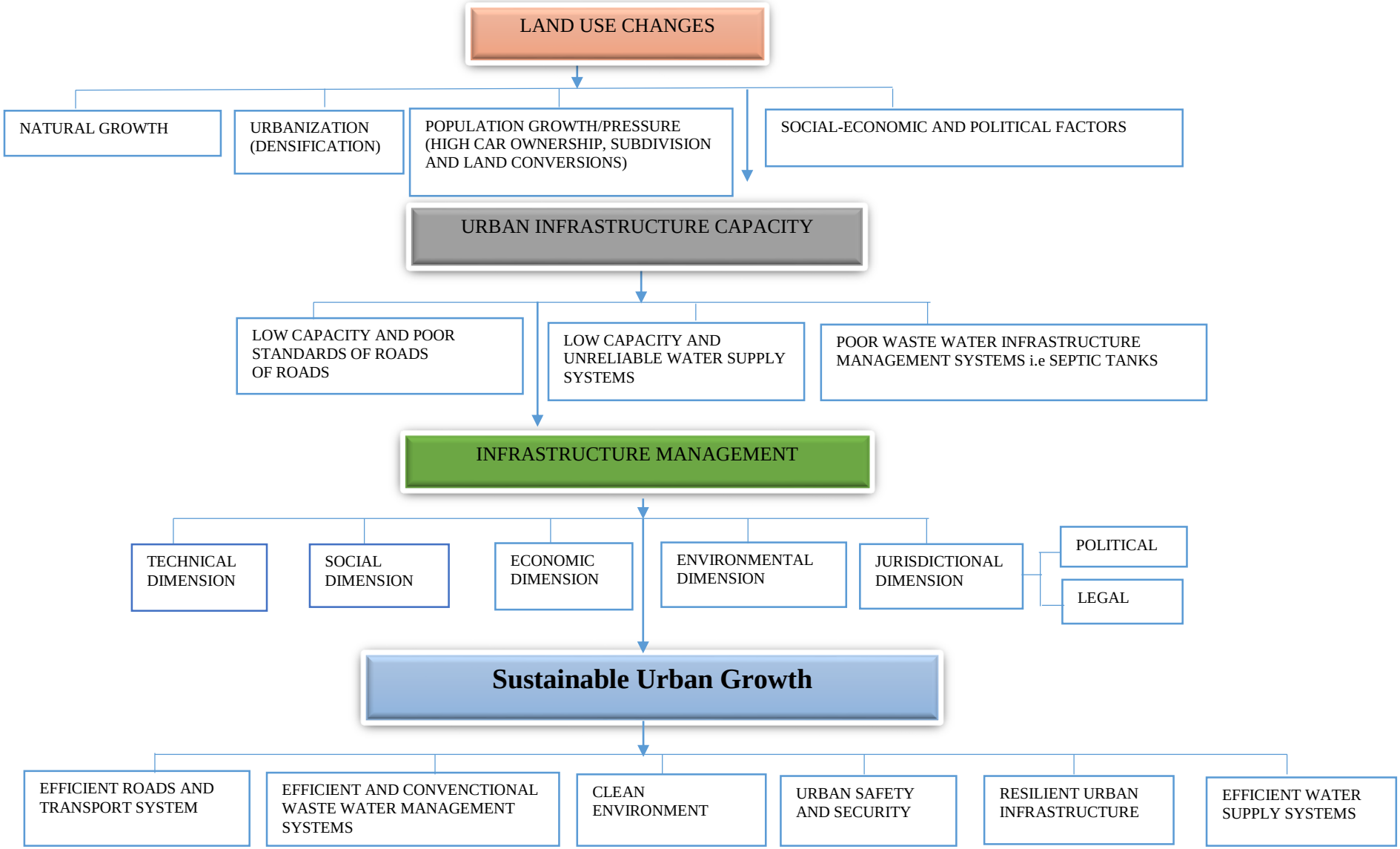
In evolving a management strategy to deal with the effects of LUC on urban infrastructure systems, the focus should be placed on dimensions of managing urban infrastructure to make them efficient, sustainable and resilient. Key emphasis must be laid on efficiency which looks at minimizing wastes, sustainability aiming at taking into the meaningful utilization of resources by the current generation without compromising on the ability of the future generation to utilize the same while resilience focuses on the proper functioning of urban infrastructure systems even after major shocks. In this regard management of the effect of land-use changes on urban infrastructure, capacity should look at the technical, economic, environmental, social and jurisdictional dimensions of management.

The technical dimension shall ensure the interconnection of urban infrastructure networks and enhance their interoperability in the same area or across jurisdictions. The economic dimension shall ensure the long-term investments and huge sunken costs on urban infrastructure systems are recuperated with minimal wastages realized. The environmental dimension shall focus on the management of urban infrastructure in the least polluting way with minimal environmental impacts from the urban infrastructure systems. Social dimension shall ensure the distribution of urban infrastructure in a socially equitable way in a non-discriminating approach. Jurisdictional dimension shall enhance coordination and collaboration of institutions in

decision making within the political and legal context across different jurisdictions. This will enhance transparency, accountability and foster good governance in implementing innovative policies and programs that increase the quality of public service delivery hence attaining economic growth (Grindle, 2004: Hellman *et al*, 2000). Such innovative policies advocate transparency and accountability, public participation and professionalism (Liddle and Mujani, 2005).

It can be concluded from the literature review that the key drivers of land-use changes are through natural growth, urbanization, population pressure, socio-economic factors and political factors among many others. These land-use changes have impacts on urban infrastructure as depicted from the current conditions manifested in strain on existing water supply systems, wastewater infrastructure, and roads. This requires interventions through dimensions of urban infrastructure management such as technical, economic, social, environmental and jurisdictional from best practice case studies. This will culminate in sustainable urban growth which manifests itself in terms of effective/efficient roads/transport systems, efficient wastewater management systems, clean environment, urban safety and security, efficient water supply systems and generally resilient urban infrastructure.

Figure 3-1: Conceptual Framework



CHAPTER FOUR: STUDY METHODS

4.1 Introduction

This chapter highlights the procedures and tools that were used in data collection, evaluation, and analysis to fulfill the objectives of the study.

4.2 Research Design

Quantitative and qualitative techniques of data analysis were used in the study. Descriptive design was used in the description of trends and comparisons of data findings to give an accurate and valid representation of the variables. Content analysis of books and journals was used and case studies were used to depict the best practices which were used in making recommendations.

4.3 Target Population

A target population is a well-defined group of people, elements or households being in Ruaka town in Ndenderu ward. The main target elements are urban built-up areas or buildings, vegetation and agriculture land. Other target populations include Ndenderu ward residents, the business community and developers and County Government officials from the Department of Land, Housing and Physical Planning, Karuri Water and Sanitation Company and Roads Department.

4.4 Sampling Design

The study adopted a random sampling design for the household questionnaires which mainly targeted the residents, business community and developers in Ndenderu Ward. It was essential to formulate a working formula to arrive at the sample size within the study area. To get a sampling size, Kothari (2004) formula for finite population size was used to get the right sample size: -

$$\mathbf{n} = \frac{\boldsymbol{Z^2.p.q.N}}{\boldsymbol{e^2(N-1) + Z^2.p.q}}$$

Where n=Sample size

N=35,750(Population)

Z=1.96(the value of standard variate at a given confidence level and to be worked out from a table showing area under the normal curve)

p=0.5 (sample population)

q=0.5(1-p)

e=0.05(given precision rate or acceptable error)

$$\text{n} = \frac{1.96^2.0.5.0.5.35{,}750}{0.05^2(35{,}750-1) + 1.96^2.0.5\,.0.5}$$

$$n = \frac{34{,}334.3}{90.3329}$$

n =**380.08 or 380**

The sampling was based on confidence level and precision rate concerning the population in Ndenderu Ward. Cochran (1967) states 30% of the population as sufficient for a study. A margin of error of 5%, confidence level of 95% and a sample proportion of 50% was used. A sample size of **380** was selected out of the population of 35,750 of Ndenderu ward as per the 2009 census.

4.5 Research Instruments

Quantitative data was collected from the County Government by administering the questionnaire and scheduled interviews with sub-county officials. The questionnaire was both closed and open-ended questions to seek in-depth information. The observation checklist and photography were also used in the process of data collection.

4.6: Data Collection

To achieve the intended objectives of the research project, both primary and secondary data were used as below discussed;

a. Secondary Data

The secondary data contributed to the formation of background information, needed to build constructively the project and the reader to comprehend the research findings. Sources of secondary data were mainly from a literature review of the existing data and previous studies on land-use changes, urban growth, urban sprawl, densification and their impacts on urban infrastructure.

b. Primary Data

Primary data on land-use changes were collected through analysis of Landsat imageries for a period between 1988 and 2019. Five remotely sensed data Landsat TM 1988, Landsat Enhanced Thematic Mapper plus ETM+ 1995, Landsat Enhanced Thematic Mapper plus ETM+ 1999, Landsat ETM+ 2010, Landsat OLI &TIRS 2019 for 30 years were used for the study. The research data that was used for this study comprised of Level 1 Landsat images acquired from Resource Centre for Mapping of Resources for Development and in particular Landsat-5 Thematic Mapper (TM), Landsat-7 Enhanced Thematic Mapper plus (ETM+) and Landsat-8 Operational Land Imager (OLI) and Thematic Infrared Sensor (TIRS) imageries.

The supplementary data was used from google earth imageries and topographical maps were to generate the location maps for the study area. Classification of land uses in the study area was into three categories notably vegetation, agriculture and built-up areas. If the current land-use changes are not controlled with an effective and efficient management strategy, then the capacity of the existing infrastructure will be unsustainable. Land use analysis reveals a decline

in agricultural and vegetation land and rises in built-up areas which compromises the efficiency of the urban infrastructure since it has not been expanded to the required capacity.

Table 4-1: Remotely Sensed Data and Their Characteristics

	Data	Sensor	Band	Resolution	Year	Source
1.	Landsat-3	TM	2, 3, 4 & 6	30m	1988	Resource Centre for Mapping of Resources for Development
2.	Landsat-5	ETM+	2, 3, 4 & 6	30m	1995	
3.	Landsat-5	ETM+	2, 3, 4 & 6	30m	1999	
4.	Landsat-7	ETM+	2, 3, 4 & 6	30m	2010	
5.	Landsat- 8	OLI	3, 4 & 5	30m	2019	
		TIRS	10	100m		

Scheduled interviews and questionnaires were also administered to residents, the business community, NEMA (National Environment Management Authority), WRA (Water Resource Authority), NCA (National Construction Authority) and County Government of Kiambu officials. This was used to collect information on the rate of land-use changes, drivers of land-use changes, their effects, challenges, and possible recommendations. This was resourceful in filling gaps identified during the literature review. Observations were used in the process of data collection with the aid of a checklist. Photographs were taken to capture the areas of interest to illustrate the scenario on the ground in terms of the problematic and opportunity areas. The main focus was on the drivers, challenges and effects of land-use changes.

4.7: Data Analysis

Landsat imageries were processed and interpreted using ArcGIS Desktop 10.3 software. The interpretation scheme adopted was a combination of supervised classification and visual modification. The LULC was estimated using a series of algorithms embedded ESRI ArcGIS

software. Mapping was the methodology used for LULC analysis for the period of 1988 to 2019 as discussed below.

Steps in Mapping Land Use Land Cover (LULC) Changes

a. Image Pre-Processing

The imageries acquired from Resource Centre for Mapping of Resources for Development having been downloaded from United States Geological Survey's (USGS) server were layer stacked and clipped as per the study area extents and then re-projected.

b. Creating A Spectral Signature File

A signature file was created by running the Iso-Cluster classification using the image classification toolbar using the ArcGIS 10.3. A signature file set for use in performing the unsupervised classification was then created and saved.

c. Land Use Classification

The land uses were classified into three categories vegetation, agriculture and built-up areas, as shown in the table below. Unsupervised classification, by use of the signature files generated and a maximum likelihood algorithm, was carried out for all imageries.

A map composition analysis, to identify the area of each class, was done by loading the resultant imageries into an ArcGIS environment. It was noted that the spatial resolution of the images was 30m i.e. each pixel represented a grid of 900 square meters and that 1 Hectare is equivalent to 10,000 square meters.

d. Accuracy Assessment

The assessment was used to check the accuracy of the classified image. The process was done in an ArcGIS environment and the comparison points were generated by the use of the stratified random technique. An accuracy report for each image was generated and for this study, the accuracy of more than 80% attained was deemed sufficient.

e. Change Detection

The analysis was determined by checking the difference between selected imageries by use of the Iso-Cluster unsupervised classification window that is activated by using the image classification toolbar in ArcGIS 10.3.

The overall rate of change between consecutive epochs was then estimated by calculating the variances between similar classes in the imageries.

Table 4-2: Land Use Classification

	Land Uses	**Description**	**Colours**
1.	Built-up areas	Residential and commercial land uses	Brown
2.	Agriculture	Farmlands and bareland	Light Green
3.	Vegetation	Areas with natural vegetation, ridges	Dark Green

Validation of Results

Four strategies were used to achieve the best practices and standards in carrying out the analysis;

a) **Kappa values:** The Kappa values represent a measure of accuracy between a classification map and the reference data. Best practices prescribe that values that are less than (<) 0.4 represent a poor kappa, those more than or equal to (>) 0.4 but less than (<) 0.8 represent a good kappa value while those that are more than or equal to (>) 0.8 represent an excellent kappa value as shown in table 4.3 For this study, kappa results that were more or equal to 0.75 were accepted and the imageries used for further analysis.

Table 4-3: Best Kappa Values

Best Kappa Values (K)		
K <0.4	Represents poor kappa	Not acceptable
0.4 <=K <0.8	Represents good kappa	Not acceptable
K>= 0.8	Represents excellent kappa	Acceptable

b) **Land Use Classification:** The maximum likelihood algorithm was used while defining the classes. Several imageries, a minimum of five, were derived and the best amongst them-imageries with the highest accuracy, was chosen to represent the classification for that year.

c) **Accuracy Assessment**: The assessment was done before classified imagery was used for the calculation of the LULC changes. Since the ideal range of reference points is usually quoted as between 30 to 50 points, 35 points were used in the accuracy assessment of the imageries. The stratified random technique, with a minimum of seven (8) points per each class, was used to distribute the reference points on the study area. An accuracy value of more than 80% was deemed sufficient. Imageries that resulted in a lower accuracy assessment were rejected and different imageries generated.

Additional collected data were analyzed through descriptive, inferential and cartographical techniques. Household questionnaire data collected was sorted, edited, entered, verified, validated and analyzed by the use of SPSS to give a final output in the form of frequencies and charts.

4.8: Presentation of Findings

The output of data analysis is presented using LULC maps depicting the nature of land use changes over time. Qualitative data was generated from scheduled interview reports, household questionnaires and observation checklist that were categorized in accordance to the study objectives and reported in narrative form to collate quantitative data.

4.9: Ethical Consideration

Clearance was sort from the Department of Architecture and Building Science, my supervisors and the National Commission for Science, Technology and Innovation. Clearance and informed consent from the County Government of Kiambu was sought for ethical handling and collection of data through the officials in the respective departments in the County Government

of Kiambu, WRA, NEMA, Regional Centre for Mapping of Resources for Development (RCMRD), Karuri Water and Sanitation Company Ltd and NCA. Clearance was sort from the County Commissioner for security purposes. Good-will was sought from the developers to facilitate the data collection process. Consultation and public participation were voluntary. Confidentiality and anonymity of data were maintained at all levels during the study period to respect the privacy of all respondents. The research looked at what is permissible to ask so that it doesn't cause any harm to researchers or other subjects and that no lying or deceit was used in getting research information. Mapping was a challenge especially when analyzing the Landsat imageries since the imageries were taken during different seasons of planting or harvesting. In some instances, there were cases of cloud cover which led to the acquisition of more Landsat imageries for comparison. A careful selection was done to eliminate instances of cloud cover within the study area boundary.

Table 4-4: Research Design

Research Objectives	Data Needs	Sources of Data	Methods of Data Collection	Methods of Data Analysis	Outputs
1. To document the land-use changes and establish their drivers in Ruaka Town, Kiambu	Literature review, existing zoning policies, and regulations, proximity to urban areas, existing infrastructure i.e roads, water, and wastewater infrastructure, the rate of return from investments, demand for housing and income-generating activities.	Literature review Zoning policies and regulations, Interviews, Questionnaires	Literature review, Observation, Interviews, Questionnaires,	Analysis of Questionnaires, evaluation of reports and plans	Maps on land use trends over the years Report on drivers of LUC. Report on the role of the County Government of Kiambu in management of land-use changes. Role of other external factors such as socio-economic and political factors
2. To establish the effects of land-use changes on existing roads, water, and wastewater infrastructure in Ruaka Town, Kiambu.	Social, economic and environmental effects of LUC on urban infrastructure	Interview Existing policies, Observation	Observation, Interviews, Questionnaires	Analysis of study findings	Report on effects posed by LUC to existing roads, water, and wastewater infrastructure.
3. To evolve a management strategy to unravel the effects of land-use changes on roads, water and wastewater infrastructure capacity.	Management of transportation/road networks Management of water and wastewater	Best practices Recommendations from the field findings	Assessment of findings and draw conclusions	Analysis of best practices.	Evolve a Management Strategy to unravel the effects of land-use change on urban infrastructure systems through the dimensions of technical, social, economic, environmental and jurisdictional (political and legal). Recommendations on the management of urban infrastructure making in land use change-resilient based on findings, best practices and experiences.

CHAPTER FIVE: DATA ANALYSIS, PRESENTATION AND INTERPRETATION

5.0 Introduction

This chapter highlights the analysis of the findings and discussions of data collected to fulfill the objectives of the study.

5.1 Response Rate

Out of 380 Household Questionnaires which were administered to the residents and business community within the study area, only 350 questionnaires were returned which translated to 92.10% response rate.

5.2 General Information on the respondents.

5.2.1 Level of Education

The study revealed that 56% of the respondents have attained university education level. This explained why most of the residents are working-class people who reside in the area in Nairobi and other neighboring towns.

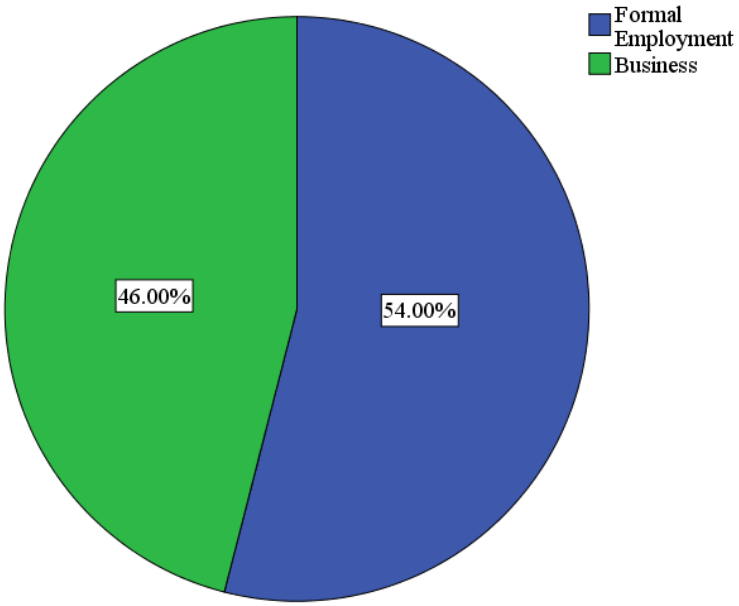
Table 5-1: Response To the Level of Education

Level of Education	Frequency	Percentage (%)
Secondary	35	10
College	119	34
University	196	56
Total	**350**	**100**

5.2.2 Respondent's Occupations.

The study established that the main occupation is formal employment and business activities. This explains the demand for residential flat development to accommodate the majority of those who work around the area and in Nairobi. The other respondents are mainly engaged in business activities that have high returns with the high population in the area.

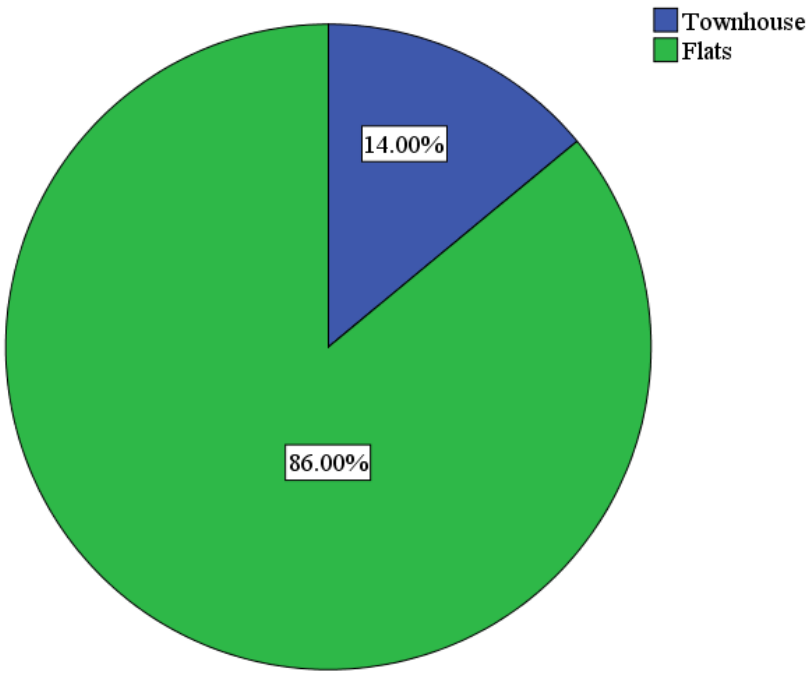
Figure 5-1: Occupations



5.2.3 Housing Typology

The study revealed that most of the housing typologies at 86% of the respondents revealed that they reside in residential flats or carry out their businesses in commercial flats developments. The findings revealed 82% of the respondents were tenants which is an indicator of the high residential developments put up for rentals due to the high rate of returns from investments.

Figure 5-2: Housing Typology



5.3 Land Use Classification and Documentation for the Period 1988-2019

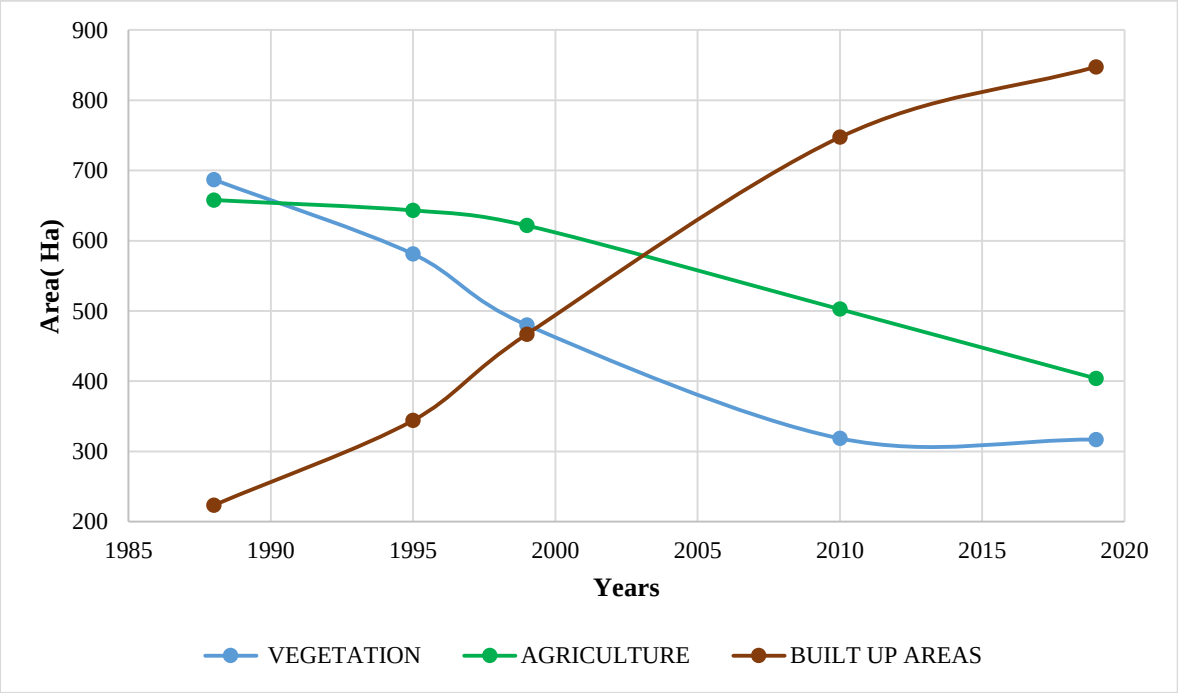
Landsat imageries for the study were classified into three distinct classes namely; vegetation, agricultural and built-up areas. The built environment would not be further classified to various land uses since from imagery it is difficult to identify the land use whether its industrial, residential, educational or commercial use. Vegetation is represented parcels of land under natural vegetation cover such as trees and shrubs. Vegetation cover is predominant along the riverine and ridges. The land-use classification was carried out from the year 1988 when there was a shift from agricultural to residential land use when coffee farming reached the peak since independence and started declining a result of price fluctuations, low productivity, rural-urban migration and also the political changes when elections were held in Kenya that triggered the shift of people to reside in these areas. Besides, the clear landsat imageries were available from 1988 when the classification and analysis would be done. The land-use change from 1988 to 2019 indicates a rapid decline in vegetation cover. Agricultural is the land under farming, bare land and cultivation. Most of these areas have been undergoing rapid decline of crop farming to built-up areas with massive land use and land cover changes. The built-up areas are areas

with buildings including commercial, residential and educational among many others. The land-use change from 1988 to 2019 indicates a rapid increase in developments.

Table 5-2: Land Use Cover Changes 1988 to 2019

Land Use / Year	1988		1995		1999		2010		2019	
	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)
Vegetation	686.97	44	581.04	37	479.88	30	318.51	20	316.89	20
Agriculture	657.9	42	643.14	41	621.54	40	502.47	32	403.83	26
Built Up Areas	223.38	14	344.07	22	466.83	30	747.27	48	847.53	54
Total Area	**1568.25**	**100**	**1568.25**	**100**	**1568.25**	**100**	**1568.25**	**100**	**1568.25**	**100**

Figure 5-3: Land Use Land Cover Changes Trends



Land Use Classification of Landsat Imageries

The research findings revealed three major land use/land cover changes:

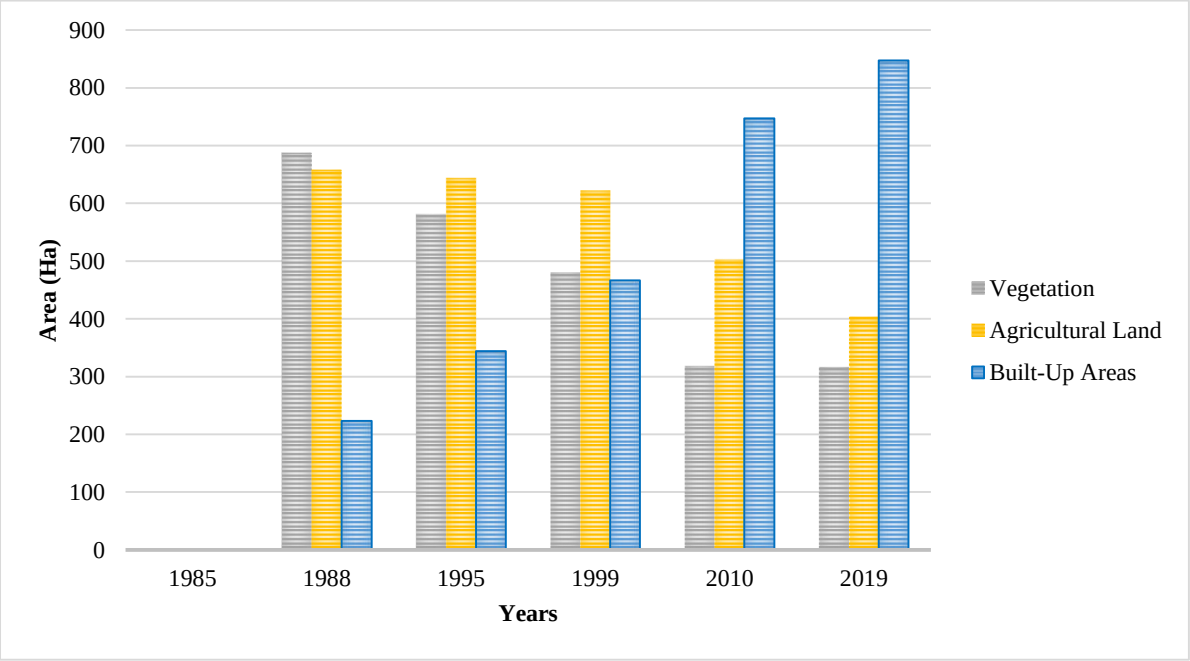
Declining Agricultural Land

The statistics indicate that vegetation cover and agriculture which occupied 44% and 42% respectively in 1988 declined significantly to 20% and 26% respectively in 2019.

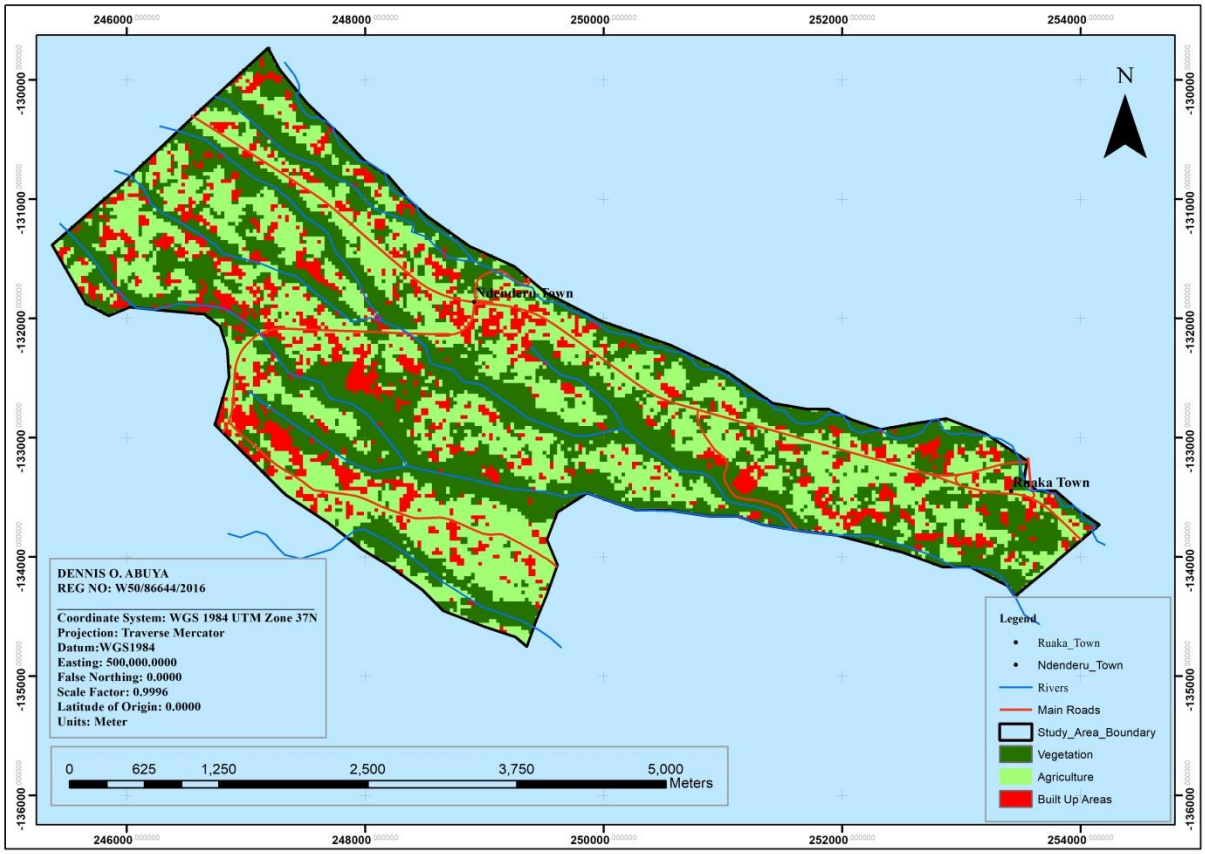
Increase in Urban Built-Up Areas

The statistics indicate that vegetation which has been declining from 44% in 1988, 37% in 1995, 30% in 1999, 20% in 2010 and 20% in 2019, agriculture declining from 42% in 1988, 41% in 1995, 40% in 1999, 32% in 2010 and 26% in 2019. Built-up area has increased rapidly from 14% in 1988, 22% in 1995, 30% in 1999, 48% in 2010 and 54% in 2019. This is attributed to land-use changes and high land conversions in the area.

Figure 5-4: Land Use Land Cover Changes Comparison

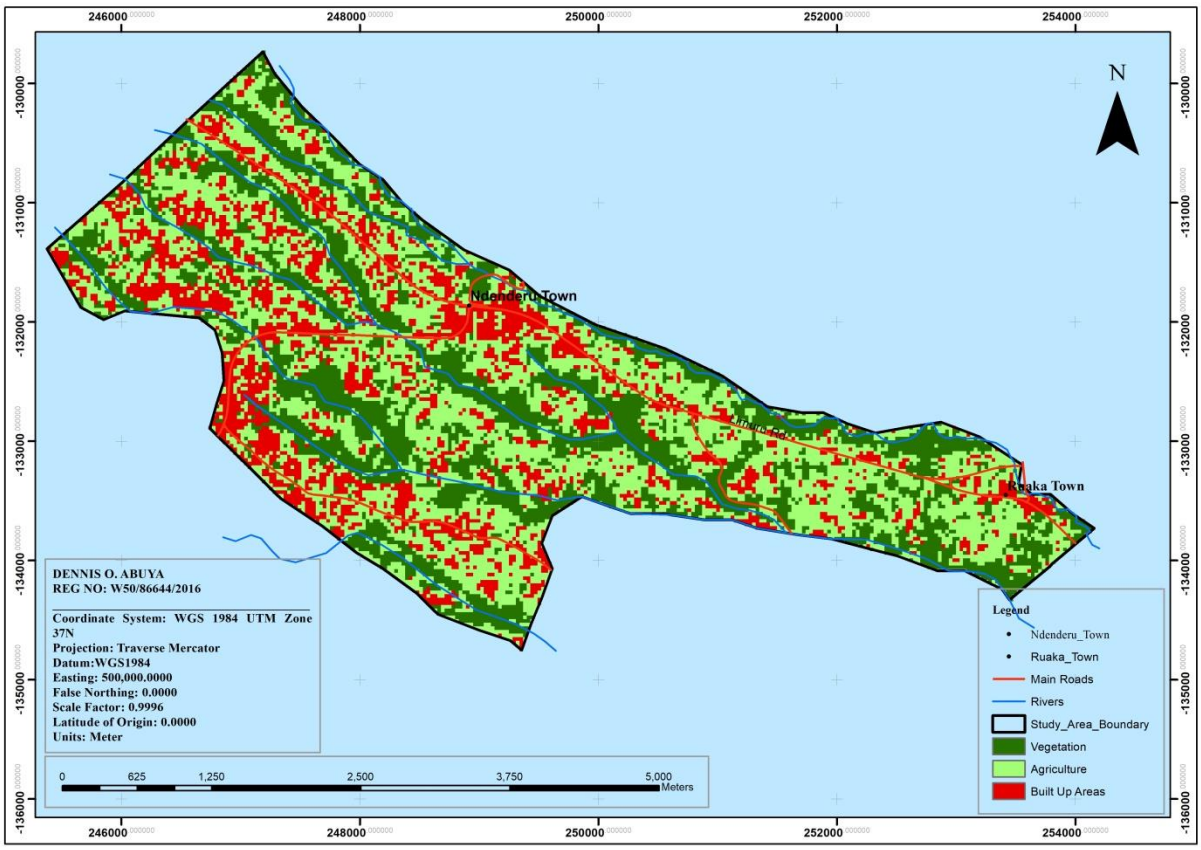


Map 5-1: Land Use Changes 1988



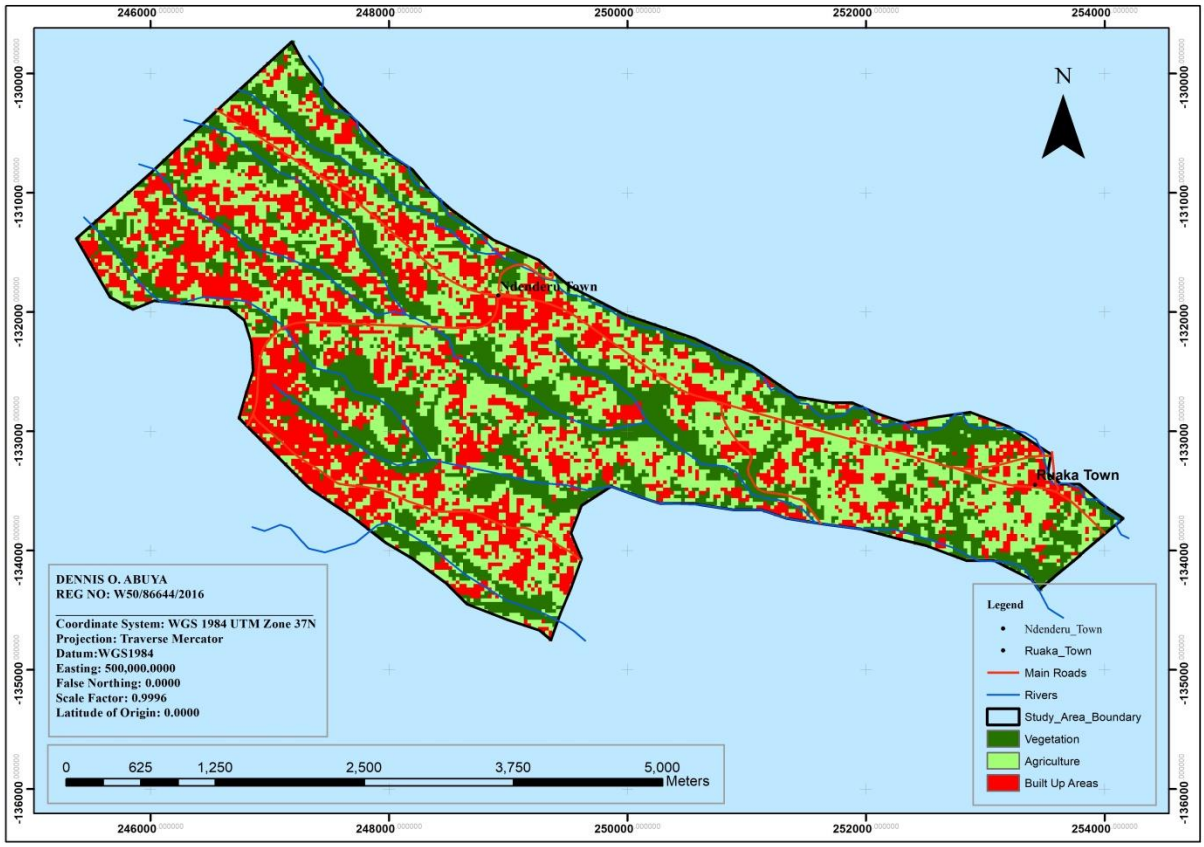
The analysis indicates that vegetation occupies 44%, agriculture 42% and built-up area 14% of the land. This indicates that the major land use was agriculture and vegetation as compared to built-up areas with clustered and dispersed settlement patterns. This indicated that the area was under the agricultural with cultivation being the main activity in the ward.

Map 5-2: Land Use Changes 1995



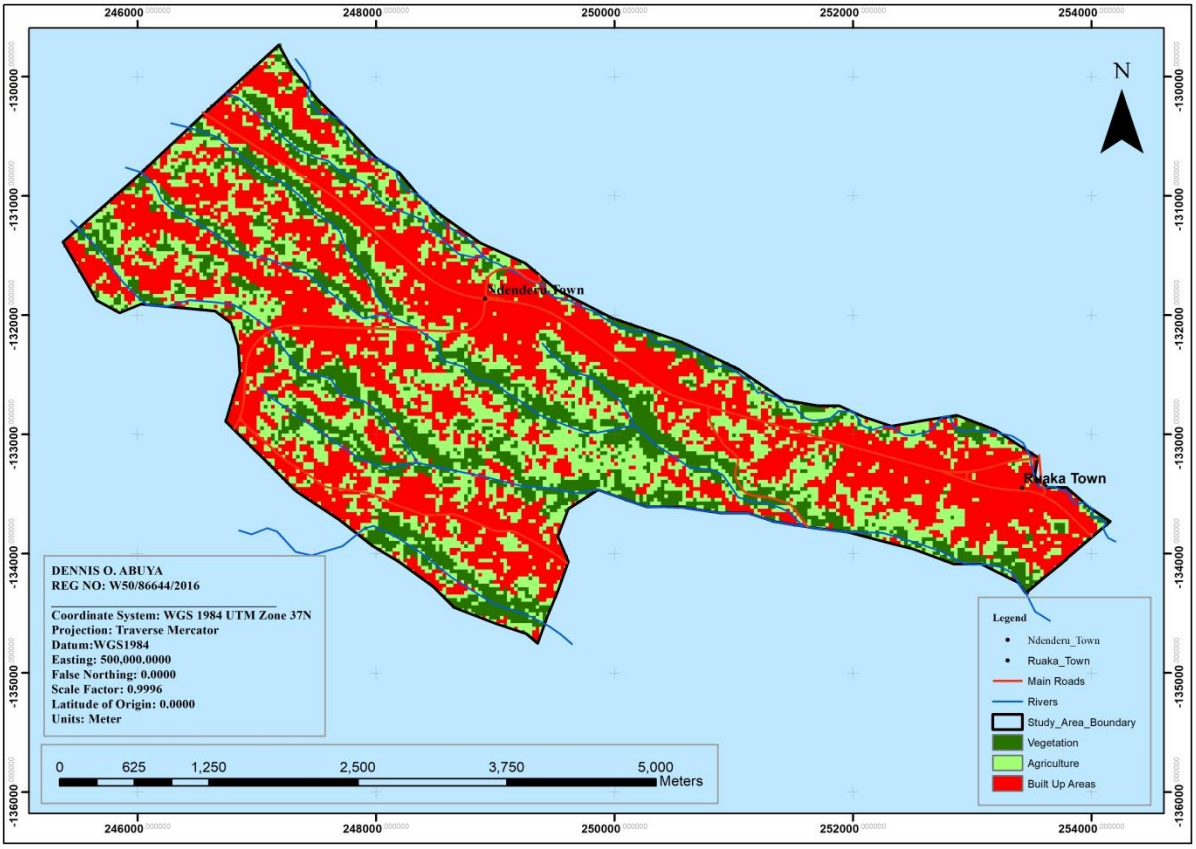
The analysis indicates that vegetation occupies 37%, agriculture 41% and built-up area 22% of the total land. This indicates a steady rise in built-up areas as compared with other previous years and more especially along the major roads where the land is relatively flat. The findings reveal both linear and dispersed settlement patterns.

Map 5-3: Land Use Changes 1999



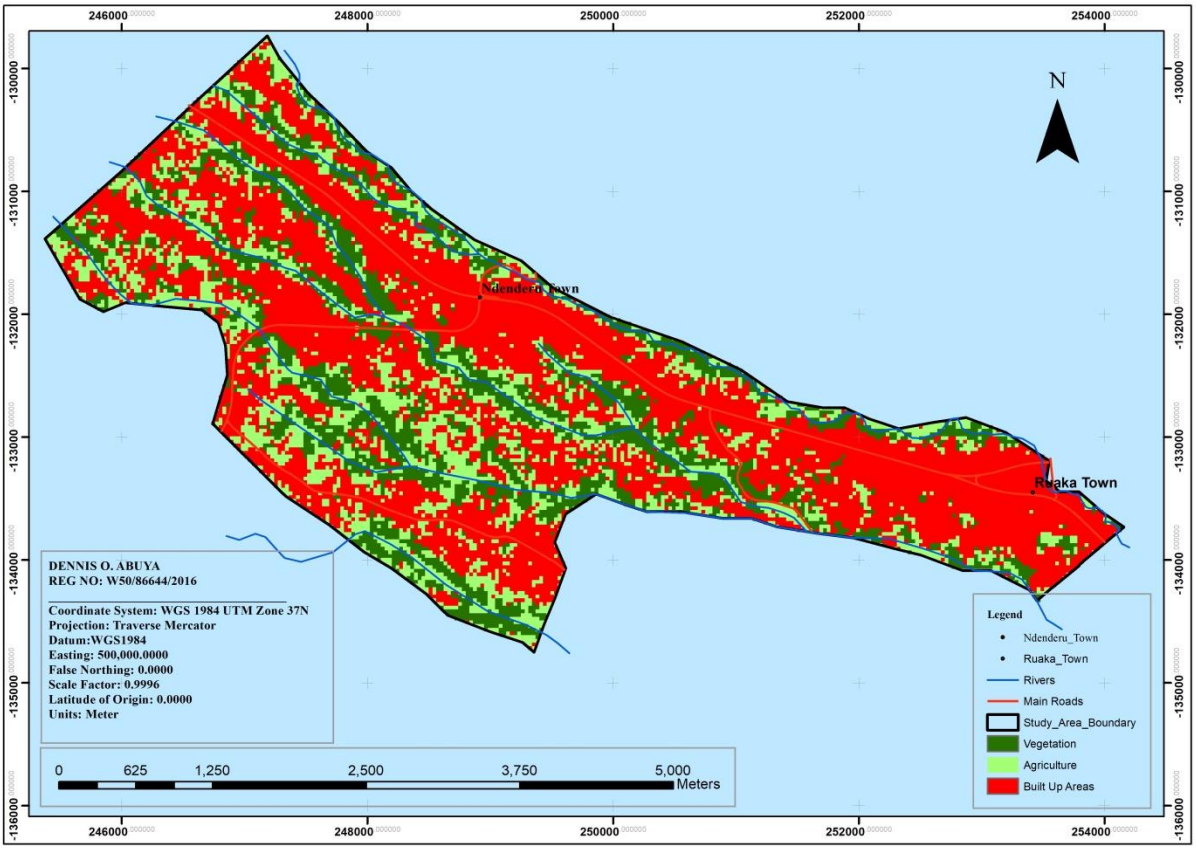
The analysis indicates that vegetation occupies 30%, agriculture 40% and built-up area 30% of the total land. This indicates a steady rise in built-up areas as compared with other previous years and more especially along the major roads where the land is relatively flat. The findings reveal both linear and dispersed settlement patterns.

Map 5-4: Land Use Changes 2010



The analysis indicates that vegetation occupies 20%, agriculture 32% and built-up area 48% of the total land. This indicates a steady rise in built-up areas as compared with other previous years and more especially along the major roads where the land is relatively flat. The findings reveal a linear settlement pattern that emerges. The findings also reveal the emergence of developments to vegetation and riparian reserves leading to encroachments.

Map 5-5: Land Use Changes 2019



The analysis indicates that vegetation occupies 20%, agriculture 26% and built-up area 54% of the total land. This indicates a steady rise in built-up areas as compared with other previous years and more especially along the major roads where the land is relatively flat. The findings reveal a linear settlement pattern that emerges. The study establishes a decline in vegetation and agriculture with a rise in built-up areas whose partial contribution is through urbanization and population growth in the area. The major land fragmentations to smaller plots are triggered by land-use changes and conversions to residential and commercial land uses as occasioned by the plot sizes that are not viable for agricultural land use. This is a clear demonstration of how Ndenderu Ward and Ruaka town are experiencing a rise in the rate of land-use changes and urban expansions characterized by an urban sprawl towards Limuru and Gachie town. The findings also reveal encroachment of development to vegetation and riparian reserves which expose the human population to disasters and calamities in-cases of climate change. Lack of

approved planning policy has encouraged massive land-use changes due to the *ad hoc* nature of planning using the development control tools which are not documented. This has led to the linear development model as illustrated in Map 5-5 with little efforts to provide adequate and efficient urban infrastructure including roads, water and wastewater infrastructure. Besides, the County Government doesn't have enough capacity to enforce development control measures to realize urban development that is commensurate to the available urban infrastructure capacity. Implications of the LUC have led to increased water scarcity and depletion of underground water aquifers as occasioned by low water production from the boreholes. The surface water has been affected since most of the rivers are seasonal. The land-use changes have seen massive encroachments of built-up areas to a riparian reserve which has led to declining of the vegetation in the conservation areas. The current traffic congestion experienced is as a result of the land conversions to residential flats that accommodate a high population depending on private cars. The high land conversions to residential and commercial developments have led to rising in onsite-liquid waste treatments such as septic tanks which often experience leakages leading to contamination and pollution of water sources.

5.4 Drivers of Land Use Changes

Development as a result of land-use changes in Ruaka town is demand-driven due to the growing economy rather than infrastructure driven development which seems to be a yawning gap between urban development and infrastructure since there is no approved land use and infrastructure development plan for the area guiding such developments. The study revealed that 66% of the respondents had lived in the area in less than 5 Years during which such land-use changes and urbanization in the area were on the rise.

Table 5-3: Number of Years Lived in the Study Area

Number of years lived	Frequency	Percentage (%)
Less than 1	14	4
1-5	231	66
6-15	56	16
16-20	42	12
Over 21	7	2
Total	**350**	**100**

Several factors led to their settlement or undertaking business and investments in the area. This included the area being an ancestral land, proximity to family members and friends, increased population growth and urbanization in the area with high demand for residential and commercial land uses and activities, proximity to workplace especially Nairobi City, availability of good infrastructure facilities and services in the area, market forces and great investment opportunities in the area with high returns/profits from the real estate industry in the area, cheaper accommodation, availability of employment opportunities in the area, land speculation with the high land values, presence of nearby institutions such as UN, UNEP and the embassies, beautiful ambiance, good conducive climate and environment with good accessibility of the area to different areas with major roads and bypasses. It was established that 74% of the respondents believe that the high rate of land-use change should be addressed to make the rate of land-use change sustainable with the provision of resilient urban infrastructure which will be able to absorb the shocks of such rapid land-use changes.

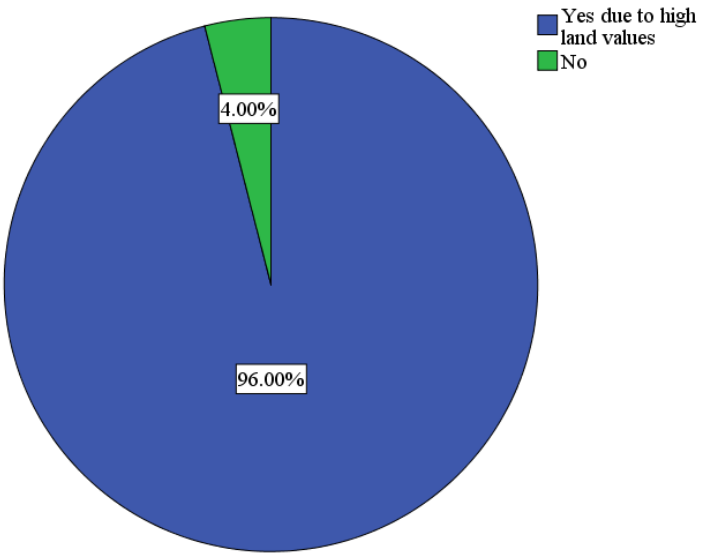
Plate 5-1: Major Urban Developments in the Area.

Plate 5-2: Land Use Changes from Agricultural to Built-Up Area

Plate 5-3: Northern Bypass and Limuru Road Traversing the Study Area.

Presence of many access roads resulted in a rise to major urban development investments in the area. Out of those interviewed, 100% of the respondents revealed that there is a high rate of land use changes from agricultural to commercial and residential land uses with 96% of the respondents indicating that these are as a result of the high rate of land subdivision in the area.

Figure 5-5: Rate of Land Subdivision



Despite these opportunities, several challenges have been faced which includes increased development with high plot ratios and plot coverage, traffic congestion, poor condition of roads which are muddy, floods in some sections, lack of adequate and clean water supply, a high population in the area with congestion, cold weather, rugged terrain which is not favorable for future development hence encouraging linear development, insecurity and hostility in the area, urban heat island as a result of the land-use changes, inaccessibility of some areas by public transport which is far from the main road.

Plate 5-4: High Development Densities in the Area.

5.5 Effects of Land Use Changes on Urban Infrastructure

This phenomenon of urban land-use changes has continued to put pressure on the remaining agricultural land hence suppressing production. Unplanned developments have emerged which has led to a strain on existing urban infrastructure facilities and services. Developments that have sprung up to don't have an efficient road, water supply, and waste infrastructure systems and therefore without any infrastructure bounded panacea, it may be a peril to the sustainability of the urban infrastructure. Residents use narrow un-tarmacked roads for access, boreholes as the main source of water supply, pit latrines and septic tanks for wastewater management.

5.5.1 Road Infrastructure.

The area has been undergoing land use transformation with a high rate of uncontrolled land subdivision in the area which has led to sudden massive negative effects. Most of the resultant access roads are narrow as revealed by 60% of the respondents indicated that they are served by 6-metre-wide roads which are not adequate for the high-rise development and densification of the area. Besides, most of the edges along the access roads are not usually trimmed which have caused obstructions along some access roads.

Figure 5-6: Size of Roads Serving Properties

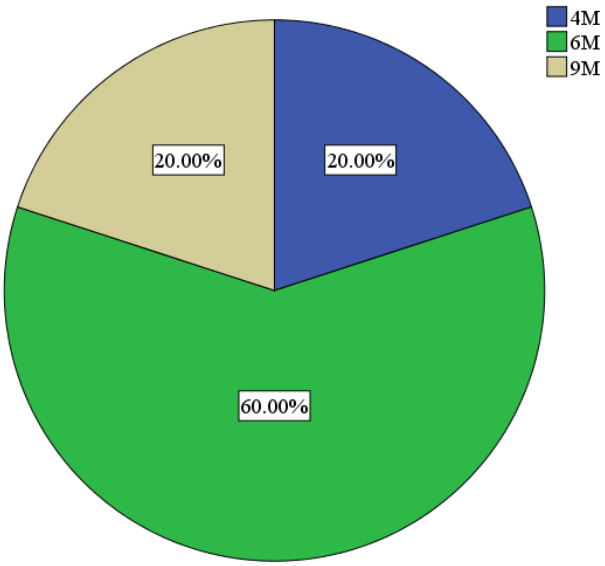


Plate 5-5: Narrow Access Roads That Serve Major Developments.

Research findings reveal that the existing travel patterns are both internal and external with the travel demand being educational, work and shopping purposes. The modal choice is both public and private with the means of transport being roads. Trip generation is mainly from the residential flats areas going to work or shopping areas. The trip distribution is mainly to Nairobi city. It was indicated by 96% of the respondents indicated that there is reliable public transport in the area. Limuru Road is the main public transport route where public modes ply to and from Nairobi city.

Plate 5-6: Availability of Public Transport along Limuru Road.

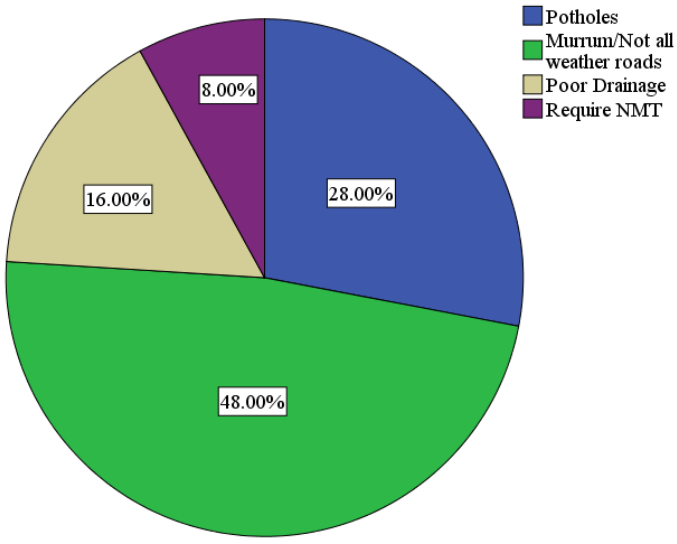
Most of the access roads which form streets are connected directly to the main road forming the network with the main node being at Ruaka CBD area. Traffic volume is at the peak mainly

during the morning and evening being the time to work or from work and on weekends with main shopping taking place at Ruaka CBD area and nearby shopping malls such as Two Rivers and Roselyn Riviera.

Plate 5-7: Two Rivers Shopping Mall.

The challenges on the major roads revealed by the respondents include presence potholes, murram roads which are not all-weather roads with weather changes, lack and poor maintenance of stormwater drainage where they exist and lack Non-Motorized/Cyclist lanes provision as indicated by 80% of the respondents.

Figure 5-7: Condition of Roads



It was noted from the respondents that most roads lack street lighting which makes the area more insecure and unsafe, especially at night. In some areas, there is a security light installation by the private developers along with some streets. Other major effects from roads and transportation included air and noise pollution, climate change, traffic delays, road accidents especially between motorists and NMT users

The main challenge in the area revealed is traffic congestion which is mainly caused by many direct exit points to the main roads, poor condition of roads that slow down movement, parking along the roadside, narrow access roads, presence of commercial activities that pull people, densification and increased high rise developments with high population in the area, presence of institutions such as UN, UNEP, Embassies, proximity to estates such as Runda estate, undesignated location of a bus stop at the junction of Ruaka and Banana route as well as high car ownership as revealed by the study that 62% of the respondents owned vehicles.

Plate 5-8: Direct Entry Points to the Main Limuru Road

It was observed that there were high motorization rates with a high rate of private car ownership in the area and therefore transport planning was more focused on the car rather than people-

centered planning and management. Accidents were observed along the major roads particularly between the NMT users and motorists since they used the same road which was not separated. This was a major concern on the level of disparity with a high rate of the population relying on NMT but there was the little provision or allocation and funding for such an alternative transport mode.

Although the area is not prone to flooding as revealed by 60% of the respondents, it was noted that in some areas floods occur due to high development coverage making the area a concrete jungle, development on natural stormwater drainage way-leaves leading to obstruction of natural water flow and as a result of lack of proper drainage channels. It was revealed from 78% of the respondents that most of the roads in the area do not have the provision of storm-water drainage channels and where they exist, they are not maintained.

Plate 5-9: Narrow Roads That Lack NMT/Drainage Wayleaves along Access Roads.

These land-use changes have brought several effects on roads as revealed from the study such as traffic congestion, a decline in the condition of roads with potholes with heavy machinery for the ongoing developments in the area, narrow roads as a result of many subdivisions with resistance by developers to surrender part of their land for road widening to accommodate the generated traffic from densification, high ground coverage of developments to cover up the high cost of land in the area as well as surrenders for road widening.

Plate 5-10: Traffic Congestion

High urbanization and population in Ruaka town have seen a traffic problem where the increased private car ownership and use which has been exponential and has resulted in huge traffic volumes. This has seen high travel demand and the generation of trips with different modes of transport vehicular, pedestrian and cycling. It was revealed from the study that 7 out of 10 cars that ply along Limuru Road are private cars. During the peak hours in the morning from 6.00 to 9.00 a.m. and 5.00 to 7.00 pm, there is usually heavy traffic with the travel speed-reducing from 60Km/Hour to 15 to 20Km/Hour. This is similar during the weekends especially when most of the residents move to the nearby shopping malls. Besides, Ruaka town lacks a central bus park or designated parking area which has seen indiscriminate parking especially on vegetation/road reserves that have led to the loss of green spaces and pollution.

Plate 5-11: Parking in Undesignated areas leading to loss of vegetation

The area is experiencing a rapidly growing economy with a transport paradox experience since it worsens with growth in development. This has seen increased car ownership leading to traffic volumes and traffic congestion leading to global warming, higher energy consumptions, higher emission levels, noise and air pollution. The high car dependency and increased trips, therefore, demand infrastructure and services which are costly. Besides, the area has experienced increased conflicts among different modes since there is no clear demarcation and dedication of lanes for different modes of transport which has often led to accidents at the junction of Limuru road and Banana Road.

Some of the indicators of such densification as a result of land-use changes include constant surface run-off and floods which has led to worn out and potholes development of the murram roads in the area as well as the overflow of storm-water from drainage channels where they exist although they are non-existence in most of the roads. Existing roads lack the drainage channels, walkways, cyclist lanes and street lighting with the increasing densities as a result of the rapid land-use changes taking place in the area. Densification of the area as seen traffic congestion due to increased car ownership and more especially on narrow access roads

whereby developers are unwilling to surrender part of their plots to pave way for road widening some of which have sharp corners which have often led to accidents. Such narrow roads cannot be adequate to provide for storm-water drainage channels, street lighting, and Non-Motorized transport/walkways/cyclist lanes.

The main arteries which serve as public transport infrastructure have not been provided with the facilities required for a conventional public transport system such as terminal facilities and proper transit interchanges. On the other hand, there has been a problem with the maintenance and upgrading of the roads with road signage which is crucial to enhance effective and efficient transport systems. Although there is no clear infrastructure plan for the area, the construction of western and northern bypass has eased congestion and increased the connectivity of the area.

The respondents made the following recommendation to roads infrastructures such as having clear and few direct exits points to the major roads, repairs, tarmacking and maintenance of roads, the subjection of all major developments to surrenders for road widening, provision of street lighting to enhance security and safety, County Government to enforce the surrender for road widening on all narrow roads as well as regulate the subdivision levels and subjection of all developers to maintain roads before and after construction in areas where they cause disruption and damages. It was equally recommended better coordination between the National and County government be enhance for efficiency and effectiveness in the maintenance and management of roads.

5.5.2 Water Supply Infrastructure.

Ndenderu ward is not served with piped water but only a small section of Ruaka Town is served with piped water by the Karuri Water and Sanitation Company Ltd. The area has a high population with high demand for water supply who use boreholes as their main source of water with a few connected with piped water within Ruaka Town. A greater percentage of

respondents at 94% indicated that they use borehole water while 6% rely on piped water or supply from Karuri Water and Sanitation Company Ltd, 94% of whom indicated that the water supply was not reliable. With the water shortage in the area, households use water of approximately 30-200 litres per household per day with an average of 40 litres per capita per day. Those that are connected experience water rationing and indicate that the water supply is not reliable since its only available for two days in a week and not for 24 hours. Wealthy residents cope up with erratic services through the use of substitutes such as buying water from the suppliers, boreholes, storage reservoirs and purification equipment to supplement the water supply. The poor who may not pursue this route which is very expensive since they cannot afford, they suffer most as they wait for the water to come or buy from the vendors whose water source and quality is unknown.

Figure 5-8: Sources of Water

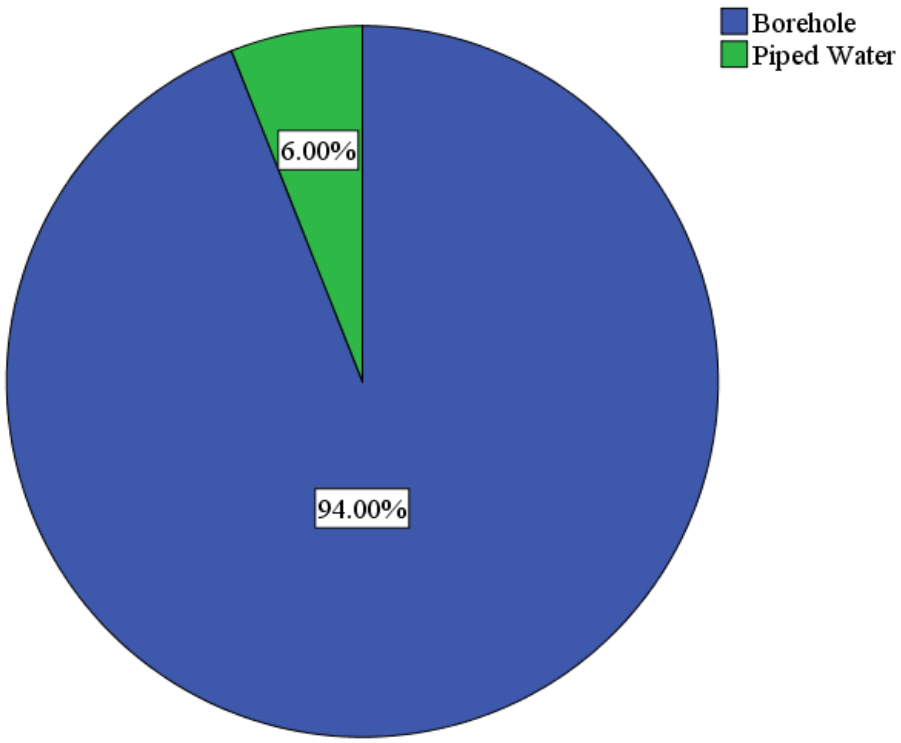


Plate 5-12: Boreholes in Ruaka Area

Karuri Water and Sanitation Company Ltd relies on water supply from four public boreholes distributed in Ndenderu Ward with Gacharage Borehole yield of approximately 15m^3 per hour, Kianjogu borehole yields 4 m^3 per hour, Ndenderu dispensary borehole yields 25m^3 per hour and Wangunyu borehole which yields 4m^3 per hour. The total production from boreholes is approximately 48m^3 per hour which translates to 18,720m^3 per month when pumping daily for 13 hours. Water supply is supplemented by piped water from Nairobi Water Company offtake at Ruaka estimated at 1,500m^3 per week and total production of 6,000m^3 per month. The amount of water supplied in Ruaka Town is estimated at a total production of 24,720m^3 per month with the revenue water being 16,068m^3 per month and Non-revenue estimated at 8,652m^3 translating to 35% of the total water production. This is the water lost to illegal connections, leakages from burst pipes and distorted meter readings. The bursting of pipes is mainly due to the high vibrations from lorries and trucks in the construction industry, lack of regular monitoring, replacement and upgrading of the piping systems which have gone beyond their lifespan. This has been occasioned by a lack of management strategy, funds and political

will to prioritize urban water supply and waste management systems. The current 4-inch mains and 1.5-inch reticulation pipes are not adequate and require upgrading and replacement within 10 to 15 years. There are approximately 2,500 individual water connections with an average of 6 people served by one connection. The total population served by water supply is approximately 15,000 people with the water supply of approximately 16,068m^3 per month and an average of 1m^3 per month per connection which is about 50% of the current projected population of about 36,860 people with total water demand of 2,949m^3 per day indicating that the water coverage is low. Water consumption is estimated at 80 litres per person per day within Ruaka which is slightly below the international best practices that require water consumption to be at 100 to 200 litres per capita per day (WHO, 2003).

Currently, in the year 2019, it is projected that there are 57, 140 people in Ndenderu ward with an average requirement of 100 litres per day which translates to the water demand of at least 5,714m^3 per day which is quite low compared to the current water production. Due to a lack of a substantive water source to serve the high demand for water in Ndenderu Ward, there is a rise in the number of private boreholes drilled in the area. However, there are plans to supply the area with adequate water from Tigoni Water supply in Limuru and the proposed Ruaka Dam estimated to yield approximately 10,000m^3 per day (Karuri Water and Sanitation Company Ltd, 2019).

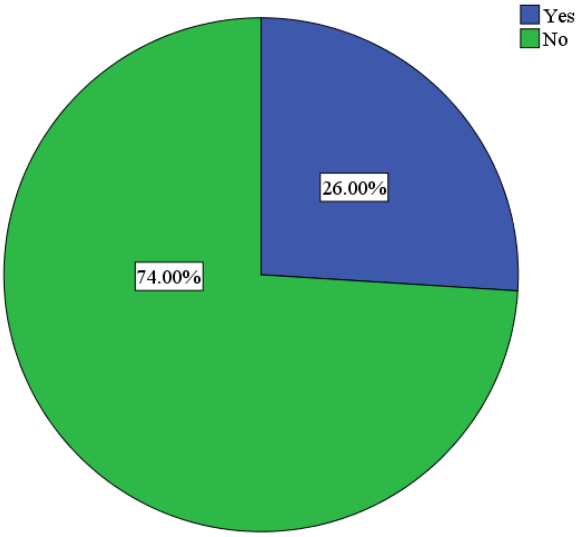
Table 5-4: Approved Tariff Schedule for Karuri Water and Sanitation Company Ltd

TYPE OF CUSTOMER	TARIFF (Ksh/m^3)	TYPE OF CUSTOMER	TARIFF (Ksh/m^3)
Domestic/Single-Dwelling Residential		**Commercial/Multiple Dwelling/Institution**	
0-6	Flat Rate of 330.	0-6	Flat Rate of 390.
7-20	65 each additional unit	7-20	75 each additional unit
21-50	80 each additional unit	21-50	90 each additional unit
51-100	100 each additional unit	51-100	110 each additional unit
101-300	120 each additional unit	101-300	130 each additional unit
Over 300	140 each additional unit	Over 300	150 each additional unit

Source: (Karuri Water and Sanitation Company Ltd, 2019).

It was established from 74% of the respondents in the household interviews that borehole water supplied was not clean and in adequate quantities and as a result, they relied on expensive bottled drinking water. The current challenge faced was the possibility of underground water pollution from the high number of boreholes that were occasioned by the land use land cover changes to the built-up environment. There are cases where septic tanks leakages into the underground water aquifers were reported.

Figure 5-9: Adequacy and cleanliness of water supplied



A report from the Water Resource Authority revealed that the water discharge in the area is high being on the lower side (Low Highland Zone) of the catchment area. The current Water Act does not limit the distances of boreholes sunk which explains the proximity of boreholes sunk in the area but it is recommended that permits be sought from the Water Resource Authority. Generally, the portability of the water in the area is good for the few sampled boreholes which were given completion permit after the drilling process. It was established that most of the applicants only apply for authorization permits to commence drilling works but in most cases, they never returned for the completion borehole permit to determine the water quality whether it is good for domestic consumption. This explained why there was no much information on the approved boreholes with completion permits and there we used a sample of those that had acquired the ultimate approval. It was estimated that there were about 1,000 boreholes sunk in Ruaka area with high water tables (Water Resource Authority, 2018).

Table 5-5: Sample Boreholes Depth and Discharge.

Borehole	Main Water Struck Level (Meters below ground level)	Total Depth	Yield of Aquifer (M^3/hour)	The quantity of ground discharge (M^3/day)	Portability of Water
Borehole 1	210-250	250	34.02	816.48	Good
Borehole 2	180	234	25.04	609.6	Good
Borehole 3	220	250	10.3	247.2	Good
Borehole 4	230	280	20	480	Good

Source: (Water Resource Authority, 2018).

The main challenges revealed on water supply in the area include encroachment of development to water sources/riparian reserves, failure of pumps to supply water due to mechanical problems or lack of power, unclean and unsafe water which is normally brown, borehole water salinity in some isolated cases, irregular water supply and water rationing by Karuri Water and Sanitation Company Ltd, fluctuating levels of borehole water especially

during dry seasons, high water contamination from pit latrines and septic tanks due to their proximity and high concentration in the area.

Plate 5-13: Encroachment of Development to Riparian Reserves.

The effects of land-use changes on water supply include a high rate of contamination from the septic tank and pit latrine wastewater, inadequate and irregular water supply, high concentration of boreholes within short radius leading to depletion of underground water, destruction of water supply infrastructure such as pipes with the presence of heavy machinery for the many ongoing developments in the area, a high resultant subdivision of neighborhood in areas where only one borehole serves the area.

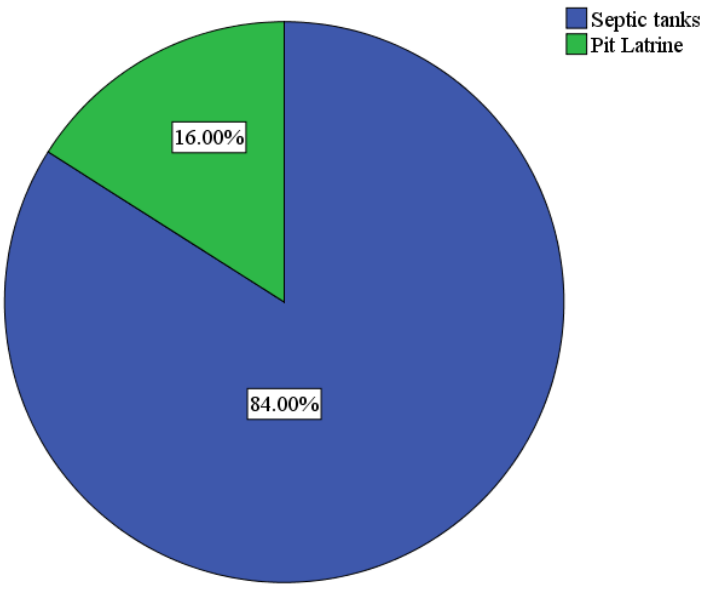
It was recommended by the respondents that the County Government supply all plots with adequate, clean and safe water which is reliable as well as the proportion of alternative water sources such as drilling of boreholes and rainwater harvesting. It was equally recommended that better coordination between Water Resource Authority and Karuri Water Sanitation

Company Ltd in the management of water resources such as boreholes which most of the County Government doesn't know.

5.5.3 Waste Water Infrastructure.

On-site wastewater treatments are used in Ruaka town because of the low cost of management in the absence of conventional sewerage systems because they are easy to construct, operate and maintain by the plot owner. The research findings indicate that 84% of the respondents use septic tanks to dispose of their liquid waste with 16% using pit latrines. Most of the areas in Ndenderu ward experience direct wastewater disposal on road reserves and rivers most of whom are as a result of leakages and spillages from the pit latrines and septic tanks. These have resulted in contamination of water sources such as boreholes, destruction of green vegetation and a foul smell which has health implication to human life.

Figure 5-10: Mode of Liquid Waste Disposal



The effects of land-use changes on wastewater infrastructure include increased foul smell from pit latrines and septic tanks with human health implications, direct drainage of wastewater to access roads, leakages and spillages to roads making them impassable and destruction of

vegetation, poor liquid waste management with an increased number of pit latrines and septic tanks which cannot be regularly maintained, high contamination with the high water table in the area and high ground coverage of developments leaving no room for wastewater infrastructure installation. It was also indicated that the process of emptying pit latrines and septic tanks is expensive and affects the health of those living around.

Plate 5-14: Leakages and Spillage of Wastewater from Developments.

It was recommended by the respondents that the County Government provide the area with an integrated conventional sewerage system to serve all the plots in the area, provide alternative wastewater management systems with recycling and reuse of the wastewater as well as provide regular maintenance and inspection of the wastewater management systems. Besides, it was indicated that septic tanks and latrines are not sustainable means of waste management and therefore should be avoided.

5.6 Role of County Government in the Management of Land Use Changes

The area does not have any approved land use/infrastructure plan or policy to guide the management of land-use changes and development in the area which are demand-driven rather

than policy/development plan-driven. However, there have been some undocumented ad hoc policy guidelines that have been used over the years. Currently, a draft Integrated Strategic Urban Development Plan has been prepared to await recommendation by the County Executive Committee Member in charge of Land and Physical Planning as well as the approval by the County Assembly.

Table 5-6: Development Guidelines (2006-2019)

GUIDELINES YEAR	MAXIMUM GROUND COVERAGE	MAXIMUM PLOT RATIO	MINIMUM PARKING REQUIREMENTS
2006-2012	Residential-65% Commercial-75%	None-Maximum Height of 4 Levels	None-Provision of Ground Parking where necessary.
2013-2016	Residential-40% Commercial-50%	Residential-150% Commercial-200%	Bedsitter/Studio-0.5 parking/unit 1 Bedroom-1 parking/unit 2 Bedroom-1 parking/unit 3 Bedroom-1 Parking/unit Commercial-1 Parking for every $100M^2$
2016-2017	Residential-45% Commercial-55%	Residential-200% Commercial-250%	Bedsitter/Studio-1 for every 3 units 1 Bedroom-1 parking/unit 2 Bedroom-1.5 parking/unit 3 Bedroom-1.5 Parking/unit Commercial-1 Parking for every $100M^2$
2017-2019	Residential-55% Below 0.045Ha Residential-50% 0.045Ha-0.1Ha Residential-40% 0.2Ha-0.4Ha Residential-35% Above 0.4Ha Commercial-60%	Residential-300% (Max. 5 Levels) Residential-400% (Max. 8 Levels) Residential-400% (Max. 10 Levels) Residential-550% (Max. 15 Levels) Commercial-350%	Bedsitter/Studio-1 for every 3 units 1 Bedroom-0.5 parking/unit 2 Bedroom-1 parking/unit 3 Bedroom-1.5 Parking/unit Commercial-1 Parking for every $100M^2$

Source: (County Government of Kiambu-Department of Land, Housing and Physical Planning, 2019).

The research findings established than most of the developments occur on plots ranging between 0.045 Ha to 0.4 Ha. Most of the developments established to accommodate the following number of units as established; 0.045Ha have accommodated up to 16 units, 0.1Ha

up to 32 units, 0.2Ha up to 60 units and 0.4Ha up to 80 Units. Due to high land values, the study established that these are a rise in the tendency of reducing the size of the housing units to maximize profits from investments which would lead to overcrowding and health risks if not strictly enforced. Most of the units range between 1to 3 Bedroom residential housing units of approximately 64 to 110M^2. These numbers of units exert a lot of pressure on existing roads, water supply, and wastewater infrastructure (septic tanks) and therefore they are not sustainable with the current capacity of the urban infrastructure systems.

There has been a rise in development application received for vetting and approval most of them which are a change of use from agricultural to residential/commercial land uses. Most of the access roads are very narrow which are often given a condition of road widening which is not normally implemented on the ground. Besides, most of the developments do not comply with the approval conditions of plot ratios and plot coverage with the low technical capacity of enforcement.

The County Government intends to increase the technical capacity through recruitment and training of staff to enhance evaluation, regular inspection and enforcement to enhance compliance. It has been observed that there is a high rate of subdivision of agricultural land in the area but very few applications are submitted. This has been attributed to the submission of the mutations to the Land Control Boards where they are approved and submitted to the registrar for titling. This has resulted in irregular subdivided plots without professional input. The end product being having narrow roads that are not developable if subjected to the building lines, plot ratios, ground coverage, setbacks and surrender for road widening. It, therefore, calls for brinkmanship from the directorate in charge to jumpstart and streamline the process.

Table 5-7: Estimates of the Number of Change of Use (Flats) Applications (2015-2019)

TYPE OF APPLICATION	CHANGE OF USER (FLATS)												
YEAR/ MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2015	12	8	10	7	22	20	8	17	46	42	15	42	**249**
2016	38	24	12	12	13	47	14	11	22	25	21	27	**266**
2017	4	7	13	8	10	5	9	11	13	7	6	8	**90**
2018	7	19	9	7	17	18	12	19	19	17	13	6	**163**
2019	12	13	10	16	33	40	16	14	16	10	17	18	**215**
SUM TOTAL	**73**	**71**	**54**	**50**	**95**	**130**	**59**	**72**	**116**	**101**	**72**	**101**	**983**

Source: (County Government of Kiambu-Department of Land, Housing and Physical Planning 2019).

Figure 5-11: Submitted Change of Use (Flats) Applications (2015-2019)

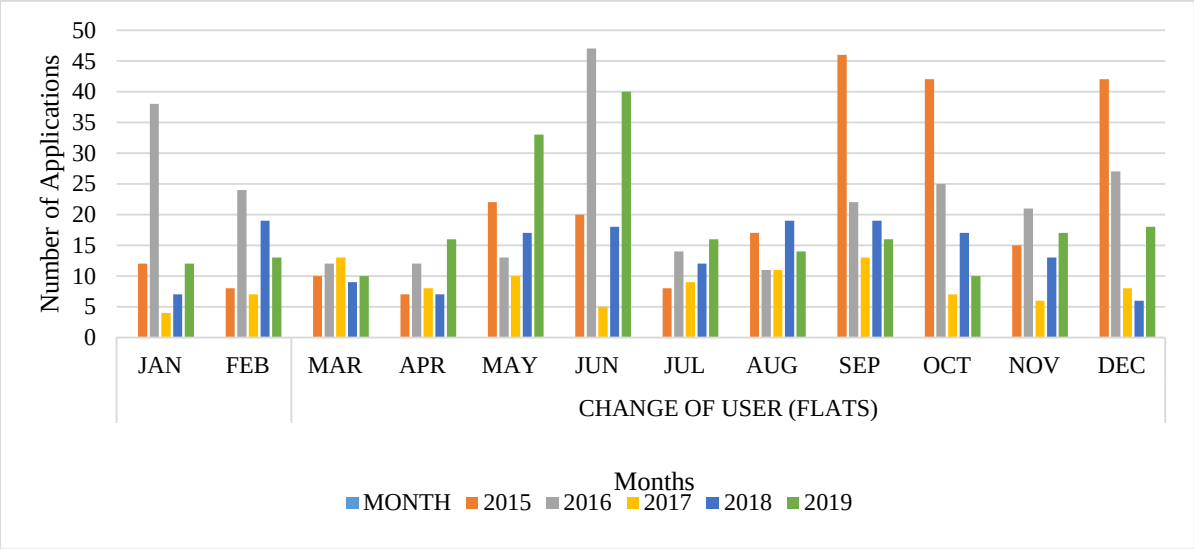
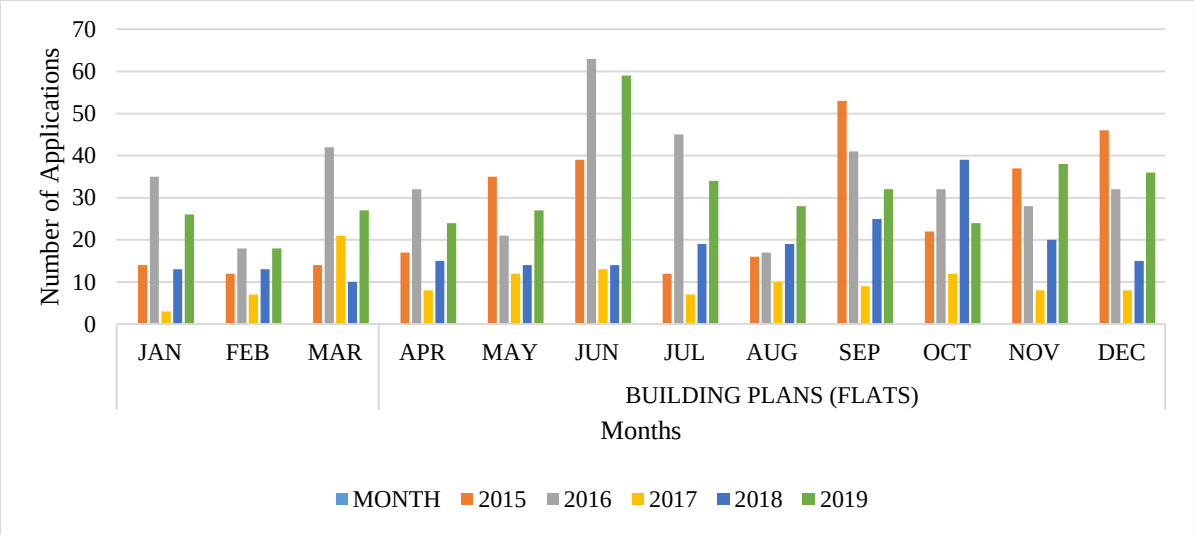


Table 5-8: Estimates of the Number of Building Plans (Flats) Applications (2015-2019)

TYPE OF APPLICATION	BUILDING PLANS (FLATS)												
YEAR/ MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2015	14	12	14	17	35	39	12	16	53	22	37	46	**317**
2016	35	18	42	32	21	63	45	17	41	32	28	32	**406**
2017	3	7	21	8	12	13	7	10	9	12	8	8	**118**
2018	13	13	10	15	14	14	19	19	25	39	20	15	**216**
2019	26	18	27	24	27	59	34	28	32	24	38	36	**373**
SUM TOTAL	**91**	**68**	**114**	**96**	**109**	**188**	**117**	**90**	**160**	**129**	**131**	**137**	**1,430**

Source: (County Government of Kiambu-Department of Land, Housing and Physical Planning 2019).

Figure 5-12: Submitted Building Plans (Flats) Applications (2015-2019)



The department has been enforcing 10% reservation of land for major developments over 0.4Ha public purpose to be set aside for public facilities and services such as playgrounds, schools, churches, health centres, and police posts among other users to serve the growing urban population. This has not been coordinated to ensure surrender is requested where there is such a population generated to demand for surrender or reservation of land. There is need to subject surrenders based on population projections and need analysis carried out so as not to have the same reservations made within the same locality such as surrender for several nursery schools within the same area rather than diversification of public purposes. The Department of Land, Housing and Physical Planning undertakes a routine inspection of buildings to monitor the non-compliant developments and to ensure that the new developments approved are implemented as per the approved plans during the post-approval stage.

The County Government of Kiambu has formulated a draft County Spatial Plan with broad land-use guidelines, Integrated Strategic Urban Development Plans with specific development guidelines for the Directorate of Physical Planning which shall guide urban development in the area. Container policy in place has not been fully implemented with the influx of container development which was initially resisted until the time the policy came into place. Other draft

policies to guide development include the outdoor advertisement policy and the draft regularization policy. This will enhance the management of the area being within Karuri Municipality, an urban area with a high rate of urbanization.

The major challenge faced is the high rate of urbanization, increased land values triggering regular revision of plot ratios and plot coverage to meet the demands of developers recuperating profit from their investments. Reduced plot ratios and ground coverage, delays in the approval process and high consultancy fees have resulted in a rise in illegal developments, forgery of development plans and seeking services from unqualified professionals. These have been difficult to enforce with low technical and financial capacity in the County.

There is a low and weak enforcement team due to financial and technical capacity. Lack of equipment, machinery and tools such as vehicles to facilitate mobility, insufficient technical staff to carry out the enforcement exercise and lack of financial resources has been a great hindrance to enforcement section to enhance compliance. The financial and technical capacity of the development control, enforcement and compliance section requires to be enhanced. Regular continuous professional development through training should be mandatory to enhance the expertise and technical capacity of the staff. The majority of the respondents reside in residential flats as evident from the analysis of the study findings. Classification of land use using Landsat imageries reveals that there is a significant decline in vegetation and an increase in built-up areas. The key drivers of these land-use changes are due to the strategic location of the Ruaka Town, the existing infrastructure among many factors which has led to rapid land-use changes and conversion of land. This has resulted in a strain on infrastructure capacity and mainly on roads, wastewater supply, and water supply infrastructure systems. The county whose mandate is to regulate development in the area faces challenges on technical and financial capacity as well as the policy guidelines to manage the land-use changes in the area.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

This chapter highlights the key findings, concludes on the effects of the findings given the study objectives and gives recommendations on measures to achieve the desired future of the study area. The study identifies the key drivers and the effects of land-use changes on the sustainability and resiliency of urban infrastructure. It, therefore, culminates into strategic interventions towards evolving a management strategy to mitigate against any further adverse impacts of land-use changes on urban infrastructure. It was imperative to explore other strategies other than evolving a management strategy on which it will be anchored. This included the element of public participation and inclusivity in the management of urban infrastructure, coordination and institutional framework which is core and inevitable in any implementation and management process.

6.1 Summary of Findings

6.1.1 Land Use Changes for the Period 1988 to 2019

The following observations and deductions were made from the analysis of the Landsat imageries;

- There has been a significant increase in built-up areas and reduction in vegetation cover over these years due to land-use changes from agricultural to built-up areas such as commercial, residential and educational among others.
- Most of the land-use changes mainly take place along the transport corridors
- There has been significant urban heat island generated along with the built-up areas along the major roads with a concentration of buildings.

6.1.2 Drivers of Land Use Changes

Pull factors are the key drivers of land-use changes. Increased population growth and urbanization in the area has resulted in high demand for residential and commercial land uses and activities. This is mainly because of the proximity to workplace especially Nairobi City, cheaper accommodation as compared to Nairobi City, availability of good infrastructure facilities and services in the area such as the Limuru road, Northern and Western Bypass with good accessibility and connectivity to other areas such as Thika and Nairobi City.

The market forces and great investment opportunities in the area have equally contributed as the investors rip heavily from the high returns/profits the real estate industry presents them. The real estate sector has presented the availability of employment opportunities in the area since most of the developments occur within the study area. Due to the high rate of urbanization, there has been landing speculation with expected high land values in the future. The presence of nearby institutions such as UN, UNEP, and the embassies has also contributed to the high growth with posh apartments being built to meet their demands. Some other developers have considered Ruaka town to have a beautiful ambiance, a good conducive climate, and the environment as compared to other areas within the metropolitan region with un-conducive high temperatures and dusty environment.

6.1.3 Effects of Land Use Changes on Urban Infrastructure

Land-use changes have brought great ravages on urban infrastructure as categorized below.

General Land Use Change Effects

The research findings revealed that most of the developments occur on plots ranging between 0.045 Ha to 0.4 Ha. The existence of the small plots is as a result of major land subdivisions which has taken place. Most of the residential flats developments accommodate the following number of units as established from the study that; 0.045Ha have accommodated up to 16 units,

0.1Ha up to 32 units, 0.2Ha up to 60 units and 0.4Ha up to 80 Units. Due to high land values, the study established that there was a rise in the tendency of property owners to reduce the size of the housing units to maximize profits from investments which leads to overcrowding and health risks if not strictly enforced. There has been a rise in development application received for vetting and approval most of them which are a change of use from agricultural to residential and commercial land use. The high rate of urbanization with increased land values in the area which have led to a regular revision of plot ratios and plot coverage to meet the demands of developers recuperating profit from their investments. Reduced plot ratios and ground coverage, delays in the approval process and high consultancy fees have resulted in a rise in illegal developments, forgery of development plans and seeking services from unqualified professionals. There is a low and weak enforcement team due to financial and technical capacity.

Lack of equipment, machinery and tools such as vehicles to facilitate mobility, insufficient technical staff to carry out the enforcement exercise and lack of financial resources has been a great hindrance to enforcement section to enhance compliance. Unfavorable cold weather of the area during cold seasons and urban heat island as a result of the land-use changes along with the built-up areas. The area does not have any approved land use/infrastructure plan or policy to guide management of LUC and development in the area which are demand-driven rather than policy and development plan-driven. The urban sprawl of urban developments has extended towards Gachie town. Climate change has greatly affected the area with the kind of magnitude of land use taking place with high water run-off experienced and flooding in some sections of the town and access roads. Over-reliance on undocumented ad hoc policy guidelines that have been used over the years has been a course of such uncontrolled LUC and developments in the area which has led to a strain on existing urban infrastructure.

a. Roads Infrastructure

Planning has mainly focused on private car transport as opposed to other modes such as NMT, Walking and Cycling which has led to a great disparity of the high rate of the population that rely on Non-Motorized Transport (NMT) but with fewer provisions, allocation and funding granted to them. Rugged terrain that is not favorable for future development has encouraged linear development leading to traffic congestion which is not managed well. Most of the units range from 1 to 3 Bedroom residential housing units of approximately 64-110M^2. This number of units exerts a lot of pressure on existing roads, water supply, and wastewater infrastructure (Septic tanks) and therefore they are not sustainable with the current capacity of the urban infrastructure systems. Lack of street lighting makes the area more insecure and unsafe especially at night, insecurity and hostility in the area. Traffic congestion and many direct exits point to the main roads, lack of parking spaces.

The main thoroughfares which serve as public transport infrastructure have not been provided with the facilities required for conventional public transport systems such as terminal facilities and proper transit interchanges. Floods in some sections of Ruaka town have increased due to a rise in built-up areas and urban development with high plot ratios and plot coverage, lack and poor maintenance of stormwater drainage where they exist. Leakages and spillages of stormwater have made most of the earth roads impassable. Some of the areas located far from the main road with access roads in bad conditions are inaccessibility by public transport. The high rate of land subdivision in the area has resulted in the rise of narrow roads. The decline in the condition of Limuru roads and other access roads with potholes are caused by the heavy machinery within the ongoing developments. The area has unpaved roads that don't withstand weather changes leading to muddy and dusty conditions. Air and noise pollution have increased due to the presence of heavy trucks on construction sites which are unregulated and deteriorating public transport (Matatu) along Limuru road. Lack of Non-Motorized and Cyclist

lanes provision is witnessed in Ndenderu ward despite the high demand for the growing population. A high rate of traffic accidents principally between NMT users and motorists which has increased due to lack of dedicated lanes for motorists and Non-Motorized Transport. Dedicated lanes along Limuru Road and footbridges at Ruaka junction are possible solutions to reduce the number of accidents in the area. Currently, there are no attempts to solve these problems and as a result, there is a need to make Limuru road a dual carriageway with narrow carriageways with raised zebra crossings to allow smooth crossing by the pedestrians.

Densification and increased high rise developments due to a high population in the area have led to congestion and the presence of commercial activities and a high population that pulls people and businesses. Undesignated location of the bus stop at the junction of Ruaka and Banana route is a result of a lack of proper management and designation of a bus stop in the area. Developments on natural stormwater drainage way-leaves have led to obstruction of natural storm-water flow.

Lack of storm-water drainage channels and where they exist, they are not maintained. There has been resistance by developers to surrender part of their land for road widening in areas with narrow roads from resultant subdivisions to accommodate the generated traffic from densification. In cases where they decide to surrender, most of the developers have resulted in putting up developments with higher ground coverage to cover up the high cost of land surrenders for road widening. High urbanization and population of Ruaka town have increased private car ownership, traffic volumes as a result of the traffic demand and the generation of trips with different modes of vehicular, pedestrian and cycling. Ruaka lacks a central bus park or designated parking area which has seen indiscriminate parking especially on vegetation/road reserves that have always led to the loss of green spaces and pollution. Increased car ownership has contributed to global warming, higher energy consumptions, higher emission levels, noise

and air pollution. The high car dependency and increased trips, therefore, demand infrastructure and services which are costly in maintenance and operation.

Roads in Ruaka and Ndenderu Ward lack regular maintenance and upgrading with the installation of street elements such as the road signage to enhance effective and efficient transport system. Lack of enforcement for submission of subdivision plans and weak land administration systems have resulted in irregular plots with narrow roads which are not developable if subjected to the building lines, plot ratios, ground coverage, setbacks and surrender for road widening. Traffic congestion has been experienced in Ruaka and Ndenderu areas due to high private car ownership for the people who live within the area. Ruaka-Ndenderu Transport Corridor has been experiencing rising motorization rates from the neighborhoods in Ruaka town.

b. Water Supply Infrastructure

Pressure on water supply systems due to increased densities has led to the inadequate and unreliable water supply. Over-reliance on borehole water might be unsafe for human consumption due to high underground water pollution unless otherwise getting quality assurance from the regulating authorities. High incompliance of completion borehole drilling permits has been reported by the Water Resource Authority. Destruction of water supply infrastructure including water pipes with the presence of heavy machinery for the many ongoing developments in the area which is unregulated and guided on areas with infrastructure installations, a high resultant subdivision of neighborhood in areas where only one borehole serves the area. The high rate of contamination of underground and borehole water has been triggered from the septic tank and pit latrine leakages and situation worsened by the high concentration of boreholes within a short radius which leads to depletion of underground water if not controlled.

c. Wastewater Infrastructure

There is over-reliance on pit latrines and septic tanks and for wastewater disposal with the increased foul smell from pit latrines and septic tanks with human health implications. Direct drainage of wastewater to road reserves and rivers as a result of leakages and spillages from the pit latrines and septic tanks. Contamination of water sources such as boreholes, destruction of green vegetation and foul smell which has health implications to human life. Pressure on existing wastewater infrastructure has led to water pollution and contamination through leakages and spillages from pit latrines and septic tanks. Destruction of vegetation has increased in Ndenderu ward due to the use of unconventional onsite waste treatment mechanisms with an increased number of pit latrines and septic tanks which cannot be regularly maintained. There is high contamination in the area having a high water table and high ground coverage of developments leaving no room for wastewater infrastructure installation. The process of emptying pit latrines and septic tanks is expensive and affects the health of those living around. Singapore has dealt with wastewater management through investment in wastewater infrastructure and ensured all industrial estates and residential areas are served with the public sewerage system. The wastewater systems are separated from stormwater drains to allow water recycling and re-use in farms and playgrounds. Strict enforcement has also enhanced the management of wastewater infrastructure through its legislative, institutional framework and strong political will in the implementation of such projects (Chiplunkar *et al*, 2012).

6.2 Conclusion

Research findings reveal that increased population growth, market forces, urbanization and proximity to Nairobi city are the key drivers of land-use changes. These drivers have resulted in rapid land-use conversions and fragmentation with little efforts to provide commensurate infrastructure to support the increased demand and capacity. The impacts have resulted in

narrow roads and unpaved roads without any provision of NMT facilities and stormwater drainage management, traffic congestion with increased private car ownership, lack of terminal facilities, increased boreholes, water contamination and encroachment to water reservoirs, use of unconventional onsite treatment methods for liquid waste such as septic tanks as well as a weak institutional capacity to manage urban infrastructure. These have effects on the inadequacy of the infrastructure capacity with the growing population. It is therefore important to evolve a management strategy to unravel the adverse effects of the LUC on urban infrastructure capacity systems notably roads, water supply and wastewater infrastructure systems to promote land use change-resilient infrastructure and realize sustainable urban growth.

6.3 Recommendations

Sustainable urban infrastructure demands urban management, system efficiency and infrastructure capacity solutions that can address the needs of the communities living in Ruaka. Management of land-use changes will address the urban infrastructure capacity challenges and promote land use change-resilient urban infrastructure hence realize the sustainable urban growth in Ruaka Town. Lessons learned from best practices were used to make recommendations and evolve a management strategy that contains the urban infrastructure capacities.

6.3.1 Management of Roads Infrastructure

There are short term achievements currently in place in Ruaka such as ongoing paving of roads in Ruaka area to gravel standards most of which are of approximately 2 Kms to 3 Kms and the opening of the draining channels. Medium-term plans such as enhancing connectivity, the security and safety of the road users in the area and long-term plans such as proposed western bypass and expansion of the existing Limuru Road.

6.3.1.1 Promoting Transit-Oriented Development

To achieve sustainable transport of transit-oriented development in Ruaka, policymakers and managers shall encourage integration as opposed to the segregation of land uses; enhance connectivity to reduce congestion and compactness to reduce urban sprawl with equity element in mind. Concentration of high density residential and commercial areas in Ruaka with smaller block sizes shall be maximized within walking distances to public transport along the western bypass, Limuru Road and Northern bypass. The integrated land uses shall be linked to the Transport Oriented Development (TOD) to enhance the implementation of the use of a sustainable mode of public transport with efficient and high capacity public transport systems integrated with NMT. These shall promote the relation of urban form (densities) with mobility especially in the design of the NMT facilities. The focus should be given to the level of access to human rights and equitable to destinations with walkable distances.

Transit-oriented development along the Ruaka-Ndenderu Transport Corridor would offer solutions to address the current transport challenges especially to the high-density developments inaccessible to public transport. This transport system will give people preference for walking, cycling or use public means of transport. As a result, this will lead to compact, walkable and livable communities in Ruaka and Ndenderu areas with major land-use activities centered along the Limuru Road and western bypass. The main focus of TOD, therefore, is to promote high-density developments along the Ruaka-Ndenderu transport corridor within walkable distance of 500M to 800M (Department of the Environment (1973) Circular 82/73) and advocate for mixed-use development in Ruaka and Ndenderu Centres where pedestrian trips can be made to shopping areas and workplaces. Therefore, it's important to have a multimodal integration mixed land use, NMT network, inclusive habitat and optimized densities.

Interconnected street network that links Western Bypass, Limuru Road and minor access roads, street-oriented building and complete streets, last-mile connectivity, traffic calming measures, managed parking and informal sector integration especially within Ruaka and Ndenderu Commercial nodes. Management of urban roads and transport systems in Ndenderu ward should enhance public-private partnerships in the provision of the high-quality and capacity transit system, installation of street lighting, preserve and create open spaces, land value capture, promoting green buildings and infrastructure, universal accessibility, safety and security. This shall be achieved through a good management system that collaborates and coordination of different agencies that work together with such as Kerra, KURA, KeNha and County Government of Kiambu.

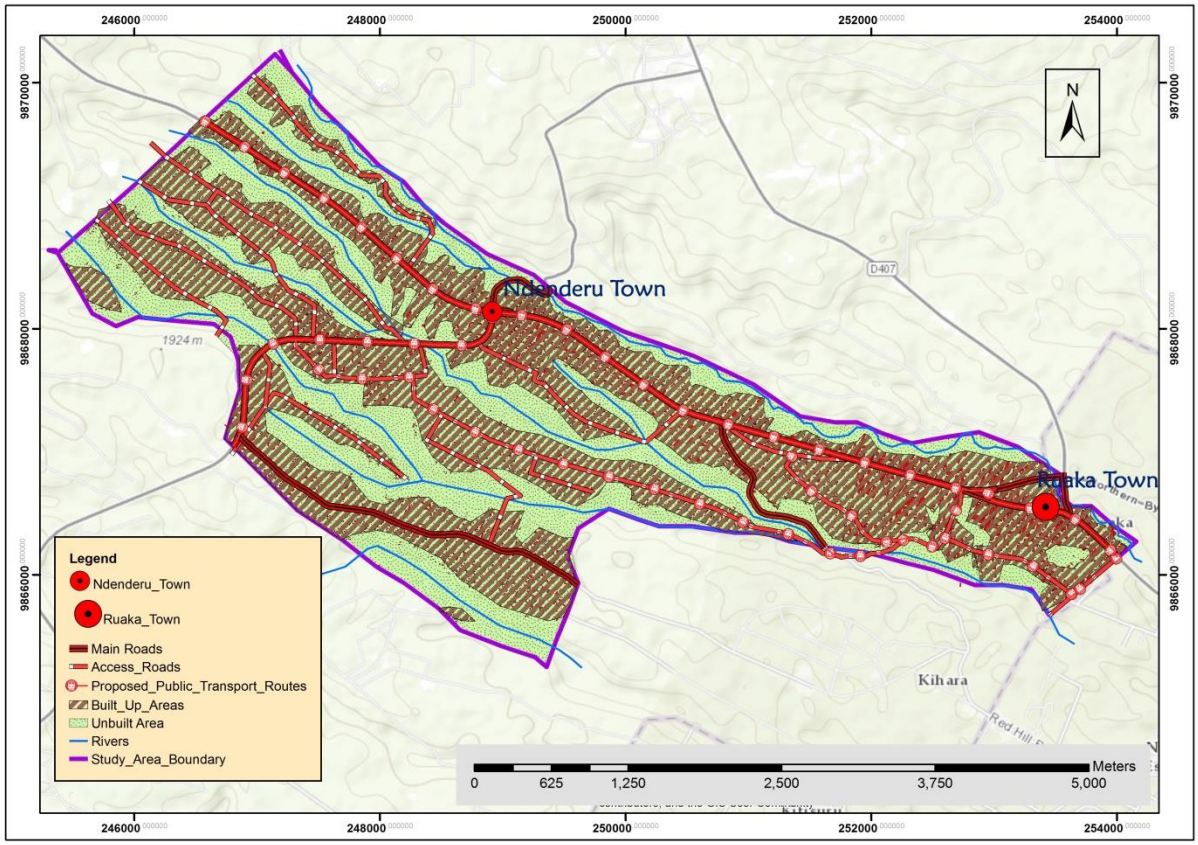
Transformation to public transport should be the ultimate goal. Nairobi Metropolitan region is experiencing rapid population growth which becomes inevitable to adopt TOD systems and integration of mass transit systems such as the BRT and LRT proposed along Nairobi-Thika Transport Corridor. It is therefore important to take advantage of the proximity to the mass transit systems to revitalize public transport along the Western and Northern Bypass as well as the Limuru Road that traverse the Ruaka Town to address the rising travel demand in the area.

Priority and focus should be given to the high capacity public transport with dedicated lanes, pedestrians and NMT users over private modes of transport. Provisions should be made and provided for high capacity and efficient public transport and NMT modes that share urban form (densities) with mobility. The proposed linkage between the public transport system, NMT and land-uses will improve on human rights access and equitable to destinations within acceptable walkable distances. This shall be coupled with revitalization strategies and paradigms often promote sustainability and functionality of the transport systems. It is important to promote shift strategies which will enhance trip efficiency by providing a shift from energy-intensive to

public transport, walking and cycling. This can only be realized through making cycling safer, secure and attractive, improving street designs that encourage walkability, promoting efficient and effective public transport, providing adequate public spaces and street furniture, promotion of seamless flow and interchange between modes of transport such as walking/cycling along with the public transport systems, the introduction of the park and ride facilities, enhancing road safety and security especially for the vulnerable groups, formulation of parking policies, enforcing hefty pricing and regulatory mechanisms more especially during peak hours.

Enhancing equity through prioritization of public transport owned by the government is critical in the management of roads and transport with increased land-use changes in Ruaka town. Most of the current public transport (Matatus) is not private transport owned by people who aim at maximizing profit contrary to the principle that public transport is a non-profit making entity. Integrated land use and transport should be enhanced in the area for better accessibility and connectivity with the location of traffic generators near the transit station. More resources and investments should be directed to Mass Transit systems with adequate facilities to serve the growing population of the area. There should be a seamless interchange between transit modes and corridors since the area has high intra and interconnectivity. High quality and affordable mass transit systems should be acquired to serve the high densities in the area since road widening has never been a solution but instead, it always increases traffic congestion. The mass transit systems should be linked with the BRT systems along Thika Road since the area is interconnected with such major roads.

Map 6-1: Roads Infrastructure Management Plan



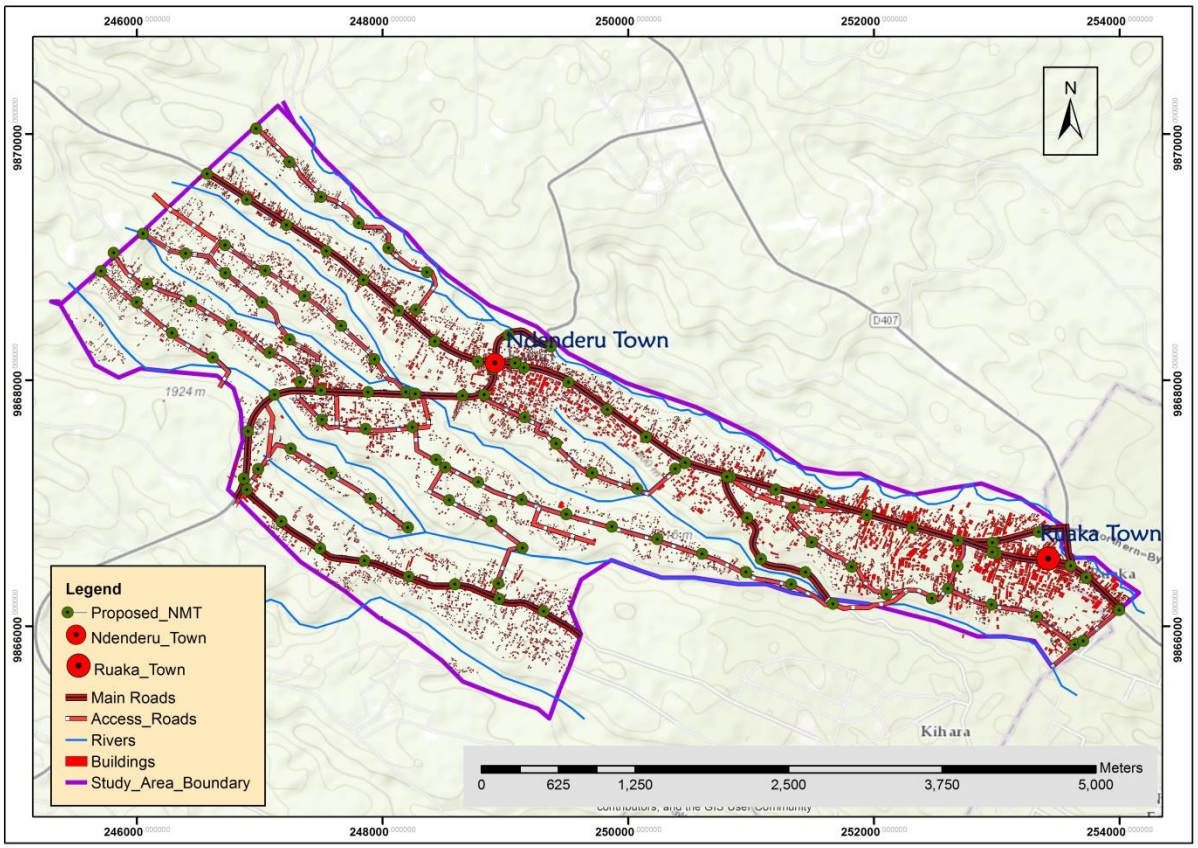
6.3.1.2 Promotion of Pedestrian and Non-Motorized Transport

There is no great city that you won't enjoy walking in or places you go on vacation are usually areas you can walk in and therefore the element of walkability must be emphasized. As a result of a high population and demand for NMT modes, it's vital to prioritize pedestrian and cyclist lanes on every street along Limuru Road and especially within Ndenderu and Ruaka Centres. It's equally important to allow connector routes in Ruaka instead of singular streets to enhance accessibility and walkability. Walkability and cycling are environmentally friendly and sustainable modes of transport that should be encouraged as shift strategies from vehicular transport options and as a result, provision for pedestrian and cyclist lanes along all roads with the dedication of some routes purely NMTs after every three blocks. Provision of good public transport and ensuring accessibility by consideration of pedestrian's walkability, cycling and short distances to work or business opportunities will embrace social inclusion which must be

a priority for urban managers. Management in Ndenderu ward shall establish connected walking networks, path surfaces, adequate walkways, the creation of bike lanes and bicycle boulevards. This shall be enhanced with pedestrian-friendly design features and the use of street furniture, integration of cycling with transit, provision of rickshaw stands/bicycle parking as well as encourage sharing.

Promotion of the pedestrian and non-motorized friendly environment is critical through the creation of accessibility to public transport through NMT uses which reduces pollution of the environment and traffic congestion, Consideration of pedestrian safety, comfort and convenience. This would be achieved through traffic calming measures such as speed bumps, pedestrian ramps, pedestrian crossings, flyovers, traffic signals, segregated and connected NMT routes. Vibrant urban spaces including street vendors, street furniture with active frontage with transparent buildings facades and public displays have to be provided along Limuru road. Infrastructure and amenities including the revitalization of existing open spaces and sanitation facilities have to be provided for pedestrians and NMT users within the vibrant Ruaka and Ndenderu towns.

Map 6-2: Non-Motorized Transport Management Plan



6.3.1.3 Enhancing Accessibility of All Public Spaces and Streets

All public spaces and streets within Ndenderu ward should be made accessible to all people. This will be achieved through the provision of mixed-use land use within walkable distances and securing parking facilities and services for NMT users. Provision of auxiliary amenities such have toilets and sanitation facilities shall be prioritized within 500-800M (Department of the Environment (1973) Circular 82/73) radius within terminal facilities. Mobility improvement and road safety shall be considered whereby safety would mean children and women can feel comfortable on such roads when left alone. Measures such as secure pedestrian crossings, dedicated lanes for NMT users, street lighting to safeguard safety and security of pedestrians shall be provided. Connected walking networks within the mixed-use development blocks shall be enhanced with adequate path and walkway surfaces to enhance the security and

safety of pedestrians. Cyclists shall be provided with bike lanes and bicycle boulevards to facilitate their operations. Cycling shall be integrated along with the transit systems by having provisions made for bicycle parking/rickshaw stands with consideration for their security and safety concerns prioritized. Improve strategies to transport systems that often enhance vehicle efficiency shall be achieved through the use of the classic environmentally friendly and energy-efficient vehicle and clean fuel technologies through regular inspection, maintenance and use of intelligent transport systems. Other key interventions to be applied include prioritization cycling and walking; encourage the use of more modern fuel-efficient vehicles, pricing and regulatory mechanisms and enhancement in the use of cleaner fuel technologies.

6.3.1.4 Increasing Accessibility, Connectivity and Network Density

The need to increase accessibility, connectivity and network density equally enhances the efficiency of transport systems. This will enhance the dispersion of high traffic volume shall be done over a network of alternative streets through the provision of the shortest route of pedestrians and NMT users to transit stations and the main Ruaka-Ndenderu Transport Corridor. Understanding the dynamics of transportation being a route used by trucks and matatus and other interaction influences such as travel demand to and from the workplace in Nairobi and provision of alternative routes. Good and improved accessibility of public transport systems by all without leaving anyone behind and with the integration of other modes of transport such as walking and cycling in a seamless and integrated manner. Reliability on the availability of public transport (Matatu) which if fairly affordable to allow passengers to travel whenever and wherever they want with the assurance of its availability along all the possible routes, time and frequency.

Transport facilities and systems must be acceptable in terms of their cleanliness, comfort, reliability, personal safety and security. Consideration should be made on the connectivity and

linkages of the limited capacity of roads which can accommodate the number of cars along various routes such Limuru Road, Western and Northern and how they connect to Kiambu Road. Transport strategies which promote and enhance accessibility, transit-oriented development, structural form of urban growth, connectivity, compact and mixed land use developments to minimize vehicle trips should be encouraged. Avoid strategies which improve the efficiency of the system is usually aimed at reducing or avoiding the need for travel. There has been an emphasis on walking and cycling, integration of land uses and transportation location of traffic generators near transit stations, pricing and regulatory mechanisms enhancing compact and mixed-use developments, enhancing a seamless interchange between the transit modes and transport corridors. It is important to have consideration of road hierarchies to facilitate in sieving traffic easily, promoting densification with regulated plot ratios and ground coverage. A review should be initiated for the parking requirements especially within the CBD areas, enhancement of visual active frontages, setbacks and building lines with consideration of shorter pedestrian blocks to encourage the use of NMT modes.

Identification of certain primary corridors as ‘mobility corridors’ and network development shall be implemented as illustrated on the infrastructure map. Increasing throughput shall be prioritized by having public transit system(s) which have more space allocation for public transit maneuvering through high-density residential developments. This will enhance serving the entire population. It is important to promote the public transit connectivity through the design intended to cater to the needs of populations. Provisions shall be made for intermodal stations to facilitate the seamless transfers and integration of NMT modes. The creation of alternative routes such as through the revitalization of Gachie road and interconnectivity of the alternatives with the existing major roads such as the Western and Northern Bypasses will ease traffic congestion along the transport corridor.

6.3.1.5 Enhancing Multi-Modal Integration

Multi-Modal Integration will enhance equitable distribution of road space to accommodate all modes of transport and priority being the mass transit systems, seamless physical connectivity of modes of transport to minimize travel time, time of transfers and cost for commuters along the Ruaka Ndenderu Transport Corridor through the provision of a variety of modes with considerations on safety, comfort, reliability in terms of time and frequencies, affordability and acceptability. The multimodal integrated model will diversify different models of transport that are efficient, comfortable to use, acceptable, affordable and reliable in terms of the frequency and availability. The main emphasis is the provision of mass transit systems such as Light Rail Transit, Bus Rapid Transit and High Occupancy Vehicle (Buses and mini-buses) with dedicated lanes. Besides, the model proposes exclusive use lanes (BRT) on Ruaka-Ndenderu Corridor. New alternative routes will be used for vehicles, trucks and other modes to ease traffic from the main transport corridor. The proposed alternative routes and bypasses shall connect Ruaka Ndenderu Road to Northern/Western Bypass. Dual Carriage facilities shall be encouraged along the major routes with an integrated NMT/Cyclists and walkability to the transit station and the main transport corridor in a seamless manner. The ultimate integrated mobility model is the hybrid of compact mixed-use and transit-oriented development models.

6.3.1.5 Inducing Modal shift

Inducing modal shift will trigger the efficiency of the transport systems. Mixed-use development shall be encouraged with the location of homes, workplaces, stations, public facilities within an accessible radius to encourage walking and cycling within the shorter distances. Parking fees shall be increased for private means of transport as well as prohibiting on-street parking.

Placemaking and Safety shall be enhanced through the creation of safe, comfortable, vibrant urban spaces, reduction of boundary walls, the building of non-opaque walls with transparency, minimum setbacks to help provide natural surveillance within areas planned for mixed-use development and more especially the commercial areas to encourage walkability while shopping. Use of traffic calming measures such as the use of curbs fly-overs and dedication of pedestrian and cyclist lanes and installation of security lights to enhance the safety and security of pedestrians.

6.3.1.6 Enhancing High Density-Mixed Income Developments

High density, mixed-income developments should be integrated to maximize densities within TOD to facilitate a high population who walk, cycle to access and use public transport. Affordable housing should be considered within the liveable communities since they are the majority who require public transport, cheap accommodation, and other amenities. Consideration of the special needs to the safety of children, women, senior citizens, disabled. Transport corridor systems shall be provided in a socially equitable way through social tariffs by lowering the public transport charges and ensure accessibility of the transport systems across all social classes or income groups. Such social services should be affordable and should be provided within walkable distances to work and shopping areas. This will ensure the charges levied are commensurate to people's incomes so that they don't end up spending most of their incomes on transport alone. Transport infrastructure shall be developed without discriminating the poor people by locating them within the acceptable walking distances without omitting those which fall within the high-end income group neighborhoods.

Mixed-Use Developments should be enhanced through the creation of livable walkable communities through the provision of basic needs of work, shopping, public amenities, and recreation hence reducing the need to travel. Restrict low-density housing, warehouses, petrol

stations which would influence private car use in the area. Cost analysis (Implementation, operation, and maintenance) of transport plans and consideration of demographic dynamics of the transport generators whether there are considerable population/routes to be served with the transportation options. The booming residential neighborhoods within the Ruaka Ndenderu Corridor should be controlled with adequate infrastructure installed that is commensurate to the magnitude of the development. Revitalization of public spaces where the NMT users. Travel time should be considered through the integration of land uses as opposed to segregation. The greater portion of land uses is segregated with commercial/workplace distances being located far away from residential zones which make commuters travel long distances. Social inclusion for all classes should be promoted through access and prioritization of pedestrians through provisions for cycling lanes and walkways within shorter distances which seems to be the greatest challenge. Enhance equity with preference and prioritization given to public transport systems with enhanced walkability.

Stakeholder engagement as an indicator of good governance should be carried out through public participation to enhance transparency, accountability and acceptability. Enhanced integration, as opposed to segregation of land uses to minimize car use should be encouraged as well as enhancement of the connectivity thus in the long run leading to a reduction in traffic congestion. The proposed High density, compact mixed-use development model will tend to consider high-density developments with residential and commercial land use being mandatory within the buildings or plots. This will equally provide for different income groups with affordable housing provision being critical. Considerations to be within these blocks include; Compact development with walkable design, Transition station, Mixed Use development nodes, High density, high-quality development within 10 minutes walking radius, Good accessibility and seamless connectivity, Reduced and managed parking

6.3.1.7 Enhancing Compact Developments

The new urbanism concept, walkable community concept and compact town development is recommended to curb urban sprawl. This concept should be recommended to address the rising land-use changes in Ndenderu ward that have encouraged urban sprawl and corridor development. This will consider travel time to commercial or employment areas such as Nairobi City. Planning for closer land uses/compact developments and structural form of mixed-use developments are some of the avoid strategies that will encourage walkability, cycling as well as minimize travel trips hence discouraging car ownership which is on the rise in the area.

Transit-oriented development that advocates concerns for the city of workers and transit, as opposed to the city of cars should be the order of the da. This should be compact and contain mixed-use development with the mixed-use economy, mixed age group and mixed land use. Mixed-use development allows walkability which cities must provide for the safety, a proper reason for a walk, comfortable and make them interesting. Compact Developments along the transport corridors will minimize sprawl occasioned in the area extending towards Gachie town. Densification should be enhanced with an increase in the Plot Ratio and Plot Coverage depending on the infrastructure available within the transport corridor blocks.

Supportive green building norms such as solar, rainwater harvesting and groundwater recharging techniques and sustainable solid waste management systems shall be adopted within the transport corridor neighborhoods. Mandatory TOD land uses such as Residential 30% and Commercial 20% (Minimum) shall be enforced to ensure the element of walkability and mixed-use development is attained to minimize the demand for car use. Provision of sanitation facilities and other support amenities especially at the transport terminals shall be taken into consideration for people with disabilities, children, the expectant women, elderly and the sick.

Charges should be levied on the private car uses with any economic, social and environmental impacts to enhance the environmental performance of transport systems with the main emphasis on prevention of noise and air pollution as well as promoting economic development. The compactness of land use developments shall be emphasized to reduce urban sprawl and be integrated with TOD models.

6.3.1.8 Management and Maintenance of Roads

Tarmacking or graveling of murram roads, regular maintenance and repair should be undertaken to control dust and muddy conditions of roads due to weather variations which makes road users uncomfortable to use such roads.

6.3.1.9 Enhance Safety and Security

Safety and security of road users, especially to pedestrians, should be enhanced through measures such as the installation of security lights, use of curbs, footbridges and dedication of NMT and cyclist lanes.

6.3.1.10 Road Widening Through Surrenders of Part of the Land

All properties that attract high population densities should be subjected to surrender of part of their land for road widening. This will provide room for other services such as utility provision, NMT and cyclist lanes consideration among many others.

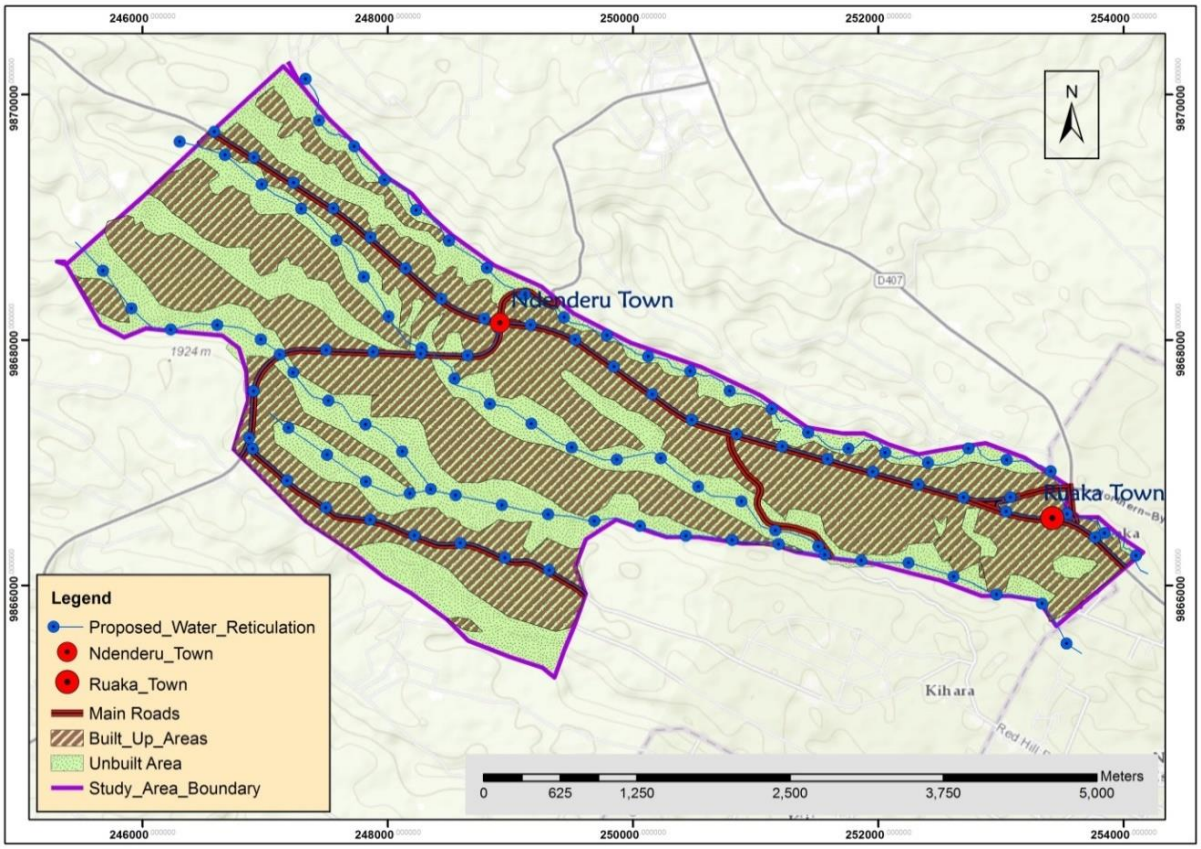
6.3.1.11 Provision of Alternative Transport Routes

Some areas that are not served with public transport network should be considered with alternative access routes to enhance the mobility of such corridors. Due to the narrow nature of roads and the high cost of compensation in the process of demolition to pave way for road expansion, some of the access roads can be dedicated as entry points and others exit points exclusively.

6.3.1.12 Manage Storm Water and Floods

To control possible flooding in the area, the rugged nature of the landscape must be capitalized by running drainage way-leaves along the roads down the slope. All stormwater drainage should be directed to the river or green infrastructure or parks to ensure that high percolation to the ground takes place. Public-Private Partnership must be promoted to enhance regular maintenance and management of the drainage way-leaves and channels. Provision should be made for green infrastructure (open spaces, green belts, and parks) to act as resilient measures to floods during rainy seasons with the rise of urban fabric due to LUC in the area. Strict enforcement of development regulations that are sustainable of plot ratios, coverage, parking requirements, setbacks and building lines among many others should be enhanced to leave more room for green open spaces for water percolation. This is through ensuring a land-use policy and development guideline is approved and is in place that restricts developments to observe the ground coverages not exceeding 65% along the Limuru Road and the Western Bypass while the rest remains at a maximum ground coverage of 55%. Other measures such as recommendations for unpaved parking areas or technologies should be encouraged to allow better drainage of water.

Map 6-3: Stormwater Management Plan



6.3.1.13 Provision of Bus-Stop and Parking Areas

Provision should be made for a public bus park and parking provisions for the commercial areas within Ruaka town. Parking strategies are essential in the CBD area with proper maintenance and management of parking facilities. There should be clear understanding and considerations made on the parking supply and demand position in Ruaka town with reservations and other strategies used to preserve space for the essential service providers. Parking strategies that should be considered include parking pricing, off-street parking facilities, restriction of on-street parking as well as traffic management strategies and travel demand management strategies.

6.3.1.14 Opening Up Missing Links

Accessibility and connectivity of all parts should be enhanced through opening missing links. This limits the travel time, enhances safety and security.

6.3.1.15 Zoning, Development Control and Enforcement. Enhance Adherence to Regulations on Subdivisions with Guidelines on Minimum Access Roads

It is essential to provide for zoning regulations to all the land uses and consider their compatibility to adjacent uses, available infrastructure to support such land uses. Besides the compatibility, densities have to be graduated such that there is no gradual shift from high density to low density in terms of the densities, land use classification and level of land subdivision. Compulsory surrender of part of plots for road widening, observation of road hierarchies, enforcement of minimum road sizes, streamline conflicting policies on who is mandated to undertake subdivision and spell out the minimum subdivision sizes-land use planning/zoning.

6.3.1.16 Environmental Transport Options For Protecting and Conservation of the Environment

It is known all over the world that cities that don't spend much on cars create huge savings and enhance air quality. Environmental transport options of protecting and conserving the environment will make urban infrastructure protect us rather than threatens us and therefore should be considered to enhance the efficiency and effectiveness of transport systems. These options include improve strategy such as environmental performance to prevent air and noise pollution, charging for any social, environmental and economic impacts, promoting energy-efficient transport modes, use of more fuel-efficient vehicles, using cleaner fuel technologies, vehicle and clean fuel technology that are environmentally friendly, regular inspection and maintenance of transport system. Other measures include the use of medium-sized vehicles with modern emission controls.

6.3.1.17 Public Participation and Consultation

Public participation and consultation should be done with stakeholders for the implementation of any proposals made to enhance the efficiency and effectiveness of roads and transport systems.

6.3.1.18 Integrated and Enhanced Inter-Agency Coordination and Collaboration in The Management of Road Infrastructure Systems

Coordination and Collaboration among institutions should be enhanced to realize the implementation. Technical interventions are key in the formulation and implementation of policies on the transport corridor with support from the political arm. This shall be done by having such critical stakeholder's engaged in decision making to get full support and ownership of the project especially regarding the corridors that traverse across different political and jurisdictional boundaries. There is a need to have proper coordination and collaboration among different institutions within the different jurisdictions of Kiambu County and Nairobi County since transport systems are managed by different institutions such as KeNha, Kerra, KURA, among others. Possible options would be pursued on whether the management of such inter-county infrastructure shall be managed by one institution within the greater Nairobi metropolitan region or be discussed as inter-county projects as provided for in the Physical and Land Use Planning Act, No. 13 of 2019. Transportation systems being a public good not provided for commercial purposes and not possible to be provided by the private entities, it should be managed well once it is implemented fully. It should be managed well since there is a lot of costs incurred and should be recuperated in the long run. Subsidies received from the transport system services within such as Northern Bypass should be utilized in a better way to improve the transport access roads along the Ruaka Ndenderu Transport Corridor

A holistic approach in integrated infrastructure management should be considered in advance taking into account all aspects of infrastructure development by providing for integrated road

infrastructure with driveway, pedestrian and cyclist lanes, Street lighting, Safety and security considerations within the urban built-up areas. All the sectors, agencies, and stakeholders should be incorporated to ensure that the nature of development is comprehensive and caters to social, physical, economic and environmental needs of the community. Most of the infrastructure development normally takes in isolation of the inputs from other sectors or related departments. The various institutions such as the National and County Government have clear coordination of their activities to ensure proper implementation through partnerships and consultations. The partnership between and among different stakeholders is essential in ensuring broad-based support to maintain the sanity of neighborhoods through joint ventures/public-private partnerships in the provision of support infrastructures such as street lighting, road widening, stormwater drainage, NMT or pedestrian and cyclist lanes, sewer and water reticulation which the government might take time to provide. Current urban problems are accelerated and worsened by existing weak and conflicting policies. Policies that enhance the coordinated and controlled development are necessary backed with urban governance and political goodwill. There is a need to formulate and implement other policies such as regularization, lower-order plans among many other policies. The penalties on the offenders should be punitive to deter any future flouting of development control rules and regulations. Court injunctions should be limited especially when they infringe on the rights of the County Government in performing their duties.

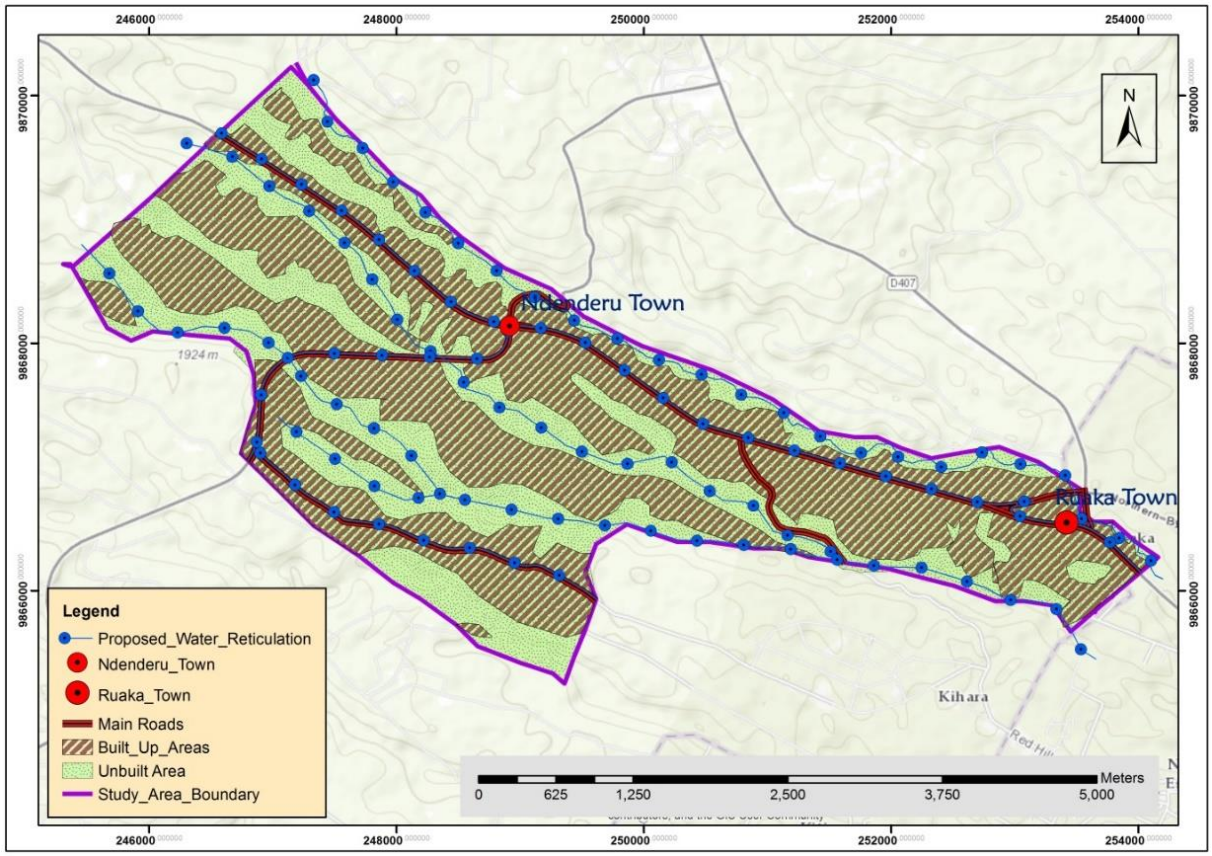
6.3.2 Management of Water Supply Infrastructure Capacity

Land-use changes with a high population and increased water demand pose great risks to the supply of sustainable urban water services which call for a transition towards improved water supply and management with major consideration on making the water supply systems resilient to such land-use changes. The following are some of the recommendations to enhance the resilience of urban water supply systems as discussed below.

6.3.2.1 Water Reticulation/Connection to Nairobi

An integrated water supply system should be installed with water reticulation serving all properties. The water should be clean and affordable tariffs be provided to the consumers.

Map 6-4: Water Reticulation Management Plan



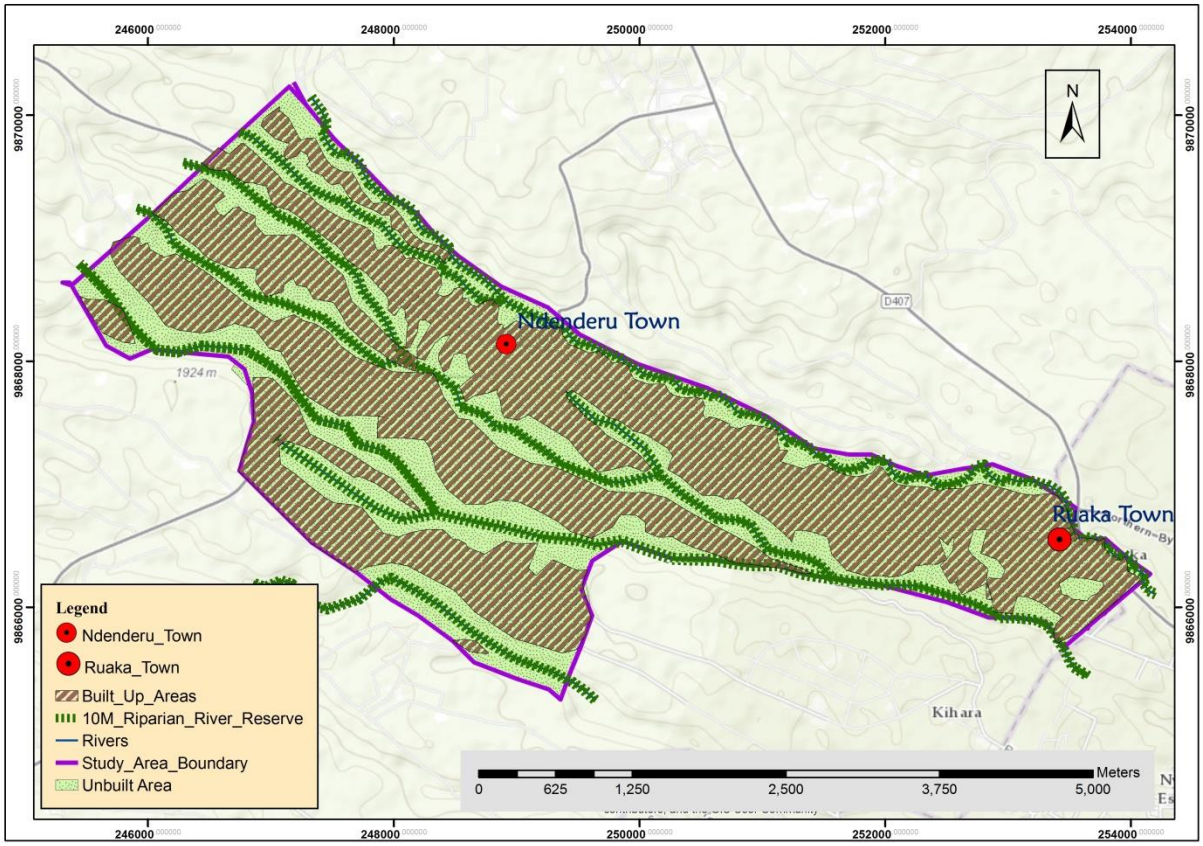
6.3.2.2 Protection of Conservation Areas and Riparian Reserves/Punitive Measures

Instead of bulldozing, leveling sites and building up to the riparian river reserves, green edges along the riparian reserves should be left as normative with a set of conservation practices within the urban fabric which always gives astounding results.

6.3.2.3 Control Water Pollution and Contamination

Developments on riparian reserves should be controlled through strict enforcement and development control measures to control pollution and contamination of Ruaka Rivers. Boreholes should be sunk away from areas close to pit latrines. Water from boreholes should at all times be treated before the use of its water to minimize the high risk of water-borne diseases.

Map 6-5: Conservation and Riparian Reserve Management Plan



6.3.2.4 Drill Public Boreholes

Public boreholes should be sunk to supplement water supply especially in areas where there is high demand. This should be treated and spatially distributed for equity in the accessibility of clean water.

6.3.2.5 Periodic Upgrade, Checkup and Maintenance

Routine checkups, upgrade of water supply infrastructure systems to meet its capacity and maintenance should be done regularly. The drilling of boreholes should be regulated to ensure sustainable exploitation of the resource.

6.3.2.6 Integrated and Enhanced Inter-Agency Coordination and Collaboration in Management

There should be an integrated, coordinated and collaborated approach of management of water resources by various inter-agencies such as the Karuri Water and Sanitation Company Ltd, Water Resource Authority and National Environment Management Authority in regulation and management of boreholes, riparian reserves, and other water sources.

6.3.3 Management of Wastewater Infrastructure Capacity

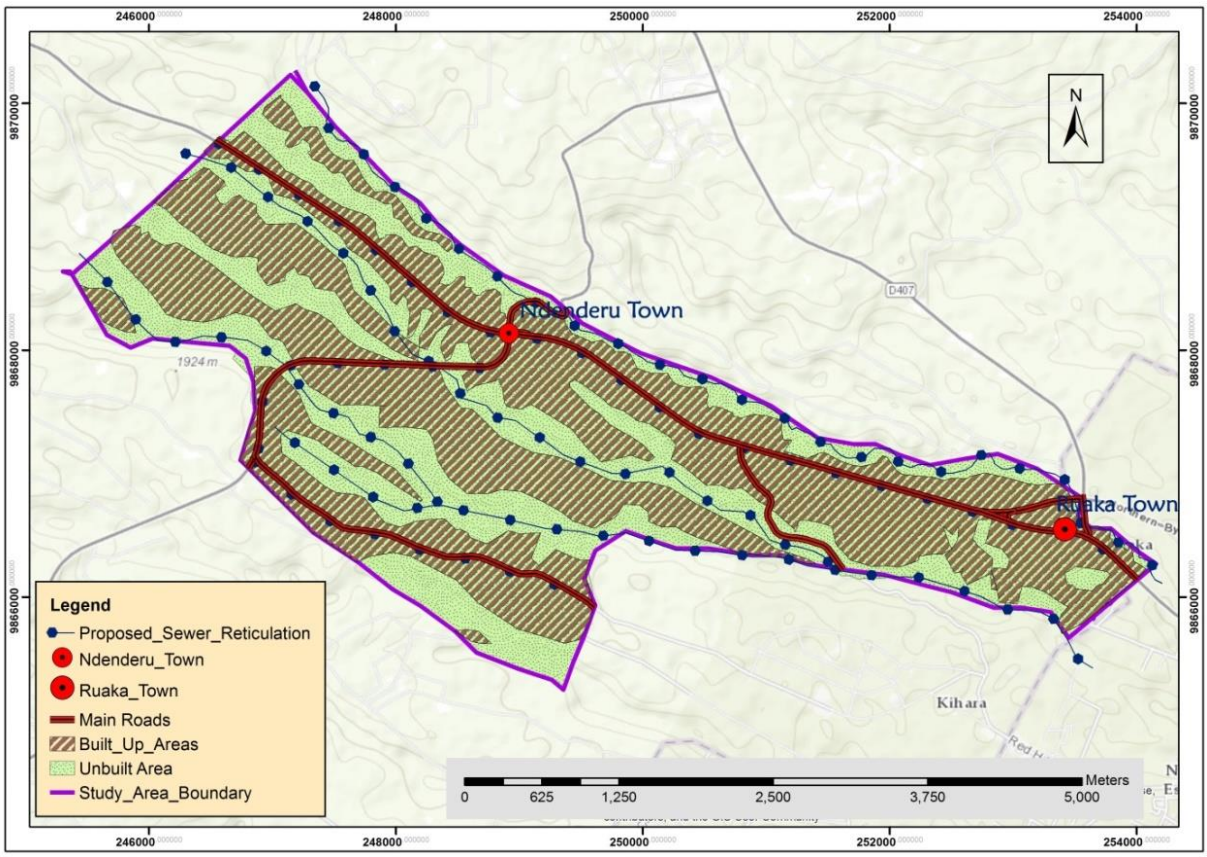
6.3.3.1 Sewer Reticulation along the Lowest Point to Connect to Nairobi City County

An integrated conventional sewerage treatment network system be installed in the area with a clear reticulation to serve all properties. This should be along the river reserve being the lowest points. Negotiations should be done with other jurisdictions such as Nairobi City County to allow the sewerage connection to its borders due to its low terrain to ease of connectivity from Ruaka Town.

6.3.3.2 Preferential Property Treatment to Those That Use Sustainable Wastewater Management

Differential property taxation should be given for those using other sustainable systems of recycling, treatment, and re-use of wastewater should be given over those using septic tanks and pit latrines.

Map 6-6: Sewer Reticulation Management Plan.



6.3.3.3 Routine Checkup and Maintenance/Punitive Measures

Regular checkups of wastewater infrastructure should be done to spot instances of leakages and spillages. Punitive measures should be given to those that flout rules by directing their wastewater to rivers and road reserves. Periodic upgrading of the capacity of wastewater infrastructure should be done to meet the expanded capacity of the infrastructure systems.

6.3.3.4 Regulate and Control Septic Tanks and Pit Latrines

Wastewater management systems such as the use of pit latrines and septic tanks should be prohibited within Ruaka town**.** This will reduce the health risks and costs and enhance the sterility of the environment.

6.3.3.5 Integrated and Enhanced Inter-Agency Coordination and Collaboration in Management

An integrated, coordinated and collaborated system of management of wastewater should exist between the County Government, private developers, and other county governments that border the jurisdiction.

6.4 Evolution of an Urban Infrastructure Management Strategy

6.4.1 Technical Dimension

Road infrastructures such as Limuru Road and Western Bypass and Northern Bypass within the study area are interconnected within the study area and across the adjoining Nairobi County jurisdictions. Although Limuru Road, Northern Bypass and the Western Bypass have been built in different times and periods of history, some out of different lengths, conditions and sizes such as the Limuru Road with many potholes, there must be a concern of upgrading, repair and interconnection to the areas that are experiencing such rapid land use changes. Interoperability of these roads between takes place across Nairobi County and Kiambu County's jurisdictions platform although they are part of the same Nairobi Metropolitan agglomeration. These roads are of different classes and are of different limited capacity such that the very narrow access roads can only accommodate a limited number of cars. Managers must introduce single routes that will not be used as dual carriageways within the settlement areas. If uncontrolled and unmanaged, the limited capacity of vehicles might crunch their capacity or bring up snarl-ups. The entire road network should be managed with alternative exit points such that if there is a failure in one end or an inefficiency exists, it doesn't extend to the road network system. The links and interfaces between different roads classes such that if there is an accident at some point of the road, it doesn't affect the rest of the system or interrelated links such as Red-Hill road or other roads leading to different parts. The urban road network systems should be integrated with multi-modal passes. Besides, the coordination should be done by one agency

with several transport lines. Management of transportation in Ruaka should ensure high-frequency departures that run day and night with regularly targeted fare reductions. The management should also ensure that future developments are built around the public transport lines such as Limuru road or within walking distances to public amenities and shopping areas such as Ruaka Square, and Ndenderu shopping centres. Traffic monitoring systems should be installed in Ruaka and Ndenderu areas for the success of the proposed integrated public transport system. The benefits gained from such an efficient and integrated transport system shall attract investors, businesses and growth in the economy in Ndenderu Ward. Water resources should have integrated water resource management systems with the diversification of water supply, expanding and building water reservoirs with the currently proposed reservoir outside the study area boundary in Muchatha area, management of water demand shall be regulated through pricing, enforcement on water conservation measures, importation of water and desalination of borehole water.

6.4.2 Economic Dimension

Urban infrastructure in Ruaka Town such as Limuru road, Northern Bypass and Western Bypass are long term investments that usually require huge sunken costs which may be difficult to recuperate over a short period since they are a public good investment for economic development and prosperity of the town. Therefore, such investments are not produced for commercial purposes but mainly as public services which no economical rational enterprise all over the world will be willing to provide since they may not be paid for. Economies of scale should be the viable option in ensuring that the costs and infrastructure services along these roads are used optimally. The management of these road infrastructure by urban managers should be undertaken most efficiently with minimal wastes. Road cutting, alteration and any other unauthorized modifications should be minimized. There are instances where private developers cut the roads without reinstating their status to the original state and this should be

controlled. Management of urban infrastructure should be mainly tagged on profitability to guarantee profitable infrastructure services that are provided. The proceeds shall be used to develop further services to generate profit to re-invest in better technologies to better treat, maintain, repair and manage the road infrastructure. Subsidies received from some of these infrastructure services should be utilized in a better way.

Ruaka town should use a progressive water tariff structure that penalizes the inefficient use of water for domestic water consumption that exceeds $40m^3$ per month for residential areas to ensure better utilization of water resources. The water management companies should undertake regular monitoring of water infrastructure to ensure the maintenance of existing water supply infrastructure as opposed to building more or expanding the infrastructure. The management of urban infrastructure should ensure earlier identification of aging infrastructure or approaching the end of the design life and retrofit it or build new resilient urban infrastructure. The high rate of monitoring to increase detection in rates and areas of blockages to ensure that they are accurately registered. Water management companies should use modern technologies such as water pressure management technology in the management of its water resource through Public-Private Partnership. The advanced water pressure reduction installation plant reduces the water pressure during the off-peak hours and at night which reduces leakages. This reduces the amount of water wastage significantly.

6.4.3 Environmental Dimension

Ruaka town and the entire Ndenderu ward being an urban area is a big polluter from the waste generated from the households and commercial areas. Management of waste infrastructure should be done in the least polluting way by use of efficient and sustainable technologies such as renewable approaches, introduction and connection of sewerage systems to the entire ward as opposed to the current unsustainable septic tanks. There is a need to identify assets likely to

suffer in case of future urban expansions and other vulnerabilities and provide solutions to curb such menaces. Management of roads and transport infrastructure should create solutions that enhance environmental conservation, reduce emissions and pollutions such as the use of non-motorized transport and pedestrianization of some of the streets in Ndenderu ward.

6.4.4 Social Dimension

Water tariffs should be provided in socially equitable ways without leaving anyone behind through social tariffs which are favorable to the customers across all social classes. Water is a basic right, it should be provided at an affordable cost where affordability should be relative to the income levels of the people in the area. This should be undertaken in a manner that they don't end up spending the whole income on water and transportation. Water supply should be developed and supplied to the entire Ndenderu ward without discrimination in other sections of the ward. Currently, the water supply infrastructure is only done within the Ruaka CBD area and the rich suburbs where the residents may have the voice and capacity to protest or control decisions or failure to supply of water. Community boreholes accessed by the residents should be constructed to supplement the current water supply. It is vital to use non-discriminating approaches in the provision of urban infrastructure. Infrastructure provision such as the roads, sewer and water reticulation should have high service coverage of the entire ward. Citizen participation and engagement should be undertaken in the implementation of all infrastructure projects for public acceptance and confidence through a public engagement campaign to educate the public on the stringent process of infrastructure production. This enables them to know how to maintain such infrastructure such as the roads, water reticulation networks and how to maintain safety of drinking water. The transportation and roads management system should be able to address the social needs by making transportation and road networks accessible, safe and secure and should be carried out equitably to accommodate the disadvantaged groups such as the people with disabilities, women and children. This can be

achieved through multimodal transport that focuses mainly on non-motorized means of transport which encourages social groups and interaction with the presence of street furniture, safe public spaces and a conducive environment. Streets in Ndenderu ward should be redesigned to regulate and encourage low-speed limits to encourage the non-motorized means of transport and pedestrian use hence enhancing the safety of such road users within Ruaka and Ndenderu towns.

6.4.5 Jurisdictional Dimension

Political factors have influenced LUC especially on policy matters and particularly on zoning regulations which have been changing over different political regimes and hence affect the decisions made on the nature of developments, plot ratios and ground coverages used in approval and implementation of plans in Ruaka and Ndenderu Ward in specific. Operation of Limuru Road, Western Bypass, Northern Bypass, and Water Supply systems in Ruaka is across political and legal jurisdictions of National Government, Nairobi County and Kiambu County. This poses technical challenges of interconnectivity and interoperability being within the larger metropolitan region.

Coordination and collaboration in running programs and activities which are inter-county in nature may require a joint effort in policymaking or resource allocation. This calls for transparency and accountability through openness, honest and free access to information to make decisions and prioritize projects and activities to ensure that allocated public resources which are meant for productivity in enhancing and development of urban infrastructure are not diverted to untargeted groups or for private consumption which would lead to growth being adversely affected. There is a demand for more reliability of the water supply, maintenance of the roads such as Limuru Road which has many potholes and demands for sewer infrastructure. There is a need for coordination and collaboration between the National Government agencies

including KURA, KeRRA, KeNHA and Kiambu County. Therefore, Ruaka urban infrastructure management systems can only be successful through urban management strategies, institutional reforms and sound urban governance through political and government commitment and prioritization of infrastructure projects.. It has been discovered that one of the best Harvard economist Ed Glaeser once said that economics offers tactics but not strategy, which meant that politics always decides what level of support received and as such we must always revise tactics to get urban infrastructure projects prioritized during the budgetary allocations to facilitate implementation.

Strong political will and effective regulatory and legislative frameworks should be put in place to enhance strict enforcement of the legislation, ensure proper management of roads, water supply and wastewater infrastructure. It is also essential to ensure there are collaboration and sensitization of its stakeholders to enhance transparency and accountability of the projects and programs in place.

6.5 Implementation Strategy

Table 6-1: Implementation Matrix

Sector	Short Term (0-2 Years)	Medium Term (3-5 Years)	Long Term (5-10 Years)	Actors
1. Roads Infrastructure	Street Lighting Installation of traffic monitoring systems Restrict traffic speed within residential areas Frequent maintenance rather than new constructions Paving the major access roads Dedicate cyclists and pedestrian lanes Surrender of roads for widening by properties with narrow access roads within the CBD areas Management strategy on coordination and collaboration in operations Make all roads infrastructure projects a priority Alternative routes optimization Improved Governance	Opening up missing links Upgrading of alternative public transport routes Provide a safe infrastructure for all road users at Ruaka e.g pedestrian crossings Public-Private Partnerships	Tarmacking all unpaved roads Road widening in the entire ward Design safer intersections and roads with interchanges at Ruaka Provide better and safer public transport Setting Out effective monitoring and evaluation systems The integrated inter-modal transport system	County Government of Kiambu Kerra KURA KeNha Municipalities
2. Water Infrastructure	Home owner awareness on system maintenance and inspection through signing contracts Inspection and regulation of boreholes and pollution to water sources Decentralization of water management systems	Sinking community boreholes at strategic locations Increasing the commercial water tariffs and residential flats with higher plot ratios. Regulation of underground water extraction to avoid its depletion	Water reticulation to the entire ward Build Water Reservoirs Build a Water desalination plant	Karuri Water and Sanitation Company Ltd Municipalities

		Place people in charge to run the infrastructure based on their merits/people suited to do run projects Regulation of water consumption that exceeds 40M^3 per month and subsidizes water use between 20m^3 to 30m^3 per month. Management strategy on coordination and collaboration in operations Use of water pressure management technology in the management of its water resource to regulate pressure during off-peak hours and at night Make all water infrastructure projects a priority Issue permits for installation and repairs Improved Governance	Provision of subsidies to water and wastewater management providers Enhancing the autonomy of service providers. Public-Private Partnerships Minimize operating costs Sustain water flow in areas of vandalism or illegal connections	Setting Out effective monitoring and evaluation systems Integrated Water Mangement System	
3.	**Waste Water Infrastructure**	High level of inspection and enforcement in construction and management of septic tanks Management strategy on coordination and collaboration in operations Make all waste water infrastructure projects a priority Controlled discharges of raw domestic wastewater to roads and rivers Improved Governance	Increase in charges for residential apartments with higher plot ratios using septic tanks. Public-Private Partnerships	Sewer reticulation to the entire ward Setting Out effective monitoring and evaluation systems Integrated Liquid Waste Management System	Karuri Water and Sanitation Company Ltd Municipalities

6.5 Areas for future research

This study proposes areas of further research to be undertaken in the following areas: -

a) Land use analysis on the same area with high-resolution images investigating the impacts of the land-use changes on climate change and its effects such as Urban Heat Island, Carbon emissions and air quality.
b) Effects of the land-use changes and the over-reliance of septic tanks as a method of wastewater management and their effects on human health in the area.
c) A correlation of land-use change and disaster/risks emergence due to the rise in development densities.
d) Impacts of land-use change and urban development on flooding in the area.
e) A correlation between land use and borehole water quality supply in the area.

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ANNEXURES:

Annex 1: Authority from The University of Nairobi-Department of Architecture and Building Science

UNIVERSITY OF NAIROBI

School of the Built Environment

DEPARTMENT OF ARCHITECTURE & BUILDING SCIENCE

E- mail: architecture@uonbi.ac.ke

P.O. BOX 30197,
Nairobi, Kenya
Telephone: 2724528
Telegrams: Varsity.

Our Ref: UON/CAE/ABS/ST

Date: 18th October ,2018

TO WHOM IT MAY CONCERN

RE: DENNIS OMOGA ABUYA – W5086644/2016

This is to confirm that the above named are **Master of Urban Management** Student at University of Nairobi, Department of Architecture & Building Science,. As part of the continuous assessment culture in the Master of Urban Management programme our students are encouraged to conduct primary research for their portfolio project.

We wish to request you to give him some of your valuable time by responding positively to his inquiries, and provision of drawings/plans/photographs, etc. This is for academic purposes only.

Any assistance accorded to him will be highly appreciated by this office.

CHAIRMAN
DEPARTMENT OF ARCHITECTUR
& BUILDING SCIENCE
UNIVERSITY OF NAIROBI

Arch. Musau Kimeu
CHAIRMAN,
DEPT. OF ARCHITECTURE & BUILDING SCIENCE

/mao.

Annex 2: Authority from the National Commission for Science, Technology and Innovation

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471,
2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No **NACOSTI/P/18/53376/27098** Date: **27th November, 2018**

Dennis Omoga Abuya
University of Nairobi
Po Box 30197-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on "***The effects of land use changes on urban infrastructure: A case study of Ruaka Town, Kiambu County, Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Kiambu County** for the period ending **26th November, 2019.**

You are advised to report to **the County Commissioner and the County Director of Education, Kiambu County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PHD
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kiambu County

The County Director of Education
Kiambu County

Annex 3: Research License from the National Commission for Science, Technology and Innovation

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. **The License is valid for the proposed research, location and specified period.**
2. **The License and any rights thereunder are non-transferable.**
3. **The Licensee shall inform the County Governor before commencement of the research.**
4. **Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.**
5. **The License does not give authority to transfer research materials.**
6. **NACOSTI may monitor and evaluate the licensed research project.**
7. **The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.**
8. **NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.**

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

National Commission for Science, Technology and Innovation

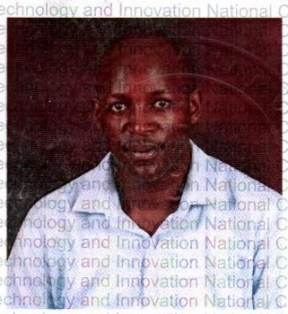
RESEARCH LICENSE

Serial No.A 22040

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. DENNIS OMOGA ABUYA
of UNIVERSITY OF NAIROBI, 29316-100 Nairobi,has been permitted to conduct research in *Kiambu County*
on the topic: *THE EFFECTS OF LAND USE CHANGES ON URBAN INFRASTRUCTURE: A CASE STUDY OF RUAKA TOWN, KIAMBU COUNTY, KENYA.*
for the period ending:
26th November,2019

Permit No : NACOSTI/P/18/53376/27098
Date Of Issue : 27th November,2018
Fee Recieved :Ksh 1000



.....
Applicant's Signature

.....
Director General
National Commission for Science, Technology & Innovation

Annex 4: Household Questionnaire to The Residents of Ruaka Town

The purpose of this questionnaire is to collect data which will be used to evaluate the effects of land use changes on urban infrastructure in Ruaka Town. The information provided through this questionnaire will be used purely and exclusively for academic purpose and will be treated confidentially. Your cooperation and assistance are highly appreciated.

Section I: Population & Demography

1. (a) Age □Less than 20 □21-30 □31-40 □41-50 □Over 51

(b) Gender □Male □ Female

(c) Marital status □Married □Single □Divorced □Widower/widow

(d) Education level □None □ Primary □Secondary □College □University

(e) Household head □ Father □Mother □Others……

(f) Household size……

2. (a) Respondents' main occupation (Economic Activities).
□Formal employment □Farming □Business □Others (Specify)……
(b) What is your monthly income? □Less than Kshs 10,000 □Kshs (11,000 - 25,000)

□Kshs (26,000 - 35,000) □Kshs (36,000-45,000) □Kshs (46,000 and above)

3. a) Housing Typology. ……

b) Are you the owner or the tenant? …….

4. a) What are your sources of water?.....

b) Is it reliable? .....

c) How many litres of water do you use per day per household?.....

d) Is the water supplied in adequate quantities and clean? □Yes □No If No Explain

5. a) What are the approximate sizes of roads serving your property?.....

b) Is the size of the road of adequate capacity? Can two vehicles bypass each other? Explain…….

c) What is the condition/state of roads? Does it require improvement?

d) Do the roads have security light? Is the area safe at night?

e) Is there provision for Non-Motorized Transport/Walkways or cycling lanes on these roads?

f) Do you own a car? If yes how many?.....

g) Is there a reliable public transport?.....

h) Is there traffic congestion and what do you think is the cause?

i) Do the roads serving your property have stormwater drainage network/channels?

j) Is the area prone to flooding during the rainy season? What would be the underlying reasons?

k) What are the challenges regarding your water supply?.....

6) a) How do you dispose of liquid waste? Explain.....

b) Is wastewater drained along the road serving your property? □Yes □No If No Explain.....

c). Are there any challenges regarding liquid waste management system you use? □Yes □No

If Yes explain.....

B.) Land Use and Environmental Implications

7). For long have you been living in your current residence?

□Less than one year □ (1-5) years □ (6-10) years □ (11-15) years □ (16-20) years □ >21 and above years

8). What factors were important in your decision to live in this area?

9). What major challenges have you faced since moving to this place?

10). Do you have land of your own in this urban centre? □Yes □No

11). If yes, how did you acquire it, what is it currently used for and what future plans do you have for it?

12). Is there an increased rate of land subdivision in the area?

b. Is there high land use change from farms/agricultural to residential flats and commercial?

c. Is the land conversion/land use change a problem in your area? □Yes □No

d. What are the main causes of land use changes (From Agricultural to residential flats/Commercial)?

e. What are the major effects of the above land use changes on roads infrastructure?

f. What are the major effects of the above land use changes on water supply infrastructure?

g. What are the major effects of the above land use changes on wastewater infrastructure/Management?

13). What are the recommendations to these challenges on roads infrastructure?

14). What are the recommendations to these challenges on water supply infrastructure management?

15). What are the recommendations to these challenges on wastewater infrastructure/Management?

THANK YOU VERY MUCH FOR YOUR CO-OPERATION!

Annex 5: Key Informant to The Officials in The Department of Land, Housing, Physical Planning, Municipal Administration and Urban Development.

The purpose of this questionnaire is to collect data which will be used to evaluate the effects of land use changes on urban infrastructure in Ruaka Town. The information provided through this questionnaire will be used purely and exclusively for academic purpose and will be treated confidentially. Your cooperation and assistance are highly appreciated.

Section I: Physical Planning

1) a. Do you have an approved zoning policy for Ruaka town? □Yes □No
   b. If yes is it implemented as per the policy?
   c. If No what is used in the planning and development control of the area?
2) a. Does the County have an infrastructure structure plan for the area?
   b. What challenges have you faced in the management of urban infrastructure?
3) What are the main land uses and trends that exist?
4) What are the urbanization rates in Ruaka?
5) a. Do the town experience rapid land use changes? □Yes □No
   b. What is the rate of development application submissions received as compared to other areas within the County? Give statistics of development applications submitted for the last 10 Years.

Type of Application	**Type of Development**	**No of Application Submitted**	**No of Applications Approved**	**Permitted PR/No of Floors**	**Permitted GC**	**Compliant Developments as per approvals**
Planning-CoU	From Agriculture to…….	Jan 15 -Dec 15 Jan 16 -Dec 16 Jan 17 -Dec 17 Jan 18 -Dec 18		e.g Yr 12-13-300% 14-16-150% 17-200% 18-?	e.g Yr 12-13-80% 14-16-40% 17-50% 18-?	
Building Plans	Commercial/ Residential	”		”	”	

   c. What is the compliance rate in terms of the approvals granted?
6) a. If yes what are the main causes of these land use changes?
   b. If yes what are the main impacts on urban infrastructure (Water Supply, Roads and Waste water infrastructure)
7) Have land use changes impacted on the land valuation roll?
8) What measures should be put in place to mitigate the impacts stated above?

Section II: Development Control, Enforcement, and Compliance.

1). Is the local authority having an approved development planning Policy guideline for Ruaka?

□Yes □No

2). If no, how is development control undertaken within this jurisdiction?
3) Give the current structure of development control in the sub-county?

Human Resources	**Machinery/Equipment/Vehicles**
Levels of Skills	**No.**
Physical Planners	
Development control Officers	
Structural Engineers	
Enforcement Officers	
Prosecutors	

4) Which the most important factor you consider during the development control and enforcement to ensure compliance?

5) a. How would you rate the effectiveness of development control and enforcement? □Satisfactory □Not Satisfactory

b. Explain your answer

6). In your opinion, what has been the most challenge or hindrance to development control and enforcement to enhance full compliance?

THE END

THANK YOU VERY MUCH FOR YOUR CO-OPERATION!

Annex 6: Key Informant Questionnaire To WRA, NEMA, AND NCA

The purpose of this questionnaire is to collect data which will be used to evaluate the effects of land use changes on urban infrastructure in Ruaka Town. The information provided through this questionnaire will be used purely and exclusively for academic purpose and will be treated confidentially. Your cooperation and assistance are highly appreciated.

Section I: Water Supply and Wastewater Infrastructure-Water Resource Authority

1) a. Is there encroachment of developments to riparian/road reserves?
   b. What is the size of riparian reserves in Ruaka area?
   c. Which areas have been encroached and to what extent?
   d. What are the impacts of such encroachments?
2) Do you have control over these water supply infrastructures? □Yes □No
   If No, Explain?
3) a. Has the land use changes/urban developments impacted on water supply and wastewater infrastructure? □Yes □No
   b. If yes what are the impacts?
4) What measures should be put in place to mitigate the impacts stated above?
5) a. How is work coordinated between the multi-agencies?
   b. Is there any point of conflict in enhancing compliance?
   c. What measures has the Authorities (County Government, WRA, NEMA, NCA) put in place to ensure developments are in harmony with the available infrastructure?
6) a. How often is water supply and wastewater infrastructure system regulated, protected, maintained and managed?
   b. What challenges have you faced in water supply and wastewater management of urban infrastructure (Roads, Water, and Wastewater)?
   c. What recommendations would you make to improve the management of infrastructure (Roads, Water, and Wastewater)?

Section II: Water Supply and Wastewater Infrastructure-NEMA

1) a. Is there encroachment of developments to riparian/road reserves?
   b. What is the size of riparian reserves in Ruaka area?
   c. Which areas have been encroached and to what extent?
   d. What are the impacts of such encroachments?
2) What are the sizes of roads in the area serving developments?
3) Do you have control over these urban infrastructures? □Yes □No
   If No, Explain?
4) a. Has the land use changes/urban developments impacted on your feeder road, water supply, and wastewater? □Yes □No
   b. If yes what are the impacts?
5) What measures should be put in place to mitigate the impacts stated above?
6) a. How is work coordinated between the multi-agencies?
   b. Is there any point of conflict in enhancing compliance?
   c. What measures has the Authorities (County Government, WRA, NEMA, NCA) put in place to ensure developments are in harmony with the available infrastructure?
7) a. How often is urban infrastructure system regulated, protected, maintained and managed?
   d. What challenges have you faced in the management of urban infrastructure (Roads, Water, and Waste Water)?
   e. What recommendations would you make to improve the management of infrastructure (Roads, Water, and Waste Water)?

Section III: Roads, Water Supply, And Wastewater Infrastructure-Nca

1) a. Is there encroachment of developments to riparian/road reserves?
   b. What is the size of riparian reserves in Ruaka area?
   c. Which areas have been encroached and to what extent?
   d. What are the impacts of such encroachments?
2) What are the sizes of roads in the area serving developments?
3) Do you have control over these urban infrastructures? □Yes □No
   If No, Explain?
4) a. Has the land use changes/urban developments impacted on your feeder road, water supply, and wastewater? □Yes □No
   b. If yes what are the impacts?
5) What measures should be put in place to mitigate the impacts stated above?
6) a. How is work coordinated between the multi-agencies?
   b. Is there any point of conflict in enhancing compliance?
   c. What measures has the Authorities (County Government, WRA, NEMA, NCA) put in place to ensure developments are in harmony with the available infrastructure?
7) a. How often is urban infrastructure system regulated, protected, maintained and managed?
   f. What challenges have you faced in the management of urban infrastructure (Roads, Water, and Waste Water)?
   g. What recommendations would you make to improve the management of infrastructure (Roads, Water, and Waste Water)?

THE END

THANK YOU VERY MUCH FOR YOUR CO-OPERATION!

Annex 7: Key Informant Questionnaire to the Department of Roads, Transport & Public Works and Karuri Water and Sanitation Company Ltd.

The purpose of this questionnaire is to collect data which will be used to evaluate the effects of land use changes on urban infrastructure in Ruaka Town. The information provided through this questionnaire will be used purely and exclusively for academic purpose and will be treated confidentially. Your cooperation and assistance are highly appreciated.

Section I: Roads Infrastructure- Department of Roads, Transport & Public Works

1) a. Is there a roads infrastructure structure plan for the area showing the distribution and networks of roads? □Yes □No

   b. If yes/no explain?

   c. Is the road infrastructure structure plan aligned to changes in land uses/Zoning regulations for the area?

   d) What is the level of connectivity, network, and accessibility of roads infrastructure?

2) a. What are the sizes of roads in the area? .....

   b. Do the roads in the area obey the road hierarchies?

   c. What is the current condition/state of roads? .....

   d. Is the capacity adequate? □Yes □No

   e. If No, what is the recommended capacity and what are the current challenges?

   f. Is there street lighting on roads in this area? □Yes □No If yes which areas……

   g. Are the roads safe and secure at night? □Yes □No If No Why? ……

   h. Do the roads experience floods during the rainy season? □Yes □No If yes what are the causes? ……

   i. Is there traffic congestion in Ruaka Area? □Yes □No If yes what are the causes?

   j. What is the nature of public transport in the area? Does it have challenges and what are they?

   k. Is there provision for Non-Motorized Transport/Walkways/Cycling along the transport systems?

3) Do you have control over the road infrastructure?□Yes □No If No, Explain.

4) a. Has the land use changes/urban developments impacted on your roads? □Yes □No

   b. If yes what are the impacts

   c. What measures should be put in place to mitigate the impacts stated above?

5) What measures has the County Government-Department of Roads, Transport and Public Works, KeNha, KURA put in place to ensure developments are in harmony with the available infrastructure?

6) a. How often is the urban infrastructure systems regulated, managed and maintained?

h. What challenges have you faced in the management of roads infrastructure?

i. What recommendations would you make to improve the management of roads infrastructure?

Section Ii: Water Supply and Wastewater Infrastructure- Karuri Water & Sanitation Company Ltd

1) a. Is there an infrastructure (Water supply and Waste Water) structure plan for the area showing the distribution and networks of water supply/reservoirs (Piped water, rivers, boreholes) and Waste Water infrastructure (Pit Latrines, Septic Tanks, Sewer Reticulation)? □Yes □No

b. If yes/no explain?

c. Is there a plan for water and sewer reticulation? □Yes □No If yes provide us with a copy of the plan showing areas to be served.

d. What is the coverage and extents of the proposed sewerage and water reticulation network?

e. Is the infrastructure structure plan aligned to changes in land uses/Zoning regulations for the area?

f. What are the sources of water for consumption supplied?.....

g. Is the capacity of water supply adequate? □Yes □No Give us the estimates of water supply/demand for the area and the estimated population supplied with water.

h. If No, what is the recommended capacity and what is the current water production/supply, demand?

i. What is the level of connectivity, network and accessibility of water supply to the households in the area? How many people are connected?

j. What is the number and capacity of the boreholes sunk in the region?

k. Is there water contamination/pollution from wastewater infrastructure available?

l. What is the water quality?

m. What is the approximate water depth of boreholes? Is the water table high or low and is it uniform?

n. . Is there a proper liquid waste management system in the area? □Yes □No If No, what is the available liquid waste management system?.....

o. Is the capacity adequate? □Yes □No Give us the estimates of waste generated for the area.

p. If No, what is the recommended capacity and what are the current challenges?

2) a. Do you have control over the water supply and wastewater management of the region? □Yes □No

b. If Yes what are the challenges, Explain.

3) a. Has the land use changes/urban developments impacted on water supply and wastewater? □Yes □No

b. If yes what are the impacts?

4) What measures should be put in place to mitigate the impacts stated above?

5) What measures has the County Government-Kiambu County Water and Sewerage Co. Ltd put in place to ensure developments are in harmony with the available water supply and wastewater infrastructure?

6) What is the source of Water that you supply and capacity in litres?

7) What is the amount of water supplied in Ruaka Town and Ndenderu Ward Customers for the last 5 Years?

8) What is the average Water Consumption per household in Ndenderu Ward?

9) What are the Water Tariffs for Commercial/Residential/Industrial Land Uses in Ndenderu Ward?

10) What is the total Current Water Demand or consumption and Water supplied?

11) What is the number of boreholes, their capacity in Ndenderu Ward?

12) a. How is the water supply infrastructure systems of this area regulated, managed and maintained?

b. Is there an integrated wastewater management plan for the area? How is the wastewater infrastructure systems of this area regulated, managed and maintained?

c. What challenges have you faced in the management of water supply infrastructure?

d. What challenges have you faced in the management of wastewater infrastructure?

e. What recommendations would you make to improve the management of water supply infrastructure?

f. What recommendations would you make to improve the management of wastewater infrastructure?

THE END

THANK YOU VERY MUCH FOR YOUR CO-OPERATION!