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DEPARTMENT OF ARCHITECTURE

ASSESSING SUSTAINABILITY OF URBAN GROWTH IN ONGATA RONGAI TOWN, KAJIADO COUNTY, KENYA

BY

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Declaration

I declare that this Thesis is my original work and has not been presented for a degree in any other university for examination.

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List of abbreviations

ANN	Artificial Neural Network
CA	Cellular Automata
GIS	Geographical Information System
GPS	Global Positioning System
FAO	Food and Agriculture Organization
EU	European Union
LULC	Land Use Land Cover
PPP	Public Private Partnership
UN	United Nations
UNEP	United Nations Environmental Programme
USA	United States of America
WARMA	Water Resource Management Authority

Definition of Terms

Land readjustment refers to a tool that allows planning and management of urban extension and densification thereby supporting sustainable urban development.

Environmental sustainability: It promotes human beings living within the limits of the biophysical environment to attain their daily needs while protecting the future generation's ability to meet their needs.

Social sustainability is promoting well-being through the understanding of people's needs at work and in residential places.

Land Use / Land Cover (LULC): This is the use of established scientific and statistical approaches of analysis of suitable source materials to classify natural elements and human activities on the landscape and within a specific time.

Abstract

The rapid development of urban areas is not only a contributor to the economic growth of developing countries but also a significant driver of environmental change and resource use. Sustainable development of urban areas is one of the global concerns and is prominently captured in the sustainable development goals. Achieving sustainable development of urban areas requires an understanding of the complexity of current users' activities and interactions in the urban space, and the potential future pathways of urban growth and its impact on the environment, people and policies as well.

This study assesses the following dimensions of sustainability: environmental, social (governance) and spatial (urban form). It further assesses historical patterns of change in urban land development using land use/land cover maps combined with other geospatial datasets such as topographical data and population data to document the historical patterns of change in Ongata Rongai between 2000 and 2020. Moreover, it models the potential future scenarios of the current urban development strategies using a Cellular Automata-based tool to predict future potential land cover characteristics around Rongai town for the period up to 2030.

Through assessment of the following indicators; Proper land use implementation, efficiency and sound transport, access to adequate basic services and infrastructure, safety and security, public participation, level of community interaction and level of sprawl indicators it shows that Ongata Rongai has not yet attained sustainable development. This is because, the research indicated the high presence of sprawl, an inefficient and unsound transport system, inadequate participation of the residents, conflicting land uses, inadequate safety, insecurity, inadequate access to basic services and infrastructure and low level of interaction among the residents of Ongata Rongai. The rapid growth has resulted in management not keeping pace with the growth.

The reasons for the inability to attain sustainable development include lack of approved plans to guide developments, presence of a poor urban land tenure system and unregulated land markets, uncoordinated institutions and lack of monitoring of urban development, lack of political will and interference by the justice system. The study recommends that the smart concept be promoted in addition to the establishment of an urban board and sensitization of public participation. To keep pace with the rapid development and promote compact development, a land readjustment strategy is recommended.

CHAPTER 1: INTRODUCTION

1.1 Background

Urban growth and development are unstoppable and dynamic by nature. The rapid development of urban areas is not only a contributor to the economic growth of developing countries but also the reduction of biodiversity through fragmentation of habitats and conversion of habitats to urban uses (Mawenda *et al*., 2020). Sustainable development of urban areas is one of the global concerns and is prominently captured in the sustainable development goals of sustainable cities and communities (Simon *et al*., 2016). Assessment of sustainable indicators has become a prerequisite to the measurement of sustainability in urban areas. In addition, the modeling and analysis of land-use/land cover (LULC) change in urban areas are essential for understanding, predicting, and promoting sustainable development of the urban environment. Thus, it is becoming increasingly important to monitor and analyze urban growth to manage urban areas in a way that promotes sustainable urban development.

The direction to a positive and good society is provided by the concept of sustainable development (Jasrotia, 2018). This is because urban sustainability focuses on various types of capital: cultural, social capital, human, and natural resource (Munda, 2004). In addition, sustainable development objectives take account of declining natural resources and economic and social characteristics and ensure that they are efficiently used as well as maximizing the satisfaction of the citizens (Jasrotia, 2018).

Accordingly, there is a need to formulate methods for the assessment of urban sustainability (Masnavi, 2007). Sustainability assessment is seen as a tool to foster faster attainment of sustainable development (Purevee, 2010). It also allows local authorities, urban planners, and other key stakeholders to analyze new developments, as well as monitor urban areas, from an economic, environmental, and social point of view (Lützkendorf & Balouktsi, 2017). The

current methods of assessment of sustainability are taking into account interactions and feedback between environmental, social and economic dimensions.

Measuring sustainability is coupled with sustainability indicators. Sustainable indicators help in visualizing the larger picture while only looking at a small part of a system and they are also units of information that shows the status of a major system (Āboliņa, 2005). Therefore, urban sustainability indicator systems need to reflect the integration of environmental, social and economic dimensions.

One urban indicator of sustainability is the urban form. These are spatial patterns of human activities at a certain point in time. Urban form can be classified as compact or sprawl though they can vary in different degrees. Sprawl is believed to be extremely unsustainable, affecting ecological, social, and economic dimensions of sustainability (Banai, 2014). Whereas a compact city is believed to promote sustainable development, stop sprawl and improve urban livability (Neuman, 2014). Densification and compact urban form reduce the utilization of land resources (UNHabitat, 2017) and are promoted in the smart growth concept.

Consequently, in the assessment of the sustainability of urban form, it is essential to understand the historical trajectories of change in the urban space, the complexity of current uses, activities, and interactions in urban space, and the potential future pathways of urban growth including its impact on the environment, people and policies in Kenya. Geospatial technologies are useful in understanding, monitoring, modeling and measuring the sustainability of urban growth. In addition, the use of geospatial technologies facilitates the development and analysis of the evidence-based assessment of urban areas.

Ongata Rongai (also known as Rongai) has been developing rapidly due to its proximity to the capital city of Kenya. The rapid growth has led to the development of trade and business that in turn has led to the economic growth of the town, that is there has been growth in commercial and real estate activities (County Government of Kajiado, 2019). Ongata Rongai being a

'dormitory' town of the capital city that is growing rapidly, there is a need to assess its ability to attain sustainability by the year 2030. The assessment will be useful for understanding and monitoring its growth to promote better decision-making that encourages sustainable growth. This study, therefore, aims at assessing the environmental, social (governance) and spatial aspects (urban form) of Ongata Rongai urban development's sustainability. To assess the spatial aspects of sustainability, particularly its urban form, the study assesses the historical patterns of land use land cover changes in urban land development and models the potential future scenarios of the current urban development strategies in Rongai town in Kajiado County. The study also aims at evaluating and assessing the sustainability of urban land development by conducting qualitative and quantitative surveys. Maps showing trends of urban growth will show if the town is growing sustainably by detecting changes in land use land cover during the last three decades and thereafter will create scenarios projecting changes in the town during the next decade. The research focuses on the environmental sustainability assessment of land development in the town of Ongata Rongai by observing the growth rate and trends.

Assessment of the sustainability of urban areas is very important in the management of cities and towns. Since it will make decision-making easier, more effective and more efficient for the planners and urban managers as they get hold of the opportunities and address the challenges of urbanization.

1.2 Problem Statement

Rapid urbanization trends have resulted to 54% of the world population living in urban areas (Banker, 2019) and this percentage is continuing to rise (Mangi, 2017). Kenya is also confronted with the rapid increase of urbanization as towns within counties are expanding mainly due to devolution, as more funds are being invested within the counties. Rapid urbanization and growing populations have had an impact on land which is a finite resource. This has caused increased insecurity of water, food and energy thereby resulting in conflicts as

well as disasters (Kauko *et al*., 2015). Changes in LULC also affect the society, economy and ecology of the urban areas. Furthermore, the divide between rural and urban areas is diminishing as these areas are today interconnected by flows of money, people, goods and resources (United Nations Committee of Experts on Global Geospatial Information Management, 2015).

Ongata Rongai is a town of high economic activity and is considered to be one of the four metropolitan areas in the broader Nairobi region geared toward realizing Kenya's Vision 2030 (Ministry of Nairobi Metropolitan Development, 2008). Ongata Rongai town is undergoing rapid growth and urban sprawl development due to its proximity to the capital city of Nairobi. The town's growth has had an impact on the area's environmental, social and economic development.

Ongata Rongai is faced with problems such as rapid population growth that has high densities along Magadi road with haphazard development that spread to the interior (Kazungu *et al*., 2011; Maleyo & Omoke, 2017). In addition, the town is experiencing the growing role of market forces in the spatial distribution of development *(*Kazungu *et al*., 2011). Moreover, there is encroaching and/or polluting of the Mbagathi River which flows through Ongata Rongai and unchecked animal keeping and settlements. Due to unplanned urban patterns and development, Ongata Rongai is faced with a poor sewage system and the occupation of human settlement and business activities in flood plains and flood-prone areas (Maleyo & Omoke, 2017).

The developments in Ongata Rongai are economically motivated and they disregard aesthetic, social and environmental long-term impacts. The pace of development is dictated by private developers and this has led to overcrowded housing, diminishing open spaces, unsanitary conditions, high densities and haphazard peripheral development. The causes of these have been due to ineffective physical planning systems, speculative land costs, informal investment

in finance and rising demand for shelter in addition to physical and social infrastructure (Kazungu *et al*., 2011).

The LULC of Ongata Rongai is therefore becoming a concern since it directly affects sustainable urban development. Proper management of resources is also required to be put into consideration to ensure its optimal achievement in meeting both the current and future generation needs of the residents. To achieve this, urban managers need a mechanism to detect, monitor, quantify, analyze, and model changes in the urban land use pattern effectively and efficiently (Mundhe & Jaybhaye, 2014).

Systematic mapping and monitoring of urban areas have the potential to improve how urban areas are managed by providing relevant information which is necessary for control of urban development and decision-making. This information is highly valuable, particularly where the pace of urbanization surpasses the authorities' capacity to cope with how cities are changing and growing. This study will contribute toward providing the baseline information that planners and urban managers can use to get hold of the opportunities as well as address the challenges of urbanization through making well-informed decisions (Goldblatt *et al*., 2016).

Moreover, providing evidence-based information can serve to improve the urban managers' ability to make decisions by enabling them to see the effects of changes occurring in the town or metropolitan areas. This study also provides a methodology that is useful in predicting the future so that urban managers can weigh their decisions before they implement a certain project. It is assumed that this will make decision-making easier, more effective and more efficient.

1.3 Research Objectives

The study aims to assess the sustainability of land development in Ongata Rongai town. It further aims at predicting potential future spatial patterns of urban growth and evaluates the sustainability of the town's growth.

The specific objectives of the study are as set out below:

- To assess environmental, social (governance) and spatial (urban form) aspects of sustainability of Ongata Rongai by assessing set indicators;
- To explore the use of remote sensing data and a Cellular Automata-based simulation tool to model LULC for 2030;
- To determine the sustainability of Ongata Rongai town from 2030's simulation by calculating Spatial cluster and outlier identification as well as the percentage of urban change;
- To recommend an urban management framework that will support sustainable urban growth.

1.4 Justification for the Study

The study was designed purposefully to assess the sustainability of urban development in Ongata Rongai town in Kajiado County in Kenya. In addition, this study is meant to provide a methodology for improving decision-making by providing evidence-based information by use of GIS technology. Ongata Rongai town is used as a case study to identify challenges facing similar towns in Kenya. Moreover, it is also used to show how to asses and model sustainability through sustainability indicators. The research also helps in developing urban management strategies that would be useful in the attainment of sustainable development. The ultimate purpose of the study is to explore the possibility of modeling land use/land cover to assess the town's sustainable development and also explore its usage in understanding urbanization and preparation of comprehensive plans. Thus, the research is useful in exploring the possibility of protecting the environment while increasing the management of urban areas. Many studies have been done in Kenya on land use/land cover change. Nonetheless, comprehensive studies on land use/land cover change modeling in Kenya's urban areas remain limited. Population figures alone have remained the primary base for the understanding of

urbanization. As a result, uninformed policy decisions have been made due to the inadequacy of land use change information which constrains effective environmental and economic planning. These uninformed decisions are very common in Kenya due to the poor state of its economy, such that it prioritizes solving pressing needs such as poverty reduction while paying no attention to the importance of having a vibrant land use system.

The study is informed by Sustainable Development Goals which have been approved by United Nations Members' States in agreement with the targets of achieving the 17 Goals by the year 2030. This research is specifically guided by goal 11 of the Sustainable Development Goal 2015-2030 which aims at realizing "Sustainable Cities and Communities". Land development contributes directly to the sustainability of cities and also affects the well-being of communities. Mapping and modeling of land use/land cover will avail crucial information needed to make better decisions in the management of Ongata Rongai and this will enable the achievement of sustainable urban areas, therefore contributing to SDGs.

1.5 Scope

Due to limitations of resources and time constraints, the research was confined to Ongata Rongai town, in Kajiado County which study lies between latitude 1.375474° and 1.454733° South and longitude 36.6507115° and 36.823865° East. Three wards constitute Ongata Rongai town, namely Nkaimurunya ward, Ongata Rongai ward and Olkeri ward (see Figure 5). In addition, it was limited to the assessment of sustainability in emerging towns in Kenya with Ongata Rongai as a case study. The variables that the study aimed at covering were the identification of social specifically, governance aspects and environmental challenges of the residents of Ongata Rongai. Other variables include LULC changes for the three periods of 2000, 2015 and 2020 that were used to map and monitor historic and current spatial-temporal trajectories. The data was used to model and assess sustainability and make a recommendation for an urban management framework for the sustainable growth of Ongata Rongai.

Data was collected based on data quality, data availability, the needs of the study, and processing requirements. It was then processed by preparing it to classify, and produce change detection data. To assess the land-use outcomes, both quantitative and qualitative surveys were performed to measure specific indicators that were used to assess the environment, social (governance) and spatial (urban form) aspects of sustainability.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The chapter discusses the literature on sustainable development and its theoretical framework. It also discusses the literature on the methodology used in modeling urban form to measure sustainability. The chapter also discusses the area of study and management of urban areas in Kenya have been highlighted as well.

2.2 Sustainable development

Sustainable development is said to be the emerging force in policies developed through this decade. Countries worldwide are aiming at attaining the Sustainable Development Goals (SDGs) agenda which was designed by the United Nations (UN) SDG 2030 (Nath *et al*., 2020) and Kenya is not an exception. The World Commission (1987) defines sustainable development as development that meets the needs of the current generation without compromising the ability of future generations to meet their own needs. In this case, development decisions should effectively incorporate social, economic, and environmental concerns (Enemark, 2001).

A sustainable development concept ensures that the resources are utilized in a manner that will ensure that both the current and future generations will have access to the resources. In this case, as growth and development are being promoted urban managers should ensure that they are addressing social, economic and environmental concerns simultaneously. The management of urban requires that land resources are utilized sustainably for purposes of attaining social just and environmentally healthy and clean communities.

Economic, social, and environmental sustainability is affected by the growth of urban areas significantly influencing land use/land cover change. There are dire consequences caused by rapid and unplanned urbanization. These include loss of biodiversity and a reduction in vegetation cover due to land fragmentation by changing arable land for the development of

infrastructure (Mawenda *et al*., 2020). The urban areas are seen as the focal point in solving environmental problems as well as the direction towards the attainment of sustainable development (Masnavi, 2007). This puts a lot of importance on urban areas to solve sustainability crises. The quality of life and economic development is achieved when the environment is protected. Thus, environmental protection should be key in the journey toward the achievement of sustainable development.

The World Bank (2016) *Kenya Urbanization Review* reported that the urban population is rapidly increasing such that half of Kenyans will be living in urban areas and the urban population will increase to equal the current entire country's population. The report also acknowledged that service provision is low, a poor functioning land market that makes provision of infrastructure expensive and predominance of informality both in housing and business. Some of its recommendations for sustainable cities are to support effective urban management and governance structures, develop sustainable solutions and land and land planning modernization.

Mutisya & Yarime's (2014) research on promoting sustainable Kenya, developed a framework for integration of environmental, economic, social and governance dimensions to support sustainable urban areas. The study established the need to put more emphasis on the governance dimension in the case of developing countries as it is where the biggest challenges lie. The study proposed the development of a governance structure that can support uncontrolled factors like the movement of population and slowness in accommodating innovative approaches.

The research by Burton (2000) examined the validity of the assertion of the possibility of a higher density urban form to promote social equity. The study on medium-sized English cities revealed that higher urban densities positively affirmed the aim of the study on some aspects of social equity and negative for others. The positive aspects are reduced social segregation, improved public transport and better access to facilities. The negative aspect was a lack of

affordable housing and the possibility of reduced living space. High-density housing cities were found to support social equity when various aspects of density were investigated.

2.3 Methodological framework

Mapping of urban growth patterns usually includes the interpretation of satellite and aerial images by using GIS and remote sensing. In the Remote sensing process, change detection is generally performed for purpose of monitoring, measuring, and evaluating the land use and land cover changes, considering spatial and temporal changes (Güler *et al*., 2007). Before change detection, the image is processed and classified to classify all the pixels in an image into different categories by users. This is done through a computer-automated process referred to as unsupervised classification and/or the supervised classification that aims to allocate cases based on their similarity to a set of predefined classes that have been characterized spectrally (Maina *et al*., 2020).

In mapping urban growth, models are used to make simple the complicated set of socio-economic and biophysical forces that affect the degree and patterns of land use/land cover change and enable the estimation of the impact of changes in land use/land cover (Lahti, 2008). Verburg *et al.*, (2004) also argue that the use of models supports the investigation of upcoming land use changes under various scenario conditions.

One of the models used in mapping urban growth patterns is the Cellular automata model that defines how land use interacts at a specific location, the environments at that location, and the land use types in the neighborhood (Engelen *et al*., 2002). Cellular automata calculate the state of a pixel based on its initial state, the conditions in the surrounding pixels, and a set of transition rules (Verburg *et al*., 2004). In several models, time-based dynamics are considered by using initial land use as a criterion for acceptable changes. Cellular automata are capable of doing that explicitly in the decision rules that determine the likelihood of the changes (Verburg *et al*., 2004).

Understanding the causes and consequences of land change is one of the prime goals of mapping/modeling urban growth (Lambin & Geist, 2006). Land use change is therefore often modeled as a function of a selection of socio-economic and biophysical variables that act as the so-called 'driving forces' of land use change (Turner II *et al*., 1993). Among several methods used in quantifying the relationship between land use change and its driving forces, expert knowledge is one of them, particularly in models that use cellular automata (Verburg *et al*., 2004).

Consequently, it is also important to understand spatial autocorrelation exhibited by land use patterns when mapping/modeling urban growth patterns. Spatial autocorrelation can be defined as the coincidence of value similarity with location similarity (Baumont & Legros, 2011). Therefore, there is positive spatial autocorrelation when similar values of a random variable measured in various locations tend to cluster in space while negative spatial autocorrelation means that similar values tend to be dispersed (Baumont & Legros, 2011). The use of spatial autocorrelation has been researched by Musakwa & Niekerk, 2014 to monitor the urban sprawl in Stellenbosch, South Africa. Two spatial statistics are used, these are Global and Local Moran Indexes to show the statistical influence of urban sprawl hots spots and cold spots. The study demonstrated the use of indexes with a combination of other visualization approaches to support planning.

The model results are compared for actual with the historic/predicted period changes in land use to validate land use change models (Verburg *et al*., 2004). There are two methods used to validate models. One is where simulated and actual are assessed by utilizing a human eye to check matching pixels. The other method is the quantitative method of goodness fit (Amujal, 2015).

2.4 The theoretical framework for urban sustainability

2.4.1 Weak/strong Perspectives on Sustainability

Sustainability can be placed into theoretical perspectives of either strong or weak sustainability approaches. Social, natural, human-made, as well as human capitals, are the four underlying frameworks on which these perspectives are built. On one hand, the weak sustainability approach supports an anthropocentric worldview that humans ought to take charge over technology, and nature and progressing scientifically can compensate for the natural resources depleted while there is indefinite continuous economic growth (Anderson, 2013; Ayres et al., 2001). One example of weak sustainability is the carbon trade where a country with high carbon emissions can compensate a country with low carbon emissions. On the other hand, the strong sustainability approach supports the rejection of inherent substitution of social and natural capital domains as well as acknowledgment of the need for a level of separation between the domains is required. An example of strong sustainability is a compact city that addresses all principles of sustainability by promoting densities and compactness. Through this sustainability approach issues such as economic productivity, low emission of greenhouse gasses and increased safety are solved (Spiliotopoulou & Roseland, 2020).

However, it is always not possible to avoid substitution but protection of natural capital should be seen as paramount for current and future generations and not only prioritizing economic growth (Lützkendorf & Balouktsi, 2017). In this regard, Ongata Rongai cannot ignore the negative environmental effect on economic growth. Urban Growth in Rongai should be assessed on environmental, social and economic sustainability to promote strong sustainability. The economic development of the area cannot substitute for the effect on the natural environment.

2.4.2 Systems theory in urban areas

There is a requirement that when studying the sustainability of a human settlement one needs to view it as a system that is adaptive, complex and networked that involves interdisciplinary study through the lens of various fields (Lützkendorf & Balouktsi, 2017). Elinor Ostrom pioneered the analysis of socio-ecological systems such as a city by proposing a framework that emphasizes the complexity of socio-ecological systems and the necessity of making consideration of the system's components, levels as well as external settings when making sustainable decisions. Her work informed that four interconnected components that interact across temporal and spatial scales comprise an urban system conceptually. These are energy flows, governance networks, socioeconomic dynamics, material and urban infrastructure and form.

An urban system is nested and is neither linear nor hierarchical. The urban system contains subsystem that is entrenched in bigger systems networking across components in space and time. For instance, fluctuations in one urban community asset, for example through the change of policy, can affect other assets or interconnected systems (Lützkendorf & Balouktsi, 2017). Another characteristic of the urban system is feedback loops that occur when persistent behavior influences flow and trends in response to changes in inventory. The system approach looks at the problem from a holistic perspective rather than a reductionist perspective. This approach is essential for sustainable work on problems that require structural changes to solve issues. These complex multi-level problems are rooted in multiple systems' society, nature, economy, and political system. Therefore, there is a need for a holistic approach to problem definition, analysis as well as decision-making (Anderson, 2013).

This theory informs that all aspects of Ongata Rongai should be addressed as they are interconnected with one another to attain sustainable development. For sustainable development, urban growth, energy flows, governance networks, socio-economic dynamics,

material and urban infrastructure and form should all be addressed as a whole. Ongata Rongai's urban development needs to also consider that although its growth cannot be stopped it must be made adaptable and resilient to maintain the social-ecological system.

2.5 Legal framework for the management of urban areas

The Kenya constitution of 2010 presented a decentralized government system, through which urban management roles are shared across national and county governments (Mwau & UN-Habitat, 2019). Urban management and administration are critical roles of the devolved governments. The efficiency and effectiveness of this role is determined critically by successful planning at the urban level. Urban Areas and Cities Act (2011) recommends that a board should be instituted to administer urban areas.

Planning is prescribed as an integrative function in development planning in the Constitution 2010, Physical and Land Use Planning Act (No. 13 of 2019), County Government Act (2012) and the Urban Areas and Cities Act (2011). Planning is supposed to be the integrator and facilitator of development planning; sectoral plans, investments and programs. Kajiado County uses various methods to practice urban planning such as planning County Spatial Plan (CSP) Integrated Strategic Urban Development Plans (IUDP), Local Physical and Land Use Development Plans. Zoning Plans, Area plans and Action Plans. These plans are formulated with the legal backing of the County Governments Act (2012), Land Act (2012), the Urban Areas and Cities Act (2011), the Physical and Land Use Planning Acts (2019) and other laws and guidelines.

Development control is also undertaken to control land developments. In addition, regulatory roles are performed aimed at determining outcomes of planning practices. These are local plans, regulations for development control such as environmental regulations, zoning ordinances, by-laws, the building code, land regulations, etc. The source of the tools is prevailing laws such as the Environment Management and Coordination Act (EMCA) (1999),

Physical and Land Use Planning Act (2019), Land Act (2012) and other national laws. The Building Code of 1968 is also used to regulate urban development (Mwau & UN-Habitat, 2019).

The counties are obliged to develop a County Integrated Development Plan (CIDP) to receive devolved funds from the National Treasury and they are also allowed to collect rates and fines within the counties.

The Constitution of Kenya requires that public participation be promoted at the county level for people to exercise their rights and when decisions that affect them are involved. Public participation promotes good governance since citizens are informed, engaged, consulted, empowered and finally there is collaboration. The County of Kajiado has a public participation Act that guides the formation of village citizen forums, ward citizen forums to sub-county forums. The Act also lists the powers, how those citizen forums are constituted and how to conduct their business.

2.5.1 Management of urban areas under the Urban Areas and Cities Act

The Urban Areas and Cities Act proposes an urban management framework to support the sustainable development of urban areas as envisaged in the Constitution of Kenya. It proposes the appointment of the board to manage municipalities and cities on behalf of the County government.

The municipality board is required to work within the mandate of the county executive. They are also required to provide services, impose levies, fees, make bylaws, ensure compliance with formulated national and county policies and finally promote the participation of the residents.

The residents of urban areas can participate in the management of urban areas through the formation of Citizen Fora. They can participate by monitoring the activities of the elected

members, engaging various government agencies and making proposals on budgets and policies both at the county and national levels.

A report by World Bank (2017) shows that the urban management board has not been instituted in all the Counties due to the reluctance of the County government to share its responsibilities, inadequate understanding of the nature of the institution, lack of a clear procedural framework, regulations as well as instruction to guide its implementation and inadequate allocation of finances by the national government to support the process.

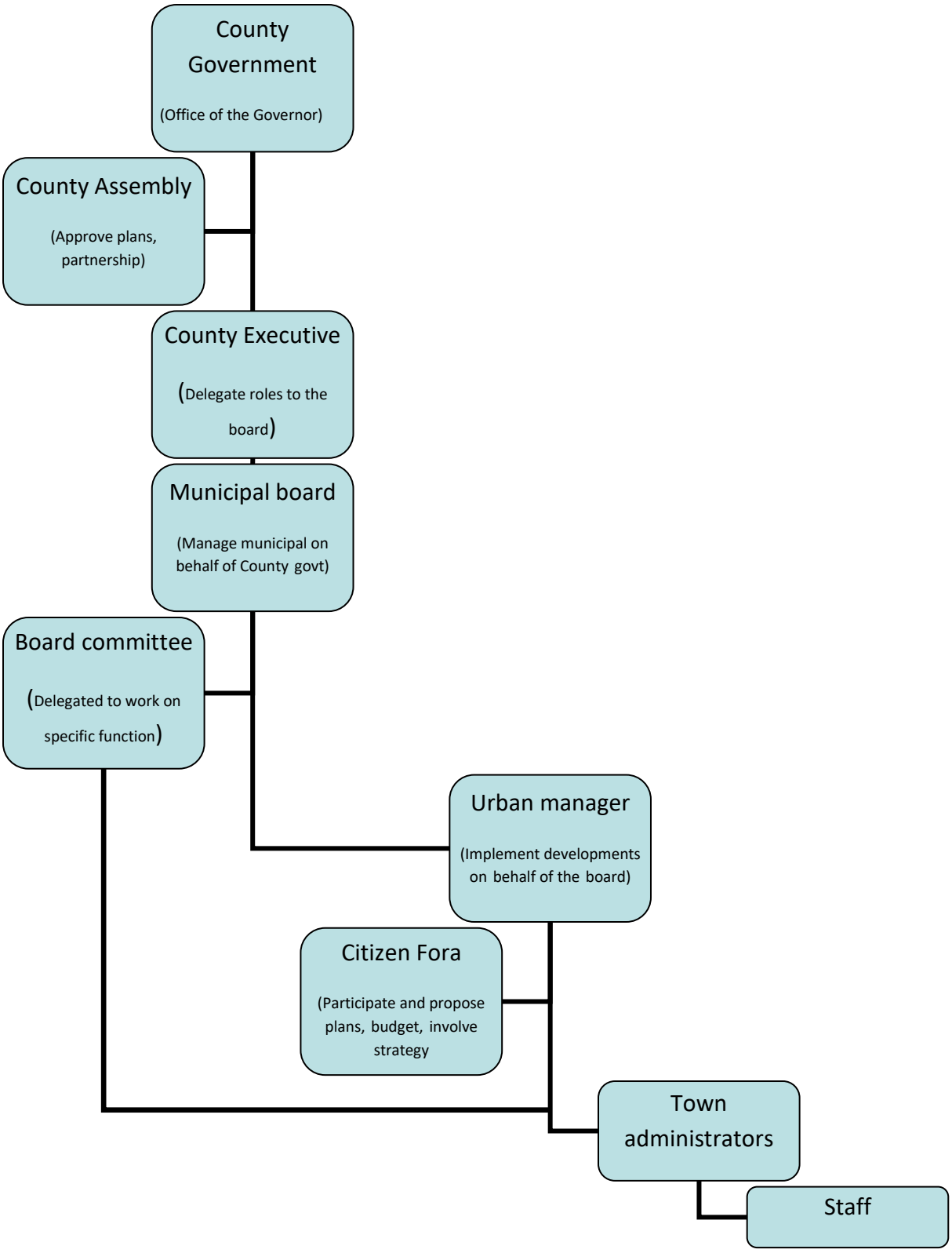

Figure 1: Proposed management structure by Urban Areas and Cities Act

2.6 Management of Ongata Rongai

2.6.1 Study Area

The study area is located in Ngong Municipality, Kajiado County, 17km south of Nairobi the capital city, and west of Ngong hills (see Figures 2 and 3). Ongata Rongai town is located at the following coordinates: 1.3939ºS and 36.7442ºE and lies 1731 meters above sea level. It is the most populous town in Kajiado County and the eleventh largest urban center in Kenya with a population of 172,569 (KNBS, 2019). This is one of the fastest-growing towns in Kenya. The town is also part of the larger Nairobi Metropolitan Region where it serves as the dormitory town for Nairobi City. Planning of the town is done both by the Nairobi Metropolitan Service (NMS) and the County Government of Kajiado.

During Kenya's pre-colonial period, the land was occupied by the Maasai community who were practicing pastoralism. The town developed from a cattle market, on the lower section, and a quarry site, on the upper side of the town and since 1950 the town has been rapidly growing to become the current township. Furthermore, due to Rongai's proximity to the capital city, intense development has been taking place since the 1990s due to the huge demand for housing by people working in the city. This has also resulted in the sprawling of the settlement beyond the border of Rongai town affecting the rural community who were formally nomadic pastoralists and forcing them to settle in addition to having alternative ways of managing cattle on small parcels thereby increasing land degradation. This has also reduced flora and fauna and increased human-wildlife conflict (County Government of Kajiado, 2019; Emily, 2000)

The town is currently occupied by a population that is multi-ethnic due to immigration that has been taking place. Through time the land tenure system has changed from community land and group ranches to individual ownership (Morara *et al.*, 2014). There has been increased crop production and intensified livestock farming by the immigrants while around the peri-urban area of Rongai town, there has been an increased variety of land uses. The change in land use

land cover has been due to intensified population pressure coupled with a lack of proper management of the town.

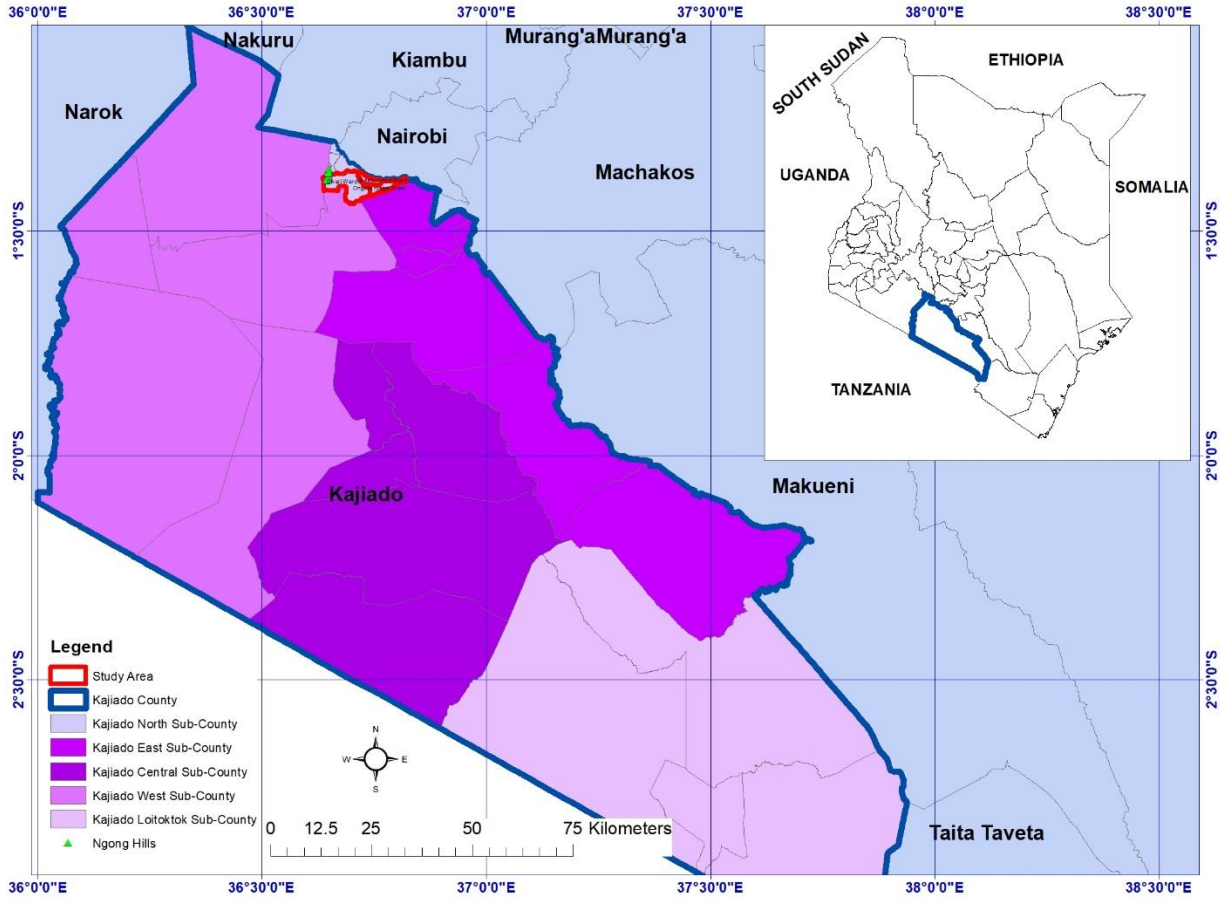

Figure 2: Location of the study area in Kajiado County and Kenya

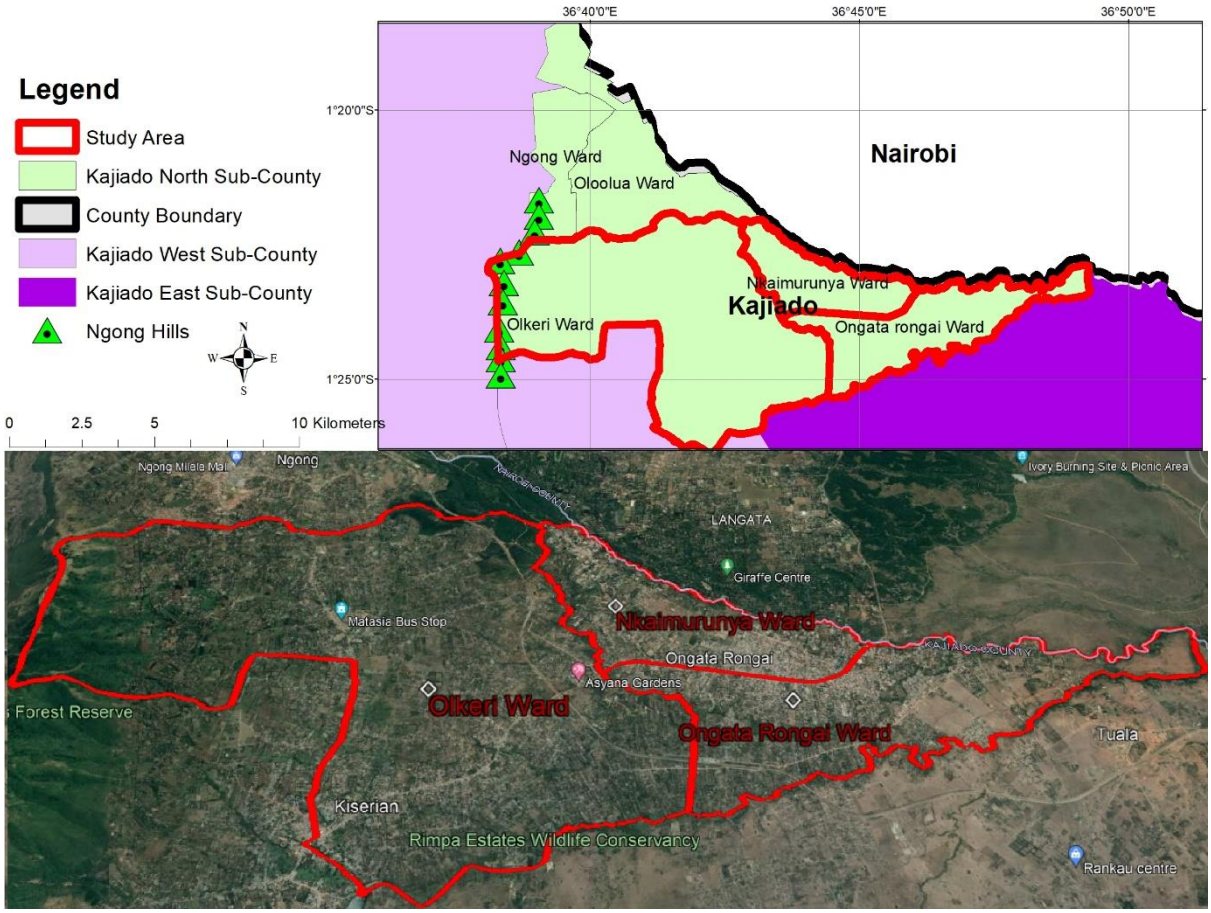

Figure 3: The location of the three wards in Kajiado North Sub-County

UN-HABITAT et al., 2020 report that Ongata Rongai is experiencing a high-density population due to its proximity to the capital city growing at a rate of 5.5% p.a. Kazungu *et al*., 2011 study indicated the urban management challenges faced in Ongata Rongai and these are: One, the failure of the legal and institutional framework to support information sharing and partnership between inter-governmental agencies in Kajiado County. Two is that Ongata Rongai is faced with inadequate human and fiscal resources, and there are also bureaucratic planning systems that make planning structures and processes in both areas incapable of dealing with the scale of planning and infrastructure problems confronting them. Three is the challenge of a dependency syndrome of the donor precipitating the adoption of unsustainable solutions. Such that developments only take place when there is support from a donor. Four is the growth patterns are uncontrolled with informal commercial activities undertaken on road reserves and junctions. These challenges have occurred due to the administrative and institutional inability

to plan and control the rapid growth of development. Finally, there is limited public participation of the community in the planning and management of Ongata Rongai.

2.7 Management of urban development for sustainable development

The urban planners and managers have a responsibility for the urban development process by not only formulating programs and strategies but also aligning community demands and political decisions towards an agreement and thereafter implementing the agreement for stated goal achievement (Teriman *et al*., 2009). Management of urban development involves regulations, techniques and programs that create a platform for the development of policy and a framework implementation to influence and guide development activities in various forms (Porter, 2007). Urban development for sustainable development is geared towards the protection of land which is a scarce resource by directing development in the right location, in the right development densities, at the right time and dealing with land market failures such as land speculation (Bengston & Youn, 2006). Compact urban development initiatives have been developed and implemented as countries pursue sustainable development.

2.7.1 Case studies in the management of urban sprawl

A case of Brunei (Brunei Darussalam) South Asia land readjustment system support of Compact Strategy for Efficient Urban Development. Brunei has a growth rate of 1.7% p.a.

Brunei introduced a compact strategy in its second master plan to promote sustainable urban growth. There was three policy that was introduced under the strategy that required more efficient use of land, allocation of commercial development in a defined area and a requirement that development is contained within an urban footprint zone. However, it lacked local plans and statutory support to guide development.

Despite the land adjustment method of urban development is a relatively new concept and without a law supporting it, the Brunei pilot project was carried out. The project was started by the Town and Country Planning Department of Brunei for purpose of land use plans implementation. In addition, the project was not allocated any special fund to facilitate the process so it means that the project was a private project initiated by the government.

The project consisted of 79% private land and 21% public land. Among the state land was road reserve that was inadequately reserved and not well connected. The project implementation went through three stages that are, initiation and planning, design and negotiation and finally implementation.

The project was initiated in 1993 by the formation of a committee comprising various government departments. The committee obtained approval from the various political government. During the planning stage, there was a consultative meeting between the committee and politicians to discuss the policies that will support the implementation of the project. These were to improve the shape of land and limitation of cash compensation, a combination of private and private land then redistribution.

The design was based on the following principles that, to relocate land that is mostly affected by roads, relocation done within the project area where possible, keeping land that has been readjusted within the same vicinity and maintenance of the minimum width of land according to the prevailing guidelines. There was state land that was set aside for relocation purposes. A 30-meter road was also set to support the current commercial development and future development.

The negotiations were held between the government and the owners/representatives on the grounds of reallocation/reshaping and infrastructure construction design and financing as well. There was a requirement for total agreement by the affected land holder as recommended by

the land law for the project to proceed implementation stage. It was recommended that the land owners work in a team where they are represented by a leader for purpose of negotiation on their behalf.

Finally, implementation was done by reshaping/reallocation works, new plots registration and construction of main roads as well. Some of the mechanisms used were Land acquisition, Land acquisition & exchange, Land consolidation & subdivision and reshaping of land. It is good to note that government did not allocate any funding for purpose of the project (Hamzah, 2017).

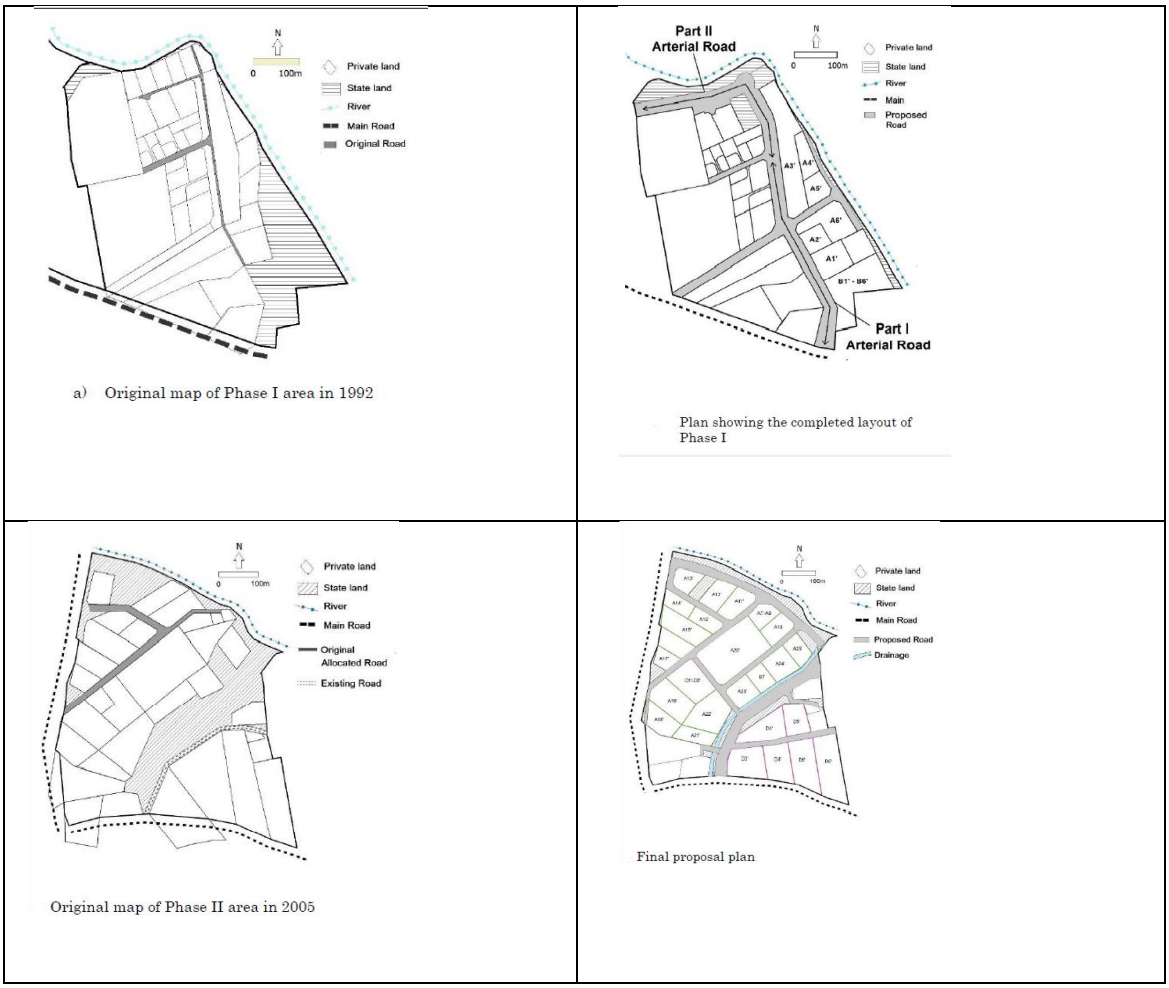

Figure 4: Map of Brunei before and after implementation of land readjustment

2.7.2 A case of Land readjustment in Kigali Rwanda

The land readjustment process in Nunga site was initiated by the district. It was also quite a new process in Kigali though the process is currently being implemented in other sites. The process involved assembling and reallocation of land and at the same time making the land owners development partners.

The first stage in this process was planning and design where the private company was engaged by the district to facilitate the process of coming up with a design that is capable of accommodating many and various people of all income categories. The next phase was engagement where the affected residents were called upon to give feedback on the plan. The committee was also elected by the resident to represent their interest and also facilitate the implementation of the plan. The committee elected were trusted by the residents and performed their roles voluntarily.

During land readjustment, the land was first consolidated, reallocated and finally registered. The district also proposed that land readjustment be a self-financed process. The process took two years to complete and roads and houses were constructed within the same period. It was noted that there was no resistance against this process and it did not invoke court cases. However, some sold their land and moved elsewhere. The reasons given for fast implementation were cadaster availability, trusted government by the people, developmental policies enforcement, and legacy and sovereignty of the political situation in Rwanda (Gasore, 2020).

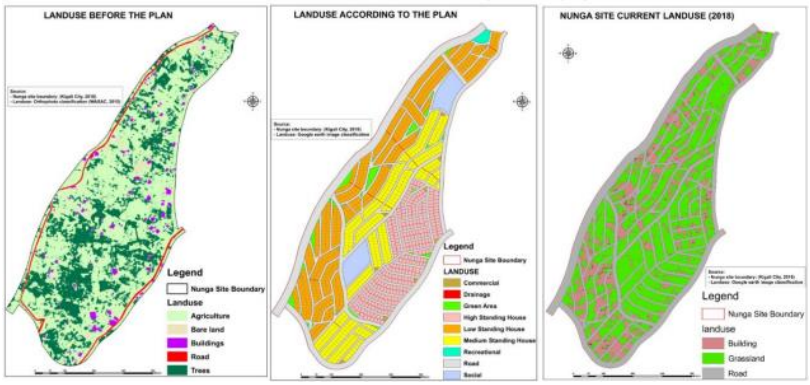

Figure 5: Before and after implementation of land readjustment in Rwanda

2.7.3 Land Readjustment Strategy

The process of readjustment application varies widely depending on the country's political situation, history, purpose, social and economic situation of the people. The process has been successful in rejuvenating urban areas, especially areas that developed without a proper plan. This process has been successfully implemented in developed countries like Germany, Spain, Japan and Korea (UN-Habitat, 2016).

The land readjustment process works best where there is effective participation of the stakeholders and there is the availability of legal backing and a cadaster in place (UN-Habitat, 2016).

2.8 Conceptual framework

Rapid and uncontrolled land development is a result of population increase, a better urban opportunity such that a massive number of people move from rural areas to urban areas and non-existence or ineffective urban management law, policy and regulations combined with poor implementation strategies. This causes urban sprawl, poor infrastructures and service delivery, food insecurity and diminishing natural resources. Management of urban development involves regulations, techniques and programs that create a platform for the development of policy and a framework implementation to influence and guide development

activities in various forms. Some of the techniques developed are assessment of urban areas to facilitate and improve decision-making as well as to improve urban policy, technology and institutions. Programs can also be developed to remedy the negative effects of rapid urbanization. Properly guided urban development leads to sustainable development that is reflected by compact urban areas, protection of the natural environment, adequate access to infrastructure and services and public participation in governance.

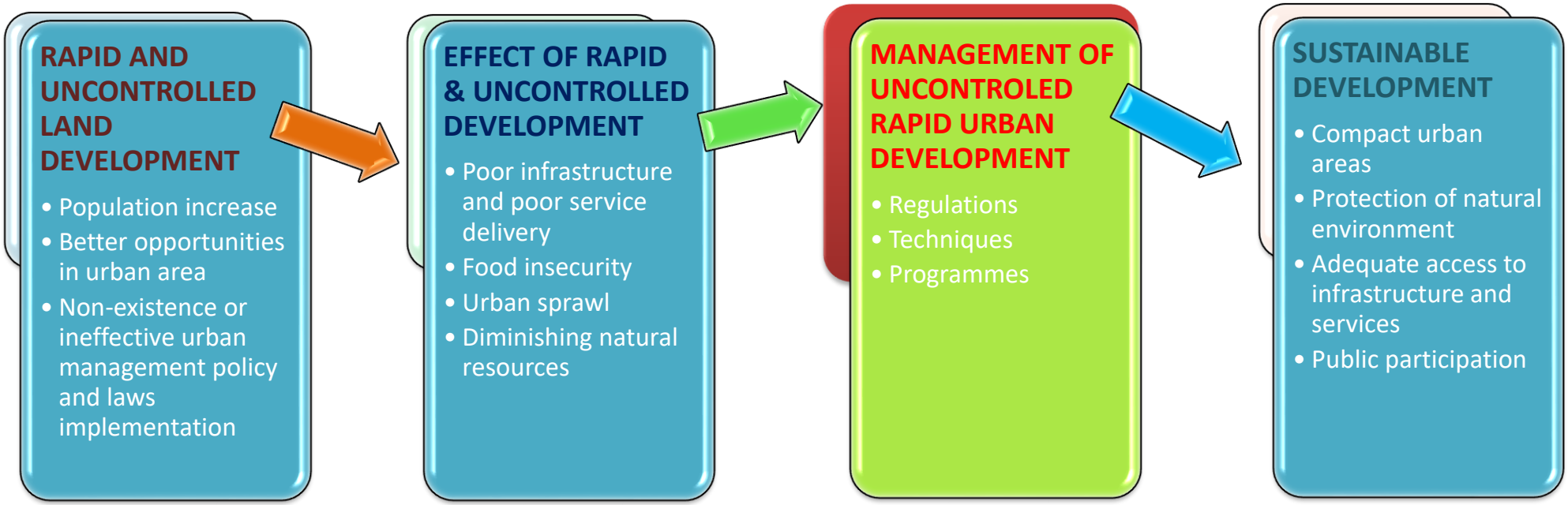

Figure 6: Conceptual framework for this study

CHAPTER 3: MATERIALS AND METHODS

3.1 Research design

The research methodology utilized both qualitative and quantitative methods to understand the concept of urban sustainability, challenges and opportunities related to Rongai town as well as map historical and current land use land cover. Through the findings, the sustainability of urban development in Ongata Rongai was assessed and measured, a management framework was recommended and a scenario of simulated growth urban development by 2030 sustainable Ongata Rongai was developed. Geographical Information systems (GIS) and remote sensing were used to identify the causes, impacts, as well as current and future trends of urban growth patterns (Al-shalabi *et al*., 2013; Liu *et al*., 2015).

Table 1: Research Matrix

Objective	Data needs	Collection method	Analysis	Information (output)
Assess environmental, social (governance) and spatial (urban form) aspects of sustainability of Ongata Rongai by assessing set indicators.	Literature review, existing social amenities and infrastructure that is schools, hospitals, social halls, roads, water system	Literature review, observation, Random and purposive sampling	Questionnaire analysis and reports evaluation	Assessment of the safety and security, public participation, access to basic services and infrastructure, effective and sound transport and satisfaction of the residents
To explore the use of remote sensing data and a Cellular Automata-based simulation tool to model LULC for 2030	Satellite images, population, Zoning, topographical data	Mapping and modeling of LULC	Observation of results Confusion Matrix	LULC maps Drivers of change maps Accuracy of classification and validation of modeling
To determine the sustainability of Ongata Rongai town from 2030's simulation by Spatial cluster and outlier identification as well as the percentage of urban change;	Predicted LULC map of 2030 LULC maps of 2020 and 2030	Calculation of Global Moran Index, Local Moran Index, Spatial cluster and outlier identification as well as the percentage of urban change	Analysis of the findings	Report of sustainability of the urban form Hot spot and cold spot map
To recommend an urban management framework that will support sustainable urban growth	Literature review, purposive sampling, report evaluation	Purposive sampling, literature review	Best practice/ case studies Analysis of the findings	Report of the analysis of literature review and interview. Recommendation of the management framework

Table 1 shows how the research was conducted. The baseline survey was conducted to establish and evaluate the sustainability indicators of Ongata Rongai. GIS and remote sensing technology were used to assess spatial sustainability indicators and measure the sustainability of the Rongai urban form. At the same time, qualitative data was used to assess the sustainability of Ongata Rongai. The finding was used to recommend a management framework and thereafter a scenario was modeled to show results of sustainable development.

3.1.1 Data collection method

Methods of collecting data were classified in two ways as follows:

3.1.1.1 Primary Data

The primary data was collected through random sampling of residents of the three wards. Moreover, a Key Informant Interview was conducted with a resource person from the land sector. Other data collected was for verification and ground-truthing. Since the area being studied is large, simple random sampling was done for every class represented for land use and land cover change. Field data was obtained by use of GPS. Samples of different types of land use land cover were taken for two reasons, namely: (i) image correction and (ii) image classification while the questionnaires were administered to collect the qualitative and quantitative data.

3.1.1.2 Secondary Data

A desktop review was conducted to conceptualize the concept of sustainability, its indicators' assessment and the usage of spatiotemporal modeling to measure and assess sustainable land development. Written documents such as journal articles, books, reports, and other documents acquired from electronic sources and the physical location were reviewed. Satellite images were considered significant data because they were used to generate LULC maps. Topographic maps were collected to generate basic layers, such as boundaries and roads, as well as to

enhance satellite images and for georeferencing purposes. Furthermore, socioeconomic data, such as population data was collected and used. A digital elevation model was collected to confirm the terrain of the area.

3.1.2 Data acquired and source

The area of interest was selected based on the demarcation of Independent Election and Boundary Commission wards (IEBC). The data on country demarcation is available on the IEBC website. Consequently, Google Earth software, an open-source program that allows users to view the earth through high-resolution satellite images, was used to confirm and observe the characteristics of the study area.

The data acquired was social, economic and environmental. These were collected using primary sources where questionnaires were administered to sampled residents of Ongata Rongai and resource persons.

The spatial data acquired was multispectral, multitemporal Landsat satellite data of Ongata Rongai and the surrounding area for the years 2000 and 2015. Multispectral Sentinel 2A image for the year 2020 was also acquired. Both the Sentinel 2A and the Landsat images were downloaded from USGS Earth Explorer. Thematic mapper images of 2000 and 2015 had a resolution of 30metres while the year 2020 image had a resolution of 10 meters. All the satellite images were brought to Universal Transverse Mercator (UTM) projection in zone 37S. Topographic maps were downloaded from OpenStreetMaps.

Population data of the three wards was acquired from Census data by the Kenya National Bureau of Statistics (KNBS) and processed in ArcMap to produce a population map. The maps were resampled to fit the same resolution as the classified images.

Table 2: Research data Requirements

Data	Sources	Year
Social, economic and environmental data	Sampled residents of Ongata Rongai and resource person	Current data
Area of study Boundaries	IEBC	Currently in use
GPS data	Field collection	2021
Multispectral Landsat 7 satellite images	USGS Earth Explorer	February 2000 and October 2015
Multispectral SENTINEL 2A satellite images	USGS Earth Explorer	January 2020
Topographical map	OpenStreetMaps	Available
Digital Elevation Map (DEM)	USGS Earth Explorer	Currently in use

3.1.2.1 Simple random sampling

A baseline survey was conducted to determine the indicators of urban sustainability and also assess the sustainability of Ongata Rongai. A form was created using Google form and shared with various social media groups for residents of Ongata Rongai. This method enabled the elimination of biases in data collection.

3.1.2.2 Purposive sampling

Key informant Interview was conducted through oral interview. The interview targeted the person who was very resourceful in planning and management of Ongata Rongai. The person whom the interview was conducted with was the physical planner of Ongata Rongai.

3.1.3 Analysis of sustainable indicators

In assessing the sustainability of urban form Masnav (2007) analyzed the following indicators, these are urban form, environmental sustainability and social sustainability. In assessing the sustainability of an urban area many indicators can be used. However, due to the limitation of resources, the following indicators were utilized in the assessment of Ongata Rongai. The urban

form selection was guided by the study done by Musakwa *et al*. (2013) while the assessment of the environment and social sustainability was guided by Masnavi (2007). In addition, governance was included as it plays a great role in the achievement of sustainability and the theme was guided by the study conducted by Rosales (2010). The study by Theart (2007) on a sustainable solution for our cities also guided the assessment of sustainability. Table 3 shows the indicators that were used in the assessment of the sustainability of Ongata Rongai.

Table 3: Indicators of assessing sustainability

Theme	**Indicator**	**Rating of sustainability**
Urban form	Spatial characteristics	The compactness of urban areas measured by Global Moran I, Local Moran I, spatial clustering and autocorrelation and percentage of Change
Environmental sustainability	Trends of change in vegetation cover Rate of increase from non-urban to urban	Increase in vegetation cover Low rate of increase from non-urban to urban.
	An efficient and sound transport system	Low use of motor vehicles, air pollution and motorcycles and mixed land use
Social sustainability	Level of social interaction	High interaction in the neighborhood
	Access to infrastructure and basic services	Adequate provision of amenities and infrastructure
	Safety and security	Living in a secure and safe neighborhood

Governance	Community participation	Level of community involvement in the management of neighborhood

3.1.4 Spatial data

Several steps were undertaken to make the data useful in the assessment and measurement of the sustainability of Ongata Rongai and thereafter the creation of a sustainable scenario using GIS and remote sensing technologies**.** The following diagram shows the processes undertaken**.**

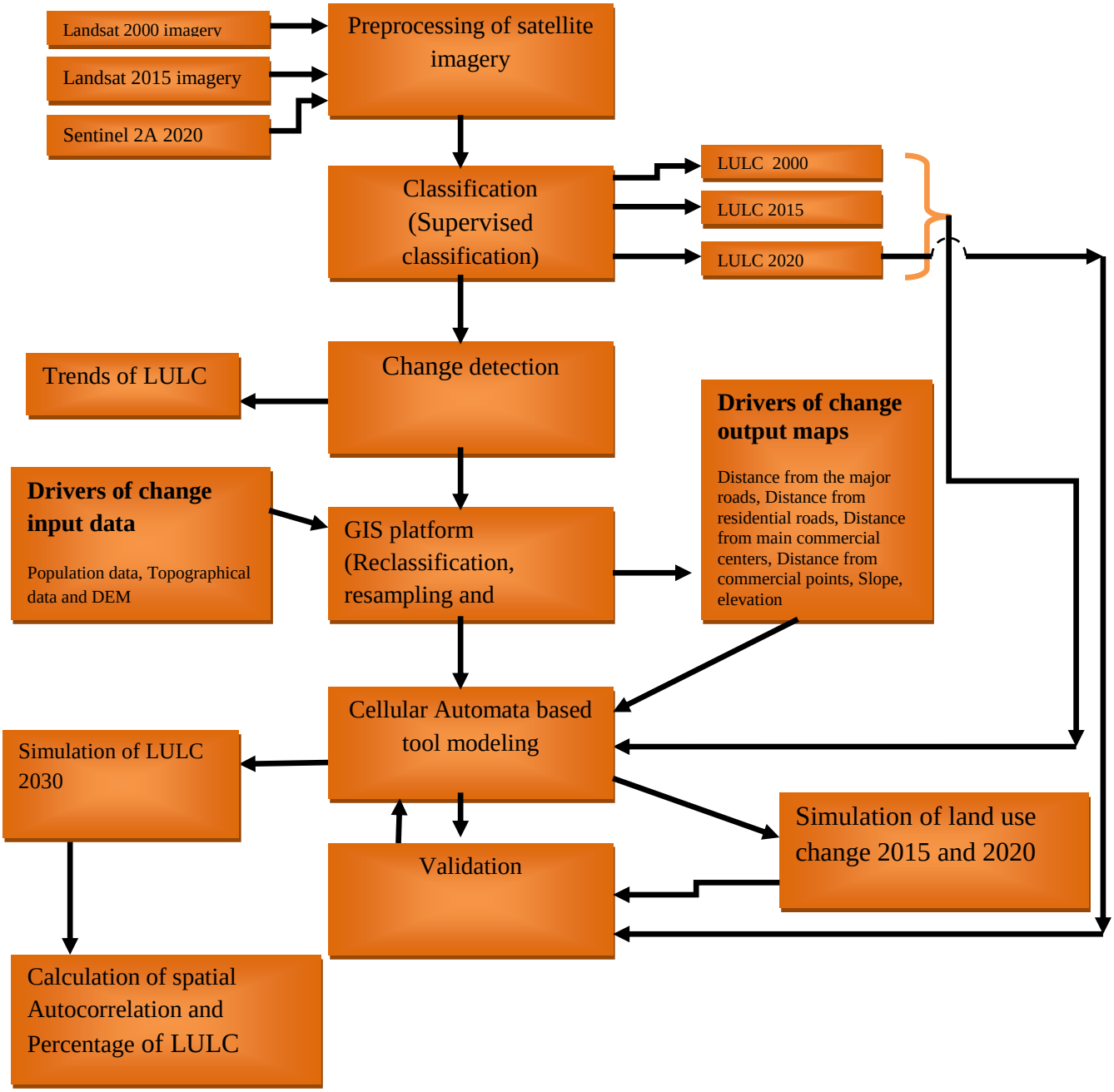

Figure 7: The process of modeling

3.1.4.1 Data Processing

Data can be prepared by following several steps to achieve the performance of LULC change detection. These steps include processing satellite images through geometric correction by using the ground control point technique and image registration by using a georeferenced image. Histogram equalization for image enhancement and spectral correction is used as well.

Other than data processing, this step also centers on preparing satellite images for land use classification. Creating a color composite is the first step in this part of data processing and is performed to visualize heterogeneous patches in the urban landscape.

Image classification

Land use and land cover maps were developed from the satellite images by defining spectral classes and by clustering image data and assigning pixels into classes. Multi-temporal Landsat data processing was done by ArcMap. The area of interest was defined to extract statistics for classification. Supervised classification was used with false-color composite bands (4, 3, and 2) to cluster pixels in a dataset in classes corresponding to the selected area of interest. A supervised classification technique was used to classify the images including minimum distance and maximum likelihood. The same process was repeated with the Sentinel 2A image.

Five LULC types were classified according to bare ground, water body, built-up, trees, and crop/grassland. The categories are useful in monitoring urban growth and change in the environment.

Table 4: Land Use Classification

Bare land /vacant lands	Open areas with little or no vegetation, exposed rocks, quarry, hilly clear-cut areas, and other idle fallow lands sometimes illegally used for agriculture
Built-up area/ Urban structures of all types	Residential, industrial, commercial, public installations, roads/highways, and other similar facilities.
Tree cover	Forest, and permanent tree-covered areas, shrubs, and trees along streams
Grass/cropland	Parks, temporary croplands, grassland, and other idle lands along streams

Water body	Permanent open water, especially manmade dams/ponds

Change Detection Techniques

Change detection is a process to identify the differences in different states of an object or phenomena by observing this object at different times (Singh, 1989). Change detection techniques for evaluating urban growth and land use changes are commonly implemented by using satellite images or LULC maps that have the same spatial resolution with the use of GIS and RS tools and software. Several urban change detection techniques exist. However, researchers have not yet agreed on which method is the best for LULC change detection because of errors in environmental and sensor factors, as well as image resolution. Kappa index and overall accuracy are mostly relied on to identify which method is more accurate for urban change detection in most studies. Generally, satellite image quality and data processing methods can be concluded to significantly affect urban change detection and ensure a low error rate.

Change detection was done for the classified LULC. ArcMap was used for thematic change detection by comparing two images during different periods.

Reclassification of LULC maps

The reclassification of LULC maps is normally done to reduce the number of classified categories. For this study since the main purpose is to observe and map the growth of urban areas, the LULC maps were classified into two classes that are urban and non-urban.

Resampling

Resampling is normally done to transform the sizes of the cells and boundaries to conform to match multi-layer raster operations. Though it changes the sizes of the cells it does not affect the layer extent. This process is very important before one does an analysis. CA is cell-based

since the transformation is done based on the neighboring cells and set rules. Having maps that have an equal spatial resolution is imperative. The cell must be equal for both rows and columns. To achieve this resampling was done using ArcMap.

3.2 Modeling

FLUS V 2.4 tool was used, which can simulate LULC using the CA method. Other parameters used are land use demand, cost matrix, and neighborhood weight.

Table 5: Parameter for CA simulation

Land use demand	Land use demand will be calculated on the number of pixels occupied by each land use after reclassification
Cost matrix	Cost matrix is the ability of the land use to change from one form to another. It will be assumed that the land use can change from urban to non-urban and vice versa.
Weight of neighborhood	A measure of the weight that one land use carries over another land use. That is the land use is more likely to change from Non-Urban and in this case probability of 0.8 was used for urban and 0.2 was used for non-urban.

To validate the simulation, the LULC 2000 was used to predict the LULC 2015 and LULC 2015 was used to predict LULC 2020 for comparison between the predicted and actual map. LULC 2015 was also used to predict land use demand for 2030 which was necessary for the simulation of LULC 2030. Thereafter, the LULC 2020 together with the predicted land use demand were used to predict the LULC map for 2030.

The Combine tool is used to combine two maps into one to show changes after simulation on the actual LULC map. Change can be identified for analysis purposes.

3.2.1 Drivers of change in Ongata Rongai

In Rongai, the following driving forces were used together with reclassified spatiotemporal data to model LULC for 2030. The drivers of change were determined by the researcher through the knowledge of the area as explained in the following text. Accessibility is very important to the growth of an urban area since the majority of the population prefers to live in areas adjacent to roads and the railway line. Through observation, the growth of Ongata Rongai is along Magadi Road where there are dense commercial and residential buildings. The growth of residential areas grows sparsely as one moves to the interior along feeder roads. This knowledge leads to the selection of distance to the main road, distance to the railway line, and distance to residential roads.

Commercial centers and commercial points are found in strategic areas and are known to attract people and other businesses around them. The main commercial center in Ongata Rongai is along the Magadi road between the Rongai stage and the Kware stage (See figure 8).

Figure 8: Main commercial Strip

Source: Adapted from Google Earth Image, 2021

Other commercial points include bus stops, petrol stations, hotels, schools, churches, supermarkets, business complexes, etc. Distance to the main commercial center and distance to commercial points were selected as drivers of change as it is expected that more businesses and residential buildings would be allocated around them.

Restricted areas are excluded from development. These areas can be set aside by the County government from development by zoning the areas. There are no areas that have been restricted for development by the county within the case study.

The terrain and slope have an impact on the settlement of people. That is, some areas are more favorable for the construction of residential buildings compared to others. For example, relatively sloppy areas are more favorable due to ease of accessibility and better drainage.

The population also plays a key role in driving change in an urban area since the higher the population the more growth is expected in the future.

Table 6: Drivers of change in Ongata Rongai

Group category	Driving forces	Source of data
Proximate causes	Distance from/to the main road network	Open street maps
	Distance from the railway line	Open street maps
	Distance from residential roads	Open street maps
Biophysical drivers	Restricted area	Open street maps
	Terrain/slope of the area	USGS Earth Explorer
Socio-economic drivers	distance from the main commercial center	Open street maps
	distance from the main commercial points	Open street maps
	Population	Kenya National Bureau of Statistics (KNBS)

3.2.2 Validation

3.2.2.1 KAPPA Index

To assess the accuracy of image classification, the confusion matrix method which is a table that is normally used to show the performance of the classification model was used. The main

purpose was to assess the accuracy of the classified image generated and ground truth data. The results of this method are overall accuracy and the Kappa coefficient.

Confusion Matrix is also used when validating the simulated image of 2015 and 2020 with the actual LULC of 2015 and 2020. Again the same results are generated to rate the quality of generated simulated images.

Table 7: Kappa coefficient rating

Kappa	Interpretation
< 0	Less than chance agreement
0.01 – 0.2	Slight agreement
0.21 – 0.4	Fair agreement
0.41 – 0.6	Moderate agreement
0.61 – 0.8	Considerable agreement
0.81 – 0.9	Good agreement

3.2.2.2 Spatial autocorrelation

Sustainable development performance is measured by describing spatial disparity and spatial spillovers. To detect, measure, and describe spatial disparities and spatial patterns (spatial association and spatial autocorrelation), some standard global and new local spatial statistics have been developed. These include Global Moran I and LISA (Anselin, 2005).

Global Moran I is significant and positive when the observed values of locations within a certain distance tend to be similar, negative when they tend to be dissimilar, and approximately zero when the observed values are arranged randomly and independently over space.

Global Moran I, Local Moran I, (Anselin, 2005), and percentage of change were used to verify of whether the urban area is growing sustainably.

Table 8: Indicators to measure the sustainability of urban form

Source: (Musakwa *et al.*, 2013)

Component	Indicator		Impact on urban sustainability	Urban planning decisions which the indicators can inform	Ideal data sets
Urban sprawl	Spatial Cluster and outlier identification	HH and HL denotes hot spots which are relatively unsustainable, whereas LL and LH denotes cold spots that are relatively sustainable	Environmental and socio-economic	Identification of urban sprawl hot and cold spots Land parcel intensification, subdivision and consolidation as well as densification strategies Promotion of social and spatial interaction through planning of different land parcel sizes. Efficient use of space to facilitate development of compact cities or the alternative making room paradigm. Planning for public transport Planning for new developments that amortize infrastructure costs.	Land cover Cadastral data
	Local Moran index (Moran I)s	A positive value denotes spatial clustering and a negative value indicates presence of outliers			
Urban extent	Percentage of change	Land use change impacts all other indication. A change from Natural ecosystem is generally unsustainable		Demarcation of urban edge and planning for future growth Rate of land transformation, i.e. non-urban to urban uses	

3.3 Software used in the study

The following six software were used for this project:

1. Google Earth Pro: It was used to visualize the map of the area of study and also observe historical ground verification for ground-truthing.
2. Google form: This tool was used to design and administer questionnaires.
3. ARC GIS: This was used for pre-processing and classification of images, to create the LULC pattern and image detection. The software was also used to reclassify and combine images as well as calculation of confusion matrix. Spatial Analyst tool, embedded in Arc Map was used in the calculation of Global Moran I and LISA.
4. Quantum GIS 2.18.15: It was used for processing OpenStreetMap, resampling LULC maps, and visualization of images and maps.
5. FLUS V2.4 tool which is CA-based was used to model and simulate LULC.
6. Microsoft Office: Microsoft Excel was used in the accuracy assessment while Microsoft Word was used in writing the project.

CHAPTER 4: RESULTS ANALYSIS

4.1 Introduction

This chapter reports, discusses and analyses the findings of the research as explained in the previous chapter to meet the objectives of the study.

4.2 Urban form

The urban form was assessed by the measurement of modeled data with various scientific methods. The process of modeling and measurement using spatial statistics is as follows:

4.2.1 Spatiotemporal patterns of urban growth identification

LULC maps and LULC statistics were produced for purposes of examination of spatiotemporal change in the growth of urban areas. The research was dependent on data availability so both Landsat data and Sentinel data were used. The Landsat images had a resolution of 30 megapixels while the Sentinel image had a resolution of 10 megapixels. The images were also taken in different months, meaning that most likely they were during different weather seasons. The ideal case was where images would have been taken with the same resolution and in the same weather conditions.

4.2.2 Classification of land use data/ multi-temporal LULC change

A classification that entails the mapping of relatively homogeneous areas over different times was done to enable spatiotemporal analysis. This is made possible by using geospatial tools and the availability of multi-temporal satellite images.

Past spatiotemporal data were classified into five categories that are: bare land, grass/cropland, tree cover, water body, and built-up areas. These five categories were used to determine change and the trends of urban growth.

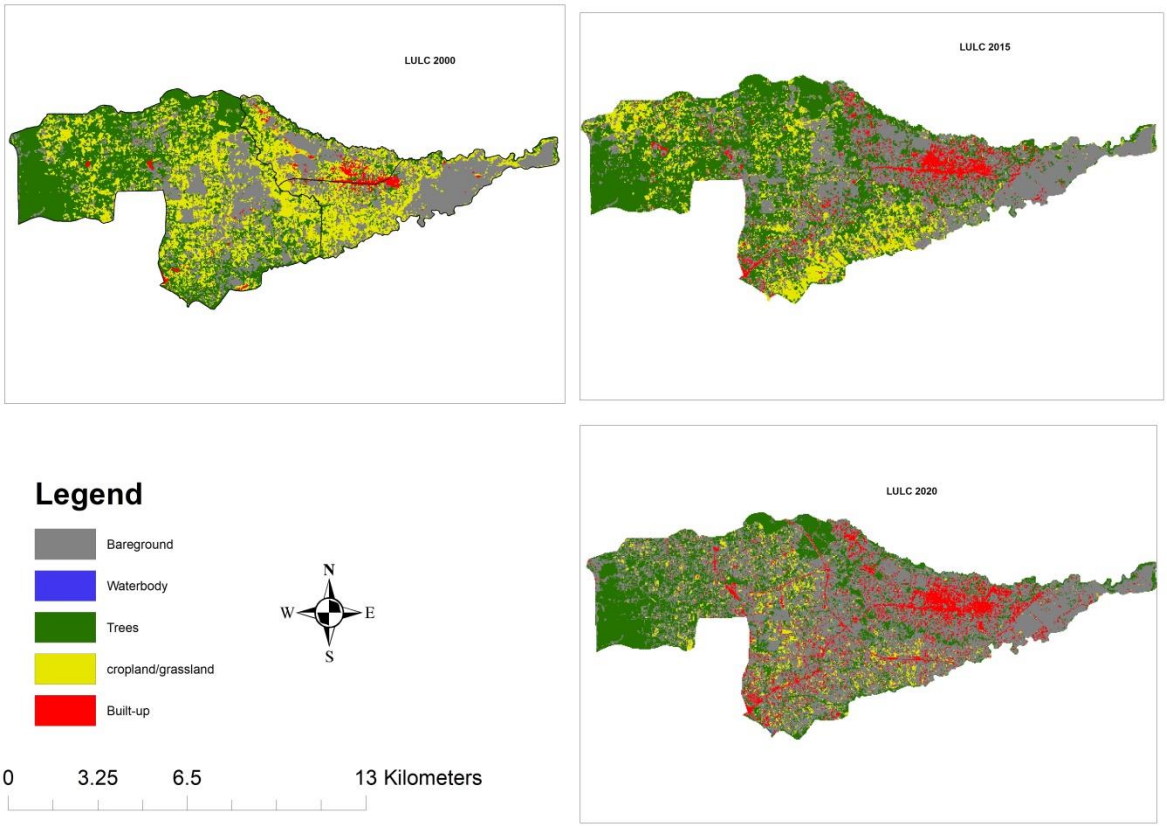

Figure 9: Ongata Rongai LULC change

From the observation of maps shown in Figure 9, LULC has been changing and it is clear that the urban area is growing. The urban areas are growing along with the major transport system which is the road. It can also be observed that vegetation has progressively reduced while there has been an increase in the bare ground over the three periods.

4.2.3 Accuracy assessment of land cover

Accuracy assessment was done after classification to assess the accuracy of the classified map with the ground truth. The process was implemented using an assessment tool in ArcMap and Microsoft Excel. The LULC of 2020 had higher overall accuracy and Kappa coefficient compared to the LULC of 2000 and LULC of 2015 of 92% and 0.91 respectively. This was attributed to the high resolution of the image of the year 2020. The LULC of 2000 had overall accuracy and Kappa coefficient of 90% and 0.87 respectively. The LULC of 2015 had 87%

and 0.82 respectively for both overall accuracy and Kappa coefficient compared. All the LULC maps were in line with the observed and ground truth.

4.2.4 LULC change and trends of urban growth

The LULC change was analyzed after LULC classification and accuracy assessment. Figure 10 below shows that there has been a steady increase in urban areas. Urban growth has increased from 1.66 in 2000 to 8.3. The bare ground has also been increasing steadily from 2000 to 2020 where it has increased at a rate of 6.4% and 14.71% between the mapped periods. Grass/cropland has been decreasing gradually between the two periods mapped. The crop/grassland decrease can be attributed to urban growth, climate change, and different seasons when the image was taken. The tree cover was the largest ground cover in 2000 but increased due to the rainy season in October and reduced in 2020 due to dry conditions as well as due to the growth of urban areas. Open water bodies are negligible in comparison with the other land covers. Water bodies have relatively remained the same.

It can also be observed that there is a continuous increase in built-up areas and bare ground while trees and grass/cropland are decreasing.

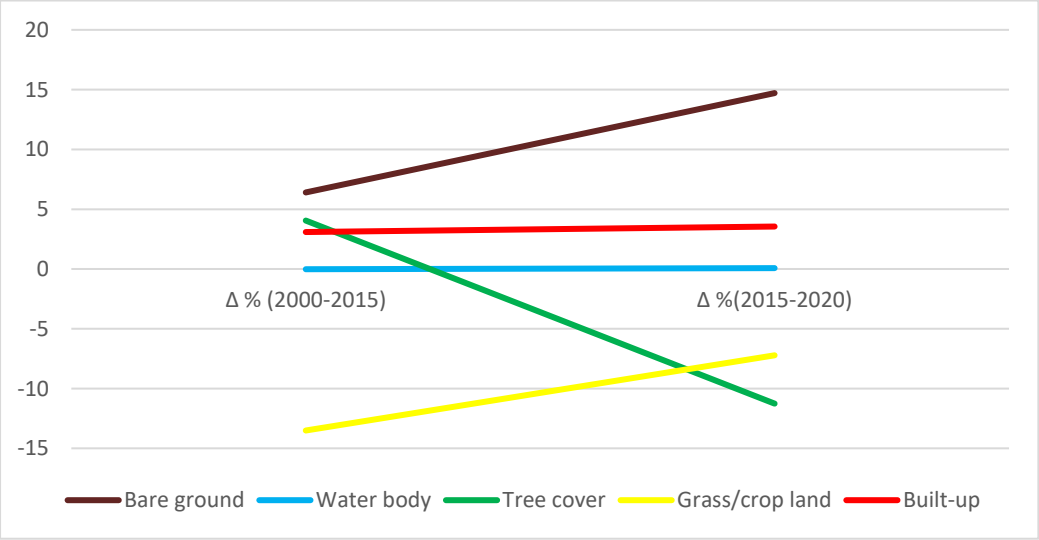

Figure 10: Trends of LULC changes

Ongata Rongai is a relatively semi-arid area and change in weather conditions affects the natural characteristics of the area by a margin. Though the change in weather conditions might have influenced the change in natural land cover, there is consistent change showing that climate change is affecting the study area. This is indicated by a change of tree cover and crop/grass to bare ground. Urban growth has also been taking up land previously occupied by bare ground, tree cover, and crop/grassland.

4.2.5 Reclassification of LULC

Reclassification was done to reduce the number of classified groups to a smaller group. In this case, since there were five categories, they were later reclassified into two classes. Bare ground, water bodies, trees, and crop/grassland were combined to form non-urban areas while the built-up areas remained urban areas as illustrated in Figure 11.

The reclassification made it easier to visualize and model the urban LULC changes.

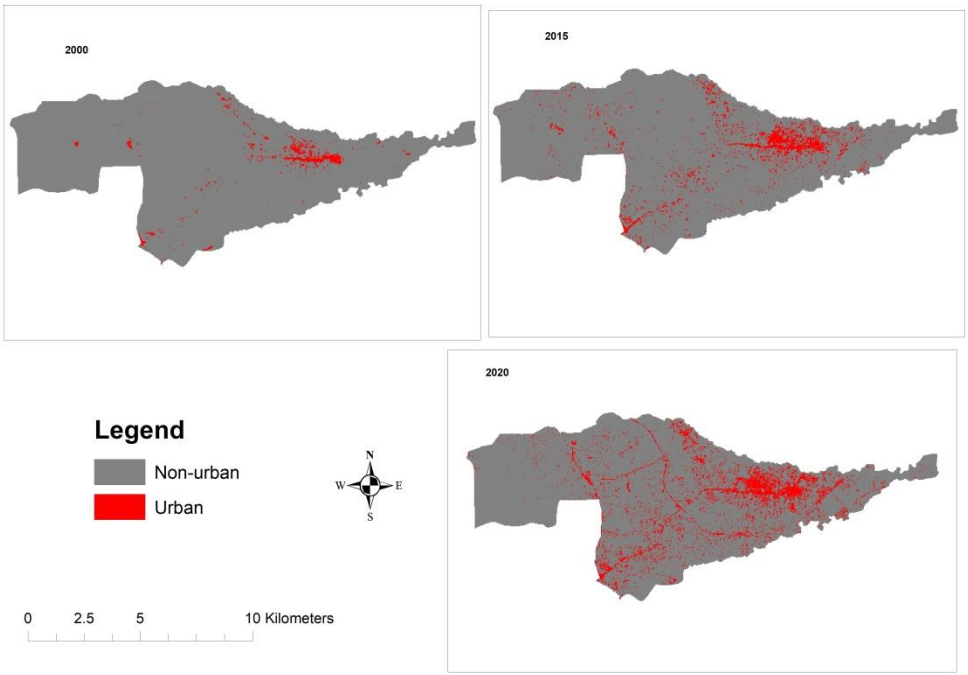

Figure 11: Land Cover Classes to depict the changes in urban surfaces in 2000, 2015 and 2020

4.2.6 Drivers of change identification

There were eight drivers of change that were used to calibrate the direction and patterns of growth. These were slope, elevation, distance from the main road, population, distance from residential roads, distance from commercial points, distance from the main commercial center, and distance from the railway line as shown in Figure 12. These drivers seem to shape the rate, direction, and trends of urban growth. Table 9 lists the nature of variables and describes the drivers that were used in the modeling of urban growth.

Table 9: Variable and description list

FACTOR	Variable	Description	Nature of variable
Dependent	Y	Urban growth or no urban growth	Dichotomous
Independent	X		
Bio-physical characteristics	Slope	Degree of slope	continuous
	DEM	Change in height	continuous
Proximate Cause	Distance to main Road	Euclidean distance to main road	continuous
	Distance to railway line	Euclidean distance to railway line	continuous
	Distance to main commercial centre	Euclidean distance to commercial centre	continuous
	Distance to commercial points	Euclidean distance to commercial points	continuous
	Distance to residential roads	Euclidean distance to residential roads	continuous
Social economical	Population	Density of an area	trichotomous
Zoning	Restricted areas: mining and forests	Restricted or not restricted 1. Restrict urban growth <1- Allow urban growth	Dichotomous

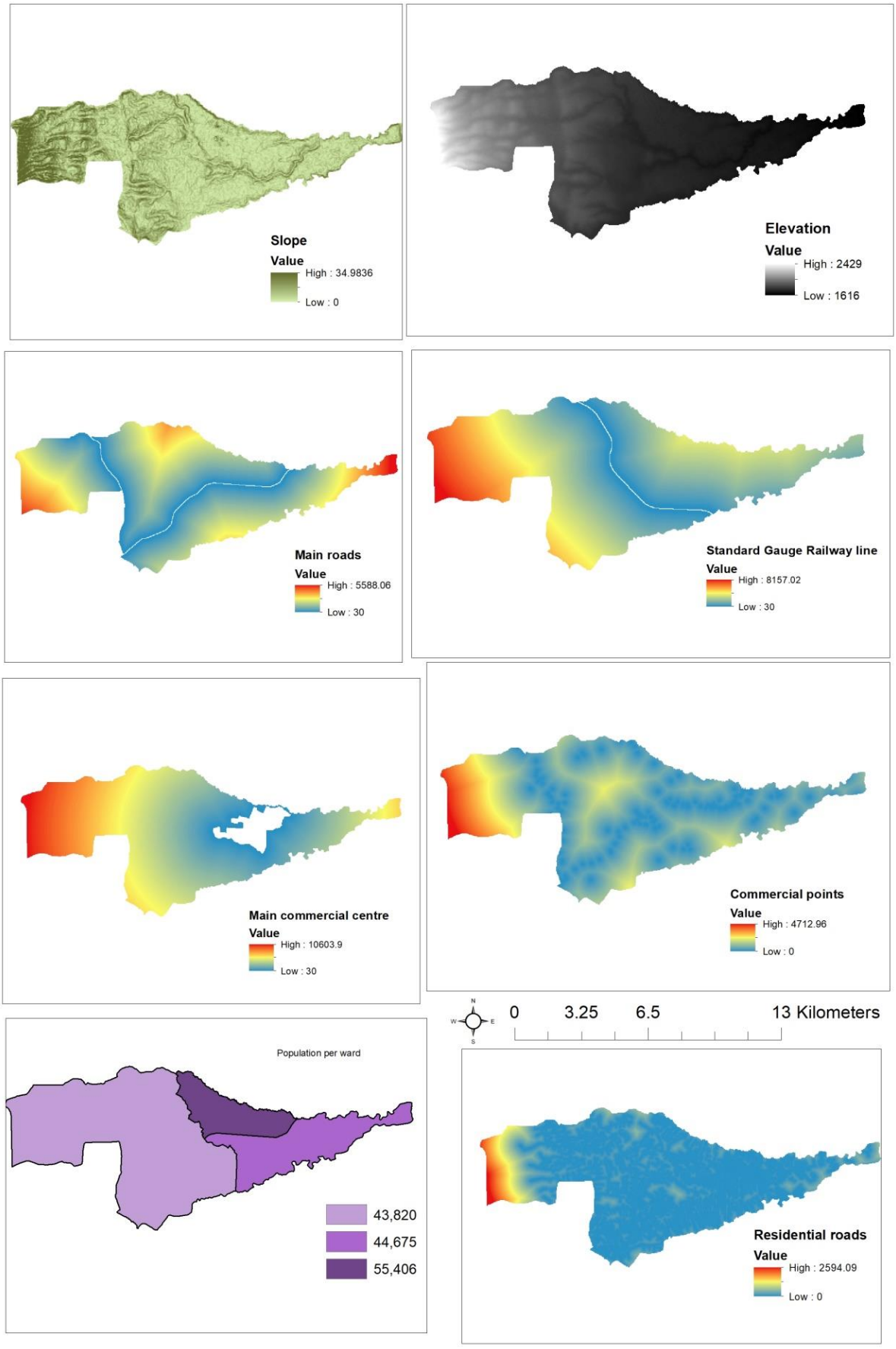

Figure 12: Driving forces for urban growth in Rongai

Resampling

All the datasets namely resampled LULC and driving forces maps were resampled to a resolution of 693*277 and with a cell size of $30m^2$.

4.2.7 Cellular Automata Modelling

CA simulation

To simulate LULC for 2015 and 2020, the change map, LULC 2000, and other parameters for simulation were used, namely land use demand, cost matrix, and weight of neighborhood. The simulation parameters were based on the researcher's knowledge and literature review as discussed in section 3.2.1.

Table 10: Parameters to simulate LULC

Year	Land use Demand		Cost Matrix		Weight of neighborhood
2000	Non-urban	87020	1	1	0.1
	urban	1846	1	0	0.9
2015	Non-urban	83592	1	1	0.1
	urban	5274	1	0	0.9
2020	Non-urban	79592	1	1	0.1
	urban	9274	1	0	0.9
2030	Non-urban	71646			
	urban	17220			

4.2.8 Validation

The reclassified LULC map of 2000 was used as a base map to predict 2015. Similarly, prediction of LULC 2020 was done where LULC of 2015 was used as the base map. Validation

measurement of the two LULC maps was done using observation by comparing the actual and predicted maps for similarities and differences. Additionally, a confusion matrix was generated and overall accuracy and Kappa coefficient were analyzed.

By observation, both the predicted maps of 2015 and 2020 seem to agree with the direction of urban growth. The urban growth seems to follow a linear urban form. This is the case where the urban area is growing along the transportation corridor. The prediction failed to foresee scattered urban development as shown in Figure 13. It can be generally concluded that the prediction fairly matches the actual/observed LULC.

Statistically, the kappa coefficient shows that the predicted map fairly matches the actual LULC with the value of 0.37 for both predicted images as shown in Table 12. The overall accuracy for the results of LULC 2015 and 2020 was 93% and 88% respectively both interpreted as highly accurate.

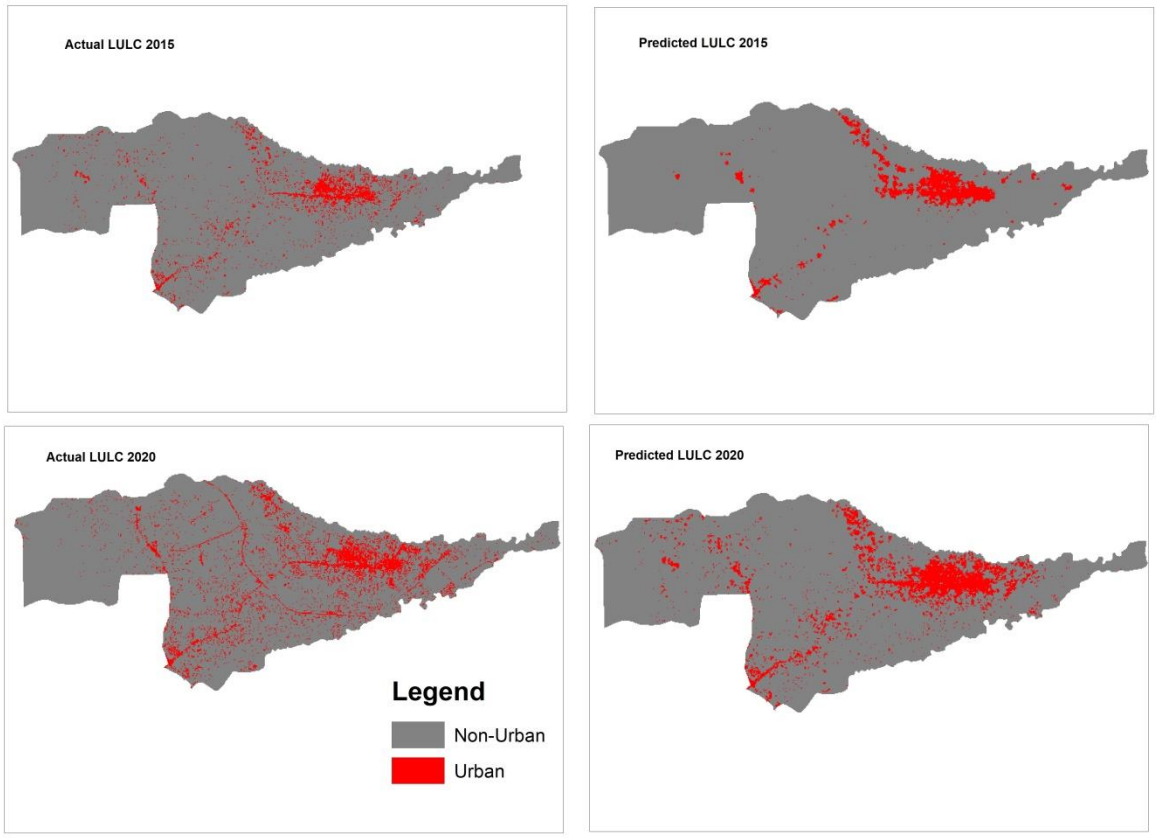

Figure 13: Actual and predicted LULC 2015 and 2020

Table 11: Kappa results for the predicted and actual years

[Kappa Coefficient]		[Overall Accuracy]	
2015	**2020**	**2015**	**2020**
0.37427	0.378657	93%	88%
Fair agreement	Fair agreement	High accuracy	High accuracy

4.2.9 Simulation of LULC 2030

The LULC of 2020 was used as a base map to simulate LULC for 2030 using land use demand data generated after the prediction of LULC for 2015. The simulated map for Rongai is shown in Figure 30 below. The predicted map was combined with the LULC 2020 to improve spatial analysis. The combined map shows the likelihood of occurrence of urban growth in 2030 in comparison with LULC 2020.

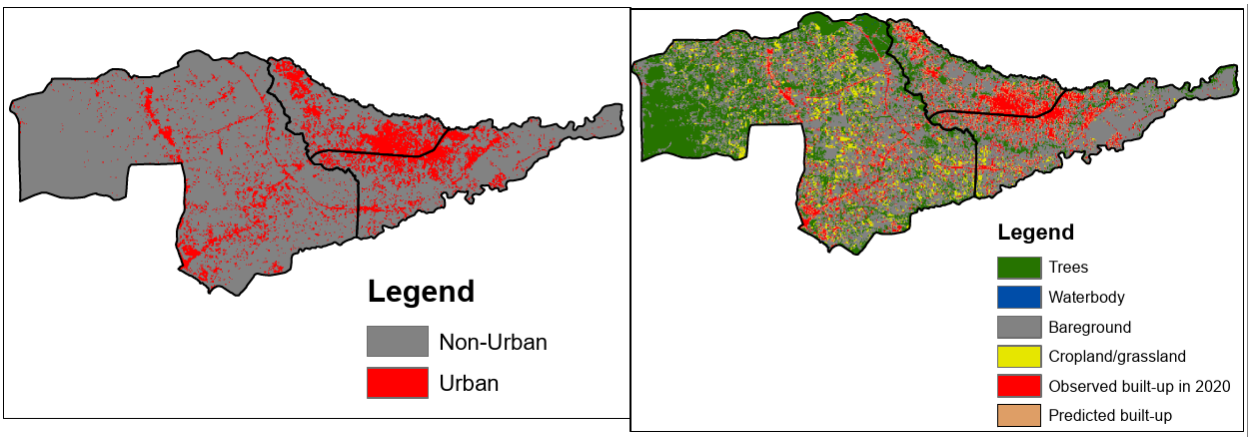

Figure 14: LULC 2030 simulation of Ongata Rongai

The predicted urban growth shows that there will be infill of the vacant land and the town will also extend outward. The other expected growth will be denser growth along the transportation corridor.

4.2.10 Analysis of urban form for sustainability

Urban sprawl causes loss of natural environment, increases the cost of infrastructure cost, social costs, pollution by increasing vehicle mileage, and loss of functional open space (Musakwa &

Niekerk, 2014). Global Moran I and Local Moran I have been effective in indicating urban sprawl by their capability to detect clusters and outliers and sprawl hotspots at a significant level (Musakwa & Niekerk, 2014).

The research used Global Moran I, Local Moran I, and percentage land use change to explore the possibility of urban sprawl. Percentage of urban development, Global Moran I, and Local Moran I were calculated on the predicted LULC 2030 map. The results were analyzed for the possibility of urban sprawl for land management recommendations.

a) Global Moran I

Global Moran I quantifies the spatial association between the same variable in neighboring locations. When neighboring areas have similar variable values, the outcome is positive and vice versa. Urban sprawl is measured using Global Moran I by evaluating the compactness of the building within an urban area by taking the buildings' location and their value (area) in an urban area (Musakwa & Niekerk, 2014). Global Moran I, evaluates if the buildings are dispersed, clustered, or randomly scattered.

The results of Global Moran I is 0.36, the value is close to 0, indicating random scattering of buildings. This is a clear indication that the area is highly unsustainable. Global Moran just gives a general valuation of the area; it doesn't show the exact location of the problem which is unlike Local Moran I.

b) Local Moran Index

Local Moran Index indicates at various individual locations, the level of spatial autocorrelation within an urban area. Thus Local Moran I is a breakdown of Global Moran I. Though the Local Moran I does not range between -1 and 1 as Global Moran I, where a negative value shows negative spatial autocorrelation (outliers) while a positive value indicates positive spatial autocorrelation (clustered) (Musakwa & Niekerk, 2014).

To better understand the spatial distribution of hot and cold spots, The HH, HL, LH, and LL cases can be mapped to see where clustering occurs (Anselin, 2005) when using Local Moran I. In the case of application in urban areas, it identifies the object which is the buildings/developments and the neighboring value, if large development and large neighboring are unlike, then they will have a high value for both which is registered as HH.

In the ArcMap, the results of the prediction of 2030 were analyzed for the location of urban sprawl and the results were illustrated in Table 13 and Figure 15 below. The table gives a summary of the findings of Anselin. There is a higher count of HH indicating the presence of leapfrogging. This was identified because the developments are found in large areas of non-developed areas. High-Low (HL) hot spots were the third-largest; in this case cluster developments are found in areas where there are still non-developed areas. The majority of urban development appears as the High-High cluster and High-low outliers. This shows that these areas are not sustainable.

Table 12: Summary of Anselin Moran I

Autocorrelation	count
HH	454
HL	226
LH	27
LL	286

The three types of sprawling seem to occur in Ongata Rongai namely scattering, linear, and clustering sprawling. The scattering sprawling is occurring all over the study area while linear sprawling is the growth that is occurring along the main road *(see appendix B*). The urban growth that is occurring in the township is clustering sprawling since it is occurring without proper planning.

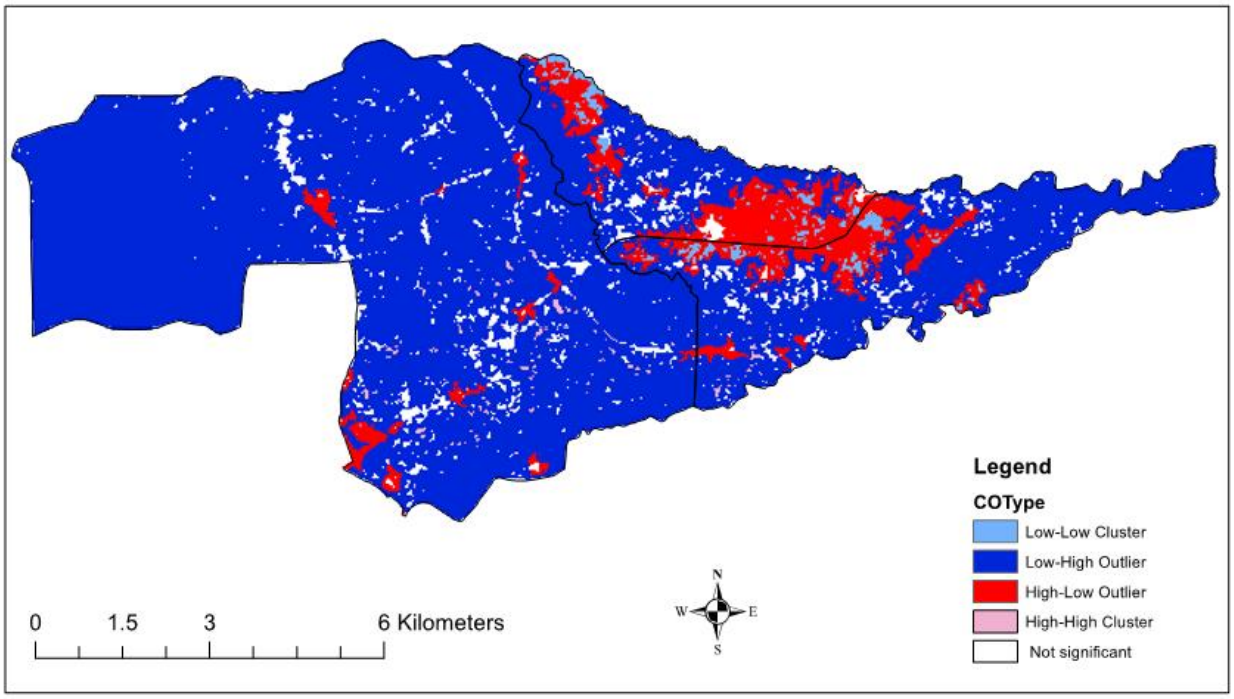

Figure 15: Results of Spatial Cluster and outlier identification

d) Percentage of Change

This is given by a mathematical formula shown below:

Percentage of change = increase/original number*100

Percentage of change = (value of predicted 2030 urban land use demand - value of urban land use demand 2020)/Total value of pixels (land use demand) *100 = (172200-9274)/88866*100 = 89.4%. in 10 years

= 8.94 per year

The urban area is increasing at a rate of 8.94 per year against the expected urban growth rate of between 3.2% -1.1% according to the World Bank. There is a high margin of growth compared to normal urban growth. Consequently, the area is changing from a natural ecosystem to urbanization. The rate at which the land is converted to a built environment may be risky for the future generation due to the lack of proper investment needed to support growth. Inadequate facilities and infrastructure as well as having unplanned urban areas while experiencing urban growth may be unsustainable.

In addition, the conversion of agricultural land into urban areas without proper planning may lead to food insecurity. This growth is also expensive for the County government to keep up investing and providing adequate facilities for the residents due to limited resources.

4.3 Baseline data

The questionnaire containing information on social and environmental was prepared and shared with a variety of Rongai social media groups including the following residential Facebook groups and church groups both on WhatsApp and Facebook. The purpose of sharing it on Ongata Rongai social media groups was to have random responses eliminating any biases. The questionnaire required only one person per household to fill out the form. It was also a requirement that they reside in one of the three wards. The location of the neighborhood was made mandatory to sieve out all the respondents outside the study area.

The data was checked for quality and missing data. The data was thereafter analyzed in an Excel sheet. The analyzed questionnaires are as follows:

4.3.1 Social-economic characteristics of the respondents

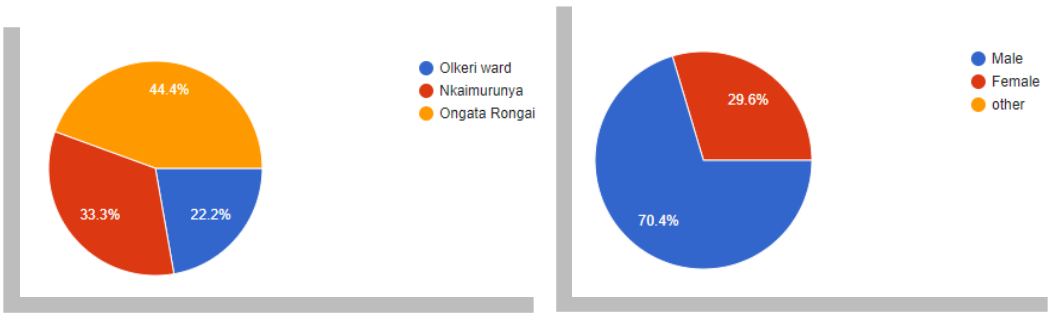

Figure 16: a) Location of respondents b) Gender of respondents

44.4% of the participant were from Ongata Rongai, 33.3% from Nkaimurunya and 22,2% were residents of Olkeri wards. There was 26.6% representation of women and 70.4 representations of men.

The household members had a mean of 3 members with the highest household having 7 members and the least was 1 member in the household. There was a mean of 1 child per household.

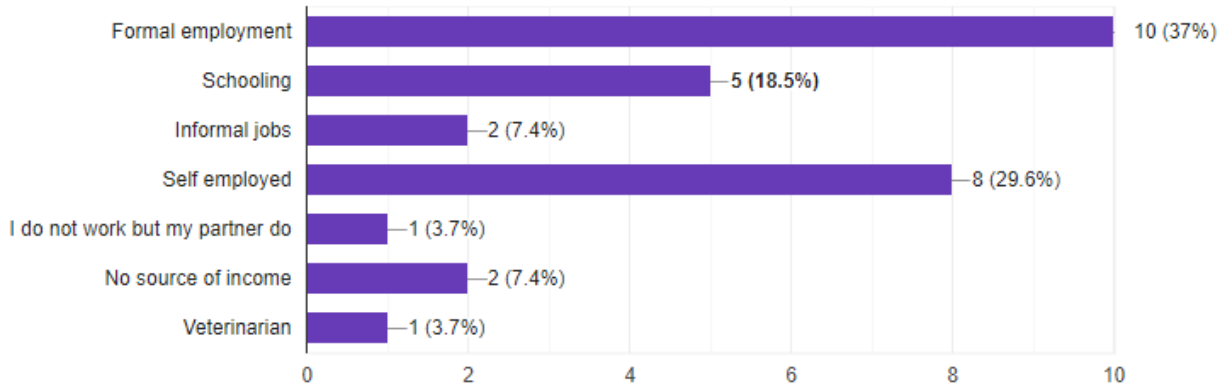

Figure 17: Occupation distribution of respondents

The majority of the respondents were in formal employment such as nursing, Computer Technicians, finance manager, etc employed in hospitals, banks, SACCOs and so forth. There were those in self-employment like selling vegetables and pharmacist while there was a percentage that was going to school and those in informal jobs such as washing clothes, masonry and many others.

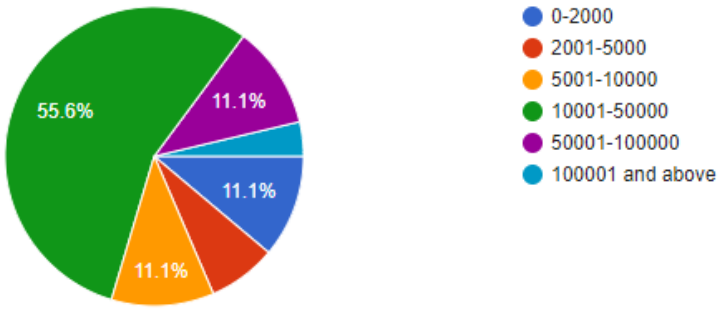

Figure 18: Economic distribution of the respondents

More than half of the respondents earn between Ksh. 10, 001 and Ksh. 50,000. There was the same number of respondents who earn Ksh. 0-2000, Ksh. 5001-10,000 and Ksh. 50,001-10,000.

4.3.1 Social sustainability

Social sustainability was assessed by the following indicators level of participation in governance issues, social interaction, access to basic facilities and safety as well as security.

Social interaction indicator

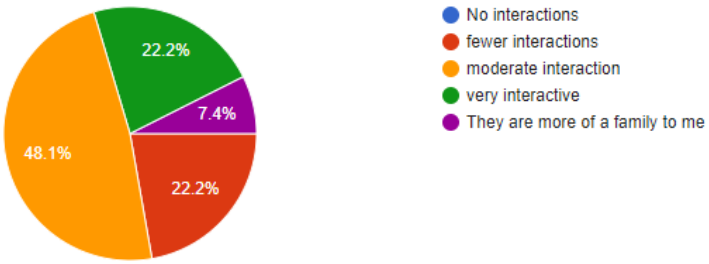

Figure 19: Level of interaction with the neighbors

The majority stated that they have moderate interaction within their neighborhood and an equal portion of 22.2% either have fewer interactions or they are very interactive within the neighborhood. These interactions are done within the plots, others visit each other, while others meet on the roads, in churches, in women's groups, in shopping centers and others at their business places.

Neighborhood satisfaction and access to basic services and infrastructure

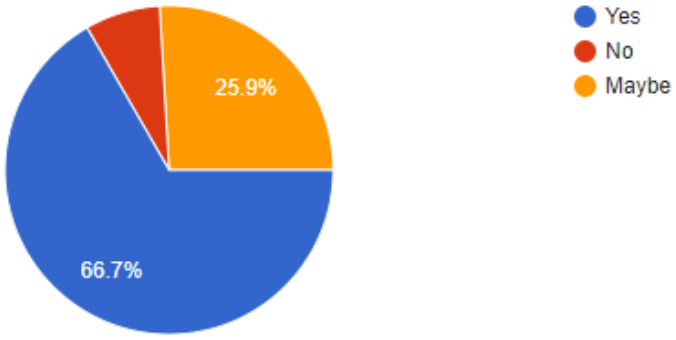

Figure 20: Satisfaction with the neighborhood

More than half are generally happy with their neighborhood. Others are not sure if they are happy with it while less than 10% are unhappy with their neighborhood. Despite high satisfaction majority of the residents do not have access to adequate water for cleaning, and most experience long commuting times to work and school. There is also inadequate access to facilities such as public schools, public hospitals and public social halls. Urban sprawl increases the cost per user by providing public services such as public transport, water and sanitation (OECD (Organization for Economic Cooperation and Development), 2018). This is explained further below:

Most of the neighborhoods use borehole water for washing and cleaning, who were the majority being 46.2% of the sample interviewed. 30.8% of the respondents buy water from water vendors and water bowser.

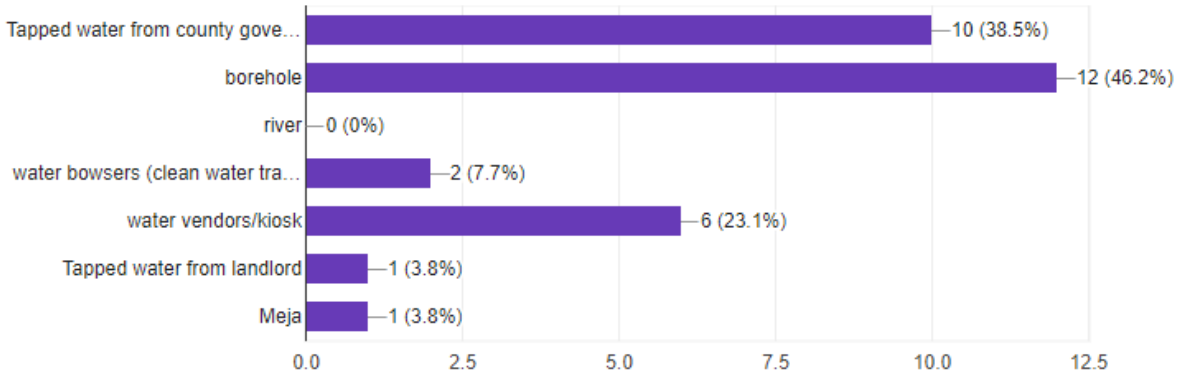

Figure 21: Sources of water for cleaning and washing

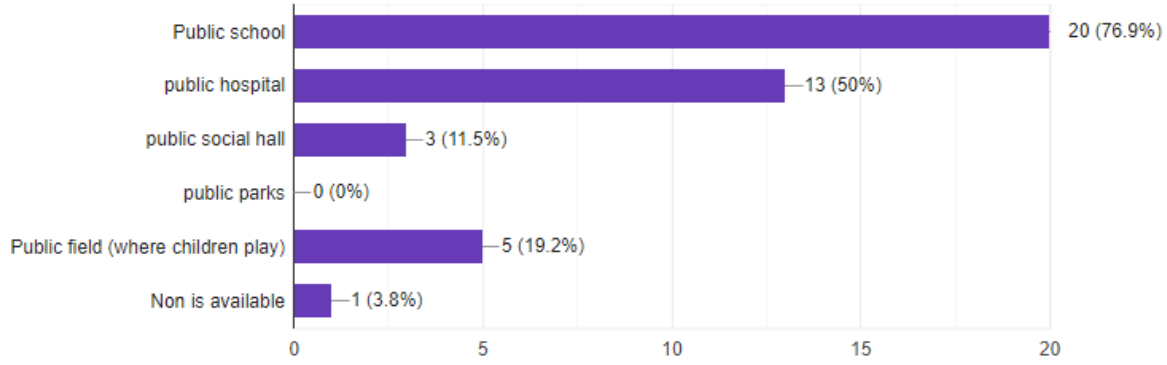

Figure 22: Availability of public facilities within the neighborhood

There were few public amenities available in the neighborhood and mostly the public schools are available. Schools such as Nkaimurunya, Nakeel, Olekasai and Arap Moi are available though not well distributed in the study area. Private schools are available to fill the gap. Public hospitals are also accessed by 50% of the respondents and the only public hospital within the study area is Saitoti hospital. The gap is filled by private hospitals and public hospitals around the study area. Only a few people have access to social halls, and public fields and there are no public parks in Ongata Rongai.

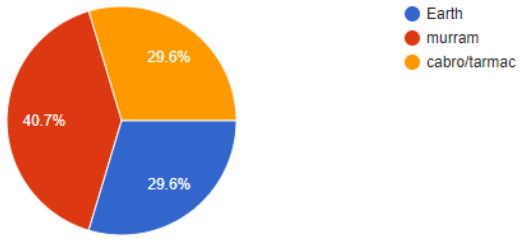

Figure 23: Condition of roads around the neighborhoods

The statistic showed that 70% of the roads in Ongata Rongai are either Earth or murram while only 30% of Ongata Rongai roads are tarmacked/paved.

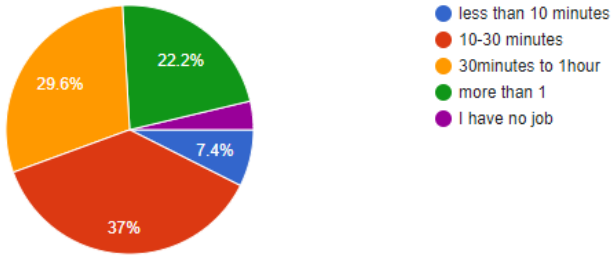

Figure 24: Period utilized to get to workplaces

The majority of the respondents take more than 30 minutes to reach to places of work. The majority of resident and especially those who work within Ongata Rongai and its environs spends 10-30 to commute to work places. The long commute especially those who spend more than an hour on the road use that time at expense of other social-economic activities, They also like to suffer isolation by spending a long time alone in addition to poor health.

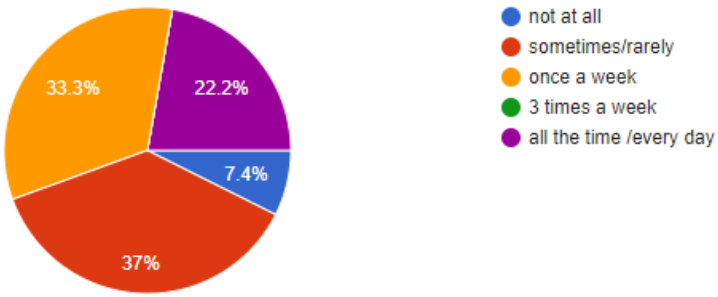

Figure 25: Number of times respondents shop outside a 3km radius

The majority of the respondents occasionally travel for more than 3Km radius to do shopping. Others go to shopping centers at least once a week to buy supplies while others go every day to buy supplies. The combination of those who go shopping once a week and those who go every day is a total of 55.5%, indicating a lack of urban mixed land use. Land use mix promotes short trips that are walkable where there is easy access to facilities, reduces transport cost and length of traveling as well as reduction of emission. Long trips are frequent in Ongata Rongai due to the occurrence of the commercial strip along Magadi Road.

Means used to commute to school also indicate a lack of land use mix since 40% of the respondents stated that their children walk to school, but the rest of the percentage use *matatu*, private vehicles/motorcycles and school buses to get to school.

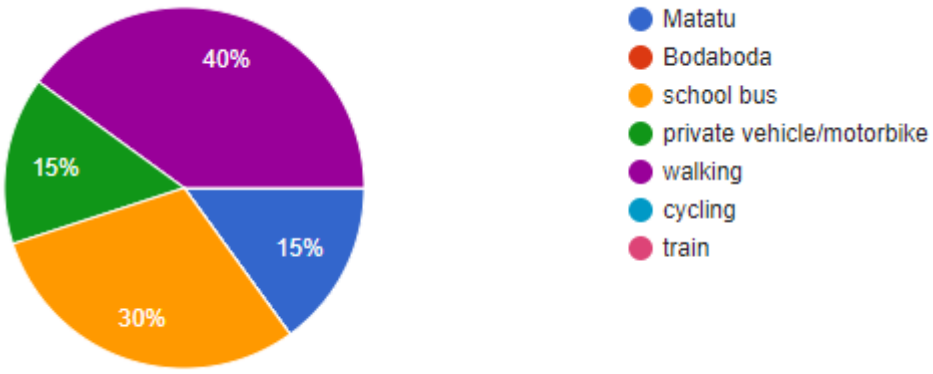

Figure 26: Mode of transportation used by children to school

Safety and security indicator

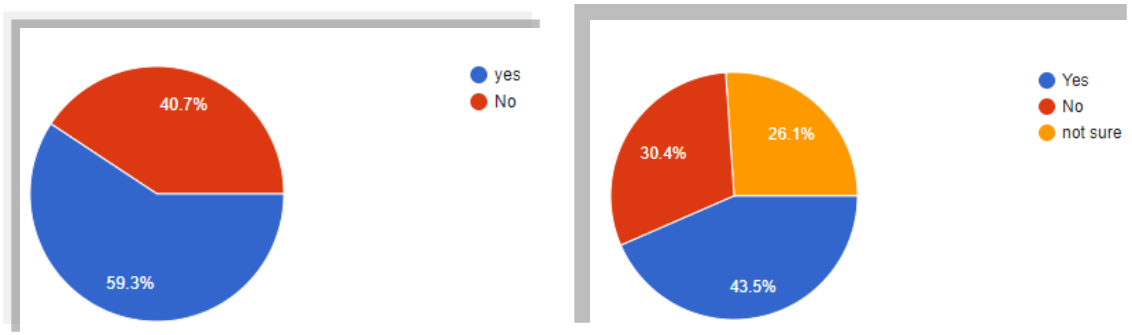

Figure 27: a) presence of pedestrian walks in the neighborhood. b) safety of the pedestrian walks

Almost 60% of respondents stated that there were pedestrian walks while 40% stated that there are none. For those who responded that there are pedestrian walks, 43.5% agreed that they were safe while 30% of the respondent agreed that they were not safe and the rest were not sure.

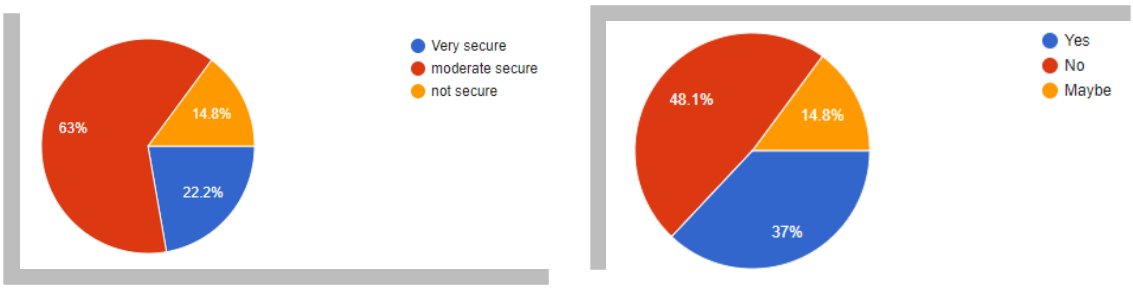

Figure 28: a) Level of security in the neighborhood b) The need to hire private security

63% of the respondents were in agreement that there was moderate security in the neighborhood while 22.2% agreed their neighborhoods were not secure. However, 37% saw the need to hire private security while 48.1% did not see a need for additional private security. Moreover, to improve security, the respondents recommended the installation of CCTV cameras and streetlighting, the construction of a police post, additional policemen/women and the promotion of *nyumba kumi* initiative.

Good governance

Good governance/management was assessed by evaluating the level of participation by the community members in the management of neighborhoods.

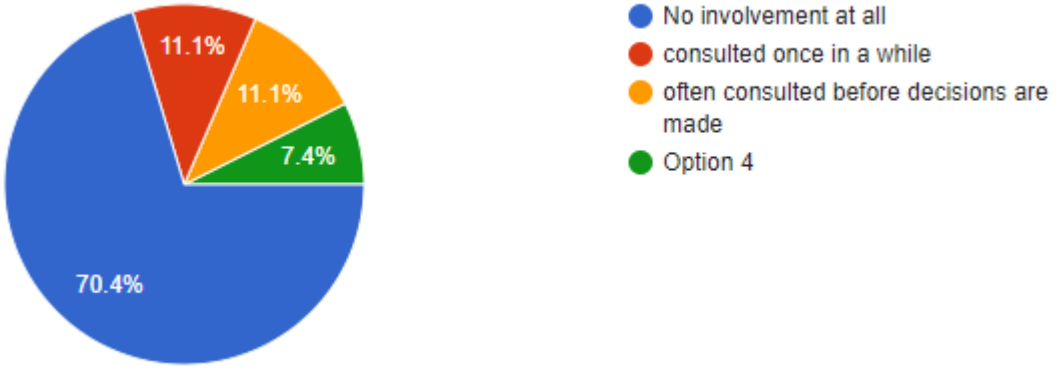

Figure 29: Participation of the community in key issues affecting their neighborhood

The majority of the residents agreed that they have never been involved by the county government in the management of their neighborhood.

4.3.2 Environmental sustainability

Environmental sustainability was assessed by analyzing trends of change in LULC, percentage of change and transportation infrastructure.

Trends of Change in land use land cover

The analysis of trends of change shows a reduction in tree cover and Grass/Cropland cover while bare land and built-up areas are increasing. The tree cover increased by 2015 then decreased significantly by 2020. This can be explained by the construction of the Standard gauge Railway line (SGR) during that time when trees were cut to make way for the SGR. Urban development such as the need for housing has also reduced the tree cover. Ongata Rongai seems to be affected by climate change since bare land is increasing at a high rate.

Table 13: Land Use Land Cover changes

Class name/year	2000	2015	2020	Δ % (2000-2015)	Δ %(2015-2020)
Bare ground	23.51	29.91	44.62	6.4	14.71
Water body	0.03	0.01	0.08	-0.02	0.07
Tree cover	29.24	33.29	22.03	4.05	-11.26
Grass/crop land	25.54	12.03	4.81	-13.51	-7.22
Built-up	1.66	4.75	8.3	3.09	3.55

Percentage of change

The predicted increase of urban areas by 2030 is expected to be 8.92 annually. An increase in urban areas without proper planning at this would reduce the biodiversity as land is fragmented.

Transport energy and air pollution indicator

Areas experiencing urban sprawl will most likely experience longer commuting distances and dependency on the vehicle rather than walking or cycling. When this occurs more air pollution, higher greenhouse gas emissions and more traffic jams will be experienced (OECD (Organization for Economic Cooperation and Development), 2018).

The majority of the respondents use *matatu* (PSV-public service vehicles) as the main mode of transportation to work. A percentage of 23.1% total of those interviewed stated that they use private vehicles or motorbikes to work. Similarly, the same portion of respondents stated that they walk to workplaces since they are within walking distance. Motorcycle riders (*Bodaboda*) are also commonly used in Ongata Rongai. There was no respondent in the sampled areas who commute by trains and bicycles.

The analysis showed that there was a longer commuting time to workplaces and schools. Distance to commercial centers is also longer since many people travel outside a 3km radius to buy items. The long commuting hours cause emissions and air pollution. Air pollution is also

indicated by lack of proper roads where only 30% of the roads are tarmacked while the rests are earth and murram road. The latter types of road are known to cause air pollution during the dry season and when used by motor vehicles and motorcycles. The dust from the road can cause asthma and other respiratory diseases. Aside from this, there is noise pollution from motor vehicles and motorcycles that can increase the stress level of the residents.

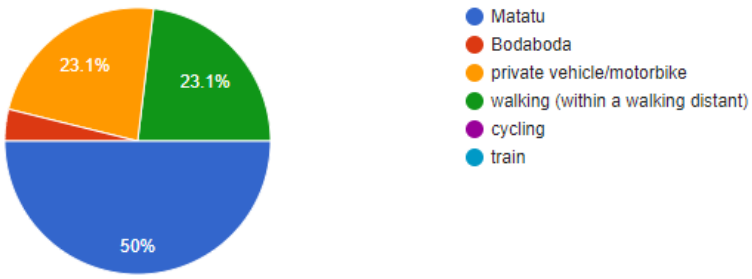

Figure 30: Mode of transportation used to work

40% of the respondents stated that their children walk to school but the rest of the percentage use automobiles to get to school. They use means such as *matatu*, School buses and private vehicles/motorbikes making it 60% of the mode of transportation used.

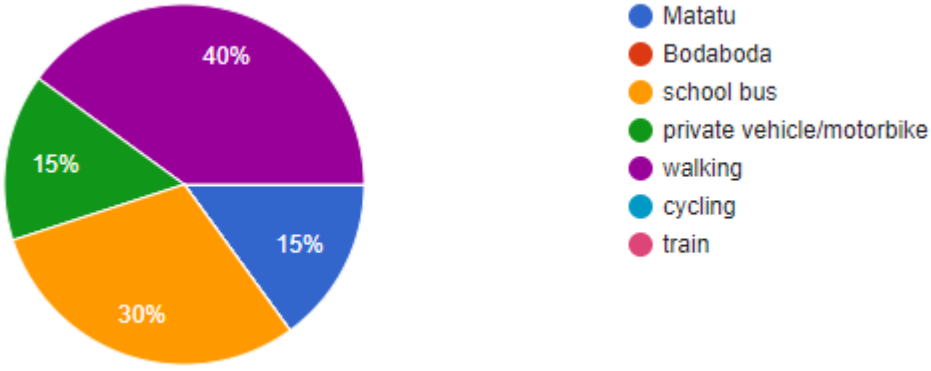

Figure 31: Mode of transportation used by children to school

Air pollution indicator

This indicator was assessed by evaluating the main mode of transportation, time utilized to get to places of work and school and condition of the road.

Figure 32: Picture showing a cloud of dust along Magadi road

4.4 Findings from Key Informant Interview

It was established that one of the challenges to the attainment of sustainable land development is the category of land tenure within Ongata Rongai. The land is owned on freehold title thereby making it hard for the urban managers to implement plans such as zoning plans. It is important to regulate land development and land use for the public interest as stated in the Kenyan Constitution, which gives the State the right to regulate land or any other interest over any land according to Article 66(1).

Ongata Rongai also lacks approved physical plans resulting in uncoordinated development patterns that are encroaching the rural areas and natural water bodies like the Mbagathi River. The lack of an approved plan has also precipitated insecurity in the area due to inadequate allocation of security services and the proliferation of informal settlements (County Government of Kajiado, 2019).

It was also found that there was discord in planning and implementation institutions. Planning is done by the department of planning while the plans are implemented by the department of

works. The departments lack a mechanism to coordinate with each other thereby causing a breakdown of information management.

Political interest is also very high in Kajiado County thereby interfering with the implementation of sustainable developments. The County has CSP, IUDP, zoning plans, and action plans in place to guide the developments. Different laws and legislation such as the Cities and Urban Act and Physical and Land Use Act are there to guide land developments. However, implementation of these is impeded by a lack of political will. The support that is required from the county government is not available and other priorities that are not relevant or against sustainable land development are supported. For example, approval for development in riparian reserves and lack of approved physical and land use plans.

An unregulated land market is also an impediment to sustainable land development. The land in Kajiado county has been subdivided and sold to different private parties. These parties buy land for development, others for further subdivision and resale and others buy for speculation. This has resulted in a false shortage of land thereby increasing the value of land to imaginable prices. This has occasioned the inability of the County government to purchase land for infrastructure development. The land is required to widen the road since the majority of the current road reserves do not meet the current need and future needs. The land is also needed for availing of social amenities such as schools, hospitals and social halls as well as open spaces.

Inadequate infrastructure, resources and services are also a factor in the lack of sustainability of Ongata Rongai. The cesspool and septic tank are the major methods of solid waste disposal while the grey water is discharged in open systems and septic tanks (County Government of Kajiado, 2019). The 2002 physical development plan of Ongata Rongai failed to allocate land for sewage treatment works. The poor condition of the roads, that is the roads do not meet the carrying capacity and at the same time some of the main roads are not tarmacked. Water in

Ongata Rongai is one of the biggest challenges since the main source of water in Ongata Rongai is boreholes. The piped water in many houses is untreated borehole water which is supplied by private operators and regulated by WARMA (County Government of Kajiado, 2019). The County lacks adequate staff to enforce the implementation of plans thereby resulting in unregulated developments. Resources such as finance and human capacity needed for better management of Ongata Rongai are also limited.

Figure 33: Magadi Road (left) traffic congestion and (right) poor drainage along the road

Figure 34: Kwa Muthaura Road in poor condition (left) condition of some of the roads connecting Kware Market (right)

Interference by the justice system is another cause of the lack of sustainable land developments. During the implementation of plans such as zoning plans, the affected parties run to court to stop implementation. Many times they win against the County government and thereby derailing or stopping altogether the implementation of plans.

The lack of a mechanism to monitor and audit land development impedes sustainable development. Therefore the urban managers cannot self-revaluate for monitoring and mitigation.

The lack of mechanism and resources to support public participation is also a challenge to the attainment of sustainability. The county fails to engage the residents due to the lack of finances required to organize such meetings. The technicality of organizing meetings to acquire meaningful information needs structures that are not currently available in the county.

The Urban and cities Act has not been fully implemented due to a lack of political will. What has been achieved in this area delineation of Ongata Rongai under Ngong municipality and there is staff employed to manage the town. However, the board that is recommended has not been instituted to fully manage the whole municipality.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter summarizes the findings and provides a conclusion for the study. It ultimately gives recommendations that will contribute toward sustainable development.

5.1 Summary of the Findings

5.1.1 Environmental Dimension

Environmental sustainability was assessed by two indicators i.e. sustainable land use and an efficient and sound transportation system. These were found to be unsustainable due to the unplanned increase of urban areas that reduce vegetation cover and due to transport systems that cause air pollution as well as long delays.

The modal split for motor vehicles (public and private) and motorcycles is (77%) which is the largest share used by Rongai residents to commute to work while 60% of the children use the motor vehicle and motorcycles to school. In addition, there is an indication that Rongai does not have mixed land use since the majority of people have to move outside three kilometers (3km) radius to shop. The other modes of transport such as trains, bicycles and walking are not well utilized due to accessibility challenges and safety reasons. Henceforth, the use of motor vehicles and motorcycles as the main modes of transportation compounded with the long periods people spend on the road promote the emission of gas fumes.

Ongata Rongai experiences many types of transport-related environmental pollution among them noise pollution, emission of the harmful compound and causing of dust in the atmosphere, especially along rough roads. The use of vehicles along the dusty road raises a lot of soil particles that are released into the atmosphere and can cause asthmatic and cold to the people living along the roads. There is also noise pollution coming from the *matatu*. Some noise-induced health effects are sleep disturbance, annoyance, stress and can cause psychiatric disorders. Furthermore, the noise can scare birds, and other animals as well as interfere with

their biological processes. Heavy traffic is also experienced in Ongata Rongai, especially during the peak hours when residents are going to work in the morning and leaving work in the evening along Magadi Road. The traffic congestion increases the release of emissions of the harmful compound in the atmosphere as well as the increase of time travel as experienced in Ongata Rongai.

The land use indicator analysis showed that the vegetation is decreasing, bare ground is increasing and urban areas are increasing steadily. It is futile to stop the growth of urban areas but growth can be managed in a way that does not affect the natural environment. In sprawling areas, development grows in a scattered manner and without a plan that guides the protection of green spaces. The urban managers should encourage compact forms where densities are encouraged to prevent unplanned growth that is costly to manage.

5.1.2 Social sustainability

Social sustainability was analyzed using four indicators. These were: governance, social interaction, access to infrastructure and services and safety as well as security.

Social interaction promotes the development of social capital, community cohesion and public health research has found a positive correlation between social interaction and individual health (Fiorillo & Sabatini, 2011). Furthermore, social cohesion fosters information sharing and creates trust among the residents. Public places are a very important part of an urban area since they offer opportunities for human interaction and communication. When people interact with one another they realize that they are faced with common challenges. It is in the public space that people attain or acquire social and personal identity (Ostadnia *et al*., 2019). However, Rongai lacks public parks and social halls and there are very few open public fields for even children to play limiting the socialization areas for adults and children.

Rongai also does not have adequate amenities such as public parks and social halls to facilitate socialization. The majority have to make an effort to visit one another while others meet by

coincidence within a shared compound and by the roadside, churches, shopping centres and so forth.

Although, the neighborhood satisfaction showed that 67% of the respondents were satisfied with their neighborhood. It was also observed that these neighborhoods lacked adequate and quality infrastructure and basic amenities. In addition, the analysis showed that the roads within the neighborhood are in poor condition, with poor/no sewage system and limited public hospitals. Roads such as Helena road, 5th Avenue, Mayor Road and several others are some of the major roads yet they do not have adequate carrying capacity and are of low quality. The residential buildings normally release sewer along the road due to a lack of a connected sewer system. Therefore, inadequate access to these basic services and infrastructure may be affecting the quality of Rongai residents. Quality urban areas are assessed on access to basic amenities. Amenities such as education, health water and sanitation are very important to humans and especially in urban areas. Infrastructure such as road networks is key to the growth of cities. The social amenities should be accessible, adequate and of good quality.

Safety and security are of more concern in urban areas and increase with rapid development. Safety and security can be of concern in a wide range of areas but in this study, safety is of concern along the road and security against crime and violence in the neighborhoods. The safety and security indicators revealed that the roads' safety and security are not adequate. There is a 59% availability of pedestrian walks and a 43.5% chance that they are unsafe. 63% of respondents were in agreement that their neighborhoods are moderately safe.

The sample that participated in the research made a recommendation that the security needs to be improved. Some of the crime and violence faced in Ongata Rongai are mugging, breakage of houses and robbery with violence, especially in residential areas in the interior. They suggested the installation of streetlights, CCTV cameras, construction of police in the

neighborhood without one, an increase of police patrol and equipping of the police officers. Others suggested *Nyumba Kumi* Initiative be revived.

Governance was assessed on the level of community participation in the management of their neighborhoods. Engagement of the public in decision-making results in better governance and outcome. In addition, public participation increases the capacity of the community members to manage and solve social issues and eliminates misunderstanding. Public participation allows the views of the public to be incorporated into the decision-making. Despite the benefits of public participation, 70% of the respondents indicated that they have never been consulted by the County. Most residents have never been consulted or involved in decision-making concerning their neighborhood. The inadequate or lack of involvement of stakeholders or the community results in the priorities of the communities not being met hence not improving the quality of life of the residents of Ongata Rongai.

Despite the County of Kajiado having a Public participation Act, Odhiambo & Opiyo (2017) report that the majority of the Kajiado residents are not aware of the Act while those who are aware reported a lack of transparency, late communication of the meetings, poor planning and poor mobilization as a result of the inadequate allocation of resources to mobilize as well as some of the official not being competent and committed to the process.

Generally, the indicators show fairly inadequate security, poor interaction and low access to basic facilities, and moderate satisfaction of residents of Rongai, therefore relatively unsustainable.

5.1.3 Urban form assessment

To perform an urban assessment, land use and land cover maps were developed from the satellite images by defining spectral classes and by clustering image data and thereafter assigning pixels into classes. Subsequently, to predict the urban growth the LULC images were reclassified, resampled, validated and modeled using a CA-based tool to make a prediction. It

was concluded that the process and software could be relied upon to predict LULC change for the year 2030 since there is a high likelihood of having correct predictions.

The methods used were able to capture a spatial aspect of data such as concentration, dispersion, and spatial autocorrelation that are useful in capturing the impact of urban sprawl on urban sustainability. The three methods of calculation of sustainability of the study area show unsustainable development. The Global Moran I had a value of 0.36 which is a value close to zero indicating the scattering of urban development while Local Moran I the majority of urban areas appeared as the High-High cluster and High-low outliers indicated that Ongata Rongai will be unsustainable by 2030. The Local Moran I show that within the urban centers there was an indication of buildings being scattered shown in areas with HH and HL. In addition, the rate of urban development towards the rural is high at the rate of 8.94 per annum. The scattering of urban development with the high change of natural environment to urban areas implies the presence of urban sprawl.

Sprawl has been discouraging for its ability to be socially and financially draining. The scattered urban development requires infrastructure (sewer, water, roads and other services) and it is expensive to ensure their access. The urban sprawl has been associated with car dependency syndrome contributing to traffic delays and air quality challenges. Motor vehicles have been said to be contributing one-third to half of the smog in large urban areas (Geller, 2003). The urban sprawl is also associated with fragmentation and loss of habitat, degradation of water and air quality and destruction of wetlands.

5.2 Conclusion

The quantitative data was successfully collected and analyzed based on the dimension of environmental protection, social cohesion and good governance. Furthermore, the historical spatiotemporal image classification was done successfully and found that urban areas are

growing steadily. Validation of the model and prediction for LULC 2030 was also done to calculate the sustainability of the Ongata Rongai. Calculation of sustainability of urban development was done by using Global Moran I, Local Moran I, spatial autocorrelation, and percentage of urban growth.

The analysis of the environment, social (governance) and urban form shows that Ongata Rongai land developments are unsustainable and by 2030 it will still be unsustainable if the same trend is maintained. The study shows that Ongata Rongai is facing urban sprawl and will continue to experience urban sprawl in the future. Furthermore, Ongata Rongai is grappling with issues such as lack of adequate infrastructure and basic amenities, poor safety and security, low interaction in the neighborhood and low public participation, poor land use and an inefficient and unsound transport system. Sustainable development cannot be achieved while urban growth is poorly managed since it will be very expensive to keep up with the provision of social amenities to scattered populations. The urban sprawl also causes pollution and increases the stress level of communities due to time wasted on traffic congestion.

Table 14: Rongai's Sustainability indicators

Dimension	**Indicator**	**Rating**
Environmental	Proper land use implementation	Low
	Efficiently and sound transport	Low
Social and Governance	Access to adequate infrastructure and basic amenities	Medium
	Safety and security	Medium
	Level of Community interaction	medium
	Public participation	Low
Urban form	Level of sprawl	High

The challenges that were found to lead to unsustainable land development were; improper land tenure issues in urban areas, lack an approved physical plan, lack of political will, lack of structure and finance to support public participation, inadequate financial and human capacity to support and guide development, unregulated land markets, Interference by the judicial system in urban management and uncoordinated and compartmentalization of key urban managers.

Rongai should strive to attain smart growth by promoting compact urban form, protecting the environment, ensuring mixed developments, and providing different modes of transport. The compact urban form or densification while ensuring there is an adequate mix of activities, public space and population density is attractive to populations. When urban areas are compact they counter the tendency of sprawl growth and reduce many other externalities of urbanization while leveraging its positive dimensions. In addition, a municipality board should be instituted to manage the town. The municipality board will promote good governance and avail the required infrastructure needed to run the town as directed by the urban and cities act.

5.3 Recommendation

The lesson learned from the best practice/case studies, literature review and the findings of the interview with the key informant was used to develop the following recommendations.

5.3.1 Promotion of smart growth concept

There is the encouragement of reinvesting in existing communities, increased efficiency in the use of existing infrastructure as well as transportation choices in the smart growth concept. Furthermore, compact development is promoted with increased mixed-land use where residential and commercial are integrated. Moreover, there is the promotion of variety and safe use of modes of transportation, in particular use of walking and cycling. The compact form also promotes the preservation of open spaces, more access to affordable and quality

infrastructure and basic amenities and land that is already used for development is reused in a more refined manner.

The smart growth concept in Ongata Rongai can be promoted by developing new policies and strategies that promote urban extent demarcation, demarcation and protection of the natural environment, discourage excess subdivision of land and promote land readjustment. Demarcation of urban extent is of concern in urban areas since it helps in the attainment of sustainable cities. When urban area are allowed to continuously expand it lead to land resource utilization through extensive development while high-quality farmland and ecological land areas are changed to built-up areas transforming the land use land cover that can lead to an ecosystem that is unstable, fragile that causes chains of unprecedented ecological and environmental challenges. Therefore, there is a need to reasonably demarcate boundaries for urban development to regulate the endless growth of urban areas, and synchronize the inconsistency between urban spatial growth demand and ecological protection for sustainable development of urban areas (Pu, 2022). Ongata Rongai urban managers need to prepare a master plan that demarcates urban boundaries based on the present state of urban development in combination with suitability evaluation while in consideration of the resource carrying capacity, economic layout and population distribution. The delineated urban boundary should be a firm line that can regulate development in urban areas, offer protection to ecological space and natural resources while allowing the prediction of adequate suitable locations for future expansion when needed.

Natural resources to be protected can as well be demarcated by establishing exact measurement, registering the area as public land and fencing it where possible. Ngong forest and Oloolua forest need to be protected, including river Mbagathi and other rivers as well.

Zoning plans can be used to control the unregulated subdivision of land in Ongata Rongai. This is where land is allocated for a specific use and land requirement guidelines are issued.

However, they have been ineffective in managing urban developments on freehold tenure. The enforcement is poorly done due to political interest and interference by the justice system.

The best strategy to promote compact urban areas is promoting the land readjustment concept in Ongata Rongai. If implemented it would avail land for the construction of roads, sewer treatments and avail land for other services such as public green spaces, schools and hospitals at a low cost. This would offer an opportunity to develop and implementation of zoning plans and master plans. To implement land readjustment in Ongata Rongai, would require policy to guide the process, cadaster register and public participation. The public participation process would involve the politician in developing the policy, the land owners and the urban management team. The land owners would benefit from land readjustment by an increase in land value and access to infrastructure and basic amenities. However, some of the land owners would be relocated and land sized made smaller to reserve for road and infrastructure. For this process to take place the people will need to trust the people involved in managing the process but this can be managed by having a transparent and open process.

The urban managers should initiate and guide the process to completion. This would require them to set the objective of the exercise, engage the politicians in developing of required policy, design and develop a plan, inform and organize a meeting for the residents of Ongata Rongai. The residents can choose their representatives to represent their demands and interest. The designed plan should be shared with the residents to make it easy for people to engage and trust the process. The land should be consolidated and then subdivided according to the new plan and registered as new title deeds are issued.

Unlike the process of compulsory acquisition which the County government is finding expensive, this process should be self-financed by the land owners since they will benefit in the long run. New by-laws can be implemented such as paying land rates to generate income

for the local government that is in turn used in providing adequate services for the residents. Other types of taxes and incentives given by land owners to enforce the plans where required. One of the challenges of this model in application in Rongai is that the land within the urban areas will be costly, housing stock may also be expensive due to high demand and consumer choices of location would be interfered with. Despite this, the concept would help in the attainment of sustainable growth.

5.3.2 Instituting of Urban Management Boards

Ongata Rongai is currently managed by the County Government. There are plans to have a decentralized urban management team to be based in Ongata Rongai though they are yet to operationalize. The team is expected to work under the County government. However, sustainable development reform in the urban management institution to accommodate the proposed management by the Urban and Cities Act of 2012 need to be instituted. The Board that is recommended by the Act will be able to run the town efficiently rather than the County Government which has other interests and priorities. The urban management board would develop efficient governance by strengthening citizen participation, building financial management system, and reform urban planning and promoting the required infrastructure and services. The board is believed that it will prioritize municipal operations as well as monitor the performance of the Ongata Rongai. The institutional framework is encouraged since it reflects an administrative structure to put a balance in a degree of autonomy while allowing participation of the citizen fostering accountability and administrative integration.

To implement the institution, there is a need to develop a sound legal basis for the establishment of the boards, the counties need to be assisted in the development of a charter that will be used to guide the working procedure of the urban board and also guide the Counties on the process of managing the finance and the reporting process.

The national government has a responsibility in developing the necessary policies and regulations that will guide the implementation of the institution and financing through the National Treasury. The County Government will have the responsibility of establishing the institution, capacity building and oversight role.

The Urban management board would invest in infrastructure and services by the construction of street lighting, roads and non-motorized transport, stormwater drainage and other socio-economic infrastructure in Ongata Rongai. The Magadi road needs to be widened, Improve the streets around Ongata Rongai and also widen, the tarmac and increase the circulation of the residential road to make them more efficient and of good quality. Non-motorized transport such as pedestrian lanes and bicycle lanes would offer safety and save time.

Sprawling causes people to live far where they have to depend on vehicles in their daily lives. The urban management board would offer better planning in a way that services such as commerce, education, housing and recreation are within walking distance. This would create mobility within the urban area so that it can be easy to walk and cycle around.

5.3.3 Public Participation

There is a need for increased community involvement - more bottom-up engagement in land management issues as this has not fully been exploited in consideration of land tenure issues. In the case of Rwanda and Brunei where land readjustments were successful, this was due to the inclusion of the residents.

Inclusion of communities in the management of their neighborhood is also necessary to promote just and equitable communities. The county of Kajiado needs to fully implement the Public Participation Act so that it can be effective. Moreover, public participation should be a process that engages the residents in a series of activities. One of the activities should be to build the capacity of the residents of Ongata Rongai by training the community leaders or the stakeholders, developing the core values and sharing them with the community and looking for

forums that would be suitable to encourage more public participation. The ward and sub-county administrators should be more engaged in promoting and educating the community on the importance of public participation.

To make public participation more effective there should be transparency by sharing all material documents and information ahead of clearly and timely communicated dates of meetings. The communication can be shared on WhatsApp groups, through the Kajiado websites and engaging the civil society working within Kajiado County. There should also be timely communication of feedback to complete the process of communication. The County should budget for incentives to encourage the community member to participate in the meeting since most residents are not aware of their rights. Finally, the county government and representatives should be credible enough to earn the trust of the people.

when organizing the meetings the organizers need to communicate in time, mobilize the residents adequately and make sure that there is transparency by allowing free sharing of information.

Desired outcome	Short-term (0-2 years)	Medium-term (3-5 years)	Long (5-10 years)	Actors
Environmentally healthy and clean communities	- Development of environmental management plan. - Assessment of physical infrastructure and development of sectorial plans.	- Mapping and demarcation of riparian reserves - Avail a sewer system and sewer treatment - Avail of adequate and clean water by digging more boreholes and treating the water - Promote low-emission automotive	- Widen the roads - Tarmac unpaved roads - Provide safe pedestrian walks and bicycle tracks - Provide public parks	- Kajiado municipality council/board - Ministry of planning - NEMA - Transport sectors (KeNHA and KURA) - Ongata Rongai citizen FORA
Socially just	- Street lighting - Increasing security post - Revive *Nyumba Kumi* Initiative	- Provide social halls to various neighborhood	- Employ more security personnel - Promote social events such as cultural festivals	- County Government of Kajiado. - Kajiado municipality council/board - Ministry of security, Education and health - Ongata Rongai community (FORA)

Good governance	- Identification of different stakeholders based in Rongai. - Creating policy and guidelines for the establishment of the urban management board. - Establishment of Municipal Management board - Funding the Municipal Management Board - Creating strategic framework for collaboration and coordination between the different departments of the County	- Develop a strategy to guide the formation and organization of community members within the neighbpourhood. - Sensitization of Rongai Community to join Citizen Fora - Employ adequate staff to run Ongata Rongai. - Promote public-private partnership	- Hold frequent public engagement to create awareness, and share information.	- National Government - County Government of Kajiado. - Kajiado municipality council/board - The Members of the County assembly - Ministry of Lands
Compact urban form	- Develop a cadastre - Redesign and approve physical development plan - Development of urban policy to guide the development of urban extent. - Develop policy and regulation to guide land readjustment. - Compulsory acquisition of land for relocation where necessary	- Survey and demarcate municipal boundaries including township boundaries. - Consolidate land and the reallocate land .	- Promote density development within the municipality. - Develop a GIS system that will assist in sharing and managing information. - The regulated land market that reflects the real land value - Manage subdivision of land	- The Members of the County assembly - Ministry of land - Kajiado municipality council/board - Stakeholders- (community FORA (landowners, Saccos, Land buying companies, developers, etc)

Table 15: Implementation matrix

5.4 Recommendations for future studies

The recommendations for future studies were based on the gaps identified during this research. They include the following:

1) While CA-based simulation tools are an important consideration of their context for application need to be looked into as well. Furthermore, tools for simulation need to be improved to be able to support more accurate predictions and be able to predict cases in developing countries where urban towns grow with little control.
2) More studies need to be done on the applicability of the smart growth concept in developing countries.
3) Further research needs to be conducted on sustainability indicators in Kenya to develop all the indicators that should be used in assessing the sustainability of urban areas.
4) Lastly, more research needs to be done on freehold tenure in urban areas to support development controls.

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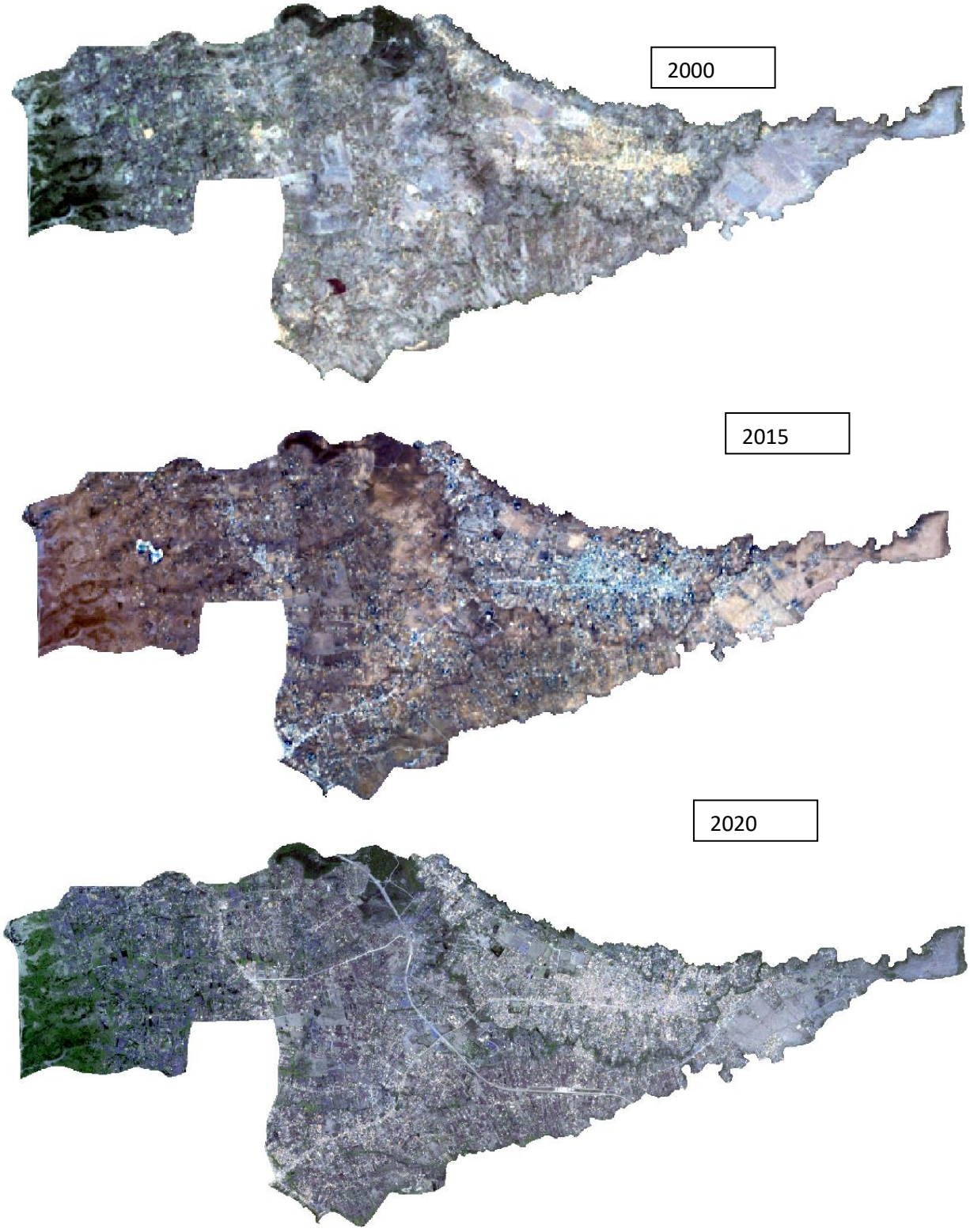
APPENDICES

APPENDIX A: Clipped composite satellite images 2000, 2015 and 2020



APPENDIX B: Aerial image showing urban sprawl in Ongata Rongai township

Source: (County Government of Kajiado, 2019)**– image was taken in 2018**

APPENDIX C: Confusion matrix to validate image classification

LULC 2000 Confusion matrix

	Ground Truth						
Classified	Bare ground	Water	Tree cover	Grass/Cropland	Built-up	Total	User's
Bare ground	20	0	0	0	4	24	83%
Water body	0	1	0	0	0	1	100%
Tree cover	4	0	20	0	0	24	83%
Grass/Crop land	0	0	0	20	0	20	100%
Built-up	0	0	0	0	15	15	100%
Total	24	1	20	20	19	76	
Producer's	83%	100%	100%	100%	79%	90%	

Overall Accuracy

Correctly classified values = 20+1+20+20+15= 76

Total value =84

Overall Accuracy (OA) 76/84 *100=90%

Kappa coefficient

$$\frac{(Total\ Sample \times Total\ Corrected\ Sample) - \sum (Column\ total \times Row\ total)}{Total\ Sample^2 - \sum (Column\ total \times Row\ total)}$$

84*76-(24*24+1*1+24*20+20*20+15*19)

84^2- (24*24+1*1+24*20+20*20+15*19)

= 6384-1742

7056-1742

4642 = **0.87**

5314

LULC 2015 Confusion matrix

	Ground Truth						
Classified	Bare ground	Water	Tree cover	Grass/Cropland	Built-up	Total	User's
Bare ground	25	0	2	2	1	30	83%
Water body	0	1	0	0	0	1	100%
Tree cover	3	0	23	0	0	26	88%
Grass/Crop land	2	0	5	27	0	34	79%
Built-up	1	0	0	1	29	31	94%
Total	30	1	30	30	30	105	
Producer's	81%	100%	77%	90%	97%	86.78%	

Overall Accuracy= 87%

Kappa coefficient = 0.82

LULC 2020 Confusion matrix

	Ground Truth						
Classified	Bare ground	Water	Tree cover	Grass/Cropland	Built-up	Total	User's
Bare ground	26	0	0	2	0	28	93%
Water body	1	3	1	0	0	5	60%
Tree cover	0	0	27	0	0	27	100%
Grass/Crop land	0	0	1	28	0	29	97%
Built-up	3	0	0	0	30	33	91%
Total	30	3	30	30	30	114	
Producer's	87%	100%	93%	93%	100%	92.68%	

Overall Accuracy =92%

Kappa coefficient = 0.91

APPENDIX D: Confusion matrix to validate images predicted

Predicted LULC 2015 confusion matrix

	Predicted			
Classified	Non-urban	Urban	Total	User's
Non-urban	42048	1667	43715	96%
Urban	1423	1072	2495	43%
Total	43471	2739	43120	
Producer's	97%	39%	93.31%	

[Commission Error]		[Omission Error]
type1	0.038133	0.032735
type2	0.570341	0.608616
[Kappa Coefficient]		0.3742
[Overall Accuracy]		0.933131

Predicted LULC 2020 confusion matrix

	Predicted			
Classified	Non-urban	Urban	Total	User's
Non-urban	29754	2044	31798	94%
Urban	2098	1652	3750	44%
Total	31852	3696	31406	
Producer's	93%	45%	88.35%	

[Commission Error]		[Omission Error]
Non-urban	0.064412	0.065867
Urban	0.559616	0.55303
[Kappa Coefficient]		0.378657
[Overall Accuracy]		0.883481

APPENDIX E: Household Questionnaire

Ongata Rongai Town Sustainability Assessment Data Collection Tool

Hello my name is Judy Kawira, a Master of Urban Management student at the University of Nairobi. I am doing a research on Assessment of sustainability in Ongata Rongai town. I would like you to kindly assist me in answering the following questionnaire with honesty and to the best of your knowledge. This is academic research and it shall only be use for related purpose. In addition, no identification is required and the respondent will remain anonymous. It will not take you more than 15 minutes. Thank you and I appreciate your effort.

To fill these questions one must be a resident of the following wards in Kajiado County: Olkeri, Nkaimurunya and Ongata Rongai ward. Secondly, it should be one person per household.

*Required

1. Date of when questionnaire filled *

Tarehe ya leo

Example: 7 January 2019

2. Q1: Where do you live *

Kata ambayo unaishi?

Mark only one oval.

- ◯ Olkeri ward
- ◯ Nkaimurunya
- ◯ Ongata Rongai

3. Gender *

Mark only one oval.

- ◯ Male
- ◯ Female
- ◯ other

4. Q2: Name of your neighbourhood *

Unaishi mtaa gani

5. Q4: Total numbers of members of household

Mnaishi wangapi kwa nyumba?

6. How many household members are over 18 years (18 years and above)

Wale mnaishi nao na wakona miaka 18 kwenda juu

7. How many household members are below 18 years (18 years and below)

Wale mnaishi nao na wakona miaka 18 kwenda juu

Occupation and transportation

8. What is your occupation? *

Unafanya kazi wapi/ kwa siku ya kawaida unafanya nini?

Tick all that apply.

- [ ] Formal employment
- [ ] Schooling
- [ ] Informal jobs
- [ ] Self employed
- [ ] I do not work but my partner do
- [ ] No source of income
- [ ] Other: _____

9. Range of income per household per month

Ukiunganisha nyote mnaofanya kazi kwa hii nyumba, ni kiwango gani ya pesa mnacho pata kwa mwezi.

Mark only one oval.

- ◯ 0-2000
- ◯ 2001-5000
- ◯ 5001-10000
- ◯ 10001-50000
- ◯ 50001-100000
- ◯ 100001 and above

10. On average, how long does it take you to get to work? *

Unachukua mda gani kufika kazini?

Mark only one oval.

- ◯ less than 10 minutes
- ◯ 10-30 minutes
- ◯ 30minutes to 1hour
- ◯ more than 1
- ◯ Other: _____

11. What mode of transportation do you mostly use to work?
Unatumia nini kufika kazini mwako?

Mark only one oval.

- Matatu
- Bodaboda
- private vehicle/motorbike
- walking (within a walking distant)
- cycling
- train

12. If you have, children what Mode of transport do they use to school?
Kama una watoto, wanatuumia nini kwa wingi kufika shule?

Mark only one oval.

- Matatu
- Bodaboda
- school bus
- private vehicle/motorbike
- walking
- cycling
- train

Availability of infrastructure and social facilities

13. What public social amenities or facilities available in your neighbourhood (within 2km radius)?

Ni vifaa ngani hapa vinapatikana kwa mtaa wenu?

Tick all that apply.

- [ ] Public school
- [ ] public hospital
- [ ] public social hall
- [ ] public parks
- [ ] Public field (where children play)
- [ ] Non is available
- [ ] Other: _____

14. Where do you mostly get water for cleaning and washing

Mnatoa maji ya kuosha na kufua wapi?

Tick all that apply.

- [ ] Tapped water from county government
- [ ] borehole
- [ ] river
- [ ] water bowsers (clean water tracks)
- [ ] water vendors/kiosk
- [ ] Other: _____

15. Condition of the roads in the neighbourhood?

Hali ya barabara zilizo kwa mtaa ziko aje?

Mark only one oval.

- ◯ Earth
- ◯ murram
- ◯ cabro/tarmac

16. What is the walking distant to your shopping centre
Unatembea kwa muda gani kwa kituo cha ununuzi

Mark only one oval.

- ◯ less than 5 mins
- ◯ 6-10 minutes
- ◯ 30 minutes
- ◯ more than hours

17. How often do you go outside your neighbourhood to shop for items (more than 3km radius)?

Mark only one oval.

- ◯ not at all
- ◯ sometimes/rarely
- ◯ once a week
- ◯ 3 times a week
- ◯ all the time /every day

Social interaction within neighbourhood

18. Are you happy with your neighbourhood?
Unapenda na kufurahia mtaa unaoishi?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

19. How would you rate the level of your interaction with your neighbours?
Eleza kiwango ambocho mnatangamana na majirani

Mark only one oval.

- ◯ No interactions
- ◯ fewer interactions
- ◯ moderate interaction
- ◯ very interactive
- ◯ They are more of a family to me

20. Where do you get to meet and interact with your neighbours?
Kwa wingi, mnapatana na majirani wako wapi?

Safety and security within neighbourhood

21. Are there pedestrians walks in the area?
Kuna barabara zilizotengewa wanaotembea kwa miguu?

Mark only one oval.

- ◯ yes
- ◯ No

22. If yes, are they safe

Kama ziko, unaona zikiwa salama?

Mark only one oval.

- Yes
- No
- not sure

23. How do you rate the security of your neighbourhood?

Unaona aje usalama wa mtaa wako?

Mark only one oval.

- Very secure
- moderate secure
- not secure

24. Do you find a need to hire third party security (private security)?

Unaona maana ya kuajili walinda usalama binafsi?

Mark only one oval.

- Yes
- No
- Maybe

25. Which tools are needed to be invested in to properly secure the community?

Ni vifaa gani ambayo vinafaa kuongezwa ili kuongeza usalama kwa mtaa?

Additional information

26. What are the level of involvement by the Kajiado County Government in management of your neighbourhood?

Ni kiwango gani mnausishwa na serikali ya Kajiado County kuhusu mambo yanayohusu mtaa wenu?

Mark only one oval.

- ◯ No involvement at all
- ◯ consulted once in a while
- ◯ often consulted before decisions are made
- ◯ Option 4

27. How can your neighbourhood be improved to make it more satisfactory to you?

Ni inafaa kuboreshwa kwa mtaa wako ili upendeze zaidi

APPENDIX E: Key Informant interview with County physical planner.

The purpose of the interview is to assess the sustainability of Ongata Rongai, Olkeri and NKaimurunya wards which are within my case study area. **An urban assessment is a strategic planning tool** that can be used to better understand and address a country's unique challenges and opportunities related to urbanization.

1) What are your views on urbanization trends and urban development in Ongata Rongai, Olkeri and NKaimurunya?
2) What plans are available to guide urban development in the three counties?
    - What is the source of financing the plans?
    - Have they been approved
    - Challenges in Implementation of Urban Development Plans
3) Institutional Capacity in management of urban areas

    - National level
    - County
    - Subcounty
4) What is your perception of sustainable development?
5) What are the Main indicators of urban sustainability?
6) What challenges are facing sustainability of Ongata Rongai (Olkeri, Nkaimurunya and Ongata Rongai)?
7) What guides development control in the three wards?

8) Do you use the following tools to control development?
    - spatial monitoring of development applications
    - level of conformity audits
9) What tools that is used to manage urban growth?

10) How can urban sustainability assessment be incorporated in the County that is if not being incorporated?

11) What are the experiences of urban planners in applying the smart city concept?