University of Nairobi

School of Engineering

EFFECTS OF LAND SUBDIVISIONS TO FOOD SECURITY
CASE STUDY: KAPUTIEI NORTH- KAJIADO COUNTY

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A project report submitted in partial fulfillment for the Degree of Master of Science in Geographical Information Systems in the Department of Geospatial and Space Technology of the University of Nairobi.

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Declaration

I, Kebaso Wycliffe Maengwe, hereby declare that this project proposal is my original work. To the best of my knowledge, the work presented here has not been presented for a proposal in any other university.

Kebaso Wycliffe Maengwe Date .....

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

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D.K. Macoco Date .....

…… Date.....

Dr.S. M. Musyoka Nyika

Abstract

Mapping land use/land cover (LULC) changes at regional scales is essential for a wide range of applications, including land use planning and food security. Farmland fragmentation is key driver of land-use changes. Land fragmentation in its extreme form can essentially limit land sustainability and food productivity. This study examined whether and how land subdivision trends affect food security for the period from 1995 to 2015. Food security parametric changes were investigated by using of Remote Sensing and Geographic Information Systems (GIS) in Kaputiei North of Kajiado County. Firstly supervised classification technique was applied to Landsat images acquired in epochs of 5 years starting from 1995 to 2015. Image classification was carried out by using maximum likelihood classifier algorithm with the aid of ground truthing data obtained from topographic maps and ground visitations. The second part focused on land subdivision trends of various categories within the time frame. This was equally applied to production and population statistics of livestock in the study area over time.

The results indicate that there has been a significant increase in settlements as a function of land fragmentation/subdivisions with corresponding decrease in food production. This affects the food security situation in Kaputiei North. Severe land cover changes have occurred in rangelands (-8.2% especially in Northern Areas), Settlements (6.2%), and Bare land (2.0%). Equally, subdivisions of less than 1 hectare have increased by 411% while those of over 100 Hectares have reduced by 89%. In the same period, meat production from cattle, sheep and goats has reduced by 78%. The study therefore concludes that uncontrolled subdivision of land in Kaputiei North is leading to land use change from agricultural to urban and this is severely affecting food security in both the short and the long term.

Dedication

I dedicated it to God Almighty who has enabled me with good health and intellectual capacity to accomplish this project. Equally I dedicate it to my loving wife, children and parents for prayers while working on the project.

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My profound gratitude goes to the Department of Geospatial and Space Technology for making it possible and necessary to pursue this course. My deepest appreciation goes to my supervisor Mr. D. K. Macoco for the constructive suggestions, criticisms, encouragement and contribution throughout the research period. My sincere thanks goes to Dr. D. N. Siriba for his insightful contribution and positive criticism which shaped this work to what it is now. , Heartfelt thanks to Kajiado Agricultural Department for the information and data extended to me. I am also grateful to Mr. Swalah of Department Of Planning in the County for the assistance with necessary data. Let me thank our able Class Representative Ms. Ambani for the sacrifice she made to ensure we had the updates on what is required from us.

Special thanks to my family members. My deepest gratitude goes to my spouse Eucabeth for the prayers and humble time during the study period. To my children, Trevor Faith and Velma for understanding that dad needs humble time to carry out his study. Finally, special thanks goes to my parents for all they did to bring me to this level, and more especially for their never ending prayers.

Finally I would like to thank all those whose contribution enabled me to study at this level. Without them this research would not have come to completion.

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List of Acronyms

ASAL……. Arid and Semi-Arid Land

FAO…… Food and Agricultural Organization

GDP…… Gross Domestic Product

GIS……. Information Systems

GLOVIS……. Global Visualization Viewer

GNP……..……. Gross National Product

GPS……...……. Global Positioning System

KMC……...…...…… Kenya Meat Commission

LULC…….…… land use land cover

NGO…….…..…. Non-Governmental Organization

RVF……...…... Rift Valley Fever

SOK……...…… Survey of Kenya

SSA……..……. Sub-Saharan Africa

USGS…….……..……. United States Geological Survey

SLC..... Scan Line Corrector

CHAPTER ONE: INTRODUCTION

1.1 Background

Land is a precious resource. According to Food and Agriculture Organization (FAO, 1985) estimates, almost 80 percent of the world's undernourished people live in rural areas and most depend on agriculture, including livestock, for their livelihoods. Land also secures the production of food for people directly or indirectly involved in agriculture. Land is also needed for a myriad of other purposes, including infrastructure and human settlements. At the same time, land is a finite resource. There is substantial evidence that access to land for the rural poor is essential for food security and economic development in developing countries. Such evidence applies to a large number of different countries and socio-economic situations. The basic assumption that access to land is an effective tool for poverty reduction is shared by international organizations, researchers and Non Govermental Organisations (NGOs).

In developing countries, most farm plots are relatively small. Reports from different countries indicate that the average size of a land holding in developing countries is between half a hectare and 12 hectares. While the majority of farmers in developing countries are small-scale farmers, the latter do not hold the biggest share of agricultural land. Instead, a major share of land is in the hands of relatively few landowners. One consequence of this is that size and distribution of land varies quite widely just as population density which ranges from as low as 2 persons per square km, in the Arid and Semi-Arid Lands (ASAL) to a high of over 2000 in high potential areas. This leads to uncontrolled subdivision of peri-urban agricultural land, hence a likelihood of food insecurity.

Food insecurity and hunger are widespread in Sub-Saharan Africa (SSA). Food security implies the provision of safe, nutritious, and quantitatively and qualitatively adequate food, as well as access to it by all people. The chronic food insecurity in SSA is largely due to the fact that 85-90 per cent of agriculture is rain-fed and accounts for 35 percent of the region's gross national product (GNP), 40 percent of exports and 70 percent of employment. With the global urban population of 3.3 billion and predicted to double by 2050 (United Nations, 1990), the associated urban dynamics will affect natural and human systems at all geographic scales (Miller and Small, 2003). City administrators, confronted with this growth, increasingly need to manage urban dynamics for example through urban planning.

Land is a limited resource and its distribution as well as tenure structures are viewed as key issues in nation's food security strategy. Land tenure systems affect agricultural productivity by influencing the efficient use of inputs and adoption of modern technology. The development of agriculture sector is very much urgent for poverty reduction and sustainable development of the country. Notwithstanding the remarkable success of the land reform process in Kenya, land fragmentation and subdivision is emerging as a side effect with detrimental implications for private and public investments, sustainable economic growth and social development.

1.2 Problem Statement

There is adequate knowledge about drivers of land use change and their potential influence on food security. Although the world food problem has always existed, its magnitude has changed because the number of people in the world is increasing rapidly and this is occurring at a time when suitable land for cultivation and livestock farming is rapidly diminishing. This situation appears grim all the more because the land's capacity to produce is ebbing away while the majority of the population in Africa continues to depend on land for their livelihood (MacNamara and World Bank, 1985). While a number of processes determine the size of farm holding, family size is perhaps the single most important one.

Urban sprawl from Nairobi ity has also led to a substantial pressure on agriculture land in Peri-urban areas including Kajiado, Machakos, Kiambu and Thika. The effect of this sprawl is most evident in land use changes leading to conversion of agricultural land to residential/commercial use. Although Kenya seems to have done well in agriculture, the country's production has fallen well behind the rapidly increasing population. It is even predicted that over time, 60 per cent of Kenya's peri -urban agriculture land will not contribute to the national economy due land degradation resulting from fragmentation (Museleku, 2013)

In many farming societies, the amount of land available to the farmer is of great importance, particularly where the main factors of production are land and labour. The uncontrolled subdivision of group ranches in Kajiado has resulted into smaller units which cannot support sustainable livestock farming. The population is increasing with no commensurate increase in the agricultural area. Farms may get smaller, and when continuously subdivided, they become economically unviable (Sklenicka, 2016). Land subdivided into overly small parcels has

considerably lower value in agricultural production, since this value decreases with parcel size. Subsequently, that farmland is devalued simply through the physical division of parcels, even when fertility and other relevant attributes influencing land value are held constant.

1.3 Objectives of the Study

Main Objective

The main objective of the study is to establish how land subdivisions trends have influenced food security in Kaputiei North, Kajiado County.

Specific Objectives

i. To evaluate how land subdivisions influences land use changes in Kaputiei North of Kajiado County.
ii. To establish how land subdivision changes are affecting livestock production
iii. To demonstrate how livestock farming is contributing to food security in the area.

1.4 Research questions

1. What are the major causes of land fragmentation/subdivisions in Kaputiei North, Kajiado County?
2. How have land use trends lead to land use changes?
3. How do land subdivisions affect livestock farming in Kaputiei North of Kajiado County?
4. How has land subdivisions affected food security in the County?

1.5 Justification for the Study

Kenya is not food secure since 16 per cent (about five million) of Kenyans are forced to survive on relief food almost every year. It has been argued that land fragmentation has created uneconomic sizes of land that cannot even assure the relevant farmers adequate food for subsistence (Karangwa, 2007). This kind of farm sizes has proved to be not economically sustainable to livestock farming especially beef cattle. Lack of land use plan has left any person with title deed to use the land whichever way one wishes with little regard to how sustainable that use is.

1.6 Significance of the Study:

County Government of Kajiado

This study will help both the County and National Government to identify key areas that need to be addressed to ensure food sustainability in the country. The study will equally help in the improvement of land management and administration to ensure prosperity and posterity.

Government

The study will propose bench - marking activities of current procedures and practice of land management key to the implementation land control procedures and poverty reduction in Kenya. The government shall be capable of up with nation land use policy as mitigation factor to planning.

Researchers

The quality and the opportunity of information held will influence the strategic decision process, and have a major impact on the future research activities in Kajiado. These includes key Information on sound land planning, livestock farming and food security in general.

1.7 Study Area

Geographical Position and Size

The study area is Kaputiei North in Kajiado County. Kaputiei North was a division by the 1979 population census covering an area of approximately 653Km^2.currently it is a ward and doubles as registration section in the Kajiado County. Part of Kitengela town is in Kaputiei North registration section and borders Machakos County to the east. It has Kitengela registration section to the north west, Kipeto and Kisaju Registration sections to the west and Kaputiei Central to the south-east, Dalalekutuk to the south and Ildamat to south west. It is located between coordinates 9798000m and 9837900m north, 254550m and 292000m Easting based on Arc Datum 1960 reference system UTM. In geographical coordinates its Located between lattitude -1^0 49’32” and -1 27’ 54” ; longitude 36^0 47’ 37” and 37^0 07’ 48” East.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Production from pastoral areas contributes considerably to food security and use of land sustainably and maintaining landscape-level environmental services, this will have benefits to ecosystems, biodiversity, as well as other land users who otherwise will most often not fully recognised (Wade, 2013).

To ensure production in pastoralism will be sustained continually and buttressed as revenue source in future can only be achieved by maintaining free movement and flexibility as significant approaches. Due to heterogeneity of ASALS these different approaches will be necessary as livelihood. The potential of fostering pastoralism investment is recommended to undergo some evaluation if or how they measure up to rules of engagement. These engagement rules promote three critical components of pastoralist source of income namely, flexibility, landscape-level planning and mobility (Wade, 2013)

This process of excision and subdivision is not always recognizable, but can have far reaching repercussions to pastoralist livelihoods. Emphasis on crop agriculture as means and interventions towards increasing food security will have negative effect on pastoralism and consequently food security, in ways policy makers will hardly notice. Addressing food security from crop agriculture point of view will negate the importance of pastoralism production towards maintaining existing food production levels in areas having marginal productivity. As agriculture expands into arid and semi-arid areas that are cumulatively suitable for use in large-scale communal ownership, the benefits realized as result of agricultural expansion may impact negatively to the pastoralism due to loss of important land resource that promote production in pastoralism (Flintan et al, 2013).

The fragmentation of land in dry landscapes has led to a series of social and environmental impacts which has caused decline in food production from pastoralism hence having a bearing on food security and the ecosystem services. The subdivision of rangelands have resulted into increased sedentarization of mobile livestock keeping populations, and resource fragmentation leading to a decline of resource base hence decreasing the capacity of sustaining the livestock and wildlife populations (Van De Molen, 2014).

Subdivision of land into smaller units often results into less viable land portions in dry lands. Since less humid areas rely on a mosaic resources which are accessible. These resources comprise of more humid areas, rivers and swamps spread all over drier areas. For the success of pastoralism the resources need to be accessed through a strategy of flexibility and ease of movement (Ekwe, 2011).

2.2 Food Security

Food security is a relatively old topic which can be traced back to the Hot Springs (USA) Conference of Food and Agriculture in 1943. Since then it has undergone several redefinitions. Food security is defined as when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life as per 2008 World Food Summit (FAO, 2008)

On the other hand food insecurity is a situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life. Any analysis of food security will scrutinize whether there is a change from security to insecurity and vice versa. Factors contributing to a state of food insecurity include improper utilization, non-availability of food, and instability over a certain period of time and lack of access. The World Food Summit of 1996 came up with objectives the main one being the fight against food insecurity.

The United Nations Food and Agriculture Organization (2010) State of Food Insecurity assesses that nearly 1 billion people are estimated to be undernourished, which represents almost 16 percent of the population of developing countries. Although the strong commitment of international institutions and the efforts conducted to reach the objective to half, within year 2015, the number of people suffering from hunger, food insecurity still represents one of the biggest challenges for a big part of the world population and must be treated with the utmost urgency (Napoli et al, 2011).

It been found out that one billion individuals who are food insecure comprise small-scale farmers residing within rural environs, mainly women and children. There exist approximately half billion small-scale farms world over that are known to support a population of over 2 billion. This figure amounts to one third of the world's population most of them exist in many developing countries predominantly in Africa and Asia, who are small scale farmers. Most of these farmers are women producing eighty percent of the food for

subsistence. There is enormous potential from these small family based farms towards making agriculture key driver for both sustainable economic growth and poverty reduction (Agency, 2008)

The 1943 conference quoted above evolved the concept of a "secure, adequate and suitable supply of food for everyone" This concept was subsequently taken up at an international level. The next step was the setting up of bilateral agencies by donor countries such as the USA and Canada in the 1950s whereby their agricultural surpluses would be shipped overseas to countries in need. By 1960s there was a growing realization that food aid could actually hamper a country's progress to self-sufficiency and thus was born the concept of Food for Development and in 1963 its institution namely the World Food Programme (WFP).

However, the era of an abundance of food was coming to an end and the 1972-1974 food crisis marked the beginning of fluctuating food supplies and prices. To counter this, insurance schemes were set up to guarantee access to food supplies and this led to enhanced coordination among donor organizations and improved monitoring of the situation on the ground in receiving countries. According to FAO, 98 percent of the world's hungry live in developing countries (Napoli et al, 2011).

It is been found out that successful domestic agricultural sector has played a very key role in achieving sustainable and complex economies. For long time the agricultural sector has been the source of income to poor people in rural areas of Africa. For example almost tree quarter of the population is rural. According to the World Bank the GDP growth based on agriculture is several fold effective in eradicating poverty than GDP growth originating outside the agricultural the sector (Agency, 2008)

2.2.1 Factors Affecting Food Security

The array of population growth, climate, and scarcity of water resource and land degradation has undeniably impacted on food security and global food production. It is worth noting that the major sources of global food insecurity range from disasters to hostile climatic conditions. The crisis has been further stimulated to greater levels by man-made disasters (Premanandh, 2011).

New technologies have been beneficial in providing means of addressing food security challenges and in turn sustain the global populace. It has been pointed out that, political will and appropriate structures to aide investment on new agricultural techniques may reduce food

scarcity common to developing countries. Numerous interventions have been focused on developing countries which are directly related to sound structure in governance, there is every necessity to have political interest delinked inorder to serve mankind with minimum basic needs such as food (Premanandh, 2011)

2.2.2 Livestock and Food security

The access to adequate food for a healthy and active living amounts to food security. Livestock can have enormous contribution in attaining food security. The main indicator of quality life associated with human development and welfare is sufficient amount of nutritious and balanced diet. Food from Animals contain high quality proteins, micronutrients, vitamins and minerals. The animal protein has greater value in diets and is very crucial since it contains vital amino acids that are lacking in cereals. Consumption of even a small quantity of animal products corrects amino acid deficiencies in cereal-based human diets thus allowing more of the total protein to be utilized because animal proteins are more digestible and also absorbed more efficiently than plant proteins (Sansoucy et al, 1995).

2.2.3 Land Tenure and Food Security

An indication of a strong link existing between food security and land tenure is evident. This connection is often defined by the security in land tenure which promotes investment in farming, land utilization and improvement. The improvements will in the long run lead to increased productivity. Improved production could supplement either revenue gained from selling produce harvested or the amount of food consumed within the home-based. The former could be instrumental to the household in purchasing food. The intensification in land tenure will therefore address by making each household food secure. In the County of Kajiado many factors contribute to insecurity of land tenure. These factors range from inadequate land for grazing, land degradation, land conflicts and customary land rights affecting women.

2.3 Pastoral Livelihood Cluster in Kenya

The counties that are practicing pastoralism comprise Isiolo, Narok, Kajiado Tana River, Turkana, Mandera, Wajir, Marsabit, Samburu, Garissa, and Moyale. These areas are prone to dry spells and experiencing variable rainfall. Lately the duration of droughts in these regions has become more frequent and longer over the past 10-15 years. The annual precipitation ranges between 250 mm to 400 mm hence very low. The major economic activity is pastoralism which is characterized by mix of nomadic, fully settled and semi-nomadic.

Livestock is the backbone of livelihood to Households because they act as a source revenue through selling of milk and live animals. In the dry lands, the livestock being major economic activity contributes up to ninety percent of jobs and generates in excess of eighty percent of earnings (Ng'ayu, 2009).

Crop production only accounts for the remaining twenty percent of the income. The prospective for diversifying into other alternative livelihoods like business or crop production is hindered by poor accessibility to ready markets for both inputs and outputs, limited technical know-how, skills and lack of reliable water (FAO, 2008).

2.4 Declining Farm Size and Related Land Tenure Issues

Land accessibility in Kenya as in utmost parts of the developing world is crucial as source of revenue to majority of the population, mainly in the ASALs where majority households lack legal title for their land. There existed National Land Policy which was approved when the country became independent in the year 1963 until the year 2009 when the National Land Policy was enacted. A complex land administration system and management has therefore resulted from existence of many incompatible land laws and lack of national policy.

Limited productivity in land and similarly minimal investment in land improvement in some parts of the country has resulted mainly due to insecurity in land tenure systems. Also, customary land holding systems is still practiced and not integrated into the formal systems of land ownership. Sources of insecurity in land tenure range from land grabbing, conflicts over land mostly involving neighboring communities and exploration by the State or Local Government. The intent of the National Land Policy of 2009 was to solve some of these issues presented by preceding land administration which was mainly concerning inharmoniousness of the land laws. The Continuing land fragmentation and reduction holdings have hastened the movement of households from agricultural productive areas to less productive regions of marginal agricultural potential.

The land holding per household ranged between 0.405 ha to 2.02 ha. Also, most large estate farms which were known to produce seeds and stock for breeding have undergone subdivision and transferred into individual ownership. Lands owned mainly by foreign and national corporations presently are the most expansive and consolidated ones (Arveti et al, 2016). Changes in land use have been caused by demographic and economic changes in recent past which have in turn led to most effects on food availability and production as well. Livestock

territories and productive arable land is progressively being converted into residential areas due to rising urbanization. Consequently, augmented human-wildlife conflict and environmental destruction becomes reality.

Land use configuration gives impression of a socio-economic situation of a country. For example, in a society that creates pressure on natural environment, the land use changes design can meet the vibrant demand as evident in Bangladesh. The result of these various disagreements takes place in natural system (Yuan and Sawaya, 2005)

The main challenge facing agricultural land in this perspective is the changing pattern in land use. Different scholars define the term land use differently. It has been understood as a formation of the natural potential of land on one hand, expertise and its physical requirements on the other and interactions between society's social and cultural background. Land use is also defined by men's activities on land, which are directly related to land. The latter is a subset of the previous (Ekwe, 2012). Land use is regarded as the inputs by people, activities and arrangements to maintain a definite land cover type or produce noticeable change.

2.5 Livestock Trends

Livestock production in the rangelands have been declining overtime due to myriad of activities on land by man., most data sources and research have shown strong indication of production of all types of livestock has been fluctuating and declining between the late 1980s and 1990s and rising thereafter in the country. For instance, FAO (2000) attributed this decline from figure of approximately 14 million in the 1990s to 11.5 million in the years 1997/1998, to a Rift Valley fever (RVF) outbreak. Stocks started to recover as from 1999 but decreased again in 2000/2001 due to severe drought. FAO (2008) found out that after the 2000/2001 drought, cattle stocks increased progressively until 2004, when the population showed signs of stagnation, which eventually dropped to about 12.5 million in 2006 due to the drought again between 2004 and 2006. Another outbreak of Rift Valley Fever (RVF) in 2006/2007 which rose dramatically, peaking at about 18 million in 2010.

Dry lands in the country account for more than 50 per cent of the livestock population which are the mains source of meat producing regions in the country, this accounts to about 7 per cent of the country's GDP and 17 per cent of the country's revenues from agricultural. In terms of acreage ASALs covers approximately 48.2 million hectares which translates to over 80 per cent of total land area of the country.

Fragmentation of land that is of low agricultural potential has brought about numerous challenges to policy makers and users of rangelands, in Africa and beyond. It is worth noting that that where subdivision does not necessarily result effective and efficient use of land resource, an unanticipated problems have occurred which are evident in East Africa. There are Lessons learned from rangeland areas that have experienced fragmentation offering valuable insights into the outcomes of transferring private property rights to areas that would arguably be more productive if defined by a system of communal property ownership (Ngethe, 1994).

Food insecurity in country for long has been associated with the rural populace and hence seen as rural problem but urban inhabitants are equally food insecure. An estimated 40 percent of the urban population resides in slums, with low and variable sources of income. Unplanned settlements are cropping up without the corresponding services to meet basic food and non-food needs. Almost half have no access to safe drinking water and sanitation coverage is very poor. In the future, growth of urban centers may benefit the economy, leading to decreased poverty rates and greater economic opportunities, but only if critical investments in urban infrastructure are made.

2.6 Threats to the productivity of drylands

The drylands and pastoralist production are threatened by excessive fragmentation of land and land use changes resulting in subdivision of resource. These dynamic forces often have adverse effects on mobility and flexibility approaches required by pastoralists. Subdividing of land into smaller, individualized parcels is both a symptom and catalyst of the menace posed by land use change (Ekwe, 2011). The expansion of the agricultural activities into drylands is proving to a key driver of this dynamics in land use. Pastoralist livelihoods should be protected from excision and alienation as key resource of rangelands known for natural pastures by privileging on crop agricultural production(Flintan et al, 2013).

2.7 Women and Land

In Kajiado County, women are key pillars in agricultural production and they play critical role, but are affected most often by tenure insecurity. The accessibility to land is defined by marriage. Women are known to practice rotation mixed farming where staple crops are cultivated which replenishes nutrients in the soil.

2.8 Land Degradation and Insufficient Land

The average pastoralist in the County cultivates land sizes ranging from three to six hectares, the rate at which land is degenerating has created a worrying trend where rangelands due to population pressure, are excised for agricultural expansions.

The rate at which group ranches land are subdivided and converted into crop farming is alarming, such that by the year 2060 it will have hit the limit, (USAID, 2009). The factors influencing this trend range from proximity to Nairobi city, population Growth in the County and its environs which has an annual growth rate of 3.06% and double digits are evident in every new generation. More people need more land to farm in the rural livelihood and no alternatives are available. Vulnerability to food insecurity according to (FAO, 2009) is contributed by cultivation of small holdings in agricultural areas by subsistence farmers, where off-farm economic activities are scarce.

Soil barrenness and climatic variability have lead to undependable harvests, making farmers to increase the land acreages through additional fields. It is becoming impossible to produce as much food as it was once done by smallholder farmers on the same amount of land due to diminishing of the soil fertility. It is due to this reason that farmers in Kajiado County are opting to clear vegetation for more land to cultivate. As a result of small farmers depending on rainfall that has increasingly become erratic for farming, poor harvests have been realized (United Nations, 1990). When more land is addedto cultivation, this it complicates the livestock farming further.

It is often common in sub-Saharan African countries that fallow land that was being rested to improve its fertility or land that was used for gathering wild food or similar products and grazing is cleared for additional fields. Therefore, not only rural people are losing their traditionally used supplementary diets like wild foods but also its fertility is declining and equivalently more marginal land is under cultivation. Unrelenting clearing of land and soil exhaustion are the result the vicious cycle (United Nations, 1990).

2.9 Land Conflict

A significant contributor to land tenure insecurity is land conflicts. The reason being the insecurity faced by land users or owners including fear of losing their rights to that land (Linkow, 2004). Increasing competition for land in Kajiado is largely related to land conflict.

Some causes of the competition include pastrolists starting to cultivate staple crops, they are also adjusting their livelihood strategies by settling permanently and are as well struggling to find adequate water and pasture for their animals. The amount of land under cultivation is therefore increasing due to this and other factors. Often people from urban areas are entering the agriculture sector as "new actors" hence acquiring large parcels of land for commercial agricultural production mainly for export. As an approach to understand the land use changes from pastoralism and settlement it essential to integrate remote sensing and GIS technologies to map out and analyse the land resource.

2.10 Remote sensing

It is the science, and to some extent art. of acquiring information about the Earth's surface (remotely) without direct contact (Dušan et al, 2015). The satellite development improves the possibility of collecting remote sensed data and it offers a good way for obtaining the information over the wide open areas. The capacity of the remote sensing to identify and monitor the earth's surface and the natural conditions has increased dramatically in the last few years and the remote sensing data have already become, the crucial instrument in natural resource management. Satellite imagery acquired through remote sensing has remarkably given scientists a way to determine the reasons for the consequences resulting due to human activity and land use/land cover changes.

2.10.1 Image classification

The process of assigning pixels pre-defined land cover classes in a continuous raster image is known as image classification. Thematic maps can then be created from the resulting raster from image classification. Two classification types namely unsupervised and supervised are possible depending on the interaction level between computer and the analyst during classification process (Nayan et al, 2016). Satellite images used in this study are between the months of April and May for 1985, 2000, 2005, 2010, and 2015. These months are known for the rain season. Also during those months vegetation is in its optimum which allows better classification of images.

Training samples are used to obtain spectral signatures which are then used to classify an image under supervised classification. Image Classification toolbar assist one to easily create training samples representing the classes to be extracted. Each pixel in the imagery would be

compared spectrally with the training samples to determine to which information class they should belong (D Lu, 2007)

In a supervised classification, the analyst selects and digitizes polygons (training areas) and places these polygons in an AOI (Area of Interest) layer from which to create the signature files rather than using an automated routine to define the most separable classes.

Someone is "telling" the computer precisely how a specific class "appears" when creating signatures. The summary statistics from the signature areas are used by supervised classification algorithm and every pixel in the image is matched to one and only one signature. The most similar signature for each pixel can then be discovered by the computer at one pixel at a time and allocated a signature class. For as clear distinction of each class as possible, the signatures must be explicit enough. For all of the pixels to be accommodated into at least one class, It is realistic that the classes range should also be comprehensive enough.

2.10.2 Landsat imagery

Landsat satellite imagery is a multidisciplinary analysis image from which more information about the earth can be obtained. Geomorphology, soil science, geology, hydrology, forestry and land use/land cover can be analyzed using Landsat images.

The Multispectral Scanner (MSS) sensor was used in Landsat 1, 2 and 3 satellites while both the Thematic Mapper (TM) and MSS sensors are present in Landsat 4 and 5 satellites but the Enhanced Thematic Mapper Plus (ETM+) sensor is only present Landsat 7 satellite. The delivery of quality remote sensing data to support applications activities and research which is the Landsat Project's mission supported by all these sensors. The Landsat imagery has many advantages namely:

- It covers a large area. Each Landsat scene covers an area of about 34000sq.km
- The swath width of Landsat ETM and TM sensors is 185 km and completes coverage with only 233 paths. Common rows are shared between MSS and TM scenes but the paths will be diverse in most cases with repetitive coverage. Changes in land cover over time can be studied.Computer compatible data. Landsat data can be digitally processed by a computer in order to produce images that are easier to interpret.
- Landsat images can be easily obtained from any of the regional remote sensing Centre
- Landsat image s has a spatial resolution of 30m meters which makes it good detail interpretation

The main limitation of Landsat imagery is that the cloud cover makes it difficult for interpretation. Misinterpretation of objects of similar spectral response from different objects and dissimilar spectral response from similar objects results in wrong interpretation and wrong identification of features.

Mid 1980 is the year when landsat Thematic Mapper (TM) mission began with Landsat 5 still in operation currently. Seven 30 meters spatial resolution spectral channels feature in this sensor. The year 1999 marked the commencement of the Landsat 7 Enhanced Thematic Mapper (ETM) mission which is still in operation. It has the same spectral channels as the TM sensor but with an additional 15 meter panchromatic channel and a second thermal channel. ETM scan line corrector failed on May 31, 2003 hence leading to ETM images missing large portions each scene since that time. The use of these images is generally not recommended and are designated as SLC-Off according to **Selçuk Reis sensors paper** On USGS sites (USGS GLOVIS website)

2.11 Land Tenure

Rules are invented by societies to regulate behaviour in land tenure because of it being an institution. Assignment of property rights to land within societies are based on rules of tenancy. They define how access is granted to land rights like restraints, associated responsibilities, transfer, control and use. In nutshell, tenure systems of land determine under what condition, for how long and who can utilise what resources. The categories of land tenure are:

Private: Rights to a private party assigned to an individual that can be a corporate body such as a commercial entity, a group of people, married couple or non-profit organization. For instance, individual families within a community may have exclusive rights to certain trees, agricultural parcels and residential parcels. Consent of those who hold the rights is required by other members of the community who are excluded from using these resources.

Communal: It may exist within a community where a right to utilise independently the holdings of the community is granted to individual member. An example is granting right to graze cattle on a common pasture by members of a community (**National Land Policy, 2009).**

Open access: No one can be omitted because specific rights are not assigned to anyone. The high seas are generally openly accessible to anyone is an example from marine tenure. May also include forests and rangelands where resources for all may be free access. “An important difference between open access and communal systems is that under communal system non-members of the community are excluded from using the common areas”.

State: Authority in the public sector being assigned the property rights. An example is like some countries that whether at a decentralized or central level of government, Forest lands may fall under the obligation of the state (**National Land Policy, 2009).**

Most forms of holdings in practice may be found within a given society, like state ownership of forests, agricultural holdings, private residential and common grazing rights. Classically the customary tenure includes exclusive private rights to agricultural and residential parcels together with communal rights to pastures. Formally recognized rights in some countries to such customary lands are bestowed in the State “in trust” for the citizens.

Certain piece of land can be set aside to be communally owned as a group ranch by a group of people registered and documented as the legal owners through being particular group ranch members. Non-members are prohibited to bring their animals to graze there and livestock movements are constrained within the group ranch's specific boundaries unlike in the past. Attempt to introduce the commercial system to radically change the existing production of nomadic subsistence orientation into the Maasai pastoralist which is more sedentary through bull fattening and the provision of credits for infrastructural development.

The market oriented system was geared towards addressing food needs through providing meat for the international and national market and similarly destocking of Maasai pastures (Glaeser and Ward, 2009)

The Kajiado District group ranches initiated the construction of facilities like cattle dips, pipelines, tanks, troughs, dams and boreholes together with adoption of livestock management techniques. They were also effective in stopping educated elites of Maasai from allocating huge chunks of former communal land set aside as individual ranches to themselves. Similarly, group ranches inspired the building of health centres, shops and schools. Continuous free roaming of wildlife over large parts of Kajiado County is said to have been achieved through the allowing by the group ranch development.

2.12 Subdivision

It is the process of dividing a land parcel into smaller portions from a larger block. It is aimed at splitting a large tract of land into smaller ones that can be developed independently of one another and are easier to develop in order to maximize the use of space and increase growth. The zoning process and selling off of the land is speeded up also by this tool. Subdivision developments are quickly swallowing many rural areas as the city expands. This type of growth is often kept by the local authorities from destroying the local areas. Subdivisions is driven by a need for affordable housing hence occurs at a rapid pace in most cases. The unfortunate side effect of growth in a community is often considered to be the subdivision growth.

TheGovernment in the early 1980s did not respond to the subdivision of group ranches in Kajiado County and no clear position was taken because the individual departments were in dispute with each other and the administration itself had doubts. Generally, it was claimed by those opposing the subdivision that the ultimate result would be decrease in livestock to the detriment of the meat production and tourism attraction functions of Kajiado County, restriction of the movement of wildlife, the loss of Maasai culture, the creation of severe soil erosion in areas where cultivation was to start and the alienation of land to the non-Maasai (Rutten, 1995).

Those who were of the view of group ranch subdivision claimed that it would facilitate better maintenance of the existing infrastructure, promote Maasai engagement in agricultural with industrial, minimize the exploitation of the poor by rich households, boost the ability to procure a loan using the freehold title deed as collateral, raise standards of living and help self advancement and enterprises.

In the entire County more than 40 group ranches were in support of subdivision. Kaputiei North in particular had individual ranches and group ranches. Olkinos and, Embolioi are group ranches within the registration section which were subdivided into individual ownership. In Olkinos the average subdivision was on the range of 46.7 ha and Embolioi was around 93.4 ha. The numbers of subdivisions in the entire Kaputiei North after the initial subdivision were in the range of 1200 parcels and most of them over 50 ha. Upon acquiring the titles, the members further subdivided and sold to land buying companies and individuals who largely bought for speculative purposes (Rutten, 1995)

CHAPTER THREE: METHODOLOGY AND MATERIALS

This section presents the methodology that will be used to design and analyze the data derived from the study. It includes research design, the target population, sampling and sample size, data collection and analysis techniques.

3.1 Research Design

The research design adopted in this study will be a descriptive design study involving factor analysis. A descriptive design research portrays a good profile of persons, events or situations. This design was adopted to establish how two main aspects namely that land subdivision and livestock production affect food security.

3.2 Population

Target population denotes to all the members of a actual or hypothetical set of individuals, objects or events to which the research wishes to generalize the outcomes of study (Kothari, 2004). The targeted population of this research will comprise of approximately 40,000 subdivisions in Kaputiei North registration section and the corresponding livestock numbers and production over time in the area of study.

3.3 Sampling

Having set the target population of this study to be 40,000 parcels (forty thousand) which is comparably small, census method will be appropriate to obtain the information required from the lands Survey Department Kajiado. Based on this and taking into account the small size of the population, the data shall be collected from the whole population (Kothari, 2004). The Census method shall be adopted because it has the advantages such as the researcher is able to bring the real information from the sample, more convenient to the researcher as all the respondents can be reached.

3.4 The Study Area

Historically, the study area was a large-scale beef farming area owned by locals communally. However, this changed when land ownership changed hands in the 1970's and 1980's and consequently, when African land-buying companies bought the land and sub-divided among their members (Ng'ayu, 2009). Most of Kaputiei North lies in the semi-arid and arid zones only 2% of the land is classified as having some potential for rain-fed cropping, mostly around the Konza Techno City. Mean annual rainfall ranges from low of 300 to 800 mm. Precipitation is bimodal, with "short rains" from October to December and "long rains" from March to May. The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado County.

There are no permanent natural sources of surface water in Kaputiei North hindering agricultural sustainability. The registration section is well served by a network of all-weather roads. In addition, numerous roads that are passable in the dry season penetrate the interior. This network effectively links the urban and trading centres and public transport is quite readily available. By virtue of its proximity to Nairobi, Kaputiei North is able to supply meat to major consumption Centre. The livestock marketing system is well developed for cattle. From the 2009 population census, the population of the study area is 92168 (Male – 52%, Female – 48%) with population density of 85 people per square kilometre. The number of households is estimated to be 29000. Figure 3.1, is a map illustrating the location of study area with respect to Kajiado County and Kenya.

Study Area

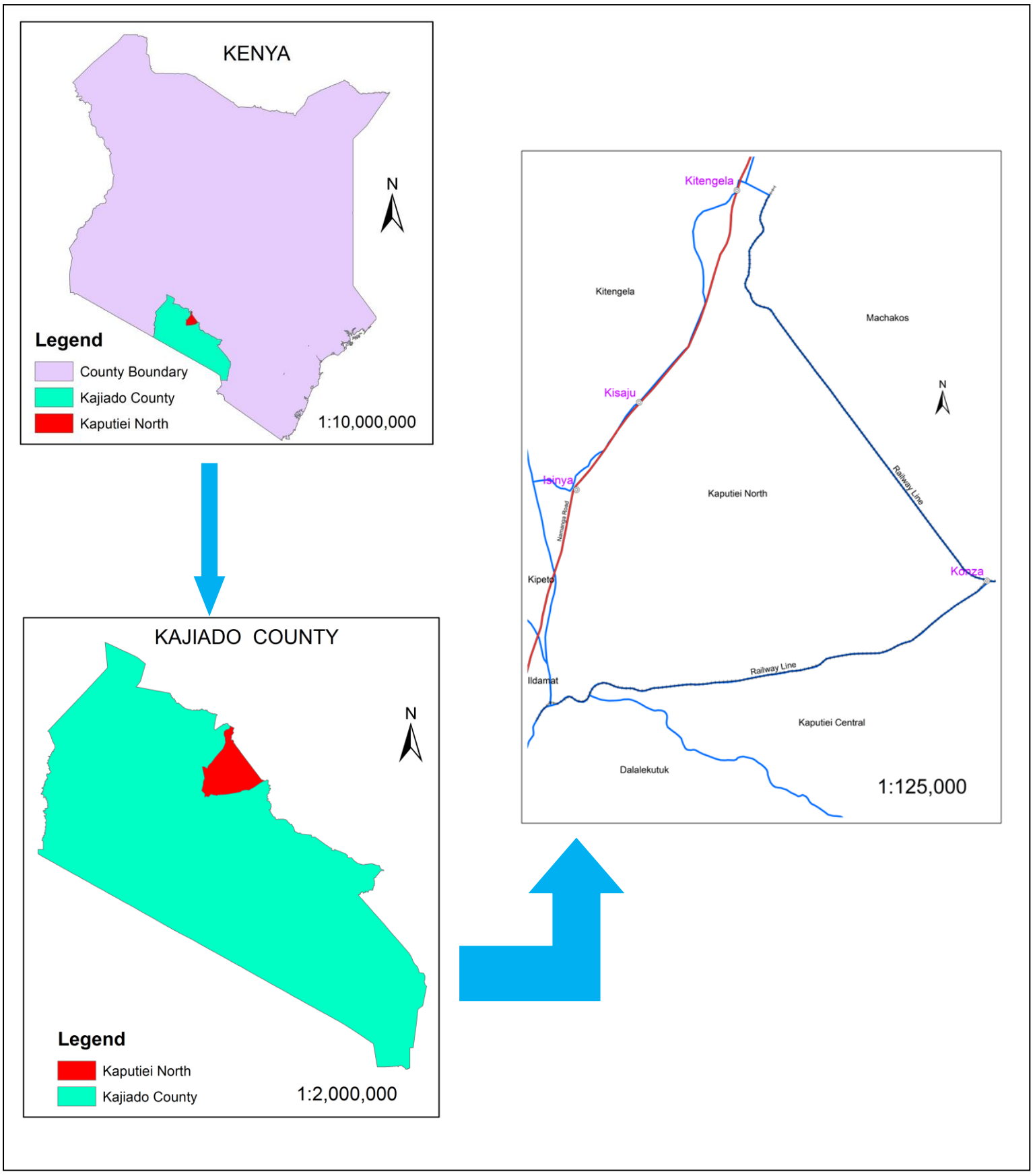


Figure 3.1: The study area

Methodology framework

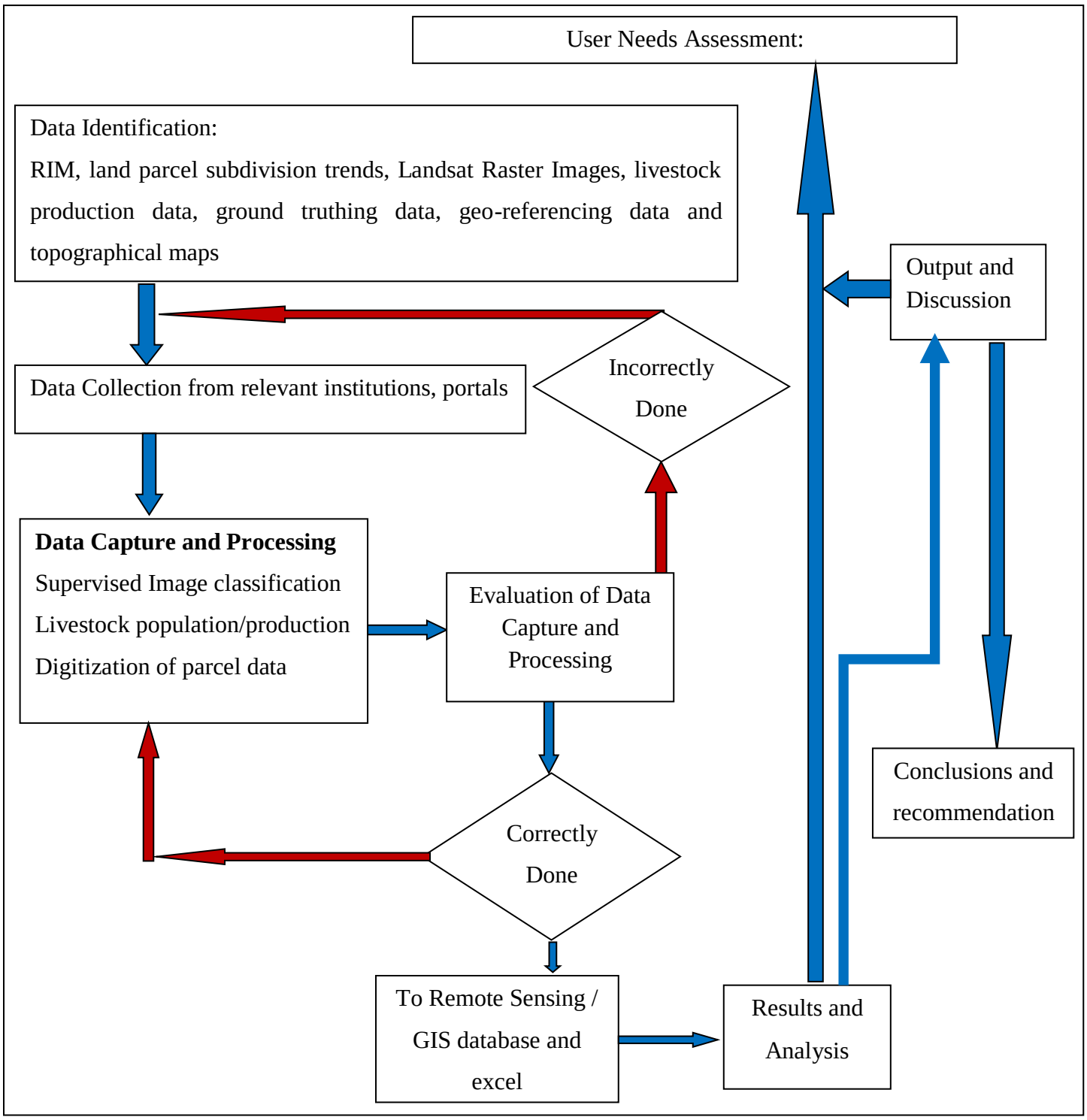


Figure 3.2: Methodology flow chart

3.5 Procedure

To examine the relationship between the land subdivision process and land use change, the boundaries of individual land plots were located and traced from scanned and georeferenced RIMs .The information collected for each land parcel included the year of land acquisition, the relationship between the current and previous land size to reconstruct the land subdivision process. Using this information as of December 2015, the land boundaries in 1995, 2000, 2005, 2010 and 2015 were retrospectively delineated. Using GIS, the boundary traces were overlaid on the geo-referenced RIMs, topographical maps and on a satellite images taken in each of the above five years, so as to measure the changes in land use composition over time and investigate the effect of land subdivision on land use change. The data for census were provided by the Kenya National Bureau of Statistics offices, Nairobi branch. This data was used to determine population trends in support of the study. Then site visits were carried out in order to obtain control points information for georeferencing and ground truthing. The livestock data were collected from the livestock office, Kajiado branch. This data was used to determine livestock production and population trends in support of the study analysis.

A set of five satellite images, taken in the wet season between 30 April and 31 May of 1995, 2000, 2005, 2010 and 2015 were acquired for land use examination from USGS portal. It was therefore possible to monitor LULC changes in the research area over a period of 20 years. For the five images, a set of 17 to 22 ground control points were identified within the research area through random sampling and the images were geometrically corrected and this equally formed the basis of ground truthing. These five images were co-registered and subjected to analysis with the land parcel boundaries. There was no cloud cover in any of the images.

The pre-processing and post image processing and analysis were carried out to enhance the quality of the images and the readability of the features using the spatial analysis tools of Erdas Imagine. The scanned and digitized RIM, topographical map and satellite images were geometrically corrected and the projection was set to Universal Transverse Mercator (UTM) projection system, zone 37. The spheroid and datum was referenced to Arc Datum 1960. All the images were geometrically co-registered to each other using ground control points into UTM projection with geometric errors of less than one pixel.

The ground control points (GCPs) were known ground points whose positions could be accurately located on the digital imagery. These features are corners of open field, railway

intersections or lawns, road intersections and road /river bridges. Global Positioning System (GPS) receiver used to obtain Co-ordinates of GCPs. A total of 17 to 22 of such points were in use in solving the transformation coefficient. A scanned/digitized topographical map subjected to process of map to map geometric transformation of the study area. on the other hand, an image-to-map transformation were applied to the remotely sensed data for Landsat using Affine Transformation, the Root Mean Square (RMS) error was used to check results of the exercise. It is the process of determining the difference in geometric transformation between the estimated location and the actual location of the control points.

Thematic land-cover maps for the study area were produced covering years 1995, 2000, 2005, 2010 and 2015 using a maximum likelihood classifier algorithm of supervised classification through classification and post-classification overlay. To be able to detect possible details, three main land cover classes namely built-up areas, open or bare lands and rangelands were mapped. Post classification comparison of change trajectory was used to map the extents and patterns of land use and land cover as well as determination of magnitude of change in the study area covering the epochs of interest. Built up areas class includes continuous and discontinuous urban fabric, industrial, commercial, transportation and other related built-up areas. Open/bare lands includes sand plains, unpaved roads and excavation sites while rangelands include green areas, non-irrigated arable land and scrubby cover. To assess change in accuracy, Kappa analysis and Error matrix were used.

3.6 Datasets and Sources

The main datasets used in the analysis came from various sources and in different formats as shown in Table3.1.

Table 3.1: Datasets and Sources

Dataset	**Characteristics**	**Data source**
Boundary	Shape file	Survey of Kenya
Road network	Scanned topographic map	Survey of Kenya
Raster Images / Landsat Images	Raster	USGS OR GLOVIS websites
Landuse planning	Shapefiles, Images	Ministry of Lands
Livestock Population	Shape files	Livestock department, Kajiado
Livestock production data	Tabular	Ministry of Agriculture

CHAPTER FOUR: RESULTS AND ANALYSIS

4.1 Introduction

The study was in endeavor to investigate land use changes emanating from subdivisions in peri-urban Kaputiei North. The findings were the basis for analysis.The results and analysis carried out in this chapter were based on the objectives of the study. The results are presented in simple descriptive statistics which include maps, bar and line graphs, and statistical tables. This have been used to display and present the study findings through classification of raw data into some meaningful and usable information.

The results were given in a format that started by presenting classified thematic maps of the five year epochs under study with tables showing change statistic in acreages. Accuracy assessment was done to evaluate the reliability of the classification results. Overlay of subdivision scheme with the thematic maps was done to establish the relationship. Land use trends were done for the three classes over 20 year period through graphs.

Equally land subdivisions trends of different categories within the same period were accomplished. The livestock production trends were also done for the purpose of understanding how it has been affected time with these land changes. Finally the discussion on these findings were done to deduce the meaning

4.2 Classification Results

The thematic maps are based on classification of Landsat images using supervised classification method through maximum likelihood classifier algorithm.

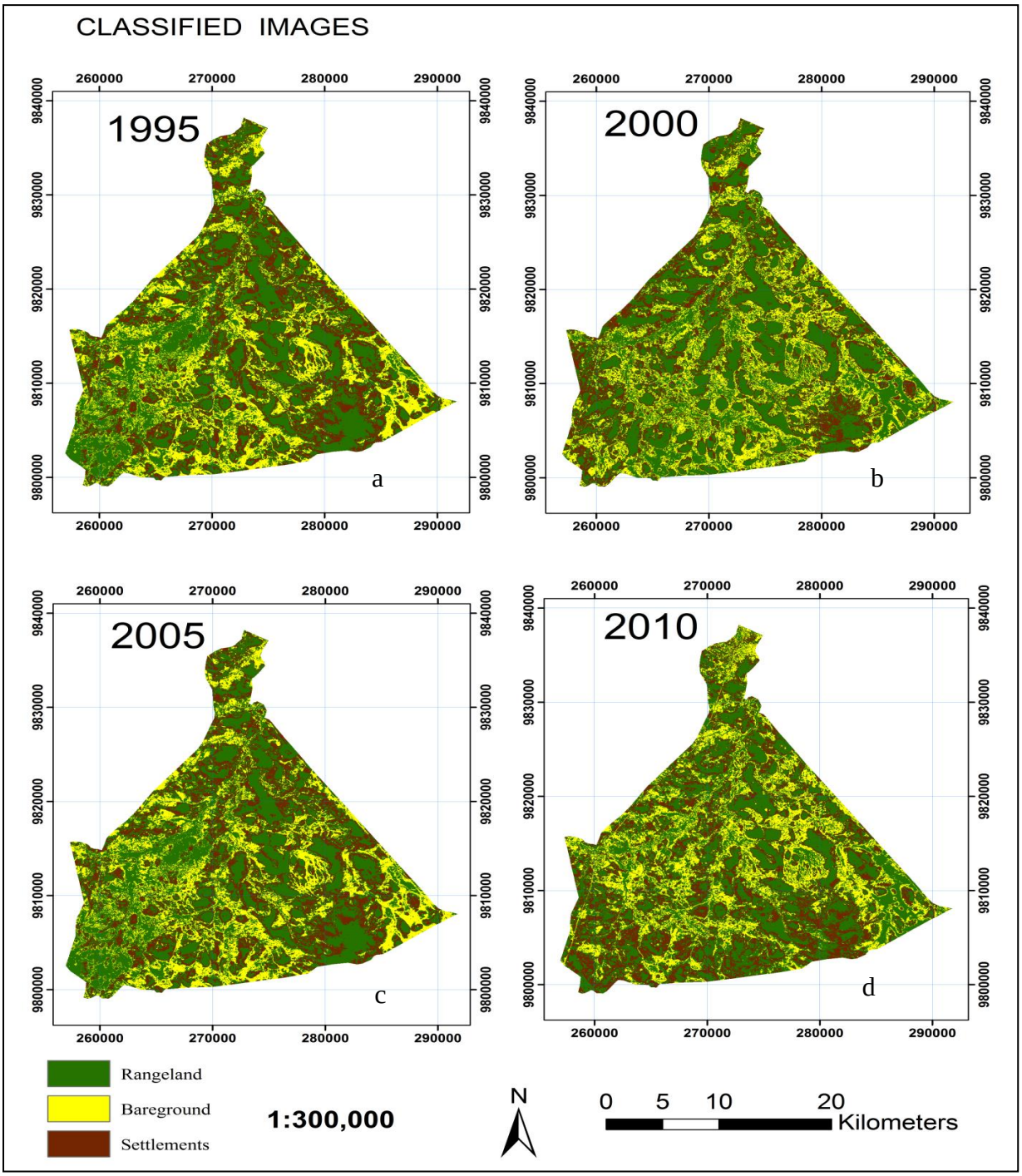


Figure 22.1; a,b,c,d: The classified images

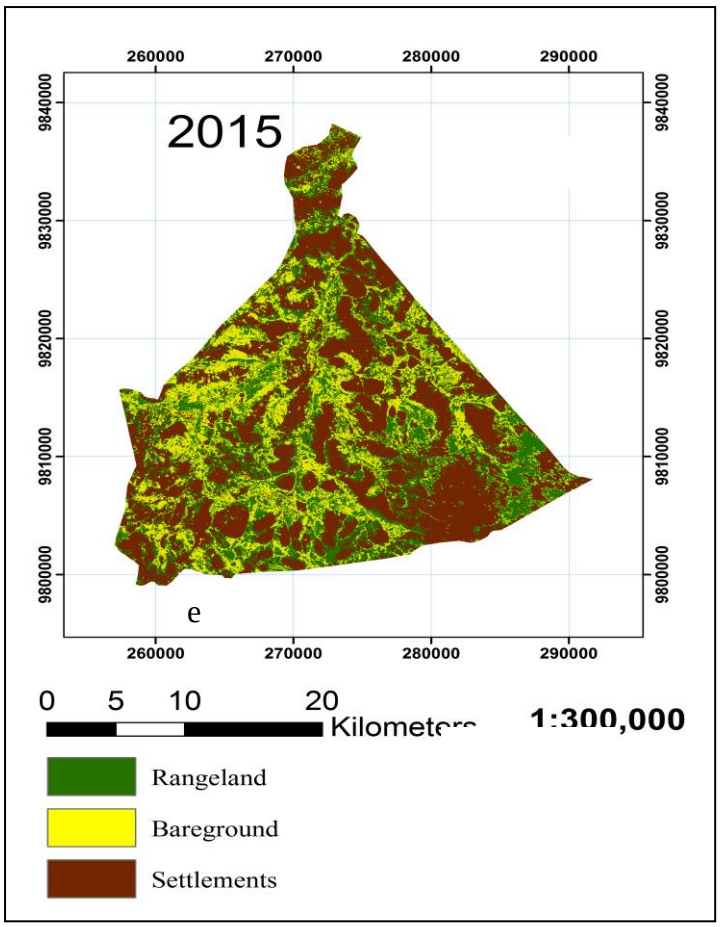


Figure 4.1 e: Classified Images of 2015

Table 22.1: Classification Statistics from 1995 to 2015

Year	Land Use/Sizes in ha			% of The Total
	Rangeland (R)	Bare Ground (BG)	Settlement(R)	
1995	38372.13	13661.55	13332.51	R=58.70 BG=20.90 S=20.40
2000	38326.95	14011.47	13025.61	R=58.64 BG=21.44 S=19.93
2005	35883.18	14315.670	15165.90	R=54.90 BG=21.9 S=23.20
2010	3527352	13999.77	16092.90	R=53.9 BG=21.90 S=24.62
2015	32919.28	15032.86	17414.05	R=50.36 BG=23.00 S=26.64

4.3 Classification Accuracy Assessment

Rangelands is the class that occupies the highest proportion of area in relation to others in both classified dates. A summary of Error matrices used to assess classification accuracy for all the five years are as shown below. These accuracies were generated through Erdas Imagine.The overall accuracies for 1995, 2000, 2005, 2010 and 2015 were, respectively, 76.0%, 80.0%, 80.0%, 70.8% and 72.2%, with Kappa statistics of 65.75%, 70.78%, 69.22%, 61.11% and 62.96%. User's and producer's accuracies of individual classes were consistently high, ranging from 64% to 76%.

```
ACCURACY TOTALS  1995
----------------
          Class    Reference  Classified  Number      Producers   Users
           Name       Totals      Totals  Correct      Accuracy   Accuracy
     ----------   ----------  ----------  -------     ---------   -----
     Rangelands            4           6       4         100.00%   66.67%
    Settlements            5           3       3          60.00%  100.00%
       Bareland            6           3       2          33.33%   66.67%

         Totals   15    12    9

Overall Classification Accuracy =     76.00%

            ----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS  1995
---------------------
Overall Kappa Statistics = 0.6575

Conditional Kappa for each Category.
-----------------------------------
    Class Name              Kappa
    ----------              -----
    Rangelands             0.6032
   Settlements    0.7020
      Bareland             0.5614

            ----- End of Kappa Statistics -----
```

ACCURACY TOTALS 2000

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Rangelands	11	10	9	81.82%	90.00%
Settlements	6	4	4	66.67%	100.00%
Bareland	7	5	4	57.14%	80.00%
Totals	24	19	17		

Overall Classification Accuracy = 80.00%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS 2000

Overall Kappa Statistics = 0.7078

Conditional Kappa for each Category.

Class Name	Kappa
Rangelands	0.8621
Settlements	1.0000
Bareland	0.7576

----- End of Kappa Statistics -----

ACCURACY TOTALS 2005

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Rangelands	11	12	9	81.82%	75.00%
Settlements	6	4	3	50.00%	75.00%
Bareland	3	1	1	33.33%	100.00%
Totals	20	17	13		

Overall Classification Accuracy = 80.00%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS 2005

Overall Kappa Statistics = 0.6922

Conditional Kappa for each Category.

Class Name	Kappa
Rangelands	0.6354
Settlements	0.6983
Bareland	1.0000

----- End of Kappa Statistics -----

ACCURACY TOTALS 2010

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Rangelands	5	6	4	80.00%	66.67%
Settlements	6	6	4	66.67%	66.67%
Bareland	7	6	5	71.43%	83.33%
Totals	18	24	13		

Overall Classification Accuracy = 70.83%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS 2010

Overall Kappa Statistics = 0.6111

Conditional Kappa for each Category.

Class Name	Kappa
Rangelands	0.5789
Settlements	0.5556
Bareland	0.7647

----- End of Kappa Statistics -----

ACCURACY TOTALS 2015

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Rangelands	10	9	7	70.00%	67.78%
Settlements	11	9	7	63.64%	77.78%
Bareland	10	9	7	70.00%	59.78%
Totals	30	27	21		

Overall Classification Accuracy = 72.22%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS 2015

Overall Kappa Statistics = 0.6296

Conditional Kappa for each Category.

Class Name	Kappa
Rangelands	0.7923
Settlements	0.5800
Bareland	0.6923

----- End of Kappa Statistics -----

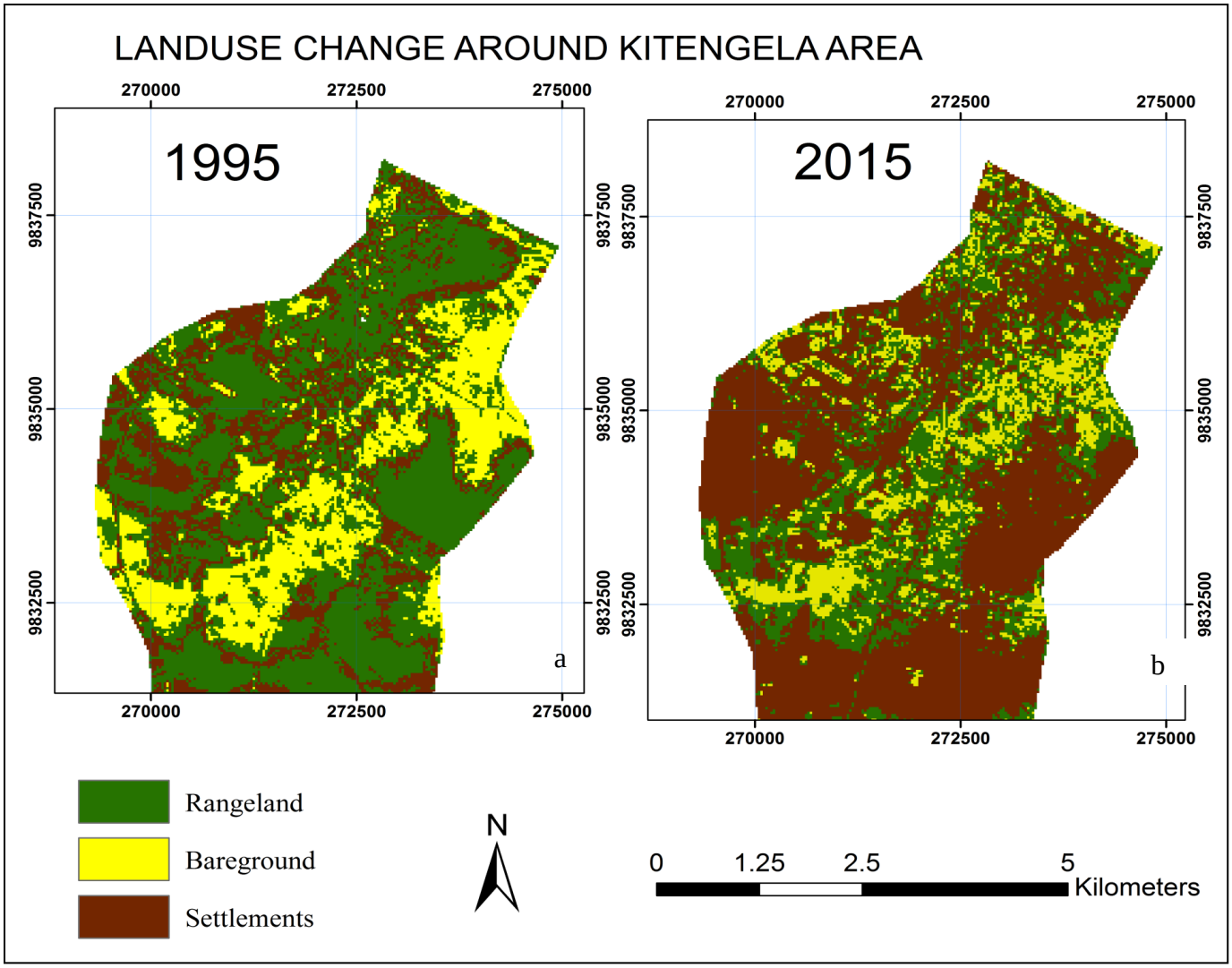


Figure 4.2 a and b: Settlements trends in kitengela area between 1995 and 2015

4.4 Land Use Change in Kitengela Area

Figure 4.2 a and b show how settlement has increased over time in Kitengela area within a span of 20 years. In the year 1995, settlement was sparse but 20 years later the larger percentage of the map appears brown giving rise to settlement as dominant class in 2015.from these trends it clear that built up areas increased over time while rangeland and bareland reduced over the same period.

Overlay of Subdivision of Parcel 31963 on 2015 Thematic Map

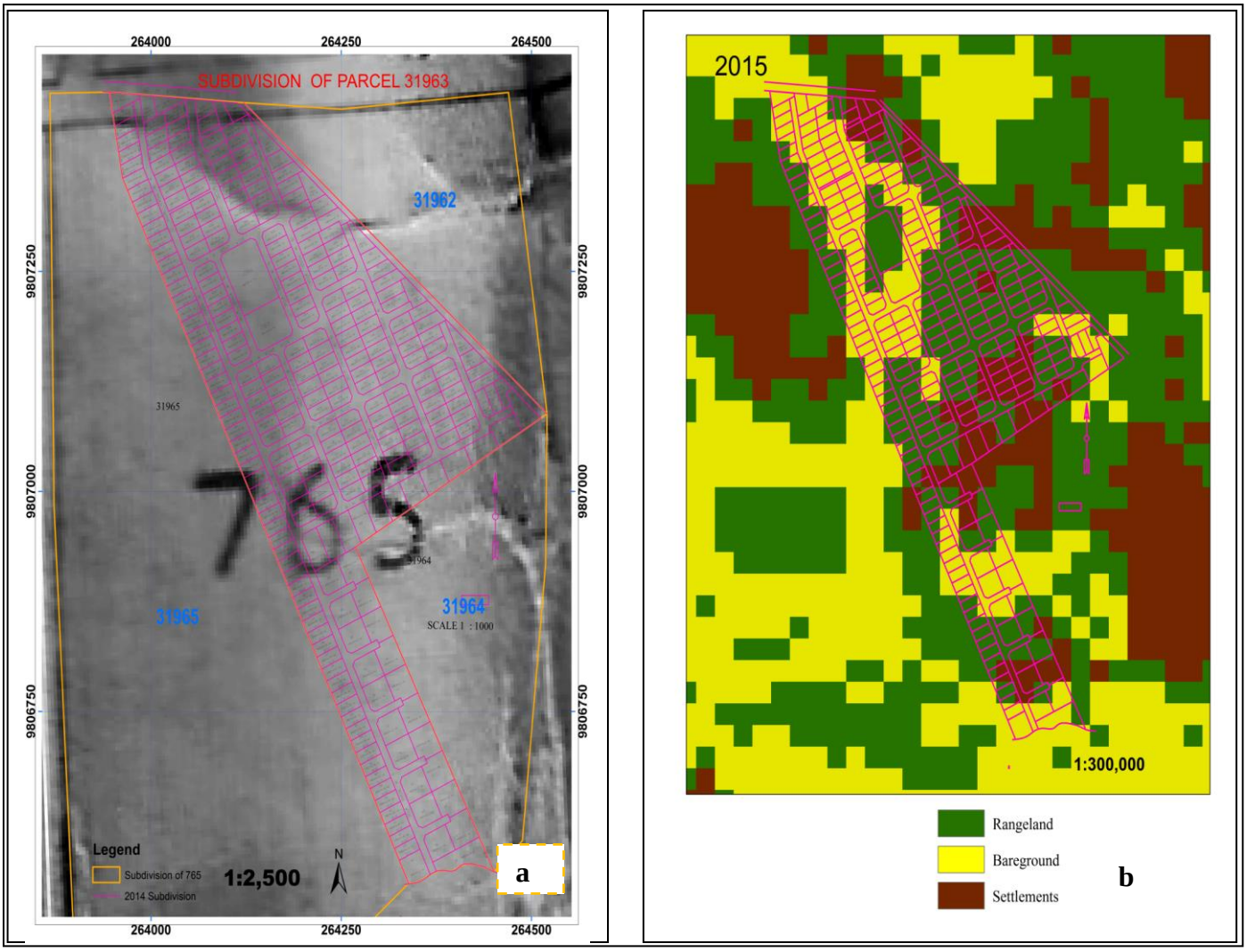


Figure 4.3 a and b: overlay of subdivision on classified 2015 image

4.5 Overlay of Subdivision Scheme on 2015 thematic map

An overlay of subdivision scheme comprising of 1/8 and 1/4 of a hectare parcels in figure 4.3a is shown on figure 4.3 b. The overlay result show some parcel have been settled hence belong to class of settlements, while others are on bareland and rangeland. This scenario shows that there are areas already appearing as rangeland on thematic maps but highly fragmented basing on parcel subdivision trends. This can be attributed to land subdivision done for speculation purposes

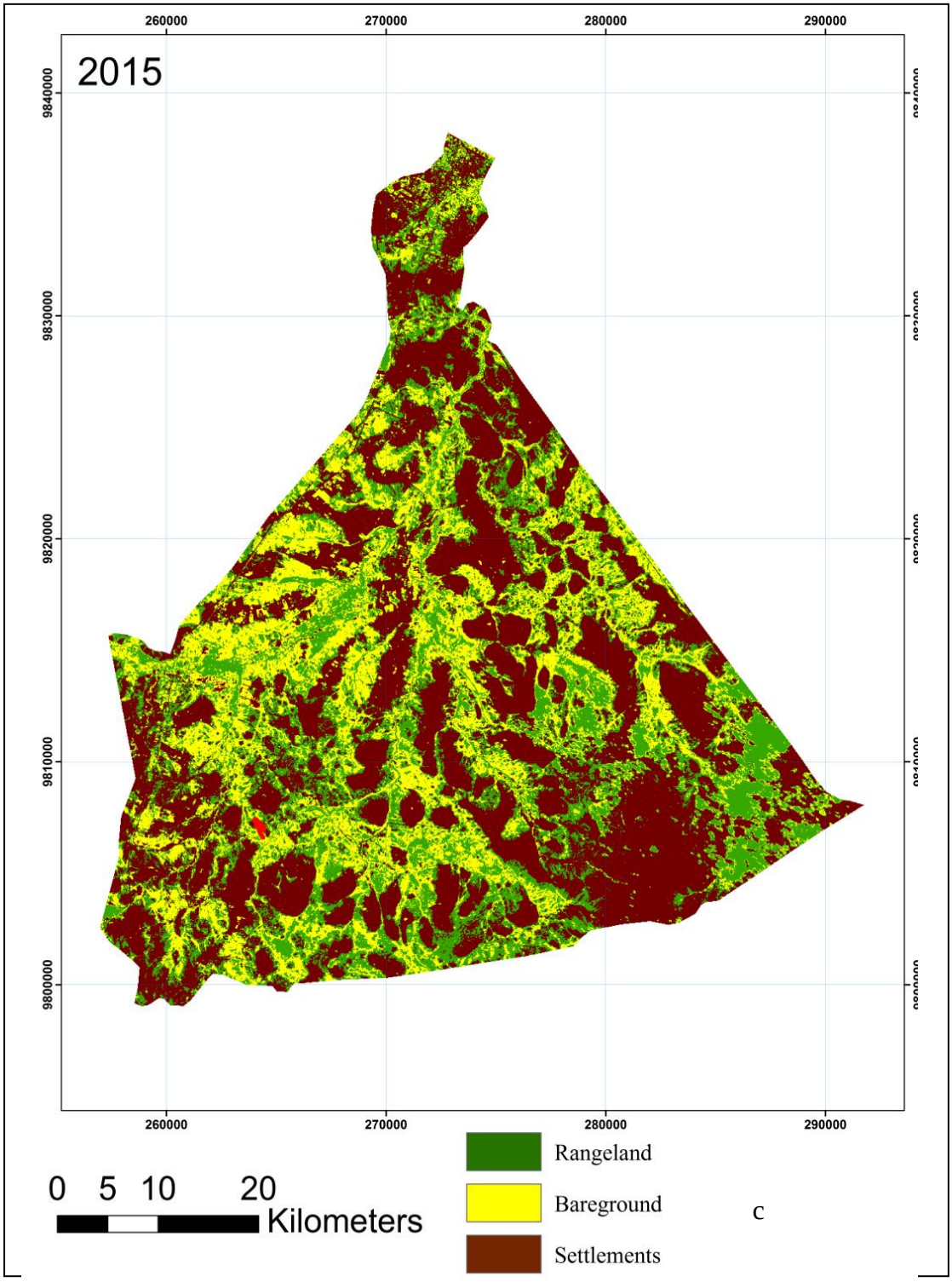
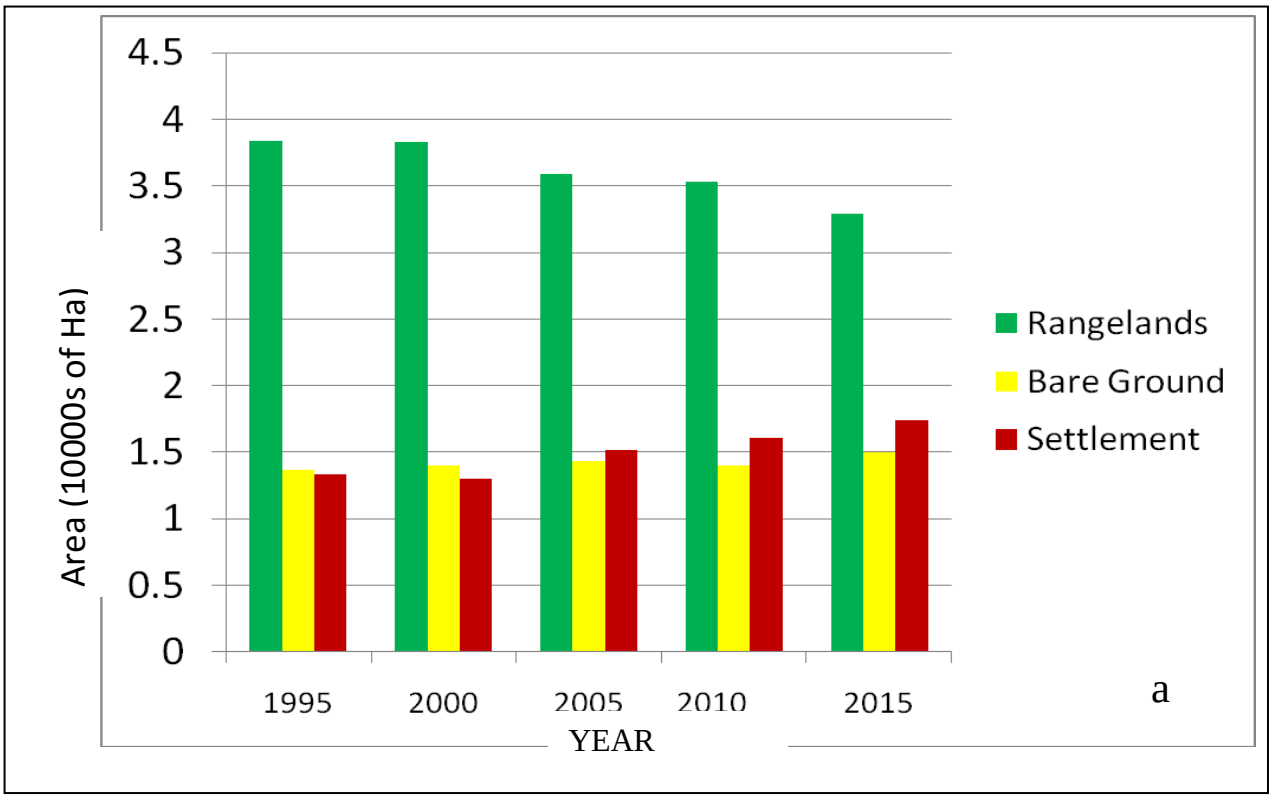


Figure 4.3 c Location of the subdivision scheme with respect to study area 34-36

Figure 4.3 c shows the location of the scheme in figure 4.4 a with respect to a study area denoted by colour red mark. Considering this location it is evident that even the remote parts of the study area have been affected by fragmentation

Combined Bar Graph for Land Use Trends



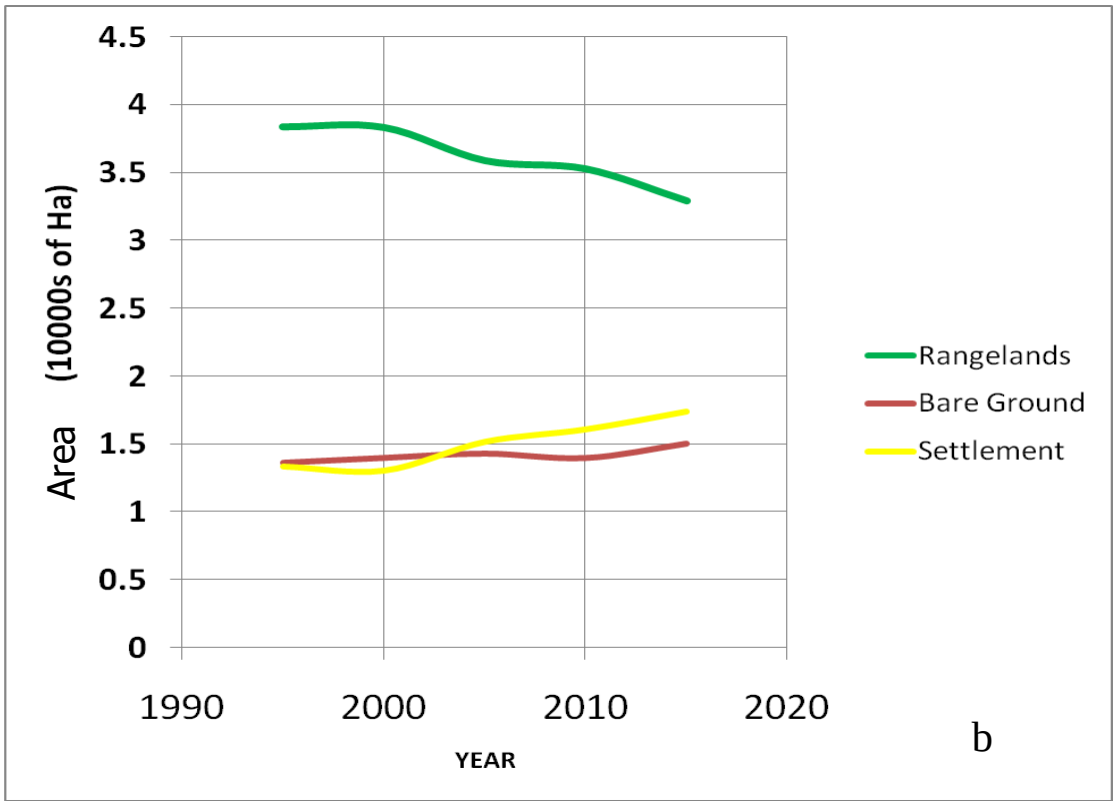
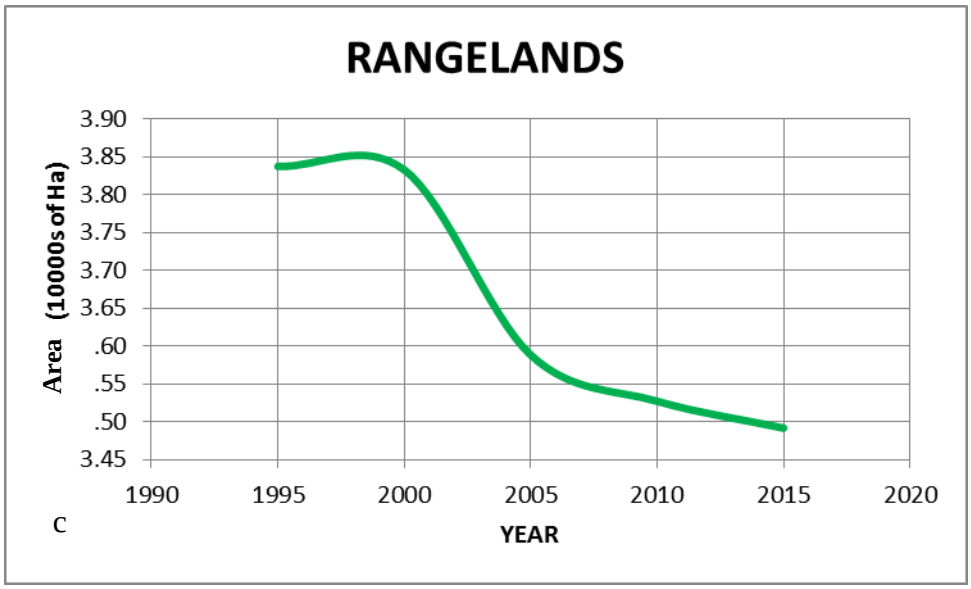
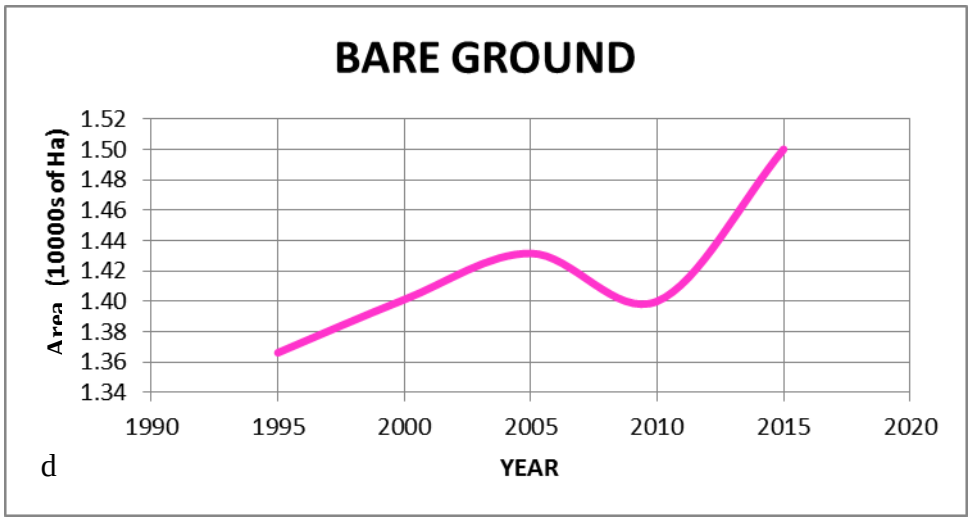


Figure 4.4 a and b: merged land use trends from 1995 to 2015

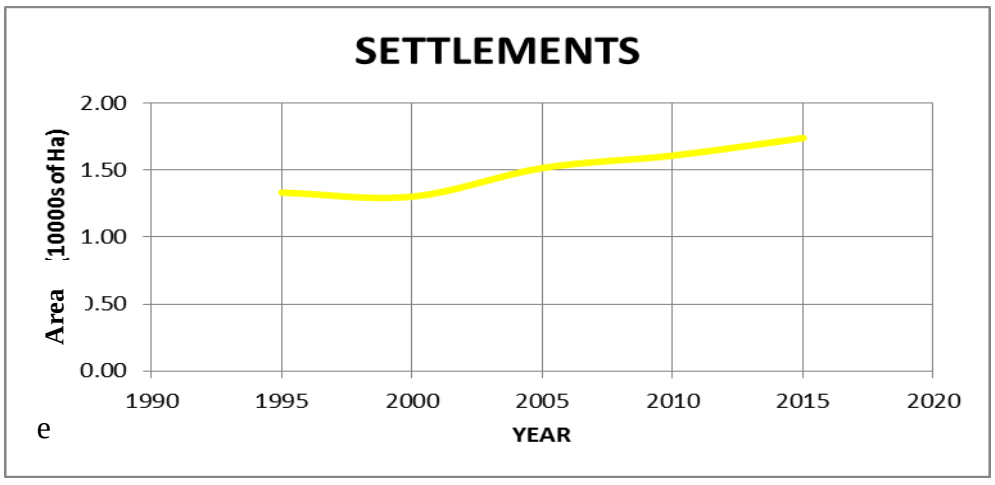
Specific Landuse trends



c



d



e

Figure 4.4 c, d and e : Landuse trends from 1995 - 2015

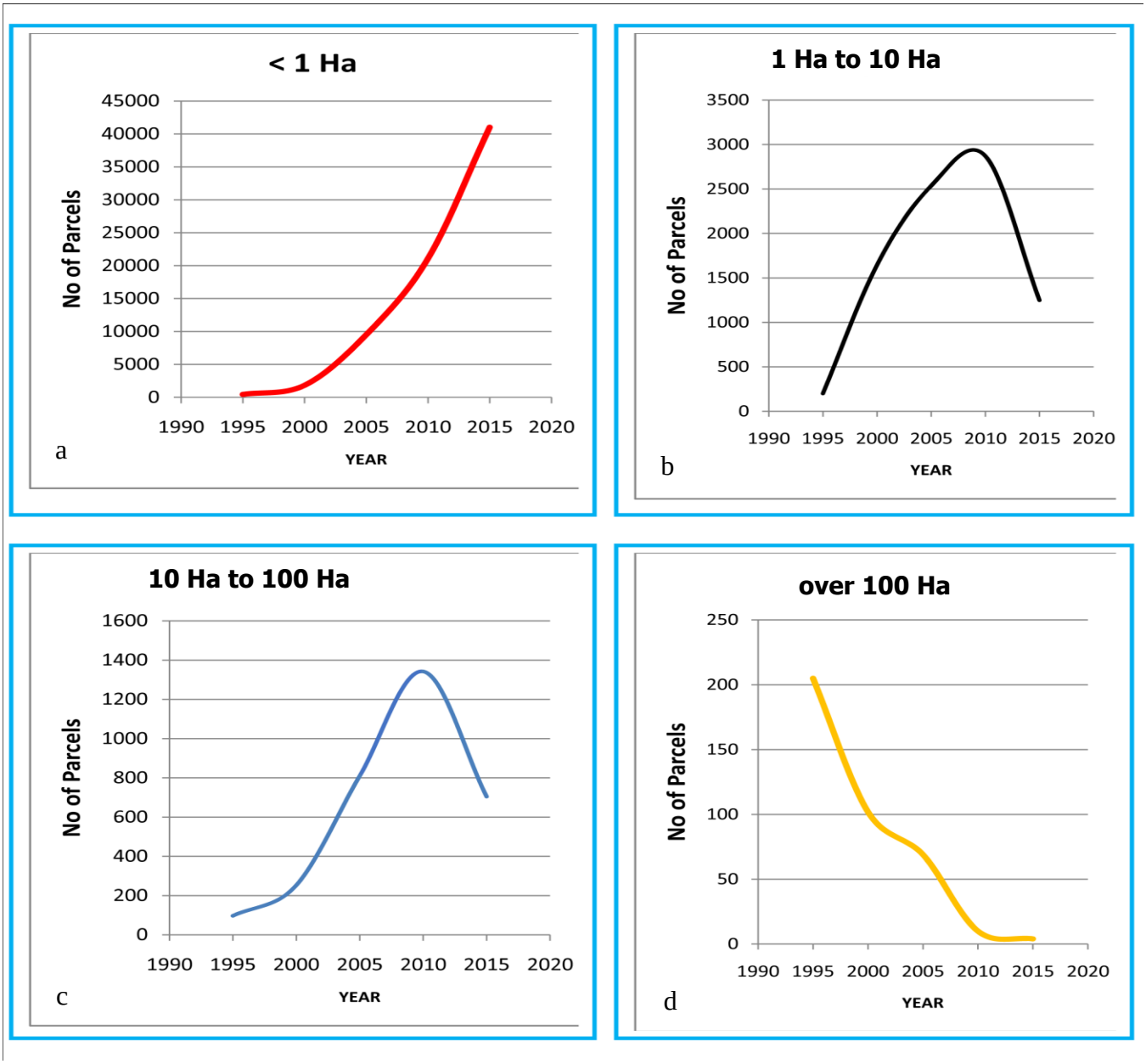


Figure 4.5 a,b,c and d Land subdivision trends from 1995 -2015 in various categories

4.6 Land subdivision trends

The subdivsion trends for varios catagories were analysed over time and the trend analysis results showed parcel with acreage below an one hectare increased as illustrated in figure 4.6 a. For parcels between one acre and 10 acres showed increased from 1995 to around 2007 but after that it started reducing signifying that most subdvision happening were in catagory of one acre and below.figure 4.5 c if for those between 10 ha and 100 ha also increased but dipped after 2007.the bigger parcels of over 100 hectares showed reduction trend.

Livestock Production Trends in kilograms

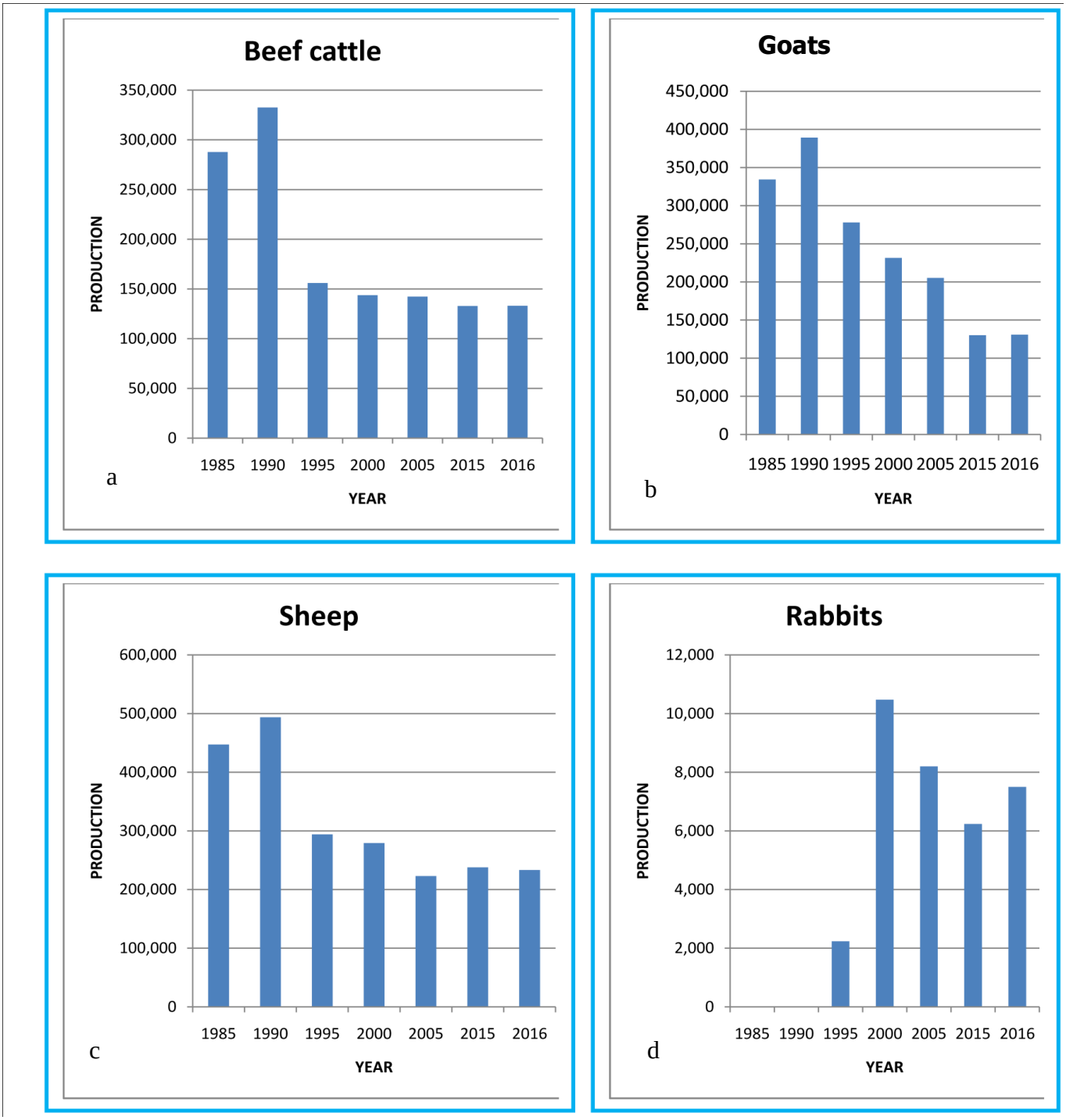
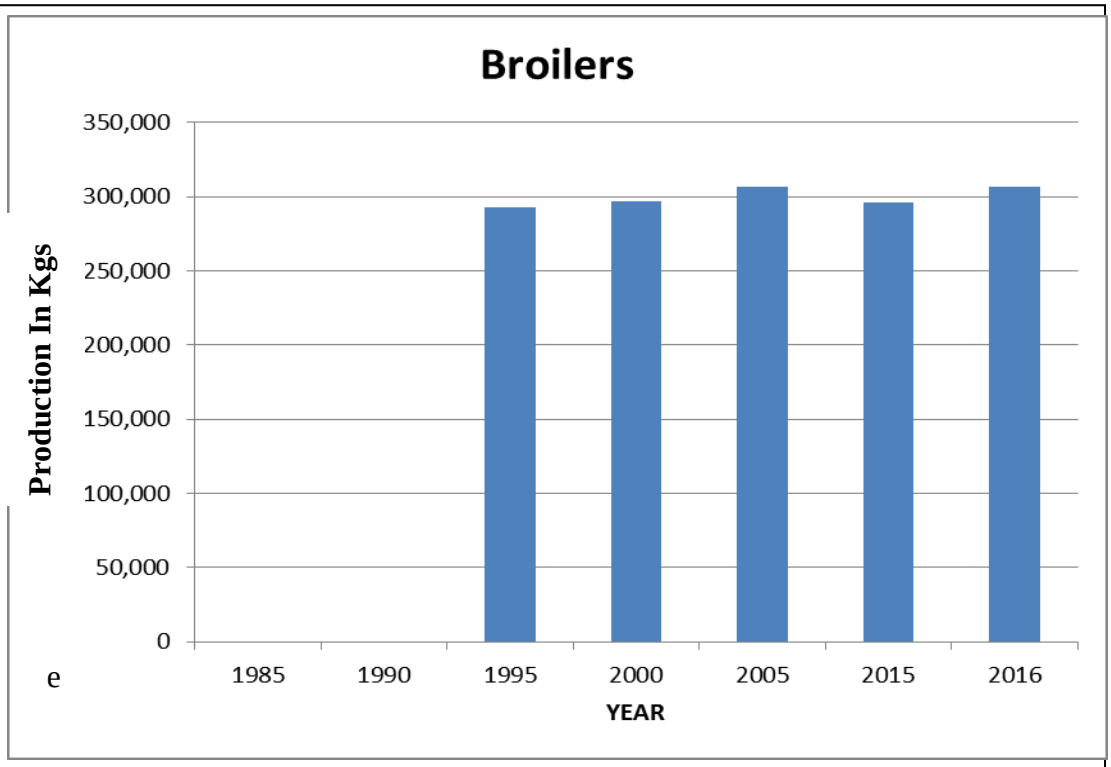


Figure 4.5 a,b,c and d showing production in kgs overtime for different livestock

The production of meat in kilograms have been on decline from 1985 t0 2015 as per the trends shown by graphs 4.5 a-d. From the classification and subdivision trends the area for natural pastures were decreasing while settlement and bare ground were increasing. This state of things might have contributed to decline in numbers of sheep goats and beef cattle hence decrease in production.



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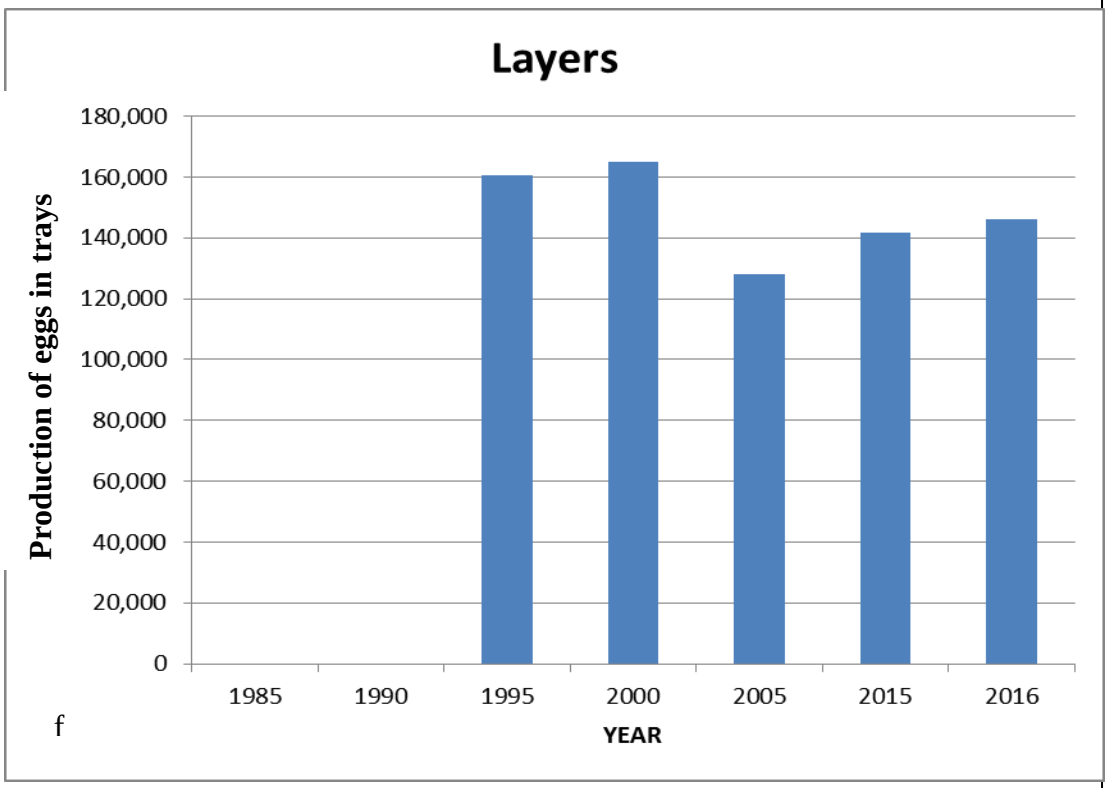

f

Figure 4.6 e and f production for broilers and layers

Figure 4.6 e and f is graph showing production from poultry overtime. The prodiction has not been affected by the reduction rangeland and increase in land fragmention instead the production has increased steadly from the year 2005, this can be attributed to increase in settlement and poultry does not depend on natural pastures as cattle sheep and goats.

Meat Production Trends (Cattle, Goats And Sheep)

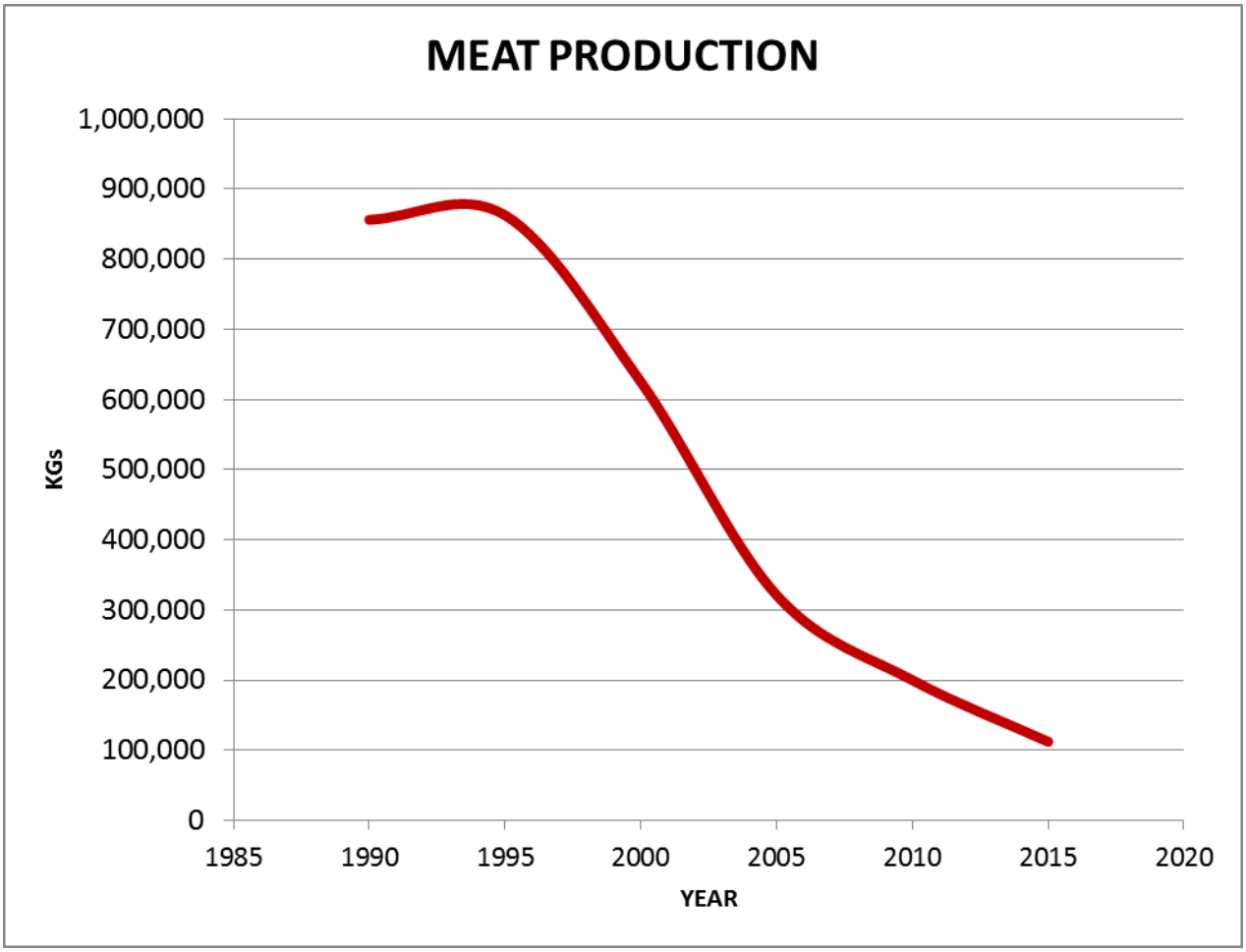

Figure 4.7: overall Meat production trends from 1990 -2015

4.7 Livestock Production Trends

The production of meat from cattle, sheep goat has been reducing over time. Figure 4.7 shows combined production of meat was highest in the year 1995 and lowest in the year 2015. This may have happened due combination of factors, key among them is the reduction of rangelands as result of land subdivision. But production from layers, broilers were showing increasing trends. This indicates that growth in settlements and fragmentation had positive correlation to this products.

4.8 Discussion of Results

Classifications of thematic maps were generated for all five years as per Figures 4.1 a-e and the individual class area on tables 4.1. Figure 4.4 b summarises the change statistics for all five year epochs. The corresponding statistical trends and values were displayed in combined bar charts of land use trends as shown in Figures 4.4 a. From 1995 to 2000, rangelands decreased by approximately 0.07 % while settlements decreased 0.47% as bareland increased by approximately 0.54%. From 2000 to 2005, rangelands decreased by approximately 3.74 % while settlements increased 3.27% as Bareland increased by approximately 0.47%. From 2005 to 2010, rangelands decreased by approximately 0.94 % while settlements increased 1.42% as bareland decreased by approximately 0.48%. From 2010 to 2015, rangelands decreased by approximately 3.6 % while settlements increased 2.0% as Bareland increased by approximately 1.53%. Comparing two extreme periods of 1995 and the year 2015, Rangelands decreased by approximately 8.4 % while settlements increased by 6.22% as Bareland increased by approximately 2.05%.

In the similar periods, From 1995 to 2000, beef meat production reduced by 27.55% from figure 4.6 a and land subdivision of parcels less than 1 Ha category increased by 417% from figures 4.4 a to d, while subdivision of parcels more than 100 Ha category increased by 50% as shown in the figures. From 2000 to 2005, beef meat production reduced by 48.64% and land subdivision of parcels less than 1 Ha category increased by 522% while subdivision of parcels more than 100 Ha category increased by 67.65%. From 2005 to 2010, beef meat production reduced further by 37.67% and land subdivision of parcels less than 1 Ha category increased further by 221% while subdivision of parcels more than 100 Ha category further increased by 14.5%.From 2010 to 2015, beef meat production reduced by 43.87% and land subdivision of parcels less than 1 Ha category increased by 194% while subdivision of parcels more than 100 Ha category increased by 40% all statistics taken from absolute numbers.

Although similar statistics could be generated for other units such as County or township, the above change statistics shed light on the question of where land use changes are occurring and their effects on food security as production of meat from beef over time dwindles. Conversions involving these three classes also represent the most significant changes. Settlements and the loss of rangelands are the most important conversions in this area. It should be noted that bare ground conversions can largely be attributed to human activity through overstocking or clearance of rangelands for crop farming purposes.

The major changes occurred within the third and fourth epochs of the study with high concentrations around Kitengela and Konza areas. Such clear patterns emerge that highlight the urbanization and thus shrinkage of farming activities is such locales. Further GIS analysis revealed a strong relationship between new development and proximity to road infrastructure. Almost half (47%) of the Kaputiei North developments detected in the classifications occurred within 2km off Namanga road, and 25% was between 2 and 4 km of various County roads.

The relationship between population growth and growth in settlement as determined from the Landsat-derived change maps how large scale conformity. According to Reizs (2008), development patterns of the metropolitan areas reflect the distribution of population and households because residential land uses take over half of the land that is developed. All the sections with significant population growth also had increases in settlement e.g. Kitengela.
To identify the significant changes with respect to land use, land subdivision is considered as one of the drivers of rangelands fragmentation. At present urban encroachment is the major threat to biodiversity because it not only causes the habitat loss of species but also results in the more devastating effects like soil degradation, uncontrolled farming practices and general deterioration of farming potential. The urban encroachment into farmland/ agricultural land is mainly an outcome of increase in population that results an increase in the needs of the people. The people living in the area have mainly used the rangeland for establishing new built ups (urbanization).

Low economic returns from agricultural activities may be the greatest influence on agricultural land use conversions in Kaputiei North. The productivity and profitability of many farms (especially small scale) may be too low due to the fact that returns from agricultural activities are lower compared to other users such as residential development. Further, there may be no incentives for farmers to preserve their agricultural land against conversions into other users going by the collapse of Kenya Meat Commission (KMC) with no other mitigations measure to fill the gap left by the exit of KMC. Consequently, beef farming is considered inferior to other land uses. Hence farmers are motivated to subdivide their land and consequently convert their farms to obtain higher returns effectively limiting food security. According to various real estate valuation firms operating in the study area like Sweet Title Limited and Guton Kenya, Optiven, and Diamond Properties. An acre of agricultural land within a radius 2 km of Namanga road after subdivision and conversion can sell at approximately Kenya shillings 5-10 million. According to Isinya Meat Suppliers, a

well-managed farm in the area would sustain 20 head of cattle per acre in feed lot system with net return of about Kenya shillings 200,000 per annum. Otherwise one needs 4 ha to support one head of beef cattle without feed lot system and for it to be profitable you need several of them hence bigger land is required. As result of this farmers opt to sell his agricultural land for the attractive price of Kenya shillings 5-10 million and diversify his investments to real estate or otherwise (Ng'ayu, 2009).

This state things explains why the rangelands and settlements are two significant land uses that seem to be affecting each other inversely as shown in figure 5.1. As settlements increase, there is a tendency of increased subdivisions leading to narrowing of the rangelands. As a result, herding estates reduce and consequently depressing livestock production, which have negative bearing to food security.

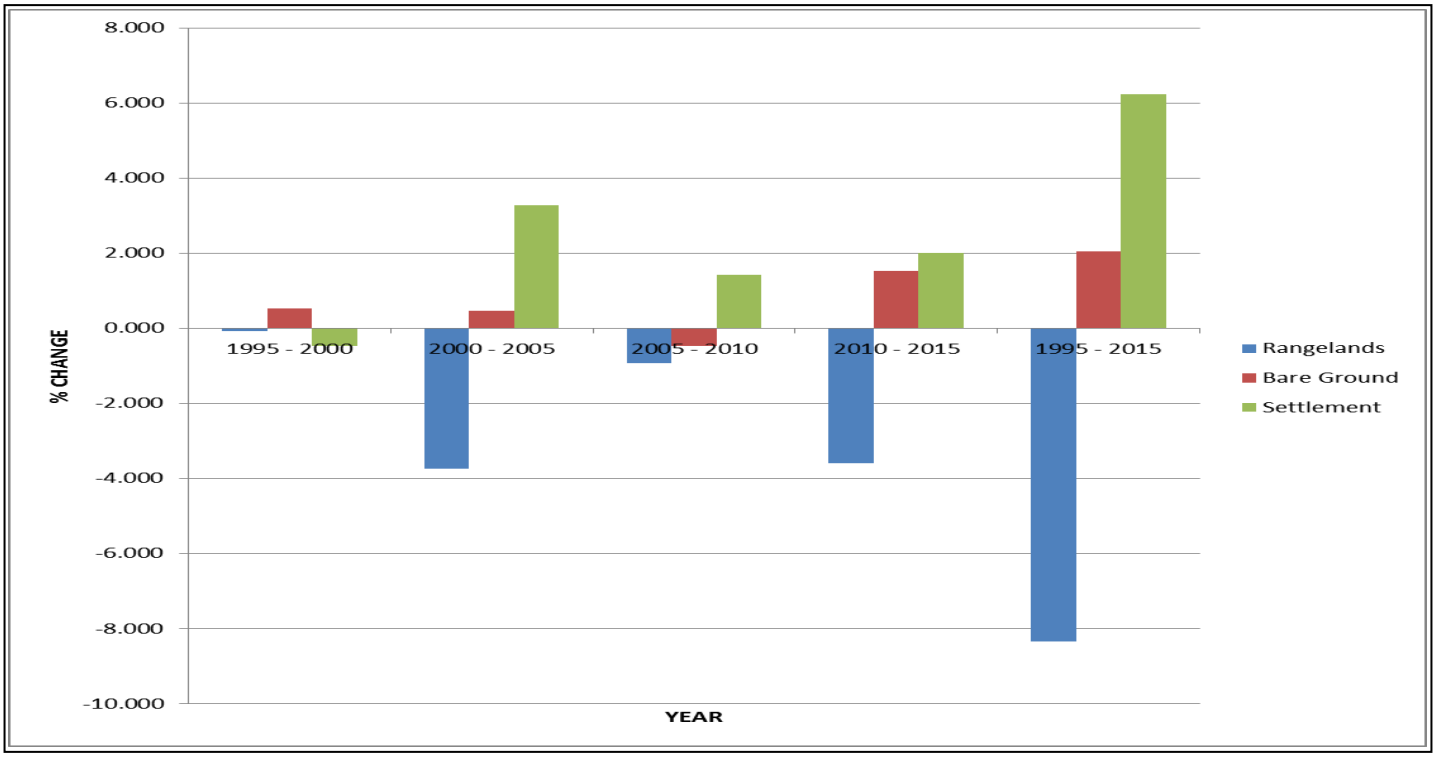

Figure 4.8: Rate of change of landuse types

The Nairobi Metro 2030 Strategy Paper of 2008, acknowledges that the boundaries of the Nairobi City will extend up to 32000km^2. This implies most of Kajiado County will fall within the Nairobi Metropolis. This kind of development is among the major causes of land fragmentation of agricultural land heralding the food insecurity due to collapse of such livestock estates.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of the research was to establish how land fragmentation/subdivision trends have contributed to food insecurity. The research work was able to integrate remote sensing and GIS to bring out trends on subdivision which in turn triggered land use changes from range land to built-up areas. Attempt was made to capture three classes accurately and the changes on land overtime were established. In view of the findings the built-up areas signifying settlement and bare ground acreages showed increasing trend while the rangeland which are known for natural pastures reduced over the same period of time.

Although from image classification some areas were classified as rangelands but the ground visits and parcel trend analysis confirmed otherwise. This as result of, most subdivisions are not accompanied with immediate settlements and erection of structures. These scenarios are common when land is bought for speculative purposes.

The study equally showed large parcels which initially existed were fragmented further into smaller units hence diminishing the capacity of land to support profitable livestock farming. This is attributed to the fact that range land which was known for natural pastures was reducing, hence affecting the successful beef cattle farming. As result of this development beef production was hampered which contributed to food scarcity and hence becoming food security issue. According to the literature reviewed, beef products have greater role in the overall food chain hence proper controls on land use planning should be in place to protect these areas from urban sprawl and uncontrolled sub divisions.

Even though the beef cattle have been affected negatively by subdivision of rangelands, it should be noted that the dairy cattle and poultry production increased overtime. This was a safe mechanism to be food secure due to settlement of people who are not naturally known for pastoralism

Based on the findings of subdivisions trends and settlement statistics of the area of study it is clear that the area can no longer support the livestock farming, and can therefore be classified as residential urban area.

5.2 Recommendations

From the findings of the study the following recommendations that are critical to optimally manage and regulate land use conversions common in peri-urban /urban fringes can be made:

1. Land as factor of production needs to be handled with utmost care since uncontrolled land subdivisions need to be checked to ensure existing natural pastures which are key ingredient to support beef cattle production are protected.
2. Since Kaputiei North has substantially been fragmented, measures should be put in place on promoting controlled subdivision in other areas of the County not yet affected by excessive subdivisions. This will require stricter policies from both National and County governments on zoning as mitigation of protecting natural pastures.
3. Based on the findings it evident that change land use change through fragmentation was more profitable than farming. It is upon the relevant Ministry in th County responsible for agriculture and livestock farming to provide incentives which will encourage beef cattle farmers not to abandon the practice by ensuring that the beef market gives handsome returns. The farmers should also have access to insurance for their livestock and extension services .
4. Policy framework should be put in place to discourage persons holding land for speculative purposes.
5. Since most of the subdivisions so far undertaken are not reflected on the maps in the Department of Survey in the County, it paramount for the government to put more funds towards updating these maps and possibly enable future studies in this field to be undertaken with high precision.
6. It is recommended that, for the purpose of future similar studies, it is necessary to make use of high resolution imageries which will give more details and possibly optimal results.

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