ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FOR SELECTED TIME PERIODS

KEBENEI MERCY CHERUTO

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL MANAGEMENT, SOUTH EASTERN KENYA UNIVERSITY

2017

DECLARATION

I understand that plagiarism is an offence and I therefore declare that this thesis report is my original work and has not been presented to any other institution for any other award.

Signature: ___________________________ **Date:____________________**

KEBENEI MERCY CHERUTO

(REG. NO: I501/WTE/20480/2014)

This thesis report has been submitted for examination with our approval as University Supervisors

Signature: ___________________________ **Date: ___________________**

DR. MATHEAUS K. KAUTI
Department of Environmental Science and Technology
School of Environment and Natural Resources Management

Signature: ___________________________ **Date:___________________**

DR. Patrick Kisangau
Department of Biology
School of Pure and Applied Science

DEDICATION

This work is dedicated to my loving mum, Victoria Chebet Ruto and to my amazing siblings Sheila, Sharon and Bob for their love and care towards me and also for the incredible support in every way towards my studies. May the Almighty God bless them all abundantly, Amen.

ACKNOWLEDGEMENT

The successful completion of this work came about as a result of massive contribution made by several people; I therefore, deem it necessary to express my profound gratitude to them.

I wish to thank my dynamic and hardworking supervisors, Dr. Matheaus K. Kauti and Dr. Patrick Kisangau, who did not only encourage, but also criticized and corrected my work to ensure quality and timely outcome. My sincere gratitude also goes out to Dr. Patrick Kariuki Chege, Institute of Mineral Processing and Mining, Department of Geology, who was of great assistance with regards to GIS and Remote Sensing analyses and who also critiqued and corrected this work every step of the way to refine it to what it is. My profound appreciation goes out to Mr. Samuel Maina of Geo-Tech Consultants for his support and assistance with regards to GIS and Remote Sensing analyses. Much appreciation goes to my field assistants for making the data collection activity a success. I also wish to thank all the respondents who accepted to share their information with me. Your participation has made this study a success.

Finally, my special acknowledgement goes out to my family and friends for their constant encouragement, prayers and inspiration during the study

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATION AND ACRONYMS

AOI	-Area of Interest
ASALs	- Arid and Semi- Arid Lands
ASTER	-Advanced Space-borne Thermal Emission and Reflection Radiometer
AVHRR	- Advanced Very High Resolution Radiometer
CLASS	- Comprehensive Large Array-data Stewardship System
CO_2	- Carbon Dioxide
DEM	- Digital Elevation Model
DN	- Digital Number
EOLi	- Earth Observation Link
ERDAS	- Earth Resources Data Analysis System
ESA	- European Space Agency
ETM	- Enhanced Thematic Mapper
ETM+	- Enhanced Thematic Mapper Plus
FAO	- Food and Agriculture Organization
GCPs	- Ground Control Points
GIS	- Geographic Information System
GoK	-Government of Kenya
IFOV	- Instantaneous Field Of View
IGBP	- International Geosphere Biosphere Programme

KM^2	- Square Kilometer
KMD	- Kenya Meteorological Department
LULC	- Land Use and Land Cover
LULCC	- Land Use and Land Cover Change
MAD	- Multivariate Alteration Detection
MODIS	- Moderate Resolution Imaging Spectroradiometer
MSS	- Multi-Spectral Scanner
NASA	- National Aeronautics and Space Administration
NIR	- Near Infrared
NOAA	- National Oceanic and Atmospheric Administration
RS	- Remote Sensing
SLC	- Scan Line Corrector
SSE	- Supervised Spatial Encoder
SWIR	- Short-Wave Infrared
TM	- Thematic Mapper
USGS	- United States Geological Survey

DEFINATION OF TERMS

Land use: Human activities which are directly related to land, making use of its resources or having an impact on these resources.

Land cover: Physical, chemical or biological categorization of the terrestrial surface e.g. grassland, forest and concrete among others.

Image enhancement: Improvement of the appearance of an image to assist in its visual interpretation and analysis

Pixels: Smallest units of an image.

Image Classification: Operations used to digitally identify and classify pixels in data

ABSTRACT

The surface of the earth is undergoing rapid land use and land cover changes (LULCC) due to various socio-economic activities and natural phenomena. The main aim of this study was to gain a quantitative understanding of LULCC in Makueni County between 2000 and 2016, and analyze the relationship between these changes and their possible underlying drivers in the County. ArcGIS 10.3.1 and ERDAS IMAGINE 2014 were used for the digital image processing and GIS analyses. Image pre-processing and enhancement were done to prepare the images for classification. Supervised classification technique was used to sort and define spectral signatures in the imagery for different land use and land cover (LULC) classes that were identified. Ground truthing was done so as to check the precision of the classified LULC maps. Change detection analysis was performed to assess the class- to-class conversions and change in areal coverage between identified LULC classes between time intervals under study. Accuracy assessment was performed to determine overall, producer's and user's classification accuracies. The study area was defined to have seven LULC categories, which were: Built up areas, water bodies, croplands, evergreen forests, bushlands, grasslands and barelands. The results revealed both increase and decrease in the areas of the LULC classes from 2000 through to 2016. Evergreen forest decreased from 3105.8 km^2 in 2000 to 1373.0 km^2 in 2016 while built up areas increased from 160.7 km^2 in 2000 to 644.5 km^2 in 2016. Possible drivers of the observed changes ranged from climatic factors such as rainfall and drought to socio-economic factors. Since the results reveal that LULCC has occurred in Makueni County, the study recommends that consistent LULC mapping should be carried out in order to establish trends that will enable resource managers to project realistic change scenarios helpful for natural resource management.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

1.1.1 Global situation of LULCC

Land Use and Land Cover Change (LULCC) is a major issue of concern with regards to change in the global environment (Prakasam, 2010). The rapid growth and expansion of urban centres, rapid population growth, scarcity of productive land, the need for more production, changing technologies are among the many drivers of LULCC in the world today (Barros, 2004). According to (Masek *et al*., 2000), LULCC respond to socioeconomic, political, cultural, demographic and environmental conditions and forces which are largely characterized by high human populations. LULCC has become one of the major concerns of researchers and decision makers around the world today.

Many researchers argue that LULCC emerged as a major aspect in the wider debate of global change and that change originates from human-induced impacts on the environment and their implications for climate change (Ginblett, 2006; Schneider and Pontius, 2001; Lambin and Geist, 2002). The indicators of these changes can be clearly seen in the current major global concerns such as increasing concentrations of carbon dioxide (CO_2) in the atmosphere, loss of biological diversity, conversion and fragmentation of natural vegetation areas and accelerated emission of greenhouses gases (IGBP, 2001).

According to the United Nations report on World Urbanization Prospects (UN, 2014), the world urban population is expected to increase by 72% by 2050, from 3.6 billion in 2011 to 6.3 billion in 2050. Thus, LULCC around the world is likely to be more since the same land is expected to absorb the population growth over the next four decades (Desa, 2012).

LULCC dynamics are widespread, accelerating, and significant processes majorly impelled by human actions and at the same time resulting to changes that impact humans (Agarwal *et al*., 2002). The LULCC dynamics modify the availability of different important resources including vegetation, soil, water, and others. According to Bruijnzeel (2004) and Chomitz and Kamari (1998), LULCC can trigger soil erosion and soil degradation, which change watershed properties. Furthermore, unsustainable land-use practices can affect soil properties causing loss of agricultural productivity with associated effects for local livelihoods and food security.

The United Nations Food and Agriculture Organization (FAO) noticed that 15 to 20 million hectares of forest disappear every year in developing countries while West Africa loses more than two third of its wooded surface (FAO, 2000). Equally, FAO predicts a further 30% loss of vegetation in Tropical Africa and the Sahel zone by 2025 (GLOWA-IMPETUS, 2005). Deforestation has been termed strongly as the primary driver of global environmental change in tropical regions such as in Africa (Roy Chowdhury, 2006; Lambin and Geist, 2002).

1.1.2 LULCC in Kenya

Land cover in East Africa is in a state of flux at a variety of spatial and temporal scale due to climate variability and human activities (Kiage *et al*., 2007). Kenya, like many other countries in the world has also experienced a great deal of LULCC over the years. The ever increasing human population has resulted to pressure on environmental resources in order to meet the day to day needs. The country has undergone rapid LULC transformations in response to the diverse economic, socio- cultural, demographic and political processes that have occurred in space and time.

In 1900-1930 (early colonial period), there was extensive land expropriation, European settlement and large-scale agricultural production (Campbell *et al*., 2003). As independence approached (1930-1963), a reduction of constraints on African land ownership and participation in commercial agricultural economy was experienced. This led to new interactions and conflicts among agricultural and pastoral communities as farmers settled in high potential areas which were formerly used by pastoralists for grazing in times of drought. There were also increased interactions with the natural and undisturbed environment in search for resources to meet the daily human needs. In the years after independence, the state nurtured the development of rural areas, through the enlargement of cash crop production especially in the highlands of central and western regions while at the same time promoting land use diversification in the Arid and Semi- Arid Lands (ASALs) (Campbell *et al*., 2003).

Due to rising population over the years, lots of pressure has been imposed on the land resources in the country where approximately 75% of the populace engages in agriculture but only 20% of its land is arable. As a result, the shortage of arable land has led to expansion of cultivation into the wetter margins of rangelands, deforestation and decline of grassland as a result of overgrazing, charcoal burning and other unsustainable land uses. These actions have far reaching implications on the integrity of natural resources and ecosystems in the country (Mwagore, 2002; Campbell *et al*., 2003).

LULCC has also taken place in Makueni County over the years. Land has been subjected to a lot of pressure due to over-reliance on its resources. There has also been rapid population growth in the County in the recent past and this has translated to over-utilization of land and its resources. Most communities are farmers and they therefore depend on land for their livelihood well-being and sustenance. The situation is worsened by the fact that the County is located in ASALs and thus the environmental and climatic conditions are not favorable for crop production. This has resulted to the locals engaging in other sustenance activities such as charcoal burning, logging and even sand harvesting, all of which result to LULCC and the resultant environmental degradation.

1.2 Statement of the Research Problem

Makueni County has undergone land cover changes over the years. These changes can be attributed to a number of factors including rapid population growth and land scarcity which have forced farming households to expand their agricultural fields into natural environments so as to be able to increase agricultural productions to meet the daily household's needs. Rapid population growth has also resulted to clearance of natural vegetation to allow room for settlement. As a result, large areas, which were under natural vegetation cover, are now exposed to clearance, which has resulted to environmental degradation and threat to biodiversity and wild life habitat loss. Urban growth and expansion has also greatly contributed to changes in LULC in the study area. Many lands which were initially naturally vegetated, bare lands and bushlands have been converted to urban centres thus contributing to the wider change in LULC over the years. Local vegetation cover change significantly and cumulatively impact on regional and global climate changes. There is inadequate information on LULCC and also there is no clear policy framework to monitor these changes in the County. These gaps have negatively contributed to environmental degradation due to unawareness and uninformed decision making process. This state of affairs forms the basis of the current study.

1.3 Objectives of the Study

1.3.1 General objective

To assess LULCC and analyze the relationship between these changes and their underlying drivers in Makueni County.

1.3.2 Specific objectives

1) To classify the major LULC categories for selected time periods; 2000, 2005 and 2016.
2) To quantify LULCC for the period 2000- 2016
3) To assess the possible underlying drivers of the detected LULCC

1.4 Research Questions

1. What are the major LULC categories for selected time periods; 2000, 2005 and 2016?
2. To what extent has LULCC occurred within the period 2000- 2016?
3. What are the possible underlying drivers leading to the observed LULCC?

1.5 Significance of the Study

This study mapped the major LULC classes and analyzed the possible underlying drivers of LULCC which contributes a great deal of knowledge to urban and regional planners, research community, as well as policy and decision makers in terms of understanding the drivers of LULCC in Makueni County, thus providing a platform for the necessary interventions. The results of this study forms a basis to provide information to County Government and National Government planners regarding LULCC and also brings insight to researchers and policy makers to understand the trends of changes in similar scenarios as a result of the documented drivers. Furthermore, the findings of this study have provided an avenue for future research in the area.

1.6 Limitations of the study

This study faced a number of limitations during its undertaking. There was quite a serious challenge in the acquisition of relevant Landsat images. This is because all the images that are freely available at USGS managed websites, for the selected periods under study, had higher percentages of cloud cover with not a single one with 0% cloud cover. This prolonged the process of data acquisition since relevant data had to be acquired for any further analysis. There was also lack of useful data dating way back before the year 2000 for the study area since most of these data were having a cloud cover ranging between 30% and 100% and could not be used for LULCC analyses. This provided a limitation on the years that could have been studied for LULCC in the study area. Financial constraints was also a limitation of this study, since the study covered the whole Makueni County and data on underlying drivers had to be collected from respondents from all the Sub-Counties to ensure representation.

1.7 Scope of the Study

This study was carried out in Makueni County and focused on analyzing the changes in LULC with regards to key aspects such as forest cover, bare land, water resources, bushlands, grasslands, croplands and built up areas for the periods between 2000 and 2016. Data collection and analysis operations were guided by use of RS and GIS. The operations, activities and data collection were strictly confined within the boundaries set by the objectives of this study.

1.8 Assumption of the Study

There were significant changes in LULC in Makueni County during the period between 2000 and 2016.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definitions and rational of LULCC studies

Land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin *et al*., 2003; Chrysoulakis *et al*., 2004; Baulies and Szejwach, 1998). On the other hand, land use is the intended employment of and management strategy placed on the land cover by human agents, or land managers to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging, and mining among many others (Zubair, 2006; Chrysoulakis *et al*., 2004). Land use change is defined to be any physical, biological or chemical change attributable to management of land resources, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses (Quentin *et al*., 2006).

LULCC may be grouped into two broad categories as modification and conversion. Modification involves maintenance of the broad LULC type in the face of changes in its attributes while conversion refers to changes from one LULC type to another (Baulies and Szejwach, 1998). According to Lambin (2005) sustainable resource use refers to the use of environmental resources to produce goods and services in such a way that, over the long term, the natural resource base is not damaged so that future human needs can be met. One of the most significant global challenges in this century relates to management of the transformation of the earth's surface occurring through LULCCs (Mustard *et al*., 2004, cited in Daniels *et al*., 2008).

It is estimated that undisturbed (or wilderness) areas represent 46% of the earth's land surface. Forests covered about 50% of the earth's land area 8,000 years ago, as opposed to 30% today. Agriculture has expanded into forests, savannas, and steppes in all parts of the world to meet the demand for food and fiber (Lambin *et al*., 2003). Based on data from diverse sources, the Forest Resources Assessment (FAO) (2000) estimated that the world's natural forests decreased by 16.1 million hectares per year on average during the 1990s, which is a loss of 4.2% of the natural forest that existed in 1990 (Lambin *et al*., 2003). Land use in East Africa has changed swiftly over the last half-century. Expansion of mixed crop-livestock systems into former grazing land and other natural areas and intensification of agriculture are the two largest changes that have been detected (Olson and Maitima, 2006). Accordingly, land cover classification has recently been a hot research topic for a variety of applications (Liang *et al*., 2002).

A great deal of research has been conducted throughout the world in an attempt to understand major shifts in LULC and to relate them to changing environmental conditions. According to Baulies and Szejwach (1998), during the next decades, land-use dynamics will play a major role in driving the changes of the global environment. Hence, global mapping of irrigated and dry land agriculture, semi-natural areas and forest cover, reflecting their dynamics, can contribute to the assessment of the biophysical implications of LULCC within the Earth's system. Generally, agriculture is found to be the major driver of land cover change in tropical regions (Lambin *et al*., 2001 cited in Daniels *et al*., 2008). Over the past 50 years in East Africa, there has been expansion of agriculture at the expense of grazing land (Olson and Maitima, 2006). Before 1950, semi-arid and sub-humid areas were predominantly pastoral with scattered settlement and cultivation but from then onwards, there has been significant transformation of grazing land to mixed crop-livestock agriculture.

Understanding the mechanisms leading to LULCC in the past is crucial to understand the current changes and predict future ones. These changes occurred at different time periods, paces, and degrees of magnitude and with diverse biophysical implications (Baulies and Szejwach, 1998). LULCCs plays an important role in global environmental change and sustainability, including response to climate change, effects on ecosystem structure and function, species and genetic diversity, water and energy balance, and agro-ecological potential (Codjoe, 2007). LULC mapping is one of the most important and typical applications of remote sensing data (Chrysoulakis *et al*., 2004). Remotely sensed data are a useful tool and have scientific value for the study of human environment interactions, especially LULCC (Dale *et al*., 1993 cited in Codjoe, 2007).

2.2 LULCC and their driving forces

"What drives/causes land-use change?" has always been one of the most common research questions in land-use change studies. To this question, driving forces can be simply defined as causes or factors responsible for LULCC (Alemu *et al*., 2015). A precise meaning of the "drivers" or "determinants" or "driving forces" of land-use change is not always clear (Briassoulis, 2000). According to Coppin *et al*. (2004), the main categories are distinguished into;

a) Biophysical and
b) Socio-economic drivers.

The *biophysical drivers* include characteristics and processes of the natural environment (weather and climate variations, landform, topography, and geomorphologic processes, volcanic eruptions, plant succession, soil types and processes, drainage patterns, availability of natural resources) while *socio-economic drivers* comprise demographic, social, economic, political and institutional factors and processes (population and population change, industrial structure and change, technology and technological change, the family, the market, various public sector bodies and the related policies and rules, values, community organization and norms, property regime).

2.3 Why RS and GIS techniques?

Curran, (1985) defines RS as the use of electromagnetic radiation sensor to record images of the environment which can be interpreted to yield useful while Aronoff (1989) defined GIS as a computer based system that provides four sets of capabilities to handle geo referenced data, viz. data input, data management (data storage and retrieval), manipulation analysis and data output. Remote sensing and GIS techniques have been widely recognized as powerful and effective tools in detecting the spatio-temporal dynamics of LULCC (Zubair, 2006; Lambin, 2005; Codjoe, 20007; Campbell, 2002; Kidane *et al*., 2012) RS provides researchers with valuable multi-temporal data for monitoring land-use patterns and processes (Lambin et al., 2001) and GIS techniques are then utilized for the analyses and mapping of these patterns (Hualou et al., 2006). Many studies have concluded that satellite imagery provides an excellent source of data for performing structural studies of a landscape

Fung (1990) in Jeffery S. Allen et al (1999) indicated the importance of techniques and methods of using satellite imageries as data sources have been developed and successfully applied for LULC classification and change detection in various environments including rural, urban, and urban fringes. GIS and remote sensing provides an ability to characterize large assessment areas and establish reference conditions (Getachew *et al*., 2011). Therefore, the use of remote sensing satellite data for land use land cover change detection and monitoring is widely applying throughout the world with the aid of technological improvement that provides high resolution images. Despite the easy to access nature of RS data, studies on LULC classification and assessing LULC changes have not been done in Makueni County despite the various documented underlying drivers of change being evident in the area. These study sought to use multi-temporal data and RS and GIS techniques to generally assess LULCC in Makueni County.

2.4 Use of RS and GIS for LULCC studies

Remote Sensing is defined as the use of electromagnetic radiation sensor to record images of the environment, without coming into contact with them, which can be interpreted to yield useful information (Zubair, 2006). Aronoff (1989) defined GIS as a computer based system that provides four sets of capabilities to handle geo referenced data, viz. data input, data management (data storage and retrieval), manipulation analysis and data output. Over the past years, RS has played a very important role in studying LULCC detection. LULCC detection studies are becoming priority tasks with the availability of a wide range of sensors operating at various imaging scales, resolution and scope. This has increased avenues for monitoring accurate and effective LULCC. Remote Sensing and GIS are being increasingly used in combination spatial analysis. GIS databases are used to improve the extraction of relevant information from RS imagery, whereas remote sensing data provide periodic pictures of geometric and thematic characteristics of terrain objects, improving our ability to detect changes and update GIS databases (Janssen, 1993 In Luis *et al.,* 2003). Both RS and GIS have been widely applied and recognized as powerful and effective tools in detecting the spatiotemporal dynamics of LULC. RS can provide researchers with valuable multi-temporal data for monitoring land use patterns and processes (Lambin *et al*., 2001) and GIS techniques make possible the analysis and mapping of these patterns (Hualou *et al*., 2006).

One important method of understanding ecological dynamics, such as natural and human disturbances, ecological succession and recovery from previous disturbances, is the analysis of changing land cover patterns (Turner, 1990). Satellite imagery provides an excellent source of data for performing structural studies of a landscape. Simple measurements of pattern, such as the number, size and shape of patches, can indicate more about the functionality of a land cover type than the total area of cover alone (Lambin *et al*., 2001). When fragmentation statistics are compared across time, they are useful in describing the type of land cover change and indicating the resulting impact on the surrounding habitat. The areas of land cover change between images can also be compared to landscape characteristics to determine if change is more likely to occur in the presence of certain environmental and human induced factors. This level of classification detail presents opportunities for analyzing land cover change patterns at a structural scale (Matt *et al*., 2004).

Remote sensing is important for estimating levels and rates of deforestation, habitat fragmentation, urbanization, wetland degradation and many other landscape-level phenomena. Such useful information can be then integrated into many regional to global scale models, including those that are used to develop parameters for carbon fluxes and hydrological cycles. Therefore, remote sensing data can be used as the basis for answering important ecological questions with regional to global implications (Vogelmann *et al*., 2001). Herold *et al.* (2005) also noted that one of the advantages of remote sensing is its ability to provide spatially consistent data sets covering large areas with both high detail and high temporal frequency, including historical time series. Fung (1990) in Allen *et al*. (1999) indicated the importance of techniques and methods of using satellite imageries as data sources have been developed and successfully applied for land use classification and change detection in various environments including rural, urban, and urban fringes. Lambin *et al.* (2003) indicated that the use of remote sensing satellite data for LULCC detection and monitoring is widely applied throughout the world with the aid of technological improvement that provides high resolution images.

In their study to evaluate LULCC and Land Degradation in Dera District, Ethiopia, Gashaw *et al.* (2014) carried out LULCC detection and Normalized Difference Vegetation Index (NDVI) analysis on two images of 1985 and 2011. The results of their study revealed that cultivated and degraded lands increased at the expense of forest, shrub and grazing lands. NDVI analysis also indicated increased land degradation which they stated as to be mainly aggravated by LULCC. In their methodological approach, Global Positioning System (GPS) and Topographical maps were utilized for ground verification and ERDAS Imagine 9.1 and ArcGIS 9.2 software for satellite image processing and analysis. Their study recommended the use of multispectral images in LULCC studies.

Olang (2009) carried out a study to analyze land cover change impact on flood events using Remote Sensing, GIS and hydrological models in Nyando River basin. In his study, land cover changes in the Nyando River basin of Kenya were analyzed and their impact on floods quantified. Three Landsat satellite images for 1973, 1986 and 2000 were used. Land cover classification results revealed immense land degradation especially with regards to decline in forest cover over the span of study. His study recommends the possibility of using multi-temporal Landsat satellite images as a cost effective way of mapping land cover changes.

In Nyando River basin, the results of a study done by Olang (2009) to assess spatio-temporal LULCC indicated that there were immense conversions from one LULC class to others. There results reveled significant conversions from grassland to agricultural lands between 1973 and 2000. Their study revealed the possibility of using two multi-temporal data to assess LULCC. The study also revealed the use of community based information approach to provide an efficient way to reveal the historical land cover states and trends. Though rigorous in time and cost, such an approach can be used to construct missing information sufficient for mapping of land cover changes in data scarce areas.

The results of a research work done by Quentin *et al.* (2006) to monitor LULLC in Nakuru revealed that 6.25 Km^2 of land in Nakuru changed to urban land-use from non-urban between the years 1986 to 2000 compared to the value of 19.70 Km^2 between the years

2000 to 2010. Thus there was rapid urban growth between the years 2000 to 2010 due to urbanization process. The results of their study revealed the influence of population growth on LULC especially with regards urbanization. Their study concludes that monitoring urban land-use and spatial-temporal changes is essential for guiding decision making in resource management

2.5 Conceptual framework

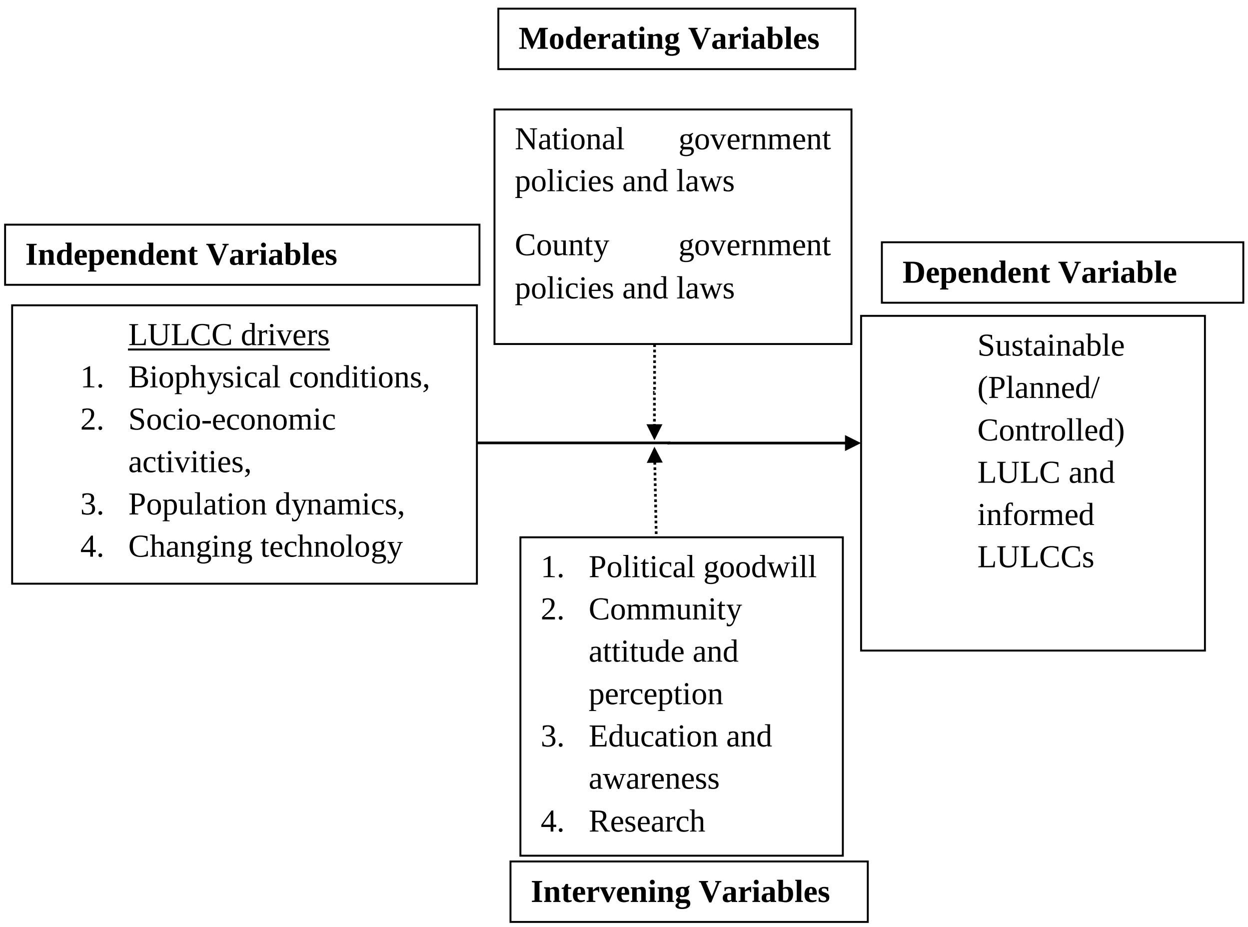

Figure 2.1: Conceptual framework

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

3.1.1 Location

Makueni County covers an area of 8,034.7 Km^2. The county lies between Latitude 1º 35´ and 3 º 00 South and Longitude 37º10´ and 38º 30´East (GoK, 2013).The map boundary for this area stretches in a north west to south west direction (Figure 3.1). The County boarders Kajiado, to the West, TaitaTaveta to the South, Kitui to the East and Machakos County to the North.

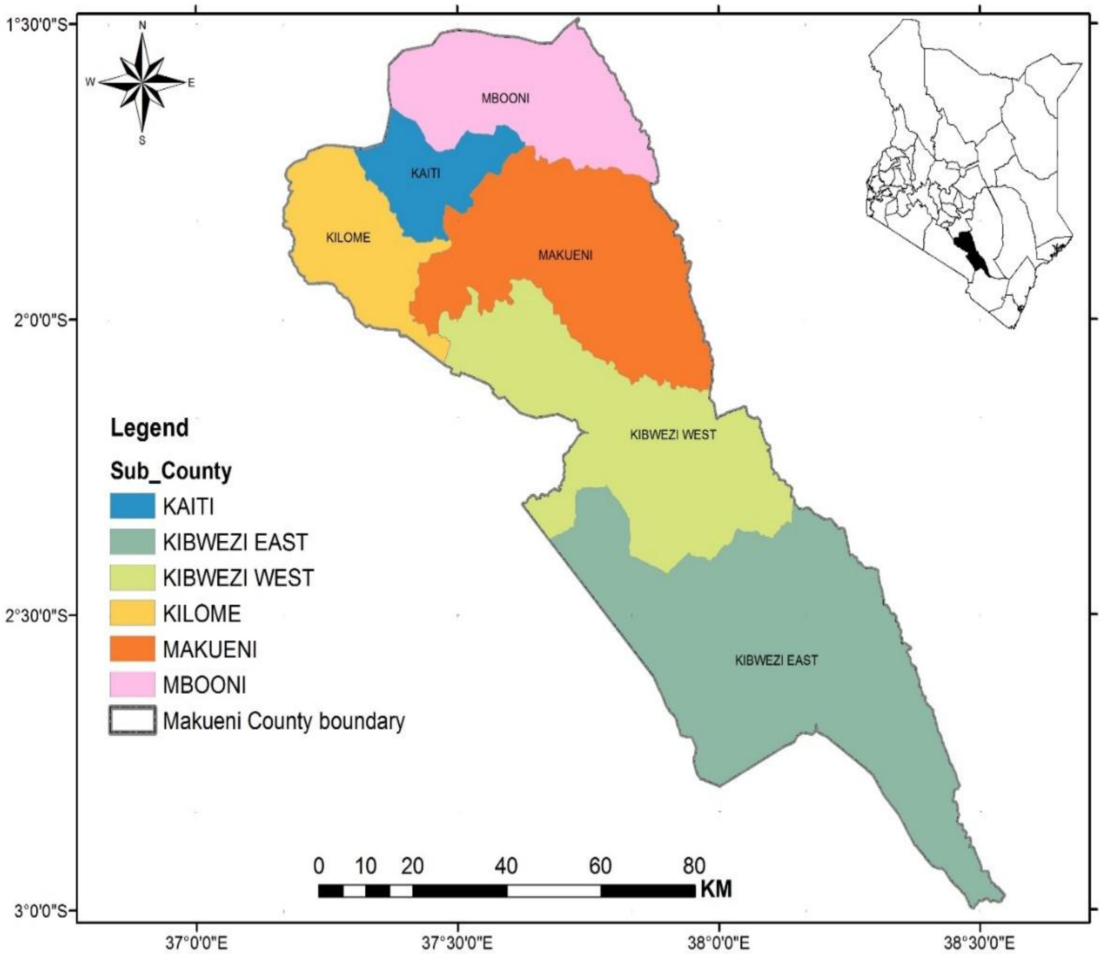

Figure 3.1: A map of Makueni County

3.1.2 Topography

The county lies in the arid and semi-arid zone in Eastern Kenya. It consists of hills and small plateaus rising between 600-1900 metres above sea level (masl). The highest point of elevation is 1900m above sea level comprising of Mbooni and Kilungu hills in the upper north west of the county with vast low lying areas in the mid stretching to the southern parts in Tsavo rising to 600m above sea level, and to the volcanic Chyulu hills in the south west boarder of the county, (Muhammad, *et al.,* 2010; GoK, 2013). Makueni County being an ASAL translates to inadequate food production from farms due to the high temperatures and low rainfall amounts associated with such areas. This means that the communities living in such areas have to device and find other ways of meeting their day- to- day activities and this may include activities such as cutting down of trees from forests. Such activities in the long run leads to changes in LULC.

3.1.3 Hydrology

The county is served by river Athi which is the most important perennial river. The river presents high potential for irrigation alongside other natural resources found in Makueni County like land, good soils and suitable climate for agriculture and livestock production and, horticulture (GoK, 2012). Makueni County falls in the Arid and Semi-Arid Lands, (ASAL) range of 50-85% of sub humid to semi-arid conditions typical in ASAL zones. The main rivers that drain the catchment include Athi, Kiboko, Kibwezi and Masongaleni which are perennial tributaries. The ephemeral tributaries include Thwake, Kaiti, Muooni, Kikuu, Thavu, Kambu and Mtito-Andei rivers. All these rivers traverse the county from West to East and drain into the Athi River which forms the Makueni-Kitui counties boundary in the East. Chyulu range is an important water catchment for both surface and ground water in the area, (Gichuki, 2000; GoK, 2012). The environmental conditions in Makueni County has resulted to over-reliance on the available water resources the County. This has in the long run led to shrinking of water resources. In order to meet the water needs, the County Government and the communities have embarked on ways to preserve water such as construction of sand dams, digging of boreholes and also creation of farm ponds. All this activities has resulted to changes in the water resources coverage along the years.

3.1.4 Agro- climatic conditions

The county's rainfall distribution is bimodal received in two rain seasons. The short rain season is between November and December (OND) and the long rain season between March and April. The upper hilly parts of Mbooni and Kilungu hills receive an average of 800-1200mm of rainfall per annum; while the drier southern low lying areas receive an average of 300-400mm per annum. The mean rainfall in the two seasons range between 200-350mm (half of the annual precipitation) largely influenced by the altitude among other factors, which is mostly depressed, barely enough to sustain the major staple food crops of maize and beans grown in the county. Temperatures range between 24.6 ºC in the upper hilly areas to 35.5 ºC in the low lying areas. The mean monthly temperatures in the area ranges between 18 ºC to 25 ºC. The months of February and October are the hottest and July being the coolest month. The agro-ecological conditions in the area support agricultural activities predominantly comprised of rain fed agriculture, crop and livestock production which dominates land use and household livelihoods in small-scale subsistence farming (Jaetzold *et al.*, 2006; Muhammad *et al.,* 2010; GoK, 2013). However, with the increasing global temperatures and climate change issues, crop production has been depressed and thus, farmers have initiated activities such as digging of farm ponds to enable irrigation agriculture. The changes in the annual rainfall and temperatures over the years have resulted to changes in agricultural and crop production activities with farming activities being stable in upper hills where the rainfall and temperatures can sustain crop production thus changes in the coverage of croplands over the years.

3.1.5 Rainfall distribution in OND season

The October-November-December (OND) season receives relatively more rainfall than the MAM season except for the lee ward side of hills in parts of Kilome districts. Recorded rainfall amounts for the OND season ranges between 50mm to over 450mm. The month of November forms the peak period of rainfall for the season. The highest rainfall (over

450mm) is recorded in the hill top areas of Tulimani, Mbooni, Kilungu and Matiliku. Areas immediately lower than the hill tops record a mean seasonal rainfall of 350-450mm. These areas include Kalawa, Kasikeu, Mbitini, Chyulu hills, Kibwezi and Makindu. Other intermediary rainfall regime (200-350mm) is recorded in, eastern sides of Kilome, western sides of Kasikeu, Nguu and Kathonzweni districts (Makueni County Meteorological Department, 2013). The short rain season (OND) comes before the chosen periods of data acquisition for this study. The mean seasonal OND rainfall distribution is shown in figure 3.2 below. It is important to note that the rainfall distribution of the rainy seasons preceding the data acquisition months for the three selected time periods did not influence the results since the time lag of the three seasons did not reach to the month of February.

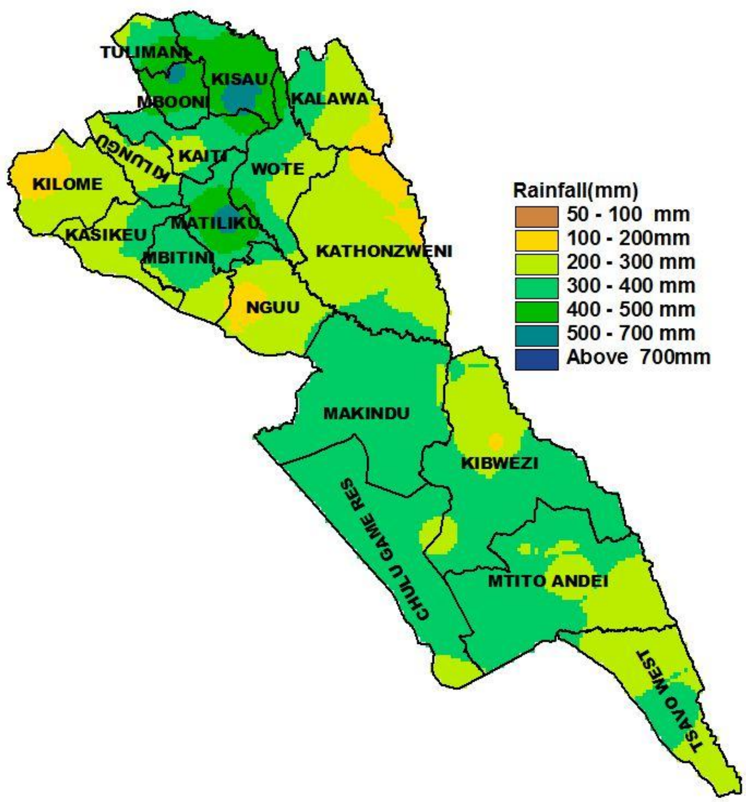

Figure 3.2: Spatial Distribution of Mean Seasonal Rainfall OND

3.1.6 Makueni County agro-ecological zones

Figure 3.3 shows the classification of agro-ecological zones in Makueni County. From the figure, the County has been divided into five agro-ecological zones, viz. Arid, Semi-arid, Semi-humid to Semi-arid, Semi-humid and Sub-humid. It was important to gather the agro-ecological information of the County since the difference in the characteristics of this zones affects distribution of LULC classes and the dynamics of LULCC. The areas under Semi-humid to Sub-humid areas are characterized by wetter conditions thus these areas receive moderately high rainfall amounts as compared to the other Arid and Semi-arid zones. This means that such areas can be able to support agricultural activities and thus major LULC class in these areas are cropland and evergreen forests. On the other hands the Arid and Semi- arid areas are likely to have grasslands and barelands as the major LULC categories.

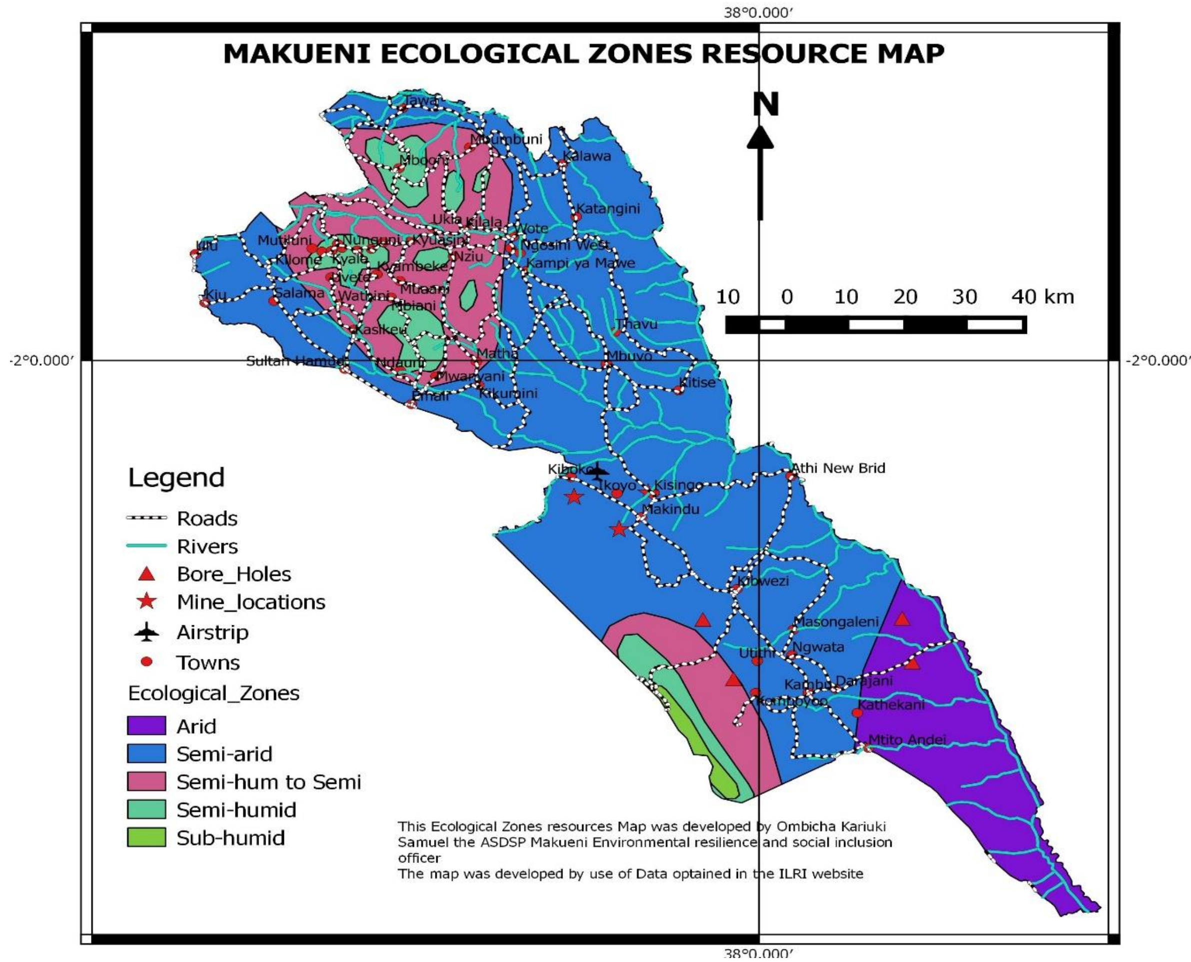

Figure 3.3: Makueni ecological zones resource maps

3.1.7 Population

The County's population as per the 2009 Kenya National Population and Housing census stood at 884,527 people (Table 3.1) as compared to 771,545 people as per the 1999 census (Table 3.2).

Table 3.1: Makueni County Demographics

Sub-County	Area	Population	Density Km^2
Kaiti	422.9 km^2	120,116	248
Makueni	1546.1 km^2	193,798	125
Kibwezi West	2100.7 km^2	165,929	79
Kibwezi East	2216.5 km^2	132,196	60
Mbooni	949.2 km^2	184,624	195
Kilome	641.3 km^2	87,864	137
Makueni County	**8034.7 km^2**	**884,527**	**110**

Source: GoK, 2013

Table 3.2: Makueni demographics (1999 census)

Division	Population
Kaiti	46,107
Kalawa	14,039
Kasikeu	35,719
Kathonzweni	65,738
Kibwezi	80,236
Kilome	46,204
Kisau	50,510
Kilungu	67,741
Makindu	50,299
Matiliku	38,867
Mbitini	48,729
Mbooni	55,984
Mtito Andei	66,663
Tulimani	32,717
Wote	40,353
Total	***771,545***

Source: GoK, 2013

Table 3.3 shows the demographic characteristics of Makueni County. It is projected that the population of Makueni County will be 989,050 people by 2017 with a projected population density of 123.5km^2.

Table 3.3: Makueni County general demographic characteristics

Population characteristics	Makueni County
Current Population	874,323
Current Population Density	109.2
Projected Population (2017)	989,050
Projected Population Density (2017)	123.5

Source: GoK, 2013

It is projected that the human population in Makueni County will reach 989,050 people in 2017 with an annual growth rate of 1.5 %. The majority of people in the labour force are within the age group of between 15-64 years comprise of 51.1% or 471,454 people as per 2012 projections (GoK, 2013). The increasing population has resulted to major LULCC due to the associated increasing need for food and settlement areas. With the growing population, there has been conversions from one category of LULC to another especially to croplands and settlement areas. Also growing population is associated with growth of built up areas such as urban centres and infrastructures such as roads and hospitals among others.

3.1.8 Socio-economic dynamics and infrastructural development

According to GoK, (2013) and Ifejika *et al.* (2007), agro-pastoralism is the main source of income for households with agriculture accounting for 78%, followed by wage employment at 10% and rural and urban self-employment at 8% and 4% respectively. The majority of people in Makueni County lack employment and meaningful source of livelihoods. The unemployed rely on agriculture and other environmental resources for their livelihoods, a trend which will continue to exist in the county at least in the foreseeable future to the detriment of the county's environmental integrity.

The state of underdeveloped infrastructure in the County and limited economic diversification opportunities influences economic activities around exploitation of natural resources and in particular land which impacts negatively on the environment. The urban population that was projected to be less than 8% in 2015 depicts a situation of overdependence on land and other natural resources by the majority of the people in the County (GoK, 2013). This over dependence on environmental resources has and will in the long run lead to serious LULCC e.g. extreme over- exploitation of forests and water resources. Many studies have revealed cases of uncontrolled urban sprawl at the expense of agricultural and forest lands. If urbanization is not well planned, its rapid growth nature can lead to uninformed LULCC.

3.1.9 Land and land use in Makueni County

The county has a total arable land of 5042.69km^2 which is 74% of the total area. A total of 1,762.71km^2 is non-arable accounting for 21.9% of the total area. There are no water masses or industrial area in the county while the urban area accounts for only 7.4% of the total area. Most of the land is used for agricultural purposes since most people depend on agriculture and livestock for their livelihood. The County has potential in horticulture and dairy farming especially the hilly parts of Kilungu and Mbooni west Sub-Counties. The lowlands are used for livestock keeping, cotton and fruit production. Fruits grown are mainly mangoes, pawpaw and oranges. These areas include; Kathonzweni, Mbooni East, Nzaui and Makueni Sub-Counties. (Makueni County Integrated Development Plan, 2013)

3.2 Data acquisition

During data acquisition, it was more preferable to download the cloud free imagery. Clouds usually block the view from the sensor to the object on the earth surface thus minimizing the observations that can be made on the image. The cloud cover for the images acquired for this study range from 0.34 to 5%. This leaves the 95% of pixels in the majority of the scenes usable for further procedures. Masking out the clouds was done since the spectral characteristics of the clouds look almost the same as that of the buildings and sands, therefore the clouds were removed to avoid misrepresentation of the percentage coverage of the buildings and sands.

3.2.1 Datasets

The Landsat archive was utilized in the LULCC analysis. This study acquired images from Earth explorer and GLOVIS archives which are managed by the USGS. Landsat 7 tiles (used to form three images for 2000, 2005 and 2016) were identified as shown in Table 3.4 to be relatively cloud free and provide appropriate time intervals which allowed for the assessment of LULCC over the identified years.

Table 3.4: Dates and scene ID numbers of Landsat Images used

Year	Day and Month	Scene/Tile	Entity Id
2000	1/ March	167/061	LE71670612000061SGS02
	1/ March	167/062	LE71670622000061SGS02
	21/ February	168/061	LE71680612000052EDC00
	21/ February	168/062	LE71680622000052EDC00
2005	12/February	167/061	LE71760612005042PFS00
	12/February	167/062	LE71670622005042PFS00
	19/February	168/061	LE71680612005049ASN00
	19/February	168/062	LE71680622005049ASN00
2016	26/ February	167/061	LE71670612016057SG100
		167/062	LE71670622016057SG100
	17/ February	168/061	LE71680612016048SG100
	17/ February	168/062	LE71680622016048SG100

3.3 Thematic information extraction

3.3.1 Image pre-processing

Images obtained from Landsat GLOVIS Archive are already preprocessed. The downloaded data comes with a metadata showing all the preprocessing procedures taken before the images are uploaded on the archive. However, some preprocessing procedures were deemed necessary before performing Image analysis.

a. Scan Line Corrector (SLC)

It is worth noting that images acquired from Landsat 7 experienced an SLC failure since May 2003. This means all the images from this time have scan line gaps due to malfunctioning of Landsat 7. The images showed an increase of the data gaps (approximately 25% loss) towards both sides of the images. Before any analysis on the Landsat imagery, these scan line gaps were corrected by applying a spatial tool for performing focal analysis in Erdas Imagine gain the desired results as shown in Figure 3.4.

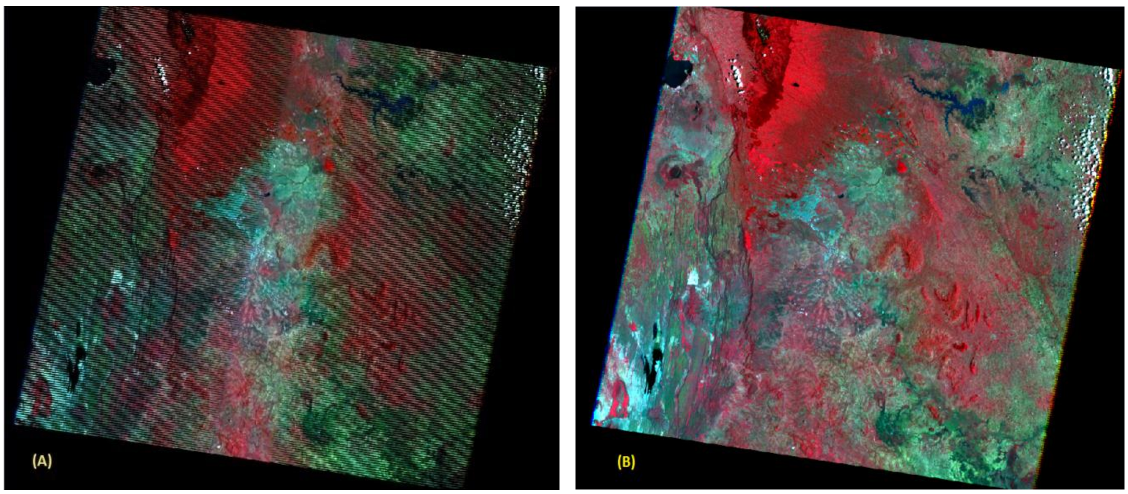

Figure 3.4: (A) Pre and (B) Post SLC correction for tile 168/61

b. Mosaicing of Tiles

Considering the fact that Makueni County falls under four separate Landsat tiles the four tiles acquired for each years (2000, 2005 and 2016) were mosaiced as shown in figure 3.5 to produce three images of 2000, 2005 and 2016. Clipping was done using a shape-file of Makueni County to produce images of the specific study area.

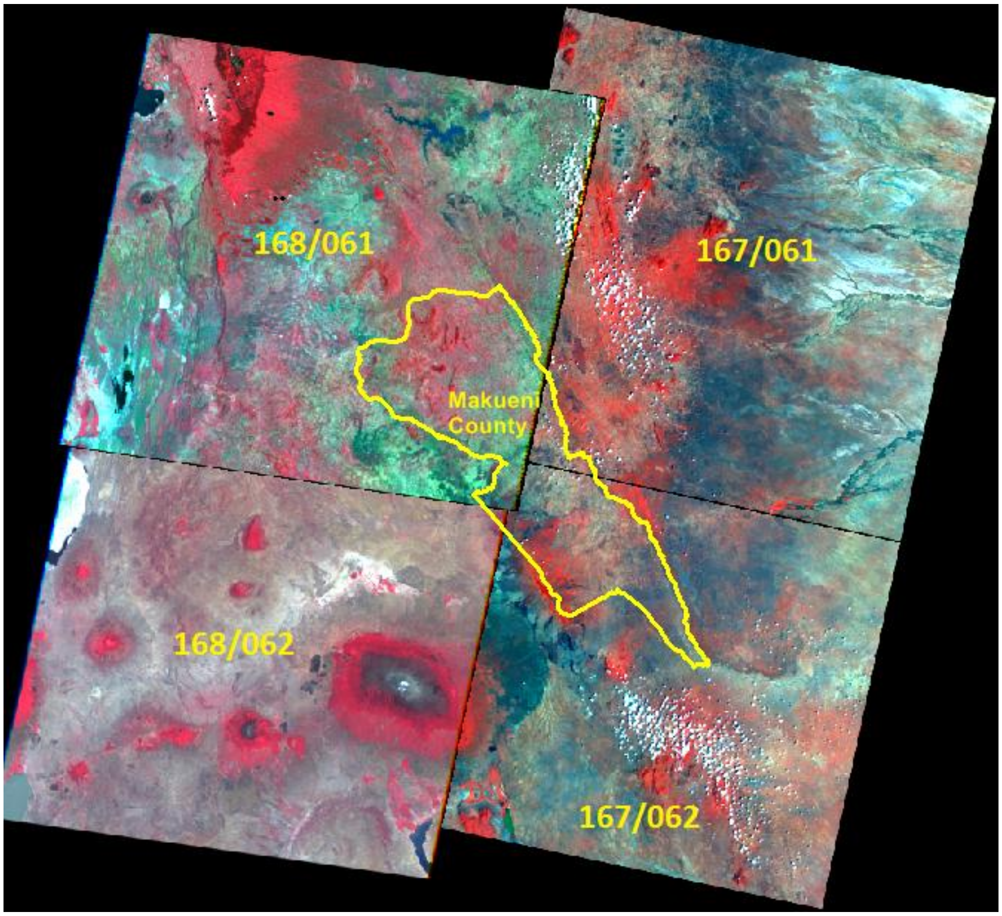

Figure 3.5: Mosaiced Landsat tiles

3.3.2 Image enhancement and transformation

Image enhancement was done to improve the visible interpretability of the images by increasing apparent distinction between the features in order to emphasize the information of interest in the images. Enhancement of the images was achieved through Principal Components Analysis (PCA) which is a procedure that involves data reduction from satellite imagery, whereby the information content from a number of bands is compressed into a few variables known as principal components for easier interpretation. The procedure provides an additional clarity on the imagery by resampling the pixel size and helps in picking up the dataset or bands which are more informative. The main use of PCA is to reduce the dimensionality of a dataset while retaining as much information as possible. The procedure computes a compact and optimal description of the dataset. It enables the identification of data patterns and compresses the data without much loss of information. For this reason, PCA has been used and recommended by many similar studies in the enhancement of images for assessment of LULCC (Zubair, 2006; Chomitz and Kamari, 1998; Masek et al., 2000; Barros, 2004). In this study, the images were subjected to PCA using the multivariate algorithm. This was done to generate Eigen images (outputs of PCA). Color composite of the Eigen images generated from the first three principal components were used for the classification and change detection procedures. This is because the other components generally contain only noise (Deng *et al.*, 2008).

3.4 Possible source of error and omission

Landsat ETM+ records reflectance from the earth surface. Each object on the earth surface has a reflectance value that is recorded and stored as a raster data. In the case of Landsat, the records are stored in grid cells which represent an area of 30m by 30m for each band. Each cell shows an average of the ground reflectance value for the object(s) in a $30m^2$ pixel. This means that some objects are somehow omitted. Only the objects that are large enough can influence the reflectance value of a pixel. We can therefore assume that object beyond these dimension cannot be clearly revealed by Landsat datasets. Combining the Landsat scenes that cover the study area means that the mosaic of the four tiles would require more time and disk space to perform a single process on them. This challenge was minimized by creating a subset area defined by the Makueni County map. This was done by introducing an Area of Interest (AOI) by manually digitizing the boundary of Makueni County map at minimal snapping error. No distortion or adjustment was done on the location of the area during this procedure. The AOI was used as a masking boundary in all subsequent processes.

3.5 Training site selection

For training site selection, reconnaissance survey to the study area was first done to determine the major LULC classes and to gather information that would guide the selection of training sites. Different areas of the study area were visited to identify the existing LULC category and their GPS coordinates collected. These coordinates were used to identify the same locations in the unclassified maps since they were points of known LULC category. The identified points were then used as training sites to guide the overall accuracy procedures. The training sites were used to develop a signature file which the software used to classify the whole image based of the characteristics of the training sites.

3.6 Supervised Image Classification

Image classification was done in order to assign different spectral signatures from the Landsat datasets based on the appropriate color composite. This was done on the basis of reflectance characteristics of the different LULC types. Different color composites were utilized to improve visualization of different objects on the imagery. Infrared color composite Near-Infrared (NIR) (4), Short-wave Infrared (SWIR) (5) and Red (3) (Figure 3.5) was applied in the identification of varied levels of vegetation growth and separating different shades of vegetation. Other color composite such as Short Wave Infra-red (7), Near Infra-red (4) and Red (2) combination which are sensitive to variations in moisture content were applicable in identifying the built-up areas and bare soils which appear pink or dark blue in the image. The bright green shades indicate vegetation while clear water appears dark blue or black as shown in image 2 of Figure 3.6.

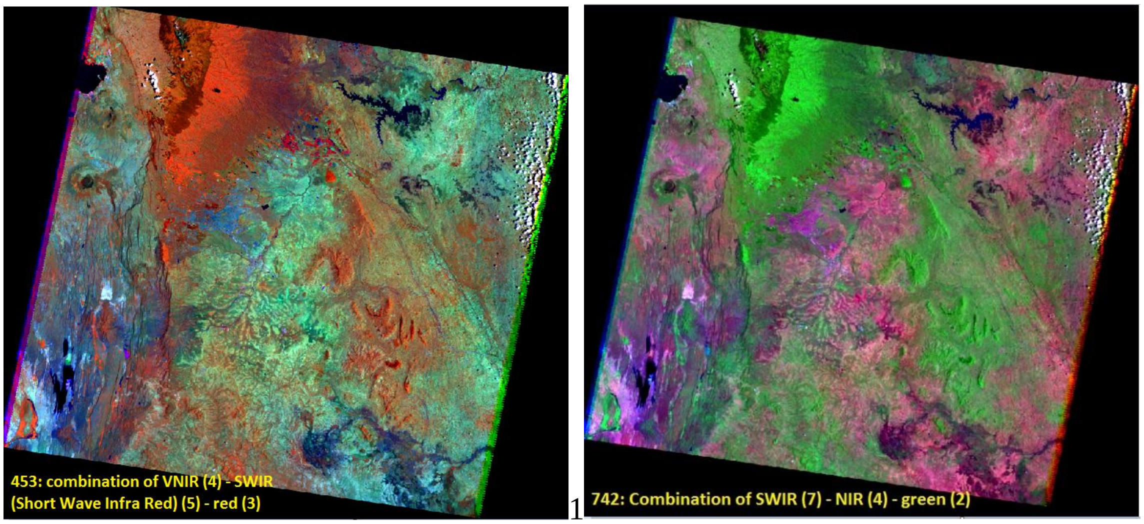

Figure 3.6: Different colour composites utilized

Supervised classification scheme with Maximum Likelihood classifier (MAXLIKE) decision rule was used by following three stages, creation of training sites, development of a signature file and image classification as shown in figure 3.7. Number of training sites varied from one LULC category to another depending on the variability of the classes due to overlap and also on ease of identification of a LULC category.

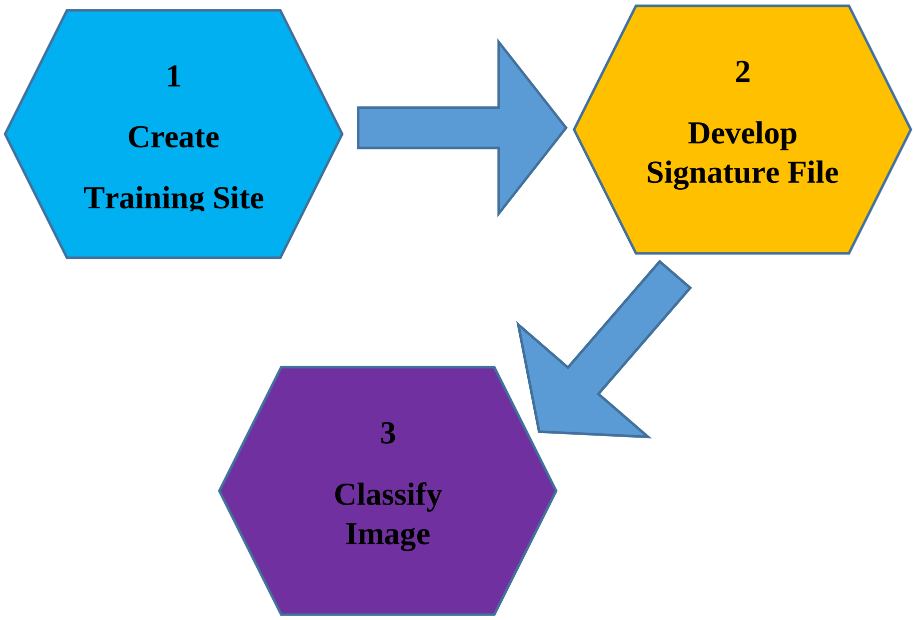

Figure 3.7: Supervised classification diagram

3.7 Ground truth

After classification, ground verification was made in order to check the precision of the classified LU/LC map. Using ancillary data as a reference, Makueni County was digitized in ArcMap. Following Zeledon and Kelly (2009). Stratified Random sampling method was applied in selecting the reference points. 165 random reference points were generated with 89 of them being within the study area to obtain representation of land classes. 30 sample reference points per class were transferred to a GPS and were physically visited for ground truthing to determine the current LULC. Based on the ground verification data, necessary correction and adjustments were made on the classification maps. The map from t_1 (2000) was compared with the map produced at time t_2 (2005) and a complete matrix of categorical change obtained.

3.8 LULC classes and definitions

Identification of different spectral signatures was important in maintaining high accuracy in the image classification. Thus, Table 3.5 shows the definitions of different LULC classes that were observed in this study.

Table 3.5: Land class and definitions for supervised classification

	Land Cover	Description
1.	**Forest**	This describes the areas with evergreen trees mainly growing naturally in the reserved land, along the rivers and on the hills.
2.	**Bushland**	Describes areas with sparse trees and shrubs.
3.	**Cropland**	The land which is mainly used for growing food crops such as maize, green grams, beans, cassava, mangos. Crops in this land are either grown by irrigation or rain-fed.
4.	**Water bodies**	This class of land cover describes the areas covered with water either along the river bed or man-made earth dams, filled sand dams and ponds.
5.	**Bareland**	This describes the land left without vegetation cover. This results from abandoned crop land, eroded land due to land degradation and weathered road surface.
6.	**Grassland**	This class of land cover defines grass as the main vegetation cover.
7.	**Built-up area**	This class describes the land covered with buildings in the rural and urban. It includes commercial, residential, industrial and transportation infrastructures.

3.9 Accuracy assessment

After image classification, accuracy assessment was carried out. This was done in order to assess how well the classification procedure worked. Stratified random sampling was used to determine the number of reference points for every identified LULC category. Reference data was collected through ground truthing with GPS and from aerial photographs from Google earth for the purposes of determining the current class types at specific locations. The reference data was then compared to the classified map. The overall accuracy was determined by use of the formula;

Total Accuracy = Number of correct plots / Total number of plots

However, the value obtained by this formula is average. It does not reveal if error was evenly distributed between classes or if some classes were bad and others good. Therefore, user's and producer's accuracy were also determined.

User's accuracy corresponds to the error of inclusion. It uses the classified maps data and thus uses the perspective of the user of the map. This type of accuracy provides information on the number of pixels in the map that are actually under the specific category. User's accuracy was determined by;

User's accuracy = number of correctly identified points in a given map / number claimed to be in the map

Producer's accuracy corresponds to the error of exclusion. It uses the reference data and thus, it is viewed from the perspective of the producer of the map. Producer's accuracy answers the question; how many pixels in the map are labelled correctly for a given class in the reference points? Producer's accuracy was determined by;

Producer's accuracy = number of correctly identified in reference points of a given class / Number actually in the reference class.

3.10 Change detection

Post- classification comparison change detection method (PCCCD) was used to determine the changes in land cover that had occurred over the selected years. It is the most common approach used for monitoring land cover changes since it produces the lowest change errors and also provides more useful information on the initial and final land cover types in a complete matrix of change direction (Campbell, 2002; Fan *et al*., 2007; Fuller *et al.*, 2003; Lu *et al*., 2004; Shalaby and Tateishi, 2007; Singh, 1999; Yang and Lo, 2002; Yuan *et al*., 2005; Currit, 2005; Petit *et al*., 2001).This method also allows detection of land use change by pixel-by-pixel comparison of land use maps created from satellite image classification, creates a change matrix to show quantitative information of 'from- to' changes visually on an image map. Here, when classified images of different years are overlaid, change areas are simply those areas which are not classified the same at different times. The changed pixels extracted between the study periods were used to define the "from-to" LULC class and the area coverage. The analysis and interpretation of different aspects of the numeric data of LULC dynamics was done in Microsoft Excel. The results were presented in form of texts, maps, tables, graphs and charts.

3.11 Identification of underlying drivers of change

The results of the third objective were obtained through a number of ways. Standard questionnaires were administered to 30 locals in each of the respective identified LULC categories to generate information on causes of the observed changes. The sampling of locals utilized the existing administrative boundaries which divides Makueni County into six Sub-Counties. Within each Sub-County, purposive sampling was used to identify five respondents in each of the identified LULC classes. Purposive sampling was used since the study purposed to collect information from locals who had lived in the area for more than fifteen years, since they were considered to have stayed in the area long enough to have knowledge of any LULCC that might have occurred in the area. Sampling of key informants was also through purposive sampling since the aim was to interview key informants who had the knowledge needed for this study and whose contribution would be relevant in achieving the objectives of this study. Questionnaires were administered to 7 key informants/ officials in various departments such as, Kenya Meteorological Department (KMD), KFS, Urban planning and agriculture department. Interviews were also done with various locals and key informants to establish the possible underlying drivers of the observed change in LULC classes. Relevant literature on similar studies was also reviewed to compare the causes of LULCC of the identified LULC categories in both similar and different environments.

CHAPTER FOUR

4.0 RESULTS

4.1 Land use and land cover classification

The fundamental outputs of this study were the land cover maps for 2000, 2005 and 2016, the area gains and losses of the identified LULC classes, as well as, the driving forces of LULCC in Makueni County. The following sections expatiate on these aspects of the output.

4.1.1 Land use and land cover classification for 2000

As previously described and presented in Table 3.3, the study area was defined to have seven LULC categories, which were: Water Bodies, Grassland, Forest, Cropland, Bushland, Built up Area/ Mining and Bareland. The LULC classification for 2000 from Landsat 7 satellite image is shown in Figure 4.1.

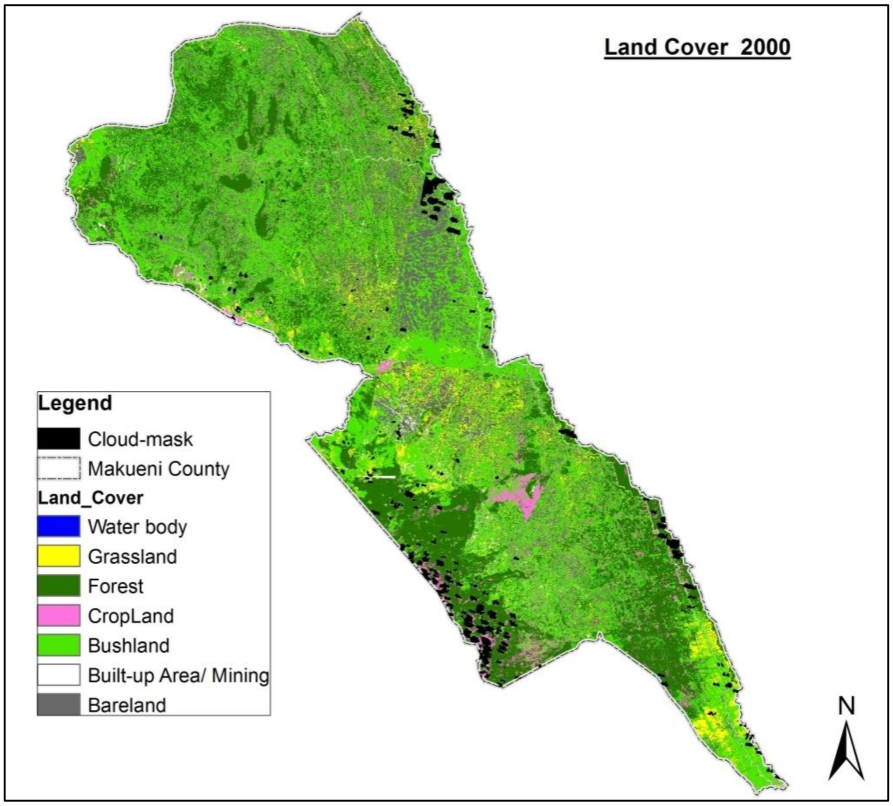

Figure 4.1: LULC classification map of the study area for the year 2000

Table 4.1 shows that majority of the study area; 3105.8 Km^2 (38.64%) and 2159.7 Km^2 (26.87%) were under forest and bushland respectively, while bareland, cropland, grassland built up area/ mining and water bodies accounted to 1324.5 Km^2 (16.47%), 723.1 Km^2 (9%), 562.9 Km^2 (7.01%), 160.7 Km^2 (2%) and 1.1 Km^2 (0.01%) respectively.

Table 4.1: LULC classes and their corresponding areas for the year 2000

Land cover type	**Area in (Km^2)**	**% Land cover**
Water body	1.1	0.01
Grassland	562.9	7.01
Evergreen Forest	3105.8	38.64
Cropland	723.1	9
Bushland	2159.7	26.87
Built up/ Mining	160.7	2
Bare land	1324.5	16.47
Total	**8037.8**	**100**

4.1.2 Land Use and Land Cover Classification for 2005

The LULC classification for 2005 from Landsat 7 satellite image is shown in Figure 4.2 below.

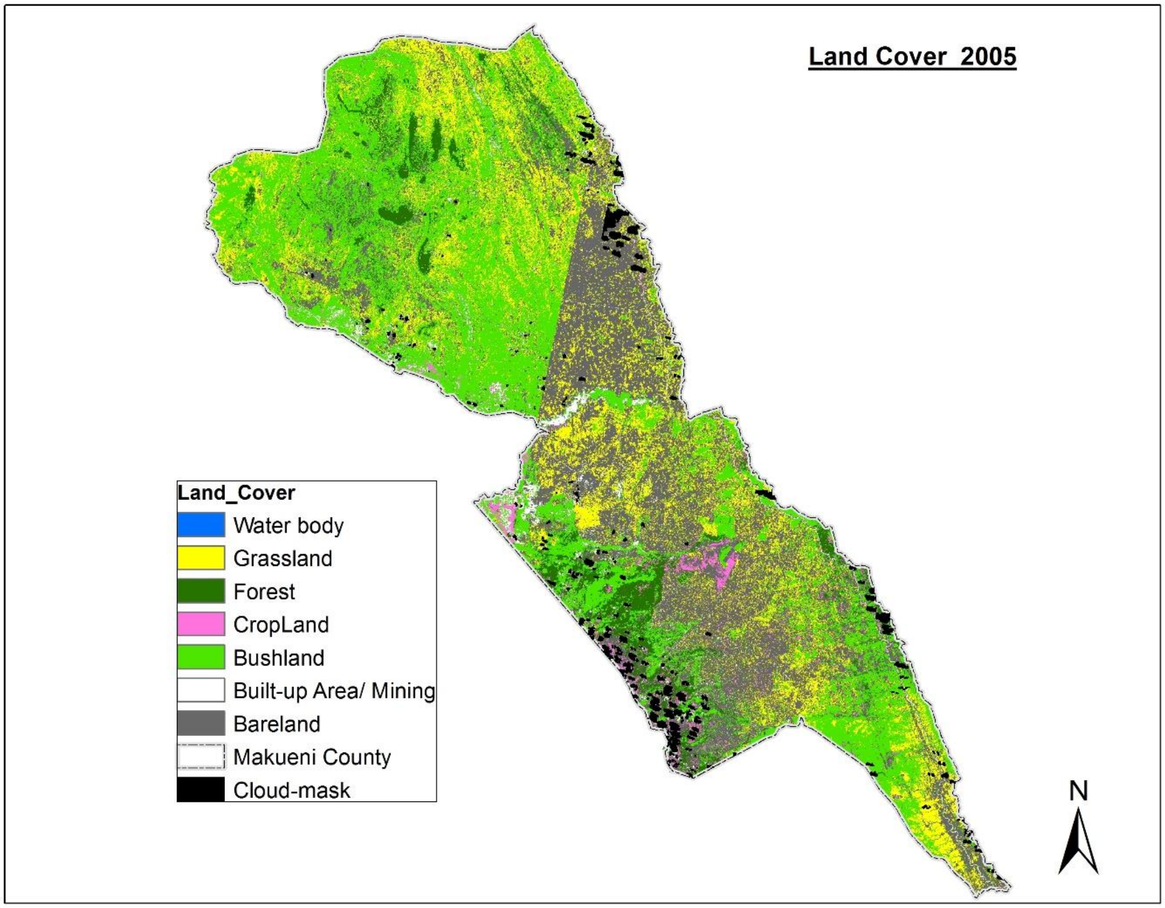

Figure 4.2: LULC classification map of the study area for the year 2005

Table 4.2 shows that the land cover with the largest areas were bushland and bareland at 3018.8 Km^2 (38%) and 2502.7 Km^2 (31%) respectively. This is followed closely by grassland as a land cover at 1633.3 Km^2 (20%). On the other hand, water bodies had very minimal coverage which averages to almost no cover when rounded off. The coverage of Built up area/ mining, cropland and evergreen trees amounted to 253.4 Km^2 (3%), 142.5 Km^2 (2%) and 487.1 Km^2 (6%) respectively.

Table 4.2: LULC classes and their corresponding areas for the year 2005

Land cover type	Area in Km^2	% Land cover
Water body	0.0	0.0
Grassland	1633.3	20
Evergreen Forest	487.1	6
Cropland	142.5	2
Bushland	3018.8	38
Built up/ Mining	253.4	3
Bare land	2502.7	31
Total	**8037.8**	**100**

4.1.3 Land Use and Land Cover Classification for 2016

Figure 4.3 below shows the LULC classification for 2016 from Landsat 7 satellite image.

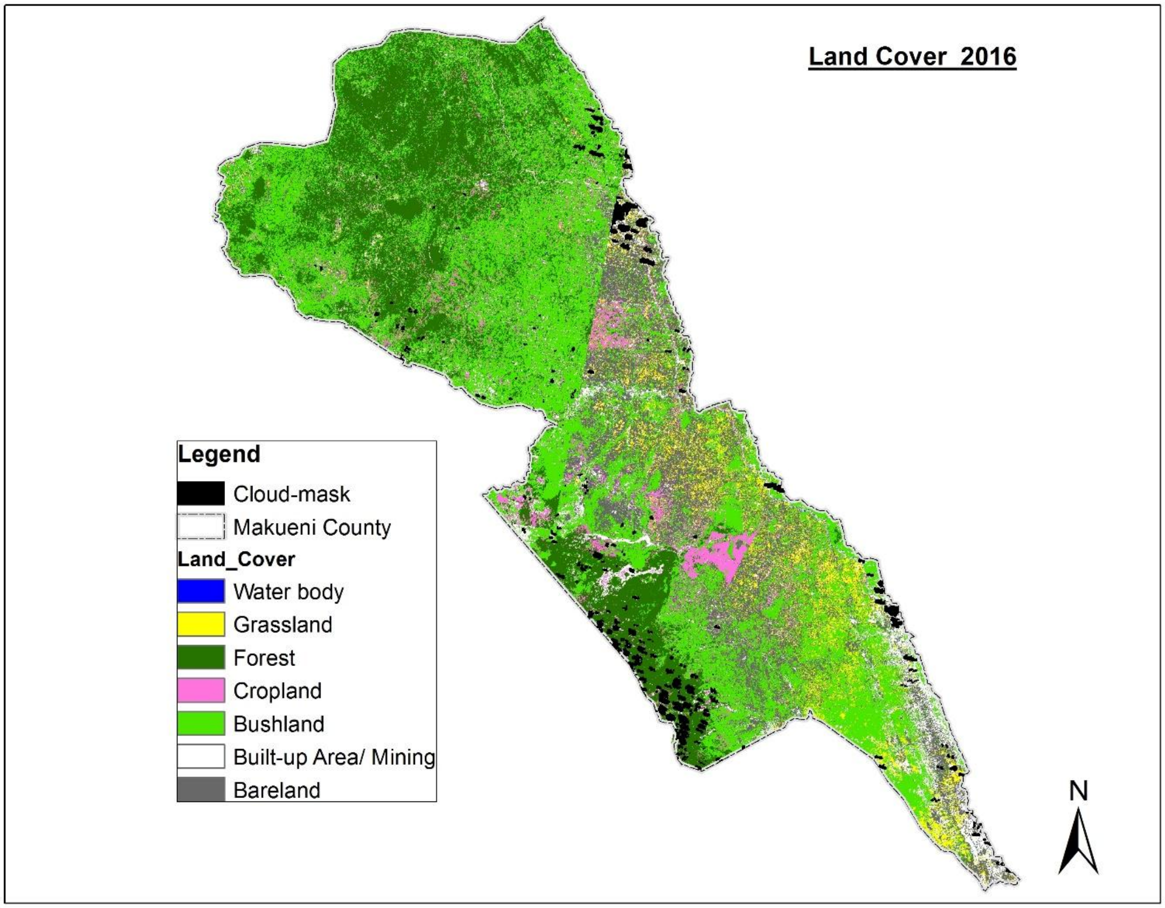

Figure 4.3: LULC classification map of the study area for the year 2016

Table 4.3 shows that most part of the study area at the time was covered by bushland 3893.2 Km^2 (48%). The study area also had a significant coverage of evergreen trees and bareland at 1373 Km^2 (17%) and 1247.1 Km^2 (16%) respectively. On the other side, water body had the least coverage at 5.7 Km^2 (0.1%). Built up areas/ mining's, cropland's and grassland's coverage were 644.5 Km^2 (8%), 480.9 Km^2 (6%) and 393.4 Km^2 (5%) respectively.

Table 4.3: LULC classes and their corresponding areas for the year 2016

Land cover type	Area in Km^2	% Land cover
Water body	5.7	0.1
Grassland	393.4	4.9
Evergreen Forest	1373.0	17
Cropland	480.9	6
Bushland	3893.2	48
Built up/ Mining	644.5	8
Bare land	1247.1	16
Total	**8037.8**	**100**

4.1.4 Land use and land cover area change

Table 4.4 below shows the transitioning area coverage in square kilometers of the classified LULC categories from the year 2000 through to 2016. From table, the areas for the different LULC classes changes across the years from 2000 to 2016. The area changes are both positive (increase) and negative (decrease). From the table, Built up areas increased from 160.7 Km^2 in 2000 to 253.4 Km^2 in 2005 and further to 644.5 Km^2 in 2016. Croplands increased from 723.1 Km^2 in 2000 to 142.5 Km^2 in 2005 and further to 480.9 Km^2 in 2016. Water bodies also underwent a significant change by decreasing from 1.1 Km^2 to a very small coverage (almost 0%) in 2005 and later increasing to 5.7 Km^2 (0.1%) in 2016. Evergreen forests decreased from a coverage of 3105 Km^2 (39%) in 2000 to 487.1 Km^2 in 2005 and later increased to 1373Km^2 (17%) in 2016. Bushlands coverage increased from 2159.7 Km^2 (27%) in 2000 to 3018.8 Km^2 in 2005 and further to 3893.2 Km^2 (48%) in 2016. Grasslands increased from 562.9 Km^2 in 2000 to 1633.3 Km^2 in 2005 and later decreased to 393.4 Km^2 in 2016 while Barelands increased from 1324.5 Km^2 in 2000 to 2502.7 Km^2 in 2005 and later decreased to 1247.1 Km^2 in 2016.

Table 4.4: Area transition for Land Cover classes between 2000, 2005 and 2016

	2000		2005		2016	
LULC Type	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
Built-up Area	160.7	2%	253.4	3%	644.5	8%
Cropland	723.1	9%	142.5	2%	480.9	6%
Water Body	1.1	0.01%	0.0	0.0%	5.7	0.1%
Evergreen Forests	3105.8	39%	487.1	6%	1373.0	17%
Bushland	2159.7	27%	3018.8	38%	3893.2	48%
Grassland	562.9	7%	1633.3	20%	393.4	5%
Bareland	1324.5	16%	2502.7	31%	1247.1	16%
	8037.8	**100%**	**8037.8**	**100%**	**8037.8**	**100%**

It was also important to analyse the areal change of the identified LULC classes between time intervals over the period under study. Thus, table 4.5 below show these changes between time intervals of 2000- 2005, 2005- 2016 and 2000- 2016. The negative values show a decrease while the positive values imply an increase in land use. The column showing change is given as a ratio. For instance there was about 72 Km^2 (40%) of land increase in built-up area from 2000 to 2005. The change in area for the LULC classes varied from one category to another and also varied through the time periods. While some classes like bush land increased in coverage between both 2000- 2005 (by 925.8 Km^2) and 2005- 2016 (by 904.4 Km^2) periods, others like water bodies decreased between 2000- 2005 (by 1.1 Km^2) and later increased between 2005- 2016 (by 5.9 Km^2).

Table 4.5: Area change in LULC classes in 2000-2005, 2005-2016 and 2000-2016

LULC Type	Change between 2000 and 2005		Change between 2005 and 2016		Change between 2000 and 2016	
	Area(km^2)	Change	Area(km^2)	Change	Area(km^2)	Change
Built-up area	71.7	0.4	404.5	1.5	476.2	2.5
Cropland	-582.2	-0.8	350.1	2.4	-232.1	-0.3
Water Body	-1.1	-1.0	5.9	5.2	4.8	4.2
Evergreen forest	-2691.1	-0.8	916.3	0.6	-1774.8	-0.6
Bushland	925.8	0.4	904.4	0.3	1830.2	0.8
Grassland	1110.5	1.9	-1282.5	-0.8	-172.0	-0.3
Bareland	1166.5	0.8	-1298.7	-0.5	-132.2	-0.1

Generally, over sixteen years (2000- 2016), the gross changes in area coverage varied from one LULC class to another with bushland experiencing the most increase and evergreen forests undergoing the most decrease in area coverage as shown in Figure 4.3 below.

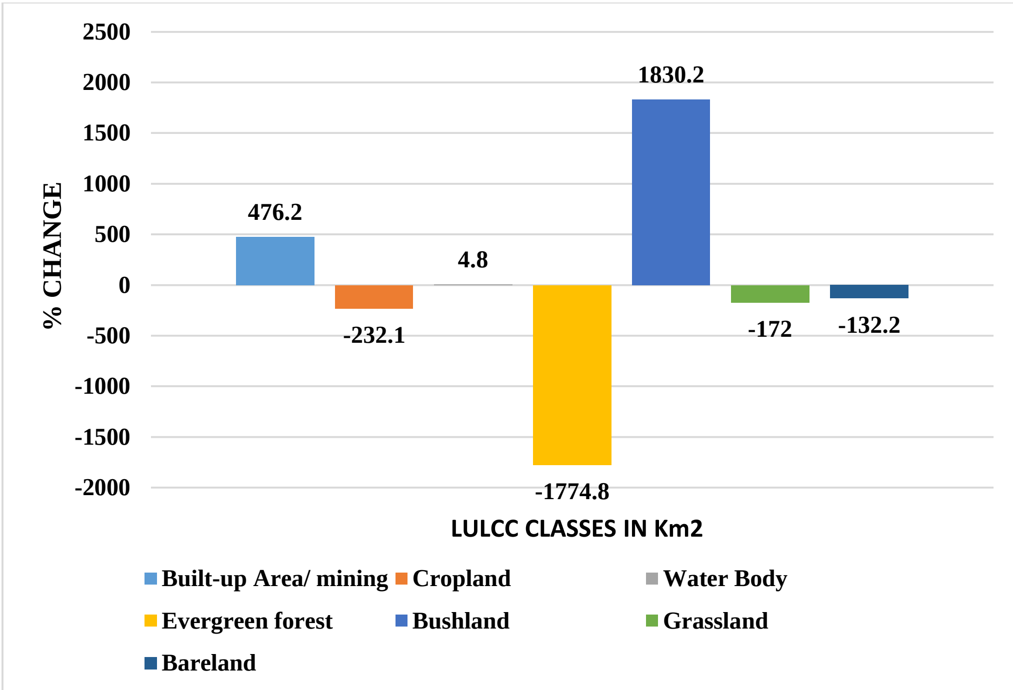

Figure 4.4: Gross percentage change in LULC categories from 2000- 2016

4.1.5 Accuracy assessment

The results of the classification accuracy assessment indicate an overall accuracy of 88.00% (Table 4.6).

Table 4.6: Accuracy Assessment of supervised classification of 2016

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy (%)	Users Accuracy (%)
Unclassified	0	0	0	-	-
Built-up	51	54	45	88.24	83.33
Cropland	21	21	17	80.95	80.95
Water body	9	11	8	88.89	72.73
Forest	34	32	30	88.24	93.75
Bushland	21	24	21	100.00	87.50
Grassland	14	11	10	71.43	90.91
Bareland	30	27	27	90	100
Totals	180	180	158		

Overall Classification Accuracy = 88.00%

4.2 LULC Change Detection for the years 2000, 2005 and 2016

As presented above, different LULC classes changed over the years from 2000-2016. Some of the categories increased in area coverage while others decreased. This changes can be described to be conversions from one LULC class to others. It was an objective of this study to quantify gains and losses and also examine LULC transition over the selected periods. It was therefore important to compute the change detection matrices for the three time intervals; 2000-2005, 2005-2016 and 2000- 2016. This also enabled the examining of the influence of time length on LULCC. The amount of change on LULC categories differs when assessed over short periods compared to observations over long periods. Table 4.7, 4.8 and 4.9 displays the change detection matrices of the different time periods (2000-2005, 2005-2016 and 2000-2016) and the amount of conversions from one land cover class to the others.

4.2.1 Change detection between 2000 and 2005

Table 4.7 below shows the change detection results of 2000- 2005. The table displays major relationships between the identified LULC categories with regards to conversions of one LULC class to another over this period. From the table, 95%, 78%, 36%, 35%, 33%, 20.4% and 10.7% of land under evergreen forests, water bodies, barelands, croplands, built up areas, bushlands and grasslands respectively in 2000 remained under the same LULC categories in 2005. However, there were also significant conversions from one land cover category to another within the same period. Table 4.7 shows that there were significant conversions from evergreen forests to bushland (58.2%) and to croplands (51%). Also, significant percentage of evergreen forests was converted to grassland (22.6%), built up areas (22%) and bareland (15%). The table also displays that 9% and 8.7% of what was croplands in 2000 was converted to barelands and grasslands respectively. Also, 8.2% and 8.0% of croplands in 2000 was converted to bushlands and built up areas in 2005. Small percentage were converted to evergreen forests (2%). From the table, 42.4 % of bushlands, 22.6% of evergreen forests, 15.4% of barelands and 8.7% of croplands were converted to grasslands while 36% of barelands, 30% of bushlands, 15% of evergreen trees, 9% of croplands, 8% of croplands and 3% of built up area were converted to barelands by the year 2005. Bushlands were majorly converted to grasslands (42.4%) and barelands (30%).

Table 4.7: Change detection matrix of 2000 to 2005

		2005													
	LULC Type	Built-up Area		Cropland		Water Body		Evergreen Trees		Bushland		Grassland		Bareland	
		Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area	Area (km^2)	% Area
2000	**Built-up Area**	**82.5**	**33%**	1.4	1%	0.0004	16%	0.5	0%	32.2	1.1%	4.4	0.3%	63.1	3%
	Cropland	19.2	8%	**49.4**	**35%**	0.0000	0%	10.2	2%	248.7	8.2%	141.3	8.7%	236.5	9%
	Water Body	0.2	0%	0.0	0%	**0.0021**	**78%**	0.1	0%	0.6	0.0%	0.0	0.0%	0.0	0%
	Evergreen Forests	55.4	22%	73.1	51%	0.0002	6%	**464.7**	**95%**	1756.9	58.2%	368.4	22.6%	373.0	15%
	Bushland	54.4	21%	12.4	9%	0.0000	0%	6.9	1%	**615.5**	**20.4%**	693.2	42.4%	741.0	30%
	Grassland	24.9	10%	4.8	3%	0.0000	0%	1.4	1%	157.7	5.2%	**174.2**	**10.7%**	194.5	8%
	Bareland	16.8	7%	1.4	1%	0.0000	0%	3.3	1%	207.1	6.9%	251.8	15.4%	**894.6**	**36%**
	TOTAL	**253.4**	**100**	**142.5**	**100**	**0.003**	**100**	**487.1**	**100**	**3018.8**	**100**	**1633.3**	**100**	**2502.7**	**100**

4.2.2 Change detection between 2005 and 2016

The second comparison made during 2005 to 2016 showed increase of evergreen forests from 487.1 km^2 (6%) in 2005 to 1373 km^2 (17%) in 2016 (Table 4.5). Based on the change detection matrix (table 4.8), 66%, 46%, 27.9%, 25%, 8% and 7% of land under barelands, bushlands, grasslands, evergreen forests, built up areas and croplands respectively in 2005 remained under the same LULC categories in 2016. From the table, some area under evergreen forests were converted to water bodies (14%), croplands (4%) and built-up areas (4%). Smaller percentages of this land cover were converted to other classes such as bushlands (2%), bareland (0.3%), water resources (0.5%) and grassland (0.5%). Despite the conversion of evergreen forests to other LULC classes, the table also displays the conversion of 50% of bushlands, 8% of grasslands, 8% of barelands, 5% of built up areas and 4% of croplands to evergreen forests during this period. The table displays 45% of barelands, 25% of bushlands, 15% of grasslands, 5% of built up areas and 4% of evergreen trees were all converted to croplands while the conversion of water bodies to other LULC classes was very minimal. The table also shows that 25%, 22.8%, 20%, 15%, 15% and 8% of grasslands in 2005 was converted to bushlands, barelands, water bodies, croplands, built-up areas and evergreen forests respectively in 2016. The results of change detection analysis of this period (Table 4.8) shows a strong conversional relationship from barelands to other classes such as grasslands (54%), croplands (45%), built up areas (36%) and bushlands (23%) and minimal conversions to water resources (13%) and evergreen forests (8%). Also, 50% of bushlands were converted to evergreen trees while 36% to both water bodies and built up areas as shown in Table 4.8 below.

Table 4.8: Change detection matrix of 2005 to 2016

	2016														
	LULC Type	**Built-up Area**		**Cropland**		**Water Body**		**Evergreen Forests**		**Bushland**		**Grassland**		**Bareland**	
		Area (km^2)	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
2005	**Built-up Area**	**50.1**	**8%**	23.9	5%	1.0	17%	74.7	5%	84.3	2%	1.1	0.3%	16.6	1.3%
	Cropland	10.7	2%	**32.8**	**7%**	0.1	1%	48.8	4%	41.2	1%	3.4	0.9%	6.0	0.5%
	Water Body	0.0	0%	0.0	0%	**0.0**	**0%**	0.0	0%	0.0	0%	0.0	0.0%	0.0	0.0%
	Evergreen Forests	25.6	4%	17.3	4%	0.8	14%	**345.9**	**25%**	87.5	2%	2.0	0.5%	4.2	0.3%
	Bushland	233.3	36%	122.1	25%	2.1	36%	684.3	50%	**1799.6**	**46%**	64.5	16.4%	112.9	9.1%
	Grassland	95.8	15%	70.1	15%	1.1	20%	104.1	8%	969.2	25%	**109.8**	**27.9%**	284.0	22.8%
	Bareland	229.1	36%	214.7	45%	0.7	13%	115.2	8%	911.4	23%	212.6	54.0%	**823.5**	**66.0%**
	TOTAL	**644.5**	**100**	**480.9**	**100**	**5.7**	**100**	**1373.0**	**100**	**3893.2**	**100**	**393.4**	**100**	**1247.1**	**100**

4.2.3 Change detection between 2000 and 2016

Generally, Table 4.9 displays the overall change pattern of all the identified LULC classes over the entire period under study (2000- 2016). From the table, 6%, 18%, 0.4%, 75%, 28%, 11% and 32.9% of area under built up areas, croplands, water bodies, evergreen forests, bushlands, grasslands and barelands in 2000 remained under the same LULC category in 2016. The table also shows that a higher percentage conversions to other classes within this period for all the identified LULC classes are; Evergreen forests to water bodies (50.1%), Bushlands to barelands (39.7%), barelands to grasslands (27%), built up areas to water bodies (16.9%), croplands to water bodies (11.7%), grasslands to built-up areas (11%) and water bodies to evergreen forests (0.5km^2). Higher conversions to a different class as shown in the table are; 50.1% evergreen forests to water bodies, 40% evergreen forests to bushlands, 39.7% bushlands to barelands, 34% bushlands to grasslands, 32% evergreen forests to built-up areas, 29% bushlands to croplands and 10% croplands to evergreen trees.

Table 4.9: Change detection matrix of 2000 to 2016

	2016														
	LULC type	**Built-up Area**		**Cropland**		**Water Body**		**Evergreen Trees**		**Bushland**		**Grassland**		**Bareland**	
		Area (km^2)	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**	**Area (km^2)**	**% Area**
2000	**Built-up Area**	**38.2**	**6%**	17.2	4%	1.0	16.9%	33.2	2%	59.8	2%	3.1	1%	29.9	2.4%
	Cropland	46.2	7%	**87.3**	**18%**	0.7	11.7%	136.4	10%	333.2	9%	29.2	7%	72.6	5.8%
	Water Body	0.2	0%	0.1	0%	**0.0**	**0.4%**	0.5	0%	0.2	0%	0.0	0%	0.0	0.0%
	Evergreen Forests	208.8	32%	112.2	23%	2.9	50.1%	**1027.2**	**75%**	1546.7	40%	81.4	21%	108.0	8.7%
	Bushland	168.8	26%	137.3	29%	0.6	11.3%	120.1	9%	**1071.6**	**28%**	132.2	34%	495.6	39.7%
	Grassland	73.5	11%	21.8	5%	0.1	1.2%	21.8	2%	268.3	7%	**42.7**	**11%**	130.2	10.4%
	Bareland	108.8	17%	105.0	22%	0.5	8.4%	33.8	2%	613.4	16%	104.8	27%	**410.7**	**32.9%**
	TOTAL	**644.5**	**100**	**480.9**	**100**	**5.7**	**100**	**1373**	**100**	**3893.2**	**100**	**393.4**	**100**	**1247.1**	**100**

4.3 The Normalized Difference Vegetation Index (NDVI)

In this study, the NDVI was evaluated for images of year 2000, 2005 and 2016 by using band 3 (R) and band 4 (NIR) in each image. Three NDVI results (Figures 4.4, 4.5 and 4.6) from three images were achieved and each image at specific date was recoded to non-vegetated land and vegetated land. The figures below shows the NDVI outputs of 2000, 2005 and 2016. From the legends, the greenest pixel had the highest NDVI value of 0.97 in 2005 compared to 0.84 in 2016 and 0.60 in 2000.

4.3.1 NDVI 2000

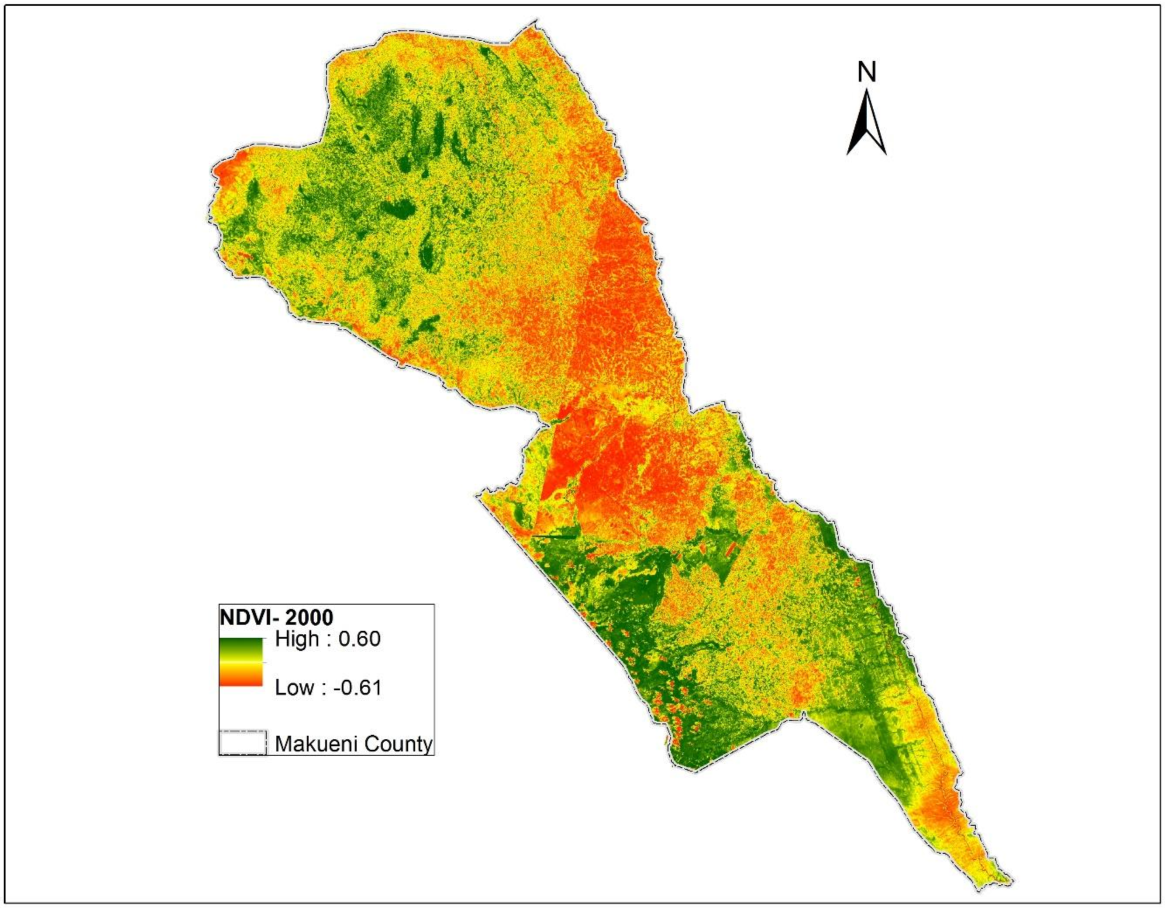

Figure 4.5: Spatial distribution of NDVI Values in 2000

4.3.2 NDVI 2005

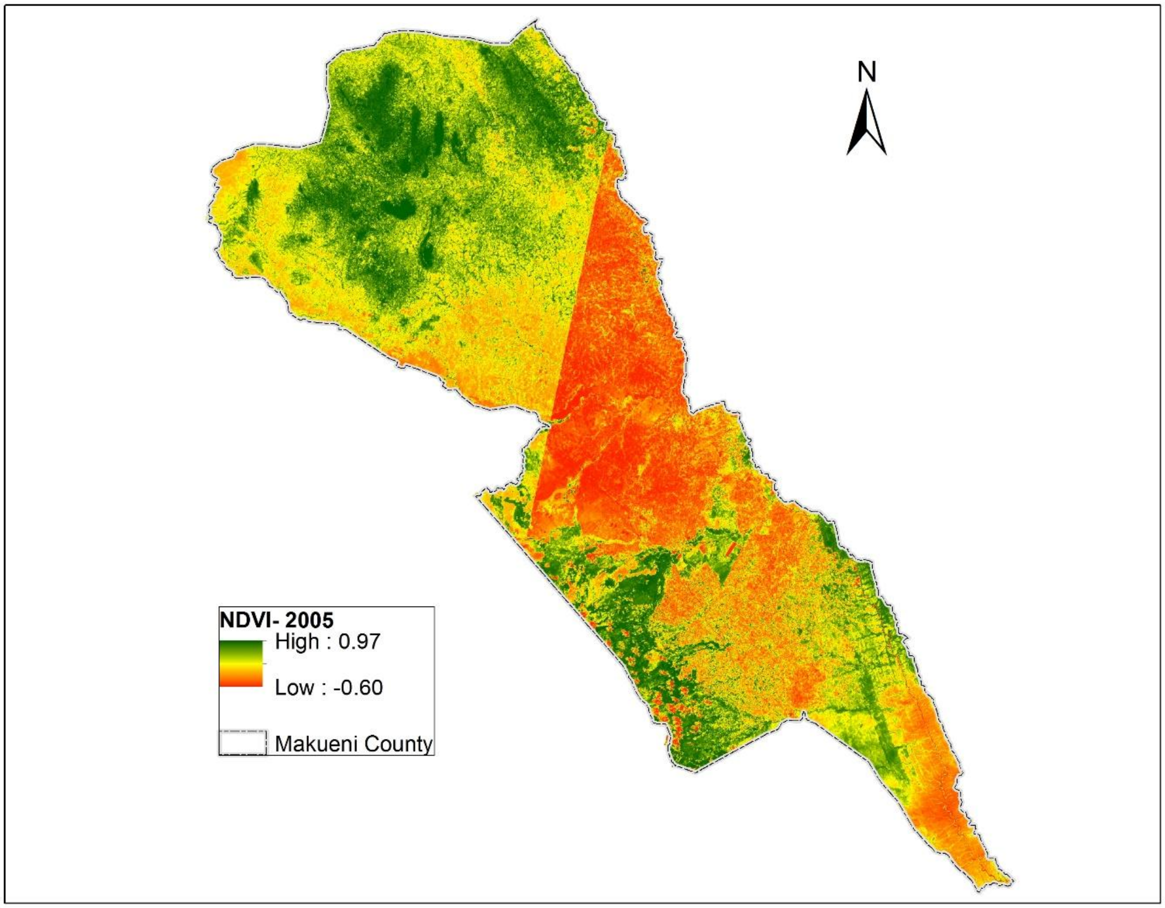

Figure 4.6: Spatial distribution of NDVI Values in 2005

4.3.3 NDVI 2016

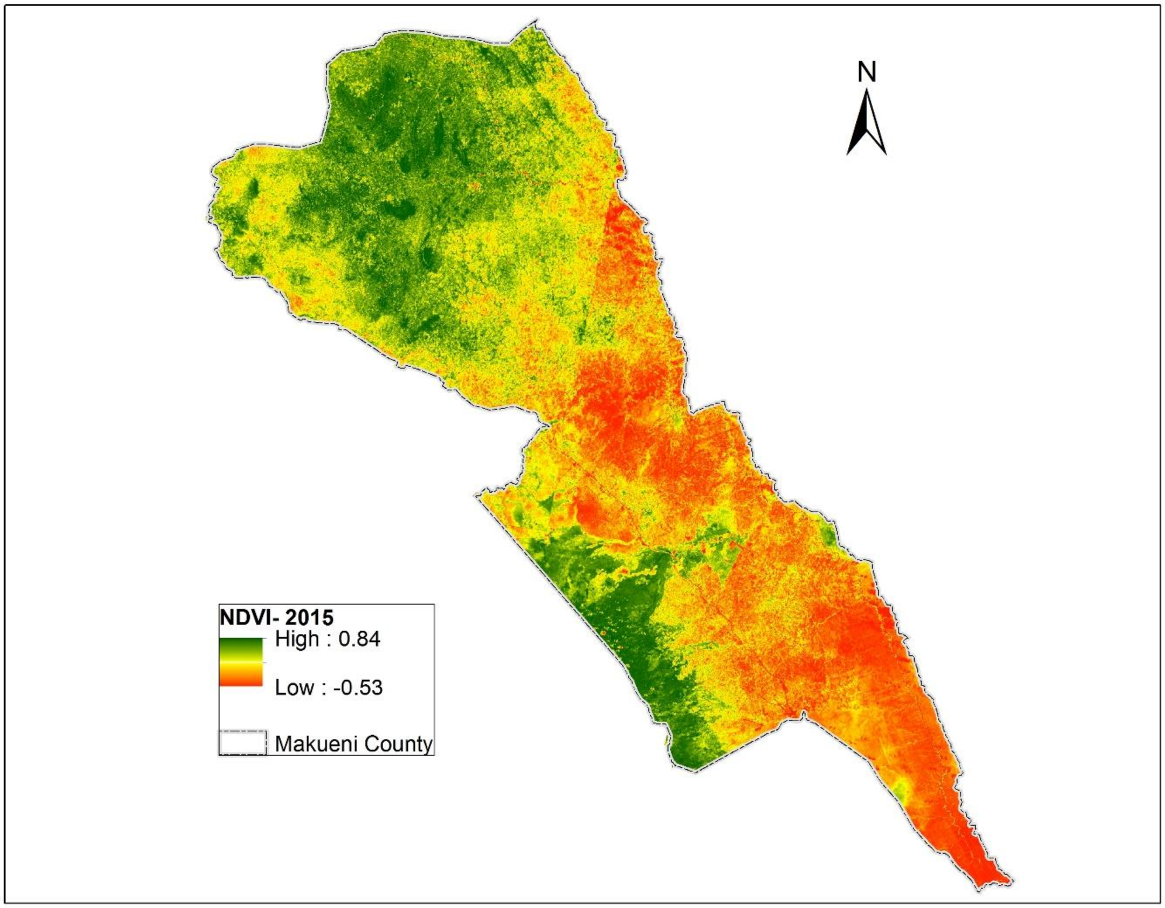

Figure 4.7: Spatial distribution of NDVI Values in 2016

4.3.4 NDVI values for 2000, 2005 and 2016

NDVI values for the three years (2000, 2005 and 2016) were calculated from the random reference points and the results obtained are as shown in table 4.10 below. From the table, the year 2000 was the most vegetated with an NDVI value of 0.18 followed by 2016 with an NDVI value of 0.092 while 2005 was the least vegetated with an NDVI value of -0.11.

Table 4.10: NDVI values for 2000, 2005 and 2016

Year	NDVI value
2000	0.183099
2005	-0.111111
2016	0.0921986

Generally from the results above, patterns of change for the different LULC categories show variation during the two periods, 2000 to 2005 and 2005 to 2016 which were being compared. Some LU/LC classes that show increasing change during first period comparison shows decreasing change during second comparison. On the other hand, some LU/LC classes that show decreasing change pattern during first period comparison shows increasing change pattern during second comparison.

4.4 Possible underlying drivers of LULCC

The third of objective of this study was to identify the possible underlying drivers of the observed change. Table 4.11 shows the results of the questionnaire survey administered to the local communities. The possible underlying drivers for the changes observed in all the LULC classes were coded and represented as shown in table 4.11. The codes used for the possible underlying drivers are described in Appendix 8.

Table 4.11: Possible underlying drivers of LULCC

LULC class	Total respondents/class	Respondents/underlying driver of LULCC (%)	Possible underlying drivers of LULCC (codes)		
			2000-2005	2005-2016	2000-2016
Built-up areas	30	78			1
		82			4
		64			3
Croplands	30	92	5		
		38	7		
		72		22	
		89		8	
		82		9	
		94		10	
		75		11	
Water bodies	30	97	5		
		78		9	
		62		9	
		75		8	
Evergreen Forests	30	43	14		
		70	15		
		70	1		
		90		18	
		78		11,23	
Bushlands	30	86			19
		76			7
		67			6
Grasslands	30	23	5		
		45	7		
		72	19		
		56		20	
		82		1	
Barelands	30	87	5		
		67	20		
		38	6,7		
		85		1	
		82		21	
Total	210				

CHAPTER FIVE

5.0 DISCUSSION

Previous studies like Lambin and Geist (2001), (2002); Leper *et al.* (2004); Rudel *et al.* (2005) have indicated that LULCC can be very extreme and rigorous. This kind of drastic change in LULC was seen in the identified LULC classes in Makueni County. The findings of this study show that underlying drivers of LULCC are specific to a location as was revealed by other similar studies elsewhere (Geist and Lambin 2002, Leper *et al.,* 2004, Rudel *et al.,* 2005). The following sections highlights the driving factors of LULCC for the seven identified LULC classes.

5.1 Change in built- up areas

During the sixteen years period, the land area under built- up areas increased (Table 4.5). The 2000-2016 change detection matrix (Table 4.9) shows strong conversion from other land cover classes to built-up area and vice versa. The observed incremental changes is as a result of greater conversion from other LULC classes to built-up areas as compared to conversions from built-up areas to other LULC classes. The respondents pointed out a number of factors to be the possible reason behind the areal increase of this LULC category. One of the major factors pointed out by an official in the department of urban planning was urbanization and the resulting economic development. Information from the office of urban planning reveal that there has been growth of over 600 urban centres within Makueni County for the period between 2005 and 2016 with an urbanization rate of 11.8%. This has resulted to great and gradual economic development in the County as a result of sprawl of urban centres. Economic activities such as banking services, hotel industries, learning institutions and many others are now available in the recent urban centres. Seventy eight

(78%) of the respondents stated population increase resulting from birth and migration from other parts of the country and the resulting need for settlement and economic activity structures as the possible major reason behind the observed increase in the areal coverage of built-up areas. This agrees with the demographic dynamics data of Makueni County where the 2009 census displays and approximate population of 884,527 people as compared to the projected 989,050 people in 2017. Eighty two (82%) of the respondents also attributed this increase to the need for social amenities for the ever growing populations. Over the years there has been construction of big hospitals e.g. Rapha Health Centre, schools and other social amenities to meet the need of the growing population.

64% of the respondents and the key informant from the department of urban planning pointed out the other factor of the observed change of built-up area coverage to be probably as a result of improved electric and road network. This infrastructural improvement has been linked to the devolution to County Government which has opened up the County for business and investment opportunities and as can be seen on the ground currently, investors have seized the opportunity leading to increased economic activities and thus increase in the built-up areas. With the implementation of County governments, major roads, industries, power plants and even electric substations are being done in the County. For instance, ground observation revealed that mega buildings have been constructed such as supermarkets and many other buildings in the County that are responsible for the observed increase in areal coverage of built- up areas. All these changes have taken place at the expense of other LU/LC categories leading to activities such as clearance of evergreen forests, bushlands and grasslands, construction on grounds that were initially bare or under farming as can be seen in tables 4.7 and 4.8. These results agrees with other similar studies by Bewket and Sterk, (2005); Emiru *et al*. (2012); Moges and Holden, (2009) and Tsegaye *et al*. (2010) who found out that urbanization, population growth and the need for social amenities were the major drivers of increase in the area coverage of built-up areas in their studies.

5.2 Change in croplands

The area occupied by croplands decreased between the years 2000 and 2005. The 2000-2005 change detection matrix (Table 4.7) shows some conversional relationships between croplands and other LULC classes during this period. This conversions that led to reduction in the areal coverage of croplands between 2000 and 2005 can be explained by a number of factors as pointed out from the questionnaires responses and interviews. Unfavorable climatic factors was brought forth by 92% of the respondents as the main probable factor of change observed cropland during 2000-2005 period. This was termed as the major reason behind conversions of croplands to barelands. Three officials from the Department of Agriculture in the county indicated that the drought experienced in the country in the year 1999 led to many farmers abandoning their agricultural lands due to the unproductivity as a result of the unfavorable climatic conditions. The severe climatic conditions made the farmers to embark on rearing the drought resistant livestock such as goats, beef- cattle and sheep. Thus, many croplands were converted to bare and bushlands. Many farmers diversified to planting of grass as pasture for livestock as well as for commercial purposes as source of income. This was a coping mechanism to climate changes since growing grass was less dependent on rainfall

The conversions to grasslands was also through abandonment- due to unfavorable climatic conditions- for natural regrowth of grass for grazing the livestock. Forty one percent of respondents stated that the unsuitable climatic conditions also resulted to farmers embarking on agroforestry activities in the crop fields as a coping mechanism. The tree planting activities were done for a number of reasons including for economic reasons and also for soil conservation. The farmers diversified their livelihoods and engaged in planting fruit trees such as Mango and Orange trees. Thirty eight percent of the respondents stated human- wildlife conflict as a likely reason for abandonment of croplands resulting to grasslands among communities that resided close to wildlife parks and reserves such as Tsavo National Park. The destructions caused by wildlife on croplands coupled with the threat to life of the communities resulted to abandonment of croplands and thus reduction of this land use category during this period. Abandonment of croplands was also as a result of migration to other productive areas and also to urban areas in search of formal employment especially by the youth. This also led to growth of natural grass and shrubs on the abandoned lands thus the evident conversions.

The reduction that resulted from conversions to built-up areas was minimal and was probably as a result of urbanization process in the County that saw small urban centres coming up to meet the economic and social needs of the residents in the County as pointed out an official in the Department of Agriculture. This results is in agreement with many studies in different part of the world in dry land conditions (Dwivedi *et al*, 2005; Garedew *et al*., 2009; Getachew *et al*, 2011; Kidane *et al*., 2012).

The 2005 to 2016 LU/LC change detection indicates that the area covered by croplands increased between 2005 and 2016. From the change detection matrix (Table 4.8), there is evident conversions from other LULC classes to croplands. The responses from surveys and interviews indicated that quite a number of factors had led to the observed increase. Key informant in the department of agriculture in the County attributed the observed change to increased education and awareness, as reveled by the results of Billah and Rahman, (2004), among farmers on the best agricultural practices, despite the semi-arid nature of the area. Seventy two percent of respondents from the community stated conservation agriculture as one of the best practices encouraged by agricultural extension officers to farmers that aided in improving agricultural activities in the harsh environmental conditions. The construction of water conservation structures at farms, as pointed out by 89% of the respondents, such as farm ponds, fish ponds and dams helped improve agricultural activities and ensured increased crop yields which encouraged more crop production thus increased areal coverage of croplands from 2005 to 2016. The other major factor behind this increase was the change in climatic conditions. For instance, the 2016 Landsat image was captured in February during which the country was receiving Elnino rains. This means that the conditions were favorable for crop production thus the increase in areal coverage of croplands in 2016. The County's demographic data, with a projected population density of 123.5km^2 in 2017 as opposed to 109.2 in 2009, agreed with the observations by 82% of the respondents, who attributed the increase in croplands between the years 2005-2016 to population increase and the resulting need for more food to feed the population. Similar observations were made by Dwivedi *et al*. (2005).

Ninety four percent of the respondents attributed the observed increase to the fact that crop production was viewed as one of the major source of livelihood sustenance as similarly reflected by study done by Emiru *et al*. (2012). People had to produce food for both consumption at homesteads and also for sell. This can also be explained to have been influenced by economic factors such as market availability and improved market prices of certain food crops such as green grams as pointed out by 75% of the respondents. The availability of market and the fair market prices made many farmers embark on crop productions and even converting part of their lands that were initially bare or under other land covers to croplands. The other major factor behind the increase of area under croplands from 2005 to 2016 is the numerous research that has been done over the years with regards to best crops for the area that are drought resistant and can still produce sufficient yields, research on best inputs to ensure increased yields, best agricultural practices to ensure soil conservation for sustainable productivity and also research to produce best seeds to boost crop yields as similarly documented in Emiru *et al*. (2012). An official in the Department of Agriculture and 65% of the local community respondents pointed out that such researches has over the years led to conversions of abandoned lands to croplands by farmers.

The other factor that came out strongly from the key informant interviews is the formation and operation of Agricultural Sector Development Support Programme (ASDSP), which is a sector programme implemented by the Government of Kenya Government of Kenya in 2014 in collaboration with development partners and other stakeholders to support the implementation of the strategies identified in the Agriculture Sector Development Strategy 2010–2020 (ASDS) and the Comprehensive African Agricultural Development Programme (CAADP). The goal of the ASDSP is to transform Kenya's agricultural sector into an innovative, commercially oriented, competitive and modern industry that will contribute to poverty reduction and improved food security. This program has helped farmers in Makueni to survive and grow during the start-up period when they are most vulnerable, provided hand-on management assistance, access to financing and exposure to critical business or technical support services that has seen increased crop production. All this has encourage the farmers to embark on serious agricultural activities which has increased the land under crop production over the years.

5.3 Change in water bodies/ resources

The reduction of land area covered by water bodies from 1.1 km^2 in 2000 to 0.003 km^2 in 2005 (Table 4.5) can be attributed to a number of factors. One of the major factor is that Makueni is generally located in an Arid and semi-arid area. The characteristics of such areas is that the mean annual rainfall received is very low and thus almost every water resources in such areas are seasonal. They can only contain water during rainy season and then dry off shortly after the rains. The reduction in areal coverage of water resources during this period can be attributed to the reduced rainfall amounts as pointed out by 97% of the local community respondents and also the key informant, Director of Kenya Meteorological Department (KMD) in Makueni County. This is evident from the mean annual rainfall data in Appendix 7. Similar driver to the reduction of water bodies was also found by Feoli *et al*. (2002). Key official in KMD also pointed out that the other reason behind this reduction was the lack of water conservation strategies e.g. water conservation structures such as earth and sand dams, water pans, dykes and farm ponds, at both household and government level. There weren't efforts to promote conservation and sustainable storage and utilization of water that was obtained during rainy seasons to ensure water availability even during seasons.

The period between 2005 and 2016 showed increase of water resources coverage from 0.003km^2 to 5.7km^2. This can be attributed to a number of factors such as the increase in the amount of rainfall received in the area as revealed by the rainfall statistics received from the KMD office in the County (Appendix 7). For instance, since October 2015 to January 2016, Elnino rains were received in the whole country. The 2016 Landsat image was acquired for the month of February during the Elnino rains. This is one of the major explanations of the increase in water resources coverage during this period. The other factor that came out strongly from 78% of the respondents is the presence of water conservation structure which was termed as initiatives at both household and government level. One key informant stated that the County Government of Makueni through the ministry of water and environment has done several dams over the past four years which has enabled presence of water for use even during the non-rain seasons. At household level, 62% of the respondents stated that there has been construction of structures such as farm ponds to store water. This and other initiative that are aimed at ensuring conservation of water as an important resource has seen the areal coverage increase during this period. The other factor which this change can be attributed to is the increased awareness on the importance of conservation and sustainable utilization of the available water resources as pointed out by key informants and 75 % of the local community respondents. This has been instrumental in changing the unsustainable ways of the communities when it comes to the utilization of water resources in the county.

5.4 Change in Evergreen Forests

The decrease in the area coverage of evergreen forest between 2000 and 2005 (Table 4.5) can be attributed to several drivers; lack of participatory approach in the conservation and management of forests, livelihood activities that were dependent on forest products, poverty levels, population increase, land ownership, weak enforcement of laws and policies to protect forest from degradation by humans, lack of and in some cases presence of weak enforcement towards protection and conservation of forests against degradation and over-exploitation and lack of education and awareness with regards to importance of forest conservation and sustainable utilization, as found out by other similar studies (Teketay, 2001; Taddese, G., 2001; Getachew *et al*., 2011; Bewket and Sterk, 2005; Amsalu *et al*. 2007; Moges and Holden, 2009). Forty three percent of the respondents pointed out that the communities adjacent the forests were not involved in the management and conservation of the forests during this period. They were not allowed to freely graze their livestock, cut down any trees, or even fetch firewood from the forests. The lack of community involvement and participation in conservation contributed to forests degradation and thus reduction in coverage in during this period. Social factors also contributed to the immense decrease in area under evergreen forests during this period. Seventy percent of the respondents attributed the decrease to poverty and population increase as similarly found out by other studies (Zeleke and Hurni, 2001 and Dessie and Christiansson, 2008). Thus, cutting down of tree was done in order to create room for settlement and agriculture for the increasing population and also create space for grazing of livestock. A key informant from KFS pointed out that the decrease can also be attributed weak enforcement of laws and policies set to protect forest from degradation. This means that the communities would utilize and over- utilize the forests near them. Lack of education and awareness, as similarly found out by Garedew *et al*. (2009), with regards to importance of forest conservation and sustainable utilization is also a factor of consideration in the study area.

The drivers of the observed increase in the areal coverage of evergreen forests, as pointed out by respondents and as established by other similar studies (Zeleke and Hurni, 2001; Geist and Lambin, 2002; Dessie and Christiansson, 2008; Garedew *et al*., 2009) ranges from policies, programmes, laws, social- economic and cultural factors. Two key informants at KFS stated that the Forest Act of 2005 was very instrumental in increasing the forest cover in the country and thus also in Makueni County. The creation and operation of community based organizations (CBOs) over the years has also promoted tree planting activities and sustainable utilization of forests in the study area as highlighted by 90% of the interviewees. The other contributor of this positive change, as stated by the interviewees at KFS, is Greening of Schools initiative launched by President Uhuru Kenyatta 2013. The Ministry of Environment, Water and Natural Resources rolled out the programme of green schools and commercial tree growing after the president directed that the initiative be up scaled into a programme and rolled out to all public schools in the country.

Seventy eight percent of the respondents indicated socio-economic factors, such as availability of market and livelihood option, to be a contributor to the observed increase due to farmers' diversification into horticulture, for instance mango and orange trees which can lead to increased tree cover in the study area.

5.5 Change in bushland

The area under bushlands increased from 2159.7 km^2 in 2000 to 3018.8km^2 in 2005 and further to 3893.2 km^2 in 2016 (Table 4.5). Table 4.9 shows a very strong conversional relationship between evergreen forests and bushlands. This observed increase in area coverage of bushlands also happened as a result of conversion from other LULC classes. The respondents interviewed under this LULC category attributed the conversion of other classes to bushlands to a number of factors. Eighty six percent of them opinionated that the main underlying driver of the observed increase of bushland coverage was as a result of the degradation of evergreen forests due to clearing for settlement and agriculture and also for timber harvesting. This was as a result of increasing population over the years which was associated with the need for more space for settlement and agriculture. The other driver that was brought out strongly by 76% of the respondents was abandonment of croplands due to various factors. Such factors included human- wildlife conflicts for the communities that lived near the parks and hills that contained wild animals. This made the farmers abandon their croplands thus conversion to bushland overtime. The other reason behind the abandonment of croplands as pointed out by 67% of the respondents was as a result of agricultural unproductivity. This led to migration of the farmers to search for productive lands or other options such as employment or business to enable them meet the day to day livelihood needs. Similar conclusions were arrived at by Tsegaye *et al*. (2010) and Tekle and Hedlund, (2000).

5.6 Change in grassland

The area under grassland increased from 562.9 km^2 in 2000 to 1633km^2 in 2005 (Table 4.5). Table 4.7 shows conversional relationships to grasslands from bushlands, evergreen forests, barelands and croplands between 2000 and 2005. This conversions happened because of a number of reasons as pointed out by the respondents. 23% of the respondents ascribed the observed change to the drought that was experienced in the country in the year 1999. This led to the abandonment of croplands due to the unfavorable climatic conditions as similarly found out by Alemu *et al*. (2015). The abandonment of agricultural lands because of unfavorable climatic conditions led to the conversion of this lands to grasslands. Many farmers diversified to planting of grass species that were drought resistant for the purposes of use as livestock feed and income. The other factor stated by 48% of the respondents to be a reason for abandonment of croplands resulting to grasslands was human- wildlife conflicts among communities that resided close to wildlife parks and reserves such as Tsavo National Park. The destructions caused by wildlife on croplands coupled with the threat to life of the communities resulted to abandonment of croplands and thus increase in the areal coverage of grasslands during this period. Seventy two percent of the respondents attributed this change to tree clearing activities. Tree clearing for timber and other reasons left the lands bare after which grass grew naturally. The felling of the sparse trees and clearing of shrubs from bushlands also led to the conversions of bushlands to grasslands. The conversions of barelands to grasslands through natural growth is also the other reason behind the increase in coverage of grasslands during this period as similarly documented by Dwivedi *et al.* (2005) and Garedew *et al*. (2009).

There was a decrease in the area coverage of grasslands from between 2005 and 2016 (Table 4.5). Fifty six percent of the respondents attributed the conversion of grasslands to barelands to be as a result of clearance of grasslands through overgrazing. Conversions to water resources happened for the purposes of construction of water conservation structures such as both sand and earth dams and water pans as stated by the key informant interviews. This is due to the rising need of sustainable ways of storage and utilization of water as a crucial resource and the available water resources. Similar findings have been documented in other studies (Framer-Browers *et al*., 2006; Getachew *et al*, 2011 and Kidane *et al*., 2012).

Reduction in areal coverage of grasslands as a result of conversions to croplands can be explained through a number of reasons. Eighty two percent of local community respondents attributed this conversions to the need for more food to feed the increasing population at both household level and generally in the County. At household level, farmers started cultivating land that was initially with grass coverage for livestock grazing. This is as a result of number of persons per household increasing over the years through birth and marriage. The conversions to croplands was also triggered by improved agricultural productivity due to education and awareness of smart agricultural activities as a way of adaptation to the effects of climate change e.g. use of zypits. This finding agrees with the results of Leemans *et al*. (2001) and Lepers *et al*. (2004).

The reduction of area coverage of grasslands as a result of 15% conversions to built-up area is due to urbanization in the County as pointed out by an official in the urban planning department in the County. The growth of small urban areas due to population growth and the resulting need for social amenities on lands that were initially grasslands contributed to the observed reduction as also concluded by Mundia *et al*. (2010).

5.7 Change in bareland

There was an increase in the coverage of barelands in the study area between the years 2000 and 2005 (Table 4.5). The increase in this LULC category can be attributed to a number of factors as pointed out by the respondents and which are also in agreement with the results of similar studies.

Eighty seven percent of the respondents stated that one major drivers of the observed change due to unfavorable climatic conditions such as the drought experienced in the year 1999. This is because the shrubs, grass and crop species in the area could not survive the drought conditions which is usually characterized by high temperatures and low rainfall amounts. This resulted in many farmers and land owners leaving their lands fallow due to low productivity as a result of unfavorable climatic factors. Sixty seven percent of the respondents stated overgrazing as the other major factor that resulted to increase in barelands during this time interval. Less knowledge on the impacts of overgrazing and the lack of knowledge on better and sustainable methods and strategies of livestock feeding is the reason behind the overgrazing that resulted to increased barelands in the study area.

For the communities living near wildlife parks, 38% of the respondents attributed the abandonment of lands to human- wildlife conflicts that was rapidly increasing and posed a great threat to human life, resulting to abandonment of croplands. Two officials from KFS ascribed the observed change in this LULC class to the high rate of deforestation during this period. Lack of community involvement led to most forest getting cleared for timber and other tree products. The results of this underlying factors agrees with conclusions of other LULC studies done in other areas (Ermias, 2006; Cihlar, 2000; Reid *et al.*, 2000).

This decrease in areal coverage of barelands between 2005 and 2016 can be explained through a number of possible underlying factors as pointed out by the respondents. Eighty five percent of the respondents pointed out increase in human population to be the major possible reason behind the reduction in area coverage of barelands. This resulted to need for more food and settlement area as found out by other similar studies (Zubair, 2006; Rindfuss and Adamo, 2004; Vitousek, 1997). Key informant interviews revealed rapid urbanization as the other reason behind the decrease in the coverage of this LULC class. The expansion of towns and other urban centers happened at the expense of the areal coverage of other LULC classes such as barelands hence the areal decrease observed. The other reason for this decrease is the afforestation and tree planting activities as pointed out by 82% of the respondents. One of the factors that encouraged tree planting is the introduction of community participation in the conservation initiatives that created a sense of ownership among the communities. This results agrees with the results of other similar studies (Zubair, 2006; Rindfuss and Adamo, 2004; Vitousek, 1997 and Mundia *et al.*, 2010).

5.8 Accuracy assessment

The results of the classification accuracy assessment indicated an overall accuracy of 88.00% (Table 4.6). This is an acceptable accuracy given that results >85% are acceptable according to the standard first suggested by Anderson (1976), and that now seem to be recognized universally (Congalton and Green 2008).

5.9 The Normalized Difference Vegetation Index (NDVI)

In this study, the NDVI was evaluated for images of year 2000, 2005 and 2016 by using band 3 (R) and band 4 (NIR) in each image. This was done to assess the presence or absence of live green vegetation in the images so as to validate the classification results obtained. The results of the NDV analyses (Figures 4.4, 4.5, 4.6 and Table 4.10) agrees with the classification results in that 2000 was the most vegetated year while 2000 was the least vegetated year. This is because Table 4.5 in shows that croplands, bushlands, grasslands and evergreen forests (which comprises the vegetated lands) had the highest coverage in 2000 as compared to the other years.

CHAPTER SIX

6.0 SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Summary of findings

- The Image classification procedures produced seven major LULC classes in Makueni County viz. built-up areas, croplands, water bodies, evergreen forests, bushlands, grasslands and barelands.

- The overall accuracy of the classification of images was 88.0% meaning there was much agreement between the reference and the classification data. The producer's and user's accuracy for all the identified classes was above 70% thus translating to the high overall accuracy achieved.

- The results of the NDVI analyses showed that the year 2000 was the most vegetated followed by 2016, while 2005 was the least vegetated. This results showed strong agreement with the classification results in which the year 2000 had highest areal coverage of croplands, evergreen forests, bushlands and grasslands which all constitutes the vegetated lands.

- The observed areal coverage changes across the years under study varied from one LULC category to another with some maintaining a constant increase (built-up areas and bushlands) over the two analysis periods (2000- 2005 and 2005- 2016). Some classes underwent decrease in the first period and an increase in the second period (croplands, water bodies and evergreen forests) and vice versa was true for other LULC categories (grasslands and barelands).

- The major possible underlying drivers of LULCC observed in built-up areas were found to be; urbanization and the resulting economic development, improved infrastructure, population growth and the resulting need for social amenities.

- The LULCC observed in croplands during the 16years period was attributed to; rapid population growth and the resulting need for food unfavorable climatic conditions, research activities, urbanization, abandonment of croplands due to human-wildlife conflicts, increased education and awareness programmes on sustainable agricultural practices and water conservation strategies.

- The changes in water bodies were attributed to possible underlying drivers, viz. Unfavorable climatic conditions such as reduced rainfall amounts, lack of water conservation structures and education and awareness on the need and importance of water conservation structures such as dams and farm ponds.

- The LULCC observed in evergreen forest during the selected study periods were attributed to; lack of community participation in forest conservation and management activities, rapid population growth and the resulting need for food and settlement areas that led to clearance of forests, weak enforcement of laws and policies that could not stop the over-exploitation of forests. The increase observed between 2005 and 2016 was attributable to; Forest Act of 2005 and its provision for community involvement in sustainable utilization and conservation of forests and also the formation and operation of KFS which provided extension services for tree farming and sustainable utilization of forests and its products.

- Clearance of evergreen forests to create room for agriculture and settlement due to rapid population growth, abandonment of croplands due to unfavorable climatic conditions and human-wildlife conflicts are the major factors that were found to be the possible underlying drivers of the LULCC observed in bushlands.

- The LULCC observed in croplands was found to be as a result of; abandonment of croplands due to unfavorable climatic conditions and human-wildlife conflict and clearance of forest for settlement and agriculture due to rapid population growth. The observed decrease between 2005 and 2016 was attributed to; urbanization and the resulting urban expansion overgrazing, clearance to pave room for construction of water conservation structures such as community dams, rapid population growth and the resulting need for food and settlement area and provision of extension services on sustainable agricultural practices amidst unfavorable conditions thus creating awareness on water efficient agricultures as an adaptation to climate change effects.

- The observed increase in area coverage of barelands between 2000 and 2005 was attributed to possible drivers such as unfavorable climatic factors thus abandonment of croplands, overgrazing on grasslands, abandonment of croplands due to human-wildlife conflict and deforestation. The decrease observed between 2005 and 2016 was attributed to; rapid population growth and the resulting need for food and settlement area, urbanization and urban centers' expansion and tree planting activities.

6.2 Conclusions

The results of this study reveals that seven major LULC classes exist in Makueni County, viz. Water bodies, croplands, built-up areas, evergreen forest, bushlands, grasslands and barelands. It is also evident from the results that LULCC has occurred in Makueni County with different magnitude of areal conversions from one LULC class to another across the selected study periods. The major possible underlying drivers of the changed observed in all the classes are the dynamics of rapid population growth, unfavorable climatic conditions, urbanization and education and awareness measures to ensure sustainable utilization of land and its resources. This study also concludes that weak enforcement of existing laws and policies that are supposed to govern utilization and ensure management of land and its important resources is one of the major drivers of the observed detrimental changes that results to environmental degradation as a result of unplanned and uncontrolled LULCC that is not guided by informed decision making process.

6.3 Recommendations

Based on the findings of the study, the following recommendations are made;

Both the County and the National Governments should ensure consistent LULC mapping in order to quantify and characterize LULC changes predict the future expected changes with the observed trends. This will help establish trends and enable resource managers to project realistic change scenarios helpful for natural resource management at all levels.

This study also recommends that education and awareness programs by the County Government through the relevant Departments be maximized and tricked down to communities on the need for sustainable utilization of land resources in order to minimize LULCC that are detrimental to the environment and in the long run affects the livelihood well-being of the communities

From the results of the possible underlying drivers, this study recommends that strict enforcement of existing laws and policies, especially with regards to the proper utilization and management of land and its resources, should be a priority at both the National and the County Government. This will go a long way in ensuring sustainability and availability of these resources for both the current and the future generations.

This study also recommends that both the County and the National Government formulate clear policy frameworks that will ensure frequent assessment and monitoring of land use resources that will guide the decision making process in as far as land use resources are concerned.

Further work should be done on specific LULC categories so as to establish their specific drivers of change and the impacts of their change to other LULC classes and also the effects on the livelihood of communities.

Similar studies should be done in other Counties in Kenya where such studies have not been done so as to help establish change trends and guide decisions related to land resources.

REFERENCES

1. Agarwal, C., Green, G.M., Grove, J.M., Evans, T.P. and Schweik, C.M. (Eds.), (2002). *A Review and Assessment of Land-Use Change Models: Dynamics of Space, Time, and Human Choice*. USDA Forest Service Northeastern Forest Research Station, CIPEC Collaborative Report No.1. USFS Publication GTR-NE-297 Center for the Study of Institutions, Population, and Environmental Change at Indiana University–Bloomington and the USDA Forest Service.
2. Alemu, B., Garedew, E., Eshetu, Z., and Kassa, H. (2015). Land Use and Land Cover Changes and Associated Driving Forces in North Western Lowlands of Ethiopia. Int. Res. J. Agric. Sci. Soil Sci. 5(1):28-44.
3. Allen, J. S. *et al*. (1999). A GIS-Based Analysis and Prediction of Parcel Land Change in a Costal Tourism Destination Area.
4. Amsalu, A., Stroosnijderb, L., and Graaffb, J. D. (2007). Long-term dynamics in land resource use and the driving forces in the beressa watershed, highlands of ethiopia. J. Environ. Manage. 83 (4): 448-459.
5. Aronoff, S. (1989). Geographic Information Systems: A Management Perspective. Ottawa, Canada: WDC Publications.
6. Barros, J. X. (2004). Urban growth in Latin American cities: exploring urban dynamics through agent-based simulation (Doctoral); University of London.
7. Baulies, X., and Szejwach, G. (1998). LUCC data requirements workshop survey of needs, gaps and priorities on data for land-use/land-cover change research organized by IGBP/IHDP-LUCC AND IGBP-DIS, Barcelona, Spain, 11-14 November 1997 LUCC report series no. 3.
8. Bewket, W., and Sterk, G. (2005). Dynamics in land cover and its effect on stream flow in the Chemoga watershed, Blue Nile basin, Ethiopia. Hydrological Processes, 19 (2): 445-458
9. Billah, M., and Rahman, G. A. (2004). Land cover mapping of Khulna city applying remote sensing technique. Proceeding, 12th Int. Conf. on Geoinformatics −

Geospatial Information Research: Bridging the Pacific and Atlantic University of Gävle, Sweden, 7-9 June 2004, pp. 707-714.

10. Briassoulis, H. (2000). Analysis of Land-use Change: Theoretical and Modeling Approaches. The web book of regional science. West Virginia University, Regional Research Institute, Morgantown, http://www.rri.wvu.edu/WebBook/Briassoulis/contents.htm(January 2016).
11. Bruijnzeel, L.A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems and Environment 104, 185-228.
12. Campbell, J. B. (2002). Introduction to remote sensing. Taylor and Francis.
13. Campbell. D.J., Lusch, D.P., Smucker, T. and Wangui, E.E. (2003). Root causes of land use change in the Loitoktok area, Kajiado district, Kenya LUCID Working paper series No.19
14. Chomitz, K.M., and Kamari, K. (1998). The domestic benefits of tropical forests. The WorldBank Observer 13 (1), 13-35.
15. Chrysoulakis, N., Kamarianakis, Y., Farsari, Y., Diamandakis, M., and Prastacos, P. (2004). Combining Satellite and Socioeconomic data for Land Use Models estimation. In Goossens, R. (Editor), Proceeding of 3rd Workshop of EARSeL Special Interest Group on Remote Sensing for Developing Countries(in press).
16. Cihlar, J., (2000). Land-cover mapping of large areas from satellites: status and research priorities. International Journal of Remote Sensing 21, 1093–1114.
17. Codjoe, S. N. A. (2007). Integrating Remote Sensing, GIS, Census, and Socioeconomic Data in Studying the Population–Land Use/Cover Nexus in Ghana: A Literature Update. Africa Development, Vol. XXXII, No. 2, pp. 197–212.
18. Congalton, R. G., and Green, K. (2008). *Assessing the accuracy of remotely sensed data: principles and practices*. CRC.
19. Coppin, P., Jonckheere, I., Nackaerts, K., Muys, B., and Lambin, E. (2004). Digital change detection methods in ecosystem monitoring: a review. International Journal of Remote Sensing, 25(9):1565–1596.

20. Crocetto, N., and Tarantino, E., (2009). A Class-Oriented Strategy for Features Extraction from Multidate ASTER Imagery. Remote Sensing, 1: 1171-1189.
21. Curran, P. J. (1985). Principles of Remote Sensing. In: Remote Sensing Today. Longman Scientific & Technical, London.
22. Currit, N. (2005). Development of a remotely sensed historical land cover change database for rural Chihuahua, Mexico. Int. J. Applied Earth Obs. Geoinf, 7: 232-247.
23. Dale, V. H., O'Neill, R. V., Pedlowski, M., and Southworth, F. (1993). 'Causes and Effects of Land Use Change in Central Rondonia, Brazil', Photogrammetric-Engineering and Remote Sensing, vol. 59, no. 6, pp. 997-1005.
24. Daniels, A.E., Painter, K., and Southworth, J. (2008). Milpa imprint on the tropical dry forest landscape in Yucatan, Mexico: Remote sensing and field measurement of edge vegetation. Elsevier, Amsterdam, The Netherlands, pp.293-304.
25. Desa, U. (2012). World urbanization prospects: The 2011 revision. Final Report with Annex Tables. New York, NY: United Nations Department of Economic and Social Affairs.
26. Dessie, G., and Christiansson, C. (2008). Forest decline and its causes in the south-central rift valley of Ethiopia: Human impact over a one hundred year perspective. Ambio 37 (4): 263-271.
27. Dwivedi, R. S., Sreenivas, K., and Ramana, K. V. (2005). Land-use/land-cover change analysis in part of Ethiopia using landsat thematic mapper data. Int. J. Remote Sensing 26 (7, 10): 1285-1287.
28. Emiru, N., Gebrekidan, H., and Tibebe, D. (2012). Analysis of land use/ land cover changes in western ethiopian mixed crop-livestock systems: The case of senbat watershed J. Biodiversity and Environ. Sci. 2(3):8-17.
29. Ermias, A. (2006). Monitoring and Evaluating Land Use/Land Cover Change Using Participatory Geographic Information System (PGIS) Tools: A Case Study of Begasheka Watershed, Tigray, Ethiopia.

30. Fan, F., Weng, Q. and Wang, Y. (2007). Land use and land cover change in Guangzhou, China, from 1998 to 2003, based on Landsat TM/ETM+ imagery sonsors 7, 1323- 1342

31. Feoli, E., Vuerich, L. G., and Zerihun, W. (2002). Evaluation of environmental degradation in northern Ethiopia using GIS to integrate vegetation, geomorphological, erosion and socio economic factors. Agriculture, Ecosystems and Environment 91: 313-325.

32. Food and Agriculture Organization. (2000). *Global Forest Resources Assessment 2000*, Main Report. FAO Forestry paper, N°140, pp. 115-120.

33. Framer-Browers, Q., Crosthwaite, J., Collaghan, J., Hollier, C., and Straker, A. (2006). Drivers of land use change: matching opportunities to motivations. A report by department of sustainability and environment, Melbourne.

34. Fuller, R. M., Smith, G. M. and Devereux, B. J. (2003). Characterization and measurement of land cover change through remote sensing: problems in operational applications? International Journal of Applied Earth Observation and Geo-information 4, 243–253

35. Fung, T. (1990). An Assessment of TM Imagery for Land-Cover Change Detection. IEEE

36. Garedew, E., Sandewall, M., Söderberg, U., and Campbell, B. (2009). Land-use and land-cover dynamics in the central rift valley of Ethiopia. Environmental Management 44 (4): 683-694.

37. Garedew, E., Sandewall, M., Söderberg, U., and Campbell, B. (2009). Land-use and land-cover dynamics in the central rift valley of Ethiopia. Environmental Management 44 (4): 683-694.

38. Gashaw, T., Bantider, A. and Mahari, A. (2004). Evaluations of Land Use/Land Cover Changes and Land Degradation in Dera District, Ethiopia: GIS and Remote Sensing Based Analysis. International Journal of Scientific Research in Environmental Sciences, 2(6), pp. 199-208.

39. Geist, H.J., and Lambin, E.F. (2002). "Proximate Causes and Underlying Driving Forces of Tropical Deforestation." *BioScience*, **52**(2), 143-150.
40. Getachew, F., Heluf, G., Kibebew, K., Birru, Y., and Bobe, B. (2011). Analysis of land use/land cover changes in the Debre- Mewi watershed at the upper catchment of the Blue Nile Basin, Northwest Ethiopia. Biodiversity and Environmental Sciences 1: 184-198.
41. Gichuki, F.N. (2000). Makueni District Profile: water Management, 1989-1998, Dry land Research Paper 3: Presented at a workshop on *Policy Requirements for Farmers Investment in Semi-Arid Africa, held on 16th -17th November at Wote, Makueni District*, Kenya. 2-3pp.
42. Ginblett, R. (2006). Modelling human-landscape interactions in spatially complex settings: Where are we and where are we going? Downloaded from:http://www.mssanz.org.au/modsim05/papers/gimblett.pdf
43. Glowa-Impetus. (2005). GLOWA-Global Change and the Hydrological Cycle. Bonn, Berlin, BMBF**:** 43p.
44. Government of Kenya. (2012). Kenya Law Reforms, *Laws of Kenya, Water Act No. 8 of 2002*, chapter 372.
45. Government of Kenya. (2012). Ministry of water and Irrigation water Resources Management Authority, *National water Management Plan (NWMP, 2030).* 8-1p, 8-14p.
46. Government of Kenya. (2012). *WRMA Strategic Plan* 2012-2017. 8-33pp.
47. Government of Kenya. (2013). *Makueni First County Integrated Development Plan* 2013-2017. 2-36pp.
48. Government of Kenya. (2013). National Drought Management Authority. Drought Monthly Bulletin for August 2013. 1p.
49. Government of Kenya. (2013). Water Resource Management Authority Brief 2013. 8p.

50. Herold, M., Couclelis, H., and Clarke, K. C. (2005). The role of spatial metrics in the analysis and modeling of urban land use change. Computers, Environment and Urban Systems, 29(4), 369–399.

51. Hualou L., Guoping T., Xiubin L., and Gerhard K. H. (2006). Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta economic area of China. Journal of Environmental Management 83 (2007) 351–364.

52. Ifejika S. C., Kiteme, B., and Wisemann, U. (2007). Droughts and Famine, The underlying Factors and Causal Links among Agro-Pastoral Households in Semi-Arid Makueni District, Kenya. *Global Environment Change.* 2-5p

53. International Geosphere- Biosphere Programme. (2001). Global Change and the Earth System: A planet under pressure**:** 33p.

54. Jaetzold, R., Schmidt, H., Hornetz, B., and Shihanya, C. (2006) Farm Hand book of Kenya, Vol 2, Natural Conditions and Farm Management Information 2nd Edition, Nairobi.

55. Janssen, L. L. F. (1993). Methodology for Updating Terrain Object Data from Remote Sensing Data: The Application of Landsat TM Data with Respect to Agricultural Fields. Thesis (Ph. D) Wageningen Agricultural University, Wageningen. In: Luis M. T. C., Jan G. P. W. C., Steven M. J. and Andrew K. S. (2003). A New Procedure for Forestry Database Updating With GIS and Remote Sensing.

56. Kiage, L. M., Liu, K. B., Walker, N. D., Lam, N. and Huh, O. K. (2007). Recent land-cover/use change associated with land degradation in the Lake Baringo catchment, Kenya, East Africa: Evidence from Landsat TM and ETM+, *International Journal of Remote Sensing 28 (19) 4285–4309*

57. Kidane, Y., Stahlmann, R., and Beierkuhnlein, C. (2012). Vegetation dynamics and land use and land cover change in the bale mountains, Ethiopia. Environmental Monitoring and Assessment 184: 7473-7489.

58. Lambin, E. F. (2005). Conditions for sustainability of human–environment systems: Information, motivation, and capacity, Global Environmental Change 15 (2005) 177–180, Elsevier.
59. Lambin, E.F., Geist H.J., and lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions, annual review of environmental resources, 28:205–41.
60. Lambin, E.F., Turner II, B.L., Geist, H., Agbola, S., Angelsen, A., Bruce, J.W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P.S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skanes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T., Vogel, C., and Xu, J. (2001). Our emerging understanding of the causes of land-use and - cover change. Global Environ. Change 11, 261–269.
61. Leemans, R., Li X., Moran, E.F., Mortimore, M., Ramakrishnan, P.S., Richards, J.F., Skånes, H., Steffen, W., Stone, G.D., Svedin, U., Veldkamp, T., Vogel, C., and Xu, J. (2001). The Causes of Land-Use and Land-Cover Change: Moving Beyond the Myths. Global Environmental Change. 2001/4.
62. Lepers, E., Lambin, E. F., Janetos, A. C., Defries, J., Achard, F., Ramankutty, N., and Scholes, R. J., (2004). A synthesis of information on rapid land-covers change for period 1981-2000. (Article in Bioscience) Feb 2005 Vol. 55 No. 2, pg. 115-124.
63. Liang, S., Fang, H., Morisette, J.T, Chen, M., Shuey, C.J., Walthall C.L., and Daughtry, C.S. (2002). Atmospheric Correction of Landsat ETM+ Land Surface Imagery: II. Validation and Applications. IEEE Transactions on Geoscience and Remote Sensing,
64. Lu, D., Mausel, P., Brondizio, E., and Moran, E. (2004). Change detection techniques. International Journal of Remote Sensing, 25(12), 2365–2407.
65. Masek, J. G., Lindsay, F. E., and Goward, S. N. (2000). Dynamics of urban growth in the Washington DC metropolitan area, 1973-1996, from Landsat observations. International Journal of Remote Sensing, 21(18), 3473–3486.

66. Matt D. D. *et al*., (2004). Computer Visualization of Forest Cover Change: Human Impacts in Northeastern Kansas and Natural Disturbance in Yellowstone Park.

67. Moges, A., and Holden, N. M. (2009). Land cover change and gully development between 1965 and 2000 in umbulo catchment, ethiopia. Mountain Research and Development 29 (3): 265-276.

68. Muhammad, L., Mwabu, D., Mulwa, R., Mwangi, W., Langyintuo, A., and La Rovere, R. (2010).Characterisation of Maize Producing Households in Machakos and Makueni Districts in Kenya. Nairobi: KARI-CIMMYT.

69. Mundia, C. N., and Aniya, M. (2006). Dynamics of land use/cover changes and degradation of Nairobi city, Kenya. *Land Degradation and Development, 17*(1), 97–108.

70. Mustard, J.F., Defries, R.S., Fisher, T., and Moran, E.F. (2004). Land-use and land-cover change pathways and impacts. In: Gutman, G., Janetos, A.C., Justice, C.O., Moran, E.F., Mustard, J.F., Rindfuss, R.R., Skole, D., Turner, II, B.L., Cochrane, M.A. (Eds.), Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface. Kluwer, Dordrecht. The Netherlands, pp. 411–429.

71. Mwagore, D. (ed.) (2002). Land use in Kenya – the case of a national land use policy, Land Reform, vol.3 [Online] Available: http://www.oxfam.org.uk/landrights/KLAfull.pdf [Accessed 2016, February 29]

72. Olang, L. O. (2009). Analysis of land cover change impact on flood events using remote sensing, GIS and hydrological models: a case study of the Nyando River Basin in Kenya. University of Natural Resources and Life Sciences Vienna. Thesis (Ph.D.). Vol 43 (24)

73. Olson, J.M., and Maitima, J.M. (2006). Sustainable Intensification of Mixed Crop-Livestock Systems, land use change impacts and dynamics 110 (LUCID) Policy Brief 1, International livestock research institute, Nairobi, Kenya.

74. Petit, C., Scudder, T., and Lambin, E. (2001). Quantifying processes of land cover change by remote sensing: Resettlement and rapid land cover changes in south-eastern Zambia. Int. J. Remote Sens., 22: 3433-3456.
75. Prakasam, C. (2010). Land use and land cover change detection through remote sensing approach: A case study of Kodaikanaltaluk, Tamil nadu. International journal of Geomatics and Geosciences, 1(2): 150-158.
76. Quentin F. B., Jim, C., Julia, C., Carole, H., and Andrew, S. (2006). Drivers of land use change, Final report: Matching opportunities to motivations, ESAI project 05116, Department of Sustainability and Environment and primary industries, Royal Melbourne Institute of Technology. Australia.
77. Reid, R. S., Kruska, R. L., Muthui, N., Taye, A., Wotton, S., Wilson, C. J., and Mulatu, W. (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. Landscape Ecology 15(4): 339–355.
78. Rindfuss, R., and Adamo, S. (2004). Population Trends: implications for global environmental change. IHDP Update. Newsletter of the International Human Dimensions Program on Global Environmental Change, 1, 1-3
79. Roy Chowdhury, R. (2006). Driving forces of tropical deforestation: the role of remote sensing and spatial models. *Singapore Journal of Tropical Geography* **27**: 82-101
80. Schneider, C.L., and Pontius Jr, R.G. (2001). "Modeling land-use change in the Ipswich watershed, Massachusetts, USA. *Agriculture Ecosystems and Environment*, **85**, 83-94.
81. Shalaby, A. and Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land use changes in the north-western coastal zone of Egypt Applied Geography 27(1): 28-41
82. Singh, A. (1989). Review Article: Digital Change Detection Techniques Using Remotely- Sensed Data. International Journal of Remote Sensing, 10(6): 989-1003.

83. Taddese, G. (2001). Land degradation: A challenge to Ethiopia. Environmental Management 27(6): 815-824.

84. Teketay, D. (2001). Deforestation, wood famine, and environmental degradation in Ethiopia's highland ecosystems: Urgent need for action. Northeast African Studies 8(1): 53-76.

85. Tekle, K., and Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu District, Southern Wello, Ethiopia. Mountain Research and Development 20(1): 42-51. Transactions on Geoscience and Remote Sensing, 28: 681-684.

86. Tsegaye, D., Moe, S. R., Vedeld, P., and Aynekulu, E. (2010). Land-use/cover dynamics in northern afar rangelands, Ethiopia. Agriculture, Ecosystems and Environment 139: 174-180.

87. Turner II, B.L., Kasperson, R.E., Meyer, W.B., Dow, K., Golding, D., Kasperson, J.X., Mitchell, R.C., and Ratick, S.J. (1990). "Two Types of Global Environmental Change: Definitional and Spatial-Scale Issues in their Human Dimensions." *Global Environmental Change: Human and Policy Dimensions,* **1**(1), 14-22.

88. United Nation, Department of Economic and Social Affairs, Population Division (2014). *World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).*

89. Vitousek, P. M., Mooney, H. A., Lubchenco, J., and Melillo, J. M. (1997). Human Domination of Earth's Ecosystems. Science 277(5325):494-499.

90. Vogelmann, J. E., Helder, D., Morfitt, R., Choate, M. J., Merchant, J. W., and Bulley, H. (2001). Effects of Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper Plus radiometric and geometric calibrations and corrections on landscape characterization. Remote Sensing of Environment, 78(1), 55–70.

91. Yang, X. and Lo, C.P. (2002). Using a time series of satellite imagery to detect land use and land cover change in the Atlanta, Georgia metropolitan area *International Journal of Remote Sensing 23 (9) 1775-1798.*

92. Yuan, F., Sawaya, K. E., Lo effelholz, B. C. and Bauer, M. E. (2005). Land cover classification and change analysis of the twin cities (Minnesota) metropolitan area

by multi-temporal Landsat remote sensing Remote Sensing of Environment 98: 317-328

93. Zeledon, E. B., and Kelly, M. N. (2009). “Understanding large-scale deforestation in southern Jinotega, Nicaragua from 1978 to 1999 through the examination of changes in land use and land cover.” *Journal of Environmental Management* 90.9 (2009): 2866-2872.
94. Zeleke, G., and Hurni, H. (2001). Implications of land use and land cover dynamics for mountain resources degradation in the North-western Ethiopian highlands. Mountain Research and Development 21: 184-191.
95. Zubair, A. O. (2006). Change detection in land use and Land cover using remote sensing data and GIS (A case study of Ilorin and its environs in Kwara State), MSc Thesis, University of Ibadan, Nigeria.

APPENDICES

Appendix 1: Locals' questionnaire

ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FROM 2000 - 2016

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

1. Date of interview	Day:	Month:	Year:
2. Name and gender	Name (optional):		Gender:
3. Village name			
4. Questionnaire No			

5. What is the highest level of education you have obtained (until now)?

a. Never went to school ☐ b. Primary ☐

c. Secondary ☐ d. Tertiary ☐

6. What do you do for a living?

....

7. For how long have you lived in this place?

<5yrs ☐ 5- 10yrs ☐ 11- 15yrs ☐ >15yrs ☐

8. How much land (in acres) do you own in this place?

<1 ☐ 1- 5 ☐ 6- 10 ☐ >10

9. What are your major livelihood activities?

....

....

10. Which of the above livelihood activities depend on the following land cover resources?

Land Use/ Land Cover Classes	How?
Cropland	
Evergreen trees	
Water bodies	
Grassland	
Bushland	
Bareland	
Built- up areas	

11. Do you think there has been a change in the following land cover resources coverage over the years you have lived here?

Land Use/ Land Cover Classes	Yes	No	Why? (possible reason for conversion)
Evergreen trees			
Croplands			
Water bodies			
Grassland			
Bushland			
Bareland			
Built- up areas			

12. In your opinion, what could be the cause of the change?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

13. (a) In your opinion, do you associate any change in the land cover resources to environmental/ natural/ climatic factors?

Yes ☐ No ☐

(b) If yes, which environmental/ natural/ climatic factors?

……………………………………………………………………………………………

……………………………………………………………………………………………

14. (a) In your opinion, do you associate any change in the land cover resources to any government/political laws, policies, programs or initiatives?

(b) If yes, which government/political laws, policies, programs or initiatives?

……………………………………………………………………………………………

……………………………………………………………………………………………

15. In your opinion, what do would you recommend to enable sustainable utilization (avoid degradation) of resources while at the same time meeting the human needs in the future?

……………………………………………………………………………………………

……………………………………………………………………………………………

Thank you for your assistance and valuable time

Appendix 2: Agriculture Department questionnaire

ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FROM 2000 - 2016

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

AGRICULTURE

1. Date of interview	Day:	Month:	Year:
2. Name and gender	Name (optional):		Gender:
3. Village name			
4. Questionnaire No			

5. What is the highest level of education you have obtained (until now)?

a. Never went to school ☐ b. Primary ☐

d. Secondary ☐ d. Tertiary ☐

6. For how long have you worked in Makueni County?

<5yrs ☐ 5- 10yrs ☐ 11- 15yrs ☐ >15yrs ☐

7. What is the area coverage of cropland in Makueni County currently?

………………………………………………………………………………………………

8. How would you describe the current state of croplands in Makueni County?

……………………………………………………………………………………………

……………………………………………………………………………………………

9. (a) Has there been observable changes in the cropland area coverage over the years your institution/ organization has worked in Makueni County and also from the available records?

Yes ☐ No ☐

(b) If yes, how?

Increase ☐ Decrease ☐

(c) If yes in 9 (a) above, what are the underlying factors that has led to the change in area coverage of the croplands in Makueni County over the years?

……………………………………………………………………………………………

……………………………………………………………………………………………

10. What are the future projections regarding the area coverage of croplands in Makueni County based on the past and present trends?

a. Increase ☐

Why?

....

....

b. Decrease ☐

Why?

....

....

11. Has the conversion of croplands to the following land use and land cover classes occurred over the years and why?

Land Use/ Land Cover Classes	**Yes**	**No**	**Why? (possible reason for conversion)**
Evergreen trees			
Water bodies			
Grassland			
Bushland			
Bareland			
Built- up areas			

12. What initiatives are in place regarding conservation and sustainable utilization of croplands in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

13. What are the challenges faced with regards to conservation and sustainable utilization of croplands in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

14. In your opinion, what recommendations would you suggest to help improve the conservation and sustainable use of the croplands in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your assistance and valuable time

Appendix 3: Kenya Forest Service questionnaire

ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FROM 2000 - 2016

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

KFS

1. Date of interview	Day:	Month:	Year:
2. Name and gender	Name (optional):		Gender:
3. Village name			
4. Questionnaire No			

5. What is the highest level of education you have obtained (until now)?

b. Never went to school ☐ b. Primary ☐

e. Secondary ☐ d. Tertiary ☐

6. For how long have you worked in Makueni County?

<5yrs ☐ 5- 10yrs ☐ 11- 15yrs ☐ >15yrs ☐

7. Which are the gazette forests in Makueni County?

……………………………………………………………………………………………

……………………………………………………………………………………………

8. How would you describe the current state of forests in Makueni County?

9. (a) Has there been observable changes in the forest area coverage over the years your institution has worked in Makueni County and also from the available records?

Yes ☐ No ☐

(b) If yes, how?

Increase ☐ Decrease ☐

(c) If yes in 9 (a) above, what are the underlying factors that has led to the change in area coverage of the forests in Makueni County over the years?

……………………………………………………………………………………………

……………………………………………………………………………………………

10. What are the future projections regarding the area coverage of forests in Makueni County based on the past and present trends?

a. Increase ☐

Why?

……………………………………………………………………………………………

……………………………………………………………………………………………

b. Decrease ☐

Why?

……………………………………………………………………………………………

……………………………………………………………………………………………

11. Has the conversion of watershed to the following land use and land cover classes occurred over the years and why?

Land Use/ Land Cover Classes	**Yes**	**No**	**Why? (possible reason for conversion)**
Cropland			
Water bodies			

Grassland			
Bushland			
Bareland			
Built- up areas			

12. What initiatives are in place regarding conservation and sustainable utilization of forests in Makueni County?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

13. What are the challenges faced with regards to conservation and sustainable utilization of forests in Makueni County?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

14. In your opinion, what recommendations would you suggest to help improve the conservation and sustainable use of the forests in Makueni County?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

Thank you for your assistance and valuable time

Appendix 4: Meteorological Department questionnaire

ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FROM 2000 - 2016

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

1. Date of interview	Day:	Month:	Year:
2. Name and gender	Name (optional):		Gender:
3. Village name			
4. Questionnaire No			

5. What is the highest level of education you have obtained (until now)?

c. Never went to school ☐ b. Primary ☐
f. Secondary ☐ d. Tertiary ☐

6. For how long have you worked in Makueni County?

<5yrs ☐ 5- 10yrs ☐ 11- 15yrs ☐ >15yrs ☐

7. How would you describe the Climate pattern of Makueni County?

……………………………………………………………………………………………

……………………………………………………………………………………………

8. (a) From your knowledge and the available records, has there been noticeable change in climate patterns (especially rainfall) over the years (specifically from the year 2000)?

Yes ☐ No ☐

(b) If yes, has this change in climate patterns affected the area coverage of the following Land Use and Land Cover classes in Makueni County, and how?

Land Use/ Land Cover Classes	**How?**
Cropland	
Evergreen trees	
Water bodies	
Grassland	
Bushland	
Bareland	
Built- up areas	

9. (a) Do you predict any more variability in climate in the future with regards to past and present trends?

Yes ☐ No ☐

(b) If yes, how will this future climate prediction affect the following land use and land cover classes?

Land Use/ Land Cover Classes	**How?**
Cropland	
Evergreen trees	
Water bodies	
Grassland	
Bushland	

Bareland	
Built- up areas	

10. As the body mandated with the function of generation and distribution of climate information to the public, what initiatives have you put in place to sensitive people on present and future climate variability?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

11. In your opinion, what recommendations would you suggest to inform and help curb the negatives changes in land use and land cover classes resulting from climate change and variability in the future?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your assistance and valuable time

Appendix 5: Preserve Africa questionnaire

ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FROM 2000 - 2016

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

PAFRI

1. Date of interview	Day:	Month:	Year:
2. Name and gender	Name (optional):		Gender:
3. Village name			
4. Questionnaire No			

5. What is the highest level of education you have obtained (until now)?

d. Never went to school ☐ b. Primary ☐

g. Secondary ☐ d. Tertiary ☐

6. For how long have you worked in Makueni County?

<5yrs ☐ 5- 10yrs ☐ 11- 15yrs ☐ >15yrs ☐

7. Which watersheds in Makueni County do you deal with?

………………………………………………………………………………………………

……………………………………………………………………………………….......

8. How would you the current situation of watershed resources in Makueni County?

…………………………………………………………………………………………

…………………………………………………………………………………………

9. (a) Has there been observable changes in the watersheds area coverage over the years your organization has worked in Makueni County?

Yes ☐ No ☐

(b) If yes, how?

Increase ☐ Decrease ☐

(c) If yes in 9 (a) above, what are the underlying factors that has led to the change in area coverage of the watersheds in Makueni County over the years?

…………………………………………………………………………………………

…………………………………………………………………………………………

10. What are the future projections regarding the area coverage of watersheds in Makueni County based on the past and present trends?

a. Increase ☐ Why?

....

b. Decrease ☐ Why?

....

11. Are the following land use and land cover classes available in the watersheds you are working on?

a. Cropland ☐ b. Evergreen trees ☐ c. Bushland ☐ d. Bareland ☐

e. Grassland ☐ f. Built up areas ☐ g. Mining areas ☐

12. Has the conversion of watershed to the following land use and land cover classes occurred over the years and why?

Land Use/ Land Cover Classes	**Yes**	**No**	**Why? (possible reason for conversion)**
Cropland			
Evergreen trees			
Grassland			
Bushland			
Bareland			
Built- up areas			

13. What are the challenges faced with regards to conservation and sustainable utilization of watersheds in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

14. In your opinion, what recommendations would you suggest to help improve the conservation and sustainable use of the watersheds in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your assistance and valuable time

Appendix 6: Urban Planning questionnaire

ASSESSMENT OF LAND USE AND LAND COVER CHANGE IN MAKUENI COUNTY FROM 2000 - 2016

The Information Collected from this Survey is strictly Confidential and is to be used for Academic Purposes Only.

URBAN PLANNING

1. Date of interview	Day:	Month:	Year:
2. Name and gender	Name (optional):		Gender:
3. Village name			
4. Questionnaire No			

5. What is the highest level of education you have obtained (until now)?

e. Never went to school ☐ b. Primary ☐

h. Secondary ☐ d. Tertiary ☐

6. For how long have you worked in Makueni County?

<5yrs ☐ 5- 10yrs ☐ 11- 15yrs ☐ >15yrs ☐

7. What is the current area coverage of Built- up areas in Makueni County?

…………………………………………………………………………………………

8. How would you describe the current state of built up areas in Makueni County?

…………………………………………………………………………………………

…………………………………………………………………………………………

9. (a) Has there been observable changes in the built up area coverage over the years your institution has worked in Makueni County and also from the available records?

Yes ☐ No ☐

(b) If yes, how?

Increase ☐ Decrease ☐

(c) If yes in 9 (a) above, what are the underlying factors that has led to the change in area coverage of the built up areas in Makueni County over the years?

……………………………………………………………………………………………

……………………………………………………………………………………………

10. What are the future projections regarding the area coverage of built up areas in Makueni County based on the past and present trends?

a. Increase ☐

Why?

……………………………………………………………………………………………

b. Decrease ☐

Why?

……………………………………………………………………………………………

11. Has the conversion of built up areas to the following land use and land cover classes occurred over the years and why?

Land Use/ Land Cover Classes	**Yes**	**No**	**Why? (possible reason for conversion)**
Cropland			
Evergreen trees			
Water bodies			

Grassland			
Bushland			
Bareland			

12. What initiatives are in place to ensure informed and sustainable urban planning in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

13. What are the challenges faced with regards to planning of urban and built up areas in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

14. In your opinion, what recommendations would you suggest to help improve and ensure informed and sustainable urban planning in Makueni County?

…………………………………………………………………………………………………
…………………………………………………………………………………………………

Thank you for your assistance and valuable time

Appendix 7: Rainfall data (2000-2016)

Form No. 10

KENYA METEOROLOGICAL DEPARTMENT (KMD)

MAKINDU: Station

Reading of …ANNUAL RAINFALL…..For …2000-2016…… ………...

PERIOD	YEAR	AMOUNT MM	NO OF DAYS
1	2000	521.0	33
2	2001	730.3	40
3	2002	491.4	56
4	2003	362.0	43
5	2004	501.2	49
6	2005	225.8	30
7	2006	873.6	56
8	2007	467.8	35
9	2008	405.6	32
10	2009	368.7	40
11	2010	537.6	41
12	2011	450.8	29
13	2012	521.8	41
14	2013	520.9	45

15	2014	498.7	28
16	2015	393.7	41
17	2016 (up to July)	237.1	23

Source: KMD, Makindu station

Appendix 8: Possible underlying drivers of LULCC and their codes

Possible underlying driver of LULCC	**Code**
Rapid population growth	1
Urbanization	2
Improved infrastructure	3
Need for social amenities	4
Unfavorable climatic conditions	5
Abandonment due to climatic conditions	6
Abandonment due to human-wildlife conflict	7
Increased education and awareness on sustainable water conservation strategies	8
Presence of water conservation structures	9
Livelihood sustenance	10
Economic factors	11
Research	12
Lack of water conservation structures	13
Lack of community participation	14
Poverty	15
Weak enforcement of laws and policies	16
Forest Act of 2005	17
Community based Organizations for conservation and sustainable utilization of forests and forest resources	18
Deforestation/ tree clearing	19
Overgrazing	20
Afforestation/ tree planting	12
Increased education and awareness of sustainable agricultural practices	22
Livelihood diversification	23