University of Nairobi

School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

ASSESSMENT OF THE LAND USE AND LAND COVER CHANGES AND THE IMPACTS ON THE ENVIRONMENT. CASE STUDY: LAIKIPIA COUNTY

BY

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F56/34314/2019

Project Report submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

JULY 2022

Declaration of originality

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Title of work: Assessment of land use and land changes and impact on the wild life using gis and remote sensing: case study; Laikipia county

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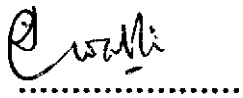
Mr. P.C. Wakoli  29/7/2022

Signature Date

Dedication

Dedicated to the people of Laikipia County.

Acknowledgement

I would like to express my great appreciation to my supervisor Mr Peter Wakoli for the constructive and valuable suggestions during the development of my research work. I wish to thank the various people for their support of the success of the project; my family and daughter for encouraging me throughout my Study.

TABLE OF CONTENTS

List Figures and Tables

List of Acronyms

GIS: Geographic Information Systems.

LULC: Land Use Land Cover

LMB: Lower Mekong Basin

MODIS: Moderate Resolution Imaging Spectroradiometer

Abstract

Laikipia County is rich in biodiversity attracting local and international tourists due to vast wildlife resources. However, the growth in the human Population prompted individuals to encroach on the protected wildlife area and forests, affecting the environment. Laikipia is widely known to harbour many pastoralist communities, and the poor market prices have led to individuals overstocking, pressuring the diminishing natural resources. The need for more agricultural land prompted the farmers to encroach on wildlife habits, which is mainly the grasslands and forest areas. The main objective of the study was to assess the land use and land cover changes in Laikipia County and the impact on the environment. The Study used Landsat satellite images from 1990, 2000, 2010, and 2020 from USGS earth explore. Ancillary data was used, such as google earth images, to help verify the land cover change over the last decades. The Study used Arc GIS and QGIS software tools to conduct a supervised and unsupervised classification of the satellite images.

CHAPTER 1: INTRODUCTION

1.1. Background

The ecosystem is essential for the survival of flora and fauna. A healthy ecosystem incorporates raw materials, water, food, cultural services (such as recreational sites and cultural values), and environment (such as Climate and hydrological systems). All these aspects of the earth's surface can be categorized as the land cover. Therefore, Land cover refers to all physical and biological things covering the land surface. They incorporate vegetation, water, bare soil, and artificial structures. Land use refers to any biological, physical, or chemical changes occurring on the ground cover attributed to management. In the contemporary era, Land use and land cover (LULC) has become a significant concern considering the current climate change effects. Land cover is an important aspect linked to other activities conducted by human beings. Consequently, land cover change significantly impacts the earth's normal processes; for example, changes in biogeochemical cycling may cause Global warming or soil erosion, changing land-use sustainability for the next decades.

Laikipia is the second-best county wildlife destination in Kenya, but the range field is shrinking to the rapid changes in the land cover and land use. The predominant activities are affecting the environment resulting in increased soil erosion, reducing grasslands, and shrieking wildlife habitats. The everyday activities in the environment in the area incorporate the wildlife resources, plant species, hydrological cycles, and the lithosphere (rocks and soil). Wildlife conservation societies face a considerable challenge from the increasing pastoralism activities, large herds that rangeland should hold, poor market prices for the livestock, climate change, and drought. The serious rubric's cube of interrelated issues has impacted the natural resources and the environment. Europeans own approximately a third of the ranches, and pastoralist families acknowledge one-third of the farms. Therefore, about 70 per cent of the total land is available for historical land use activities such as ranching, agriculture, wildlife conservation, and tourism. The majority of the corporate or private land falls under a long-term or leasehold agreement with the government, thus, conferring the majority of the property rights to individuals. Most lease grants were conducted during colonialism, and they are likely to be renewed for 10 to 20 years.

The common problem facing the environment in Laikipia is the changing trends in the rangelands, Grassland, forest lands, bare land, and anthropogenic factors. There has been a significant loss of soil cover and wildlife as the private ranch owner has created viable ways for the pastoral communities to have adequate access to water and grass resources. The trend has been part of the rangeland matrix of livestock and wildlife, allowing efficient movements. Some pastoral communities would traverse to Samburu and Isiolo through the private conservancies and ranches. However, the growing Population and unsupervised livestock growth have overstretched the land used to meet the increasing communal and personal needs. For example, from mid-2016 to early 2017, illegal livestock cases increased to 250,000 cattle and 350,000 shoats during the drought period ("The Trouble with Laikipia," n.d.). More livestock encroached on the Aberdares, Mt. Kenya, and Kikuyu homelands. Natural disasters, diseases, and murders increased from the invasion. According to the aerial census, in 1985, the number of cattle and shoats was 127,735 and 283,459, respectively. Data collected in 2016 indicated that the number of cattle and shoats in the area was over 250,000 and 546,000 ("The Trouble with Laikipia," n.d.).

The typical individual farm extent for small-scale owners is 2 hectares, and for large-scale owners is 20 hectares. Laikipia has approximately 48 ranches that are more than 2000 hectares. The ranches cover more than 50 per cent of the overall land in the County. Individuals and companies own 30 ranches, while the community owns 13 farms. The group ranches are located in the northern part of the County covering approximately 67,720.2 hectares ("Land and Land Use - County Government of Laikipia," n.d.). The community groups hold approximately 10.06 hectares of the ranch per household. The private farms carry beef cattle keeping and wildlife conservation in ranches covering approximately 4,046.9 hectares.

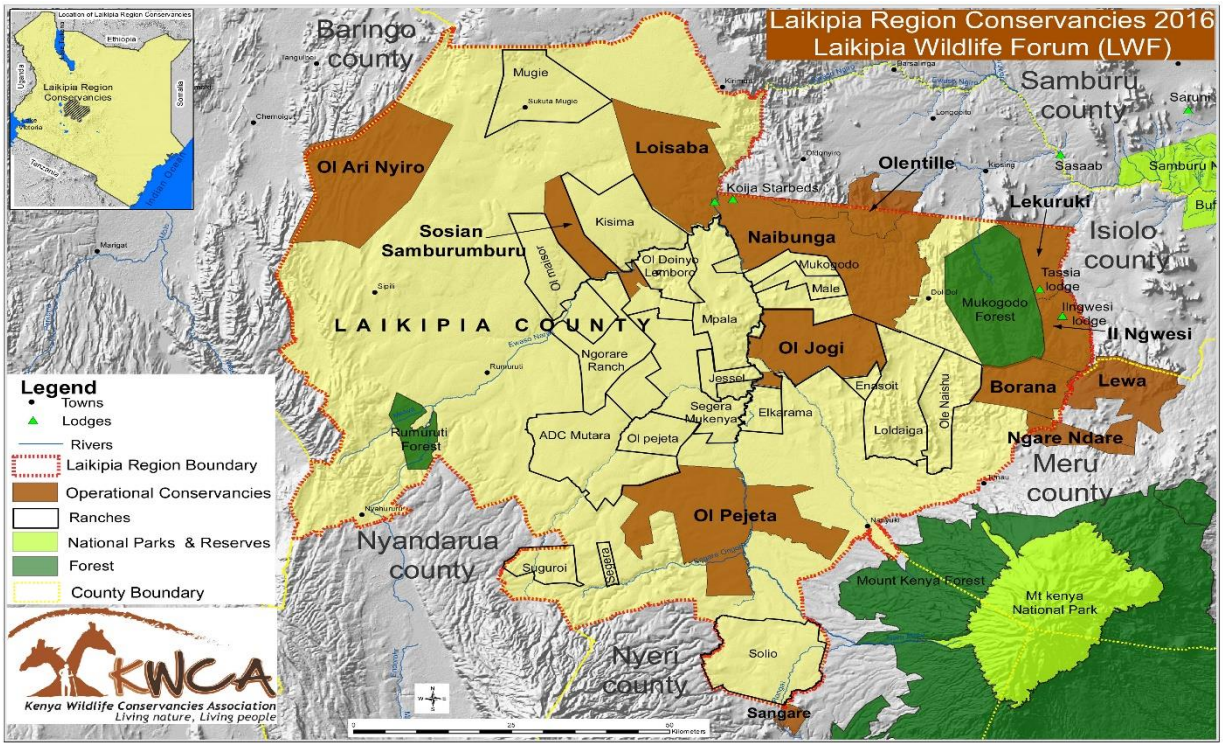


Figure 1.1: Laikipia Wildlife Conservancies

Obtained from: https://kwcakenya.com/regional-associations/laikipia-conservancies-association/

Research affirms that approximately 530,000 families dwell within five kilometres of Lariak forest, Marmanet, and Rumuritu solely on the riparian forest for agriculture and other economic gains (Waithaka, 2010). The shrinking wildlife habitats reduce elephants' food availability, prompting them to destroy crops grown near the forests. The researchers need to apply GIS and Remote Sensing to try and solve the situation and rehabilitate the environment in Laikipia. Accordingly, over the past few years, there have been intense human and wildlife conflicts leading to deaths, crop destruction, livestock killings, and permanent damage to human beings (Muriithi, 2016). On December 16, 2021, approximately 130 victims demanded government compensation for the losses. However, the government insists that some human being killed or permanently injured were traversing the nature conservancies. Moreover, the crops destroyed are due to encroaching the protected areas; thus, they move to look for new feeding grounds. Therefore, the land uses in Laikipia County have resulted in immense environmental effects, but we can use GIS and Remote Sensing to envision the extent of the problem.

1.2. Statement of the Problem

Over 50 per cent of the Laikipia land is undergoing excessive land use. Society is not taking the right approach to increase water retention, reduce soil cover loss, and reduce the loss of habitats and wildlife. The rangelands are drained by intensive grazing leading to soil erosion, and the agricultural activities apply unsustainable soil management practices. Research highlights that Laikipia is experiencing increased commercial horticulture in the arid and semi-arid regions (*county statistical abstract Laikipia county 2019 Laikipia county statistical*, (n.d.). According to KNBS (2007), in 2009, the County had a population size of 399,227, and in 2018, the Population had risen to 541,985 (*COUNTY STATISTICAL ABSTRACT LAIKIPIA COUNTY 2019 LAIKIPIA COUNTY STATISTICAL*, n.d.). There is a significant decrease in the wildlife land sizes compared to the 1990s because the rising Population means more pressure on the predominant natural resources. The high demand for food and firewood supply has been increasing, creating an immense change in the land cover. The increasing number of livestock has led to overgrazing, leaving loose bare soil susceptible to soil erosion. As a result majority of the people look for other means of survival, such as charcoal burning and clearing forests, to start farming activities.

County government and resource planners in Laikipia County have not applied GIS and Remote sensing technology to help monitor LULC to identify the extent of the problem and provide the necessary course of action to mitigate environmental-related issues. Over the globe, researchers have used spatial data to determine the land cover change through NDVI analysis which has helped to reduce vegetation depletion in various areas. In the Study, there have been significant changes in Laikipia, and through the Analysis of Landsat images, we identified how far land uses have changed. The regional and County planners require up-to-date information to help manage land development and plan the necessary changes. In Laikipia, the

difference is very rapid; as a result, it is difficult to maintain up-to-date information on the land cover changes. Remote sensing and GIS effectively identify the problem and provide information for the regional planners, environmentalists, government, and society. While remote sensing and GIS give a method of monitoring rate change, they also offer the positional reference of the existing and new land cover and land use. After integrating the varied datasets, the information users can make informed decisions based on the available information on the digital database. The data gathered from the research can help restore the environment, especially in

regions with intense degradation activities, through Analysis of the variations. Therefore, to identify the rates of land cover change in Laikipia County, the researcher applied GIS and Remote sensing techniques to determine the variations and how it has influenced agriculture and wildlife.

1.3. Objectives

The main objective of the study was to assess the Land Use Land Cover Changes (LULCC) in Laikipia County and their impact on the environment.

1.3.1. Specific objectives

1. Map the LULCC that occurred in Laikipia County between 1990 and 2020.
2. Determine the trend of the LULCC in the County during the stated period.
3. Assess the impact of the LULCC on the environment.

1.4. Justification for the Study

The choice of Study is based on the need to manage and restore the natural resources in Laikipia to help reduce aridity, improve agricultural activities, and minimize human-wildlife conflict. Viewing the earth's features from space is a fundamental approach to synthesizing the impact of LULC on natural resources. Laikipia County's land uses are dynamic due to the increasing Population and livestock pressuring the environment's natural resources. GIS and remote sensing helped to spatially identify how the land cover has changed and what impact it has on the predominant natural resources. Data acquired from the Analysis is essential for the environmentalists by informing them of what is happening in the environment and ecosystem. The national government can help input measures that will minimize human and animal conflicts predominant by reclaiming the original wildlife habitats, which are informed by data collected from GIS and remote sensing.

CHAPTER 2: LITERATURE REVIEW

According to Spruce and others (2020), anthropogenic factors along the Lower Mekong Basin (LMB) in South East Asia have resulted in a loss of forests, fisheries, natural ecosystems, and wildlife. The human population is rapidly increasing; thus, more agricultural land is needed. Hence the communities in the Lower Mekong Basin have used most of the wild habitant lands to expand rice farming. The LMB regions have undergone profound land cover changes over the past decades, but the uncertainties remain to what geographic extent the LULC has spread. A wide variety of satellite data has been applied to help quantify the scope of the impact using SPOT- 4 Vegetation, MODIS, and Landsat data. In a study conducted by Hassan et al. (2016), LULC plays an integral part in analyzing the global variation because data obtained after Analysis is crucial in the decision-making process for environmental planning and ecological management. Empirical studies affirm that land use land cover changes have become an essential aspect of many sectors such as environment, forestry, ecology, and agriculture (Kitina Nyamasyo & Odiara Kihima, 2014). The elements are directly associated with soil degradation, water quality changes, soil erosion, and crop loss (Pielke, 2005). Therefore, change detection has become an integral part of monitoring and managing natural resources globally.

The land uses, and land cover topic has attracted scientists from all disciplinarians to help unravel the ecosystem's problems. Land use and land cover change over a long period in response to the activities on the earth's surface (Mallupattu & Sreenivasula Reddy, 2013). The majority of these activities emanate from economic, social, and biophysical conditions that are set by human beings. However, the impacts can only be quantified through aerial photographs, satellite measurements, and reports from land users and owners. The most significant changes in Kenya is the reducing forest cover, increase in human population, and urbanization. Human beings primarily control what is on the earth's surface; thus, the other things must adapt (Western, Russell, & Cuthil, 2009). The typical impact of LULC is climate change which has influenced the more significant part of Laikipia ("Land and Land Use - County Government of Laikipia," n.d.). Historically, Kitina Nyamasyo and Odiara Kihima (2014) stipulate that most of the communities in Laikipia were pastoralists, and the increasing number of herds has caused immense soil erosion. Overstocking emanates from poor market prices that prevent individuals from selling their livestock at a loss.

2.1. Application of GIS and Remote Sensing in LULC

GIS and Remote Sensing possess tools that are applicable in environmental management. For example, it was to identify the intriguing land cover changes emanating from land use practices in Taita hills in the South Eastern parts of Kenya. The research identified an immense decrease and increase in the sisal farms near Voi and Mwatate, respectively. The Population in Voi town has significantly increased in Voi town encroaching on the sisal plantation. Moreover, the water resources rapidly declined due to siltation (Pellika et al., 2004). The ongoing shrinking of the wildlife resource, high Population, and overgrazing are among the common problem affecting the County. The Kenya Wildlife Service in the region has tried to intervene and prevent encroachment, but the human need keeps increasing. In a study conducted in Kieni in Central Kenya, the forest land in 1987 was 35.46 per cent, but in 2017, the forest covered 19.17 per cent of the total Land in Kieni (Maina et al., 2020). The significant change was in the size of farmlands; in 1987, the land only covered 12.54 per cent of the total land, but in 2017 it had increased to 32.66 percent. (Maina et al., 2020). GIS and Remote sensing has been applied in Kakamega forest to map the land use and land cover changes

Several approaches has been used to analyze the LULC such as satellite remote sensing and GIS due to its accuracy. GIS and Remote Sensing is a repetitive process and applies geo-referencing techniques. The digital process has been applied by the researchers in areas that require human intervention to identify the extent of particular environmental issues. The post-classification change detection stage done on ArcGIS 10 can help identify the change rate over a specific

period of time. The change detection technique is an essential process in monitoring and managing urban and rural growth by providing qualitative Analysis of the spatial distribution of phenomena (Prins, 1992). LULC has been applied in Pakistan to analyze the extent of unorganized urban development and how it impacts the economy. The urban sprawl has created micro climates, increased pollution, and fragmented natural habitats. Research denotes that the spatial patterns in Islamabad, Pakistan have affected the ecological processes of the area. The increasing population has resulted to people encroaching natural resources habitats to increase the agricultural land. Urbanization has increased chaos in the city resulting in deteriorating human health. Therefore, it is essential to identify the trends and rate of LULC necessary for creating the proper land use policy in Pakistan.

2.2. GIS and Remote Sensing techniques

Over the years, researchers have used GIS and Remote sensing-based techniques to analyze land use and land cover changes in many regions globally. The method incorporates image classification, generalizing, smoothing, and filtering.

2.2.1. Image classification

According to Al-Doski, Mansorl, and Shafri (2013), remote sensing data is essential in producing land use and land cover maps, and this is achievable through image classification. Image classification is glued to the notion that various feature types on the globe possess varying remittance properties and spectral reflectance. The author explains image classification as categorizing all pixels within raw remote satellite data to acquire the given land cover themes and labels. Aplin and Atkinson (2004) highlight that various classification approaches have been developed and applied to provide land cover maps. They incorporate supervised (human-guided) and unsupervised (calculated through software). Supervised classification is based on the notion that the analyst can select the sample size in a particular image that represents specific classes and then direct the image processor to utilize the training site as the reference for the classification of the entire pixels in the image (Al-Doski, Mansorl, & Shafri, 2013). The training sites are also known as the input classes or testing sites. They are selected based on the user's knowledge (Al-Doski, Mansorl, & Shafri, 2013). The analyst also sets the bounds of how other similar pixels must be grouped. The bounds are often created based on the strength of reflectance or brightness in specific bands. The user labels the number of classes the image will be classified into. On the other hand, unsupervised classification refers to the grouping of similar pixels done through software analysis of the image without the analyst giving the sample classes (Al-Doski, Mansorl, & Shafri, 2013). The computer automatically highlights which pixels are related, thus grouping them into distinctive courses. The user has an advantage of identifying with algorism the software should use and the necessary output classes but do not help in the classification process. Notably, the researcher needs to be aware of the area under classification, and the classified sites represent what is actually on the ground.

2.2.2. Image filtering, Smoothing, and Generalization

Image filtering incorporates neighbourhood operations where the values for each pixel are recalculated based on the neighbouring pixels (Aber et al., 2019). The approach eliminates

misclassified single cells within the classified image using the majority filter. Smoothing is used to minimize noise or to create a lower pixelated image. Most smoothing techniques rely on low pass filters. Still, one can also smooth the appearance by applying the median or average value for a group of cells moving through the image. Generalization refers to cleaning up classified images to create several isolated zones (Aber et al., 2019). It helps the individual to use less detailed data.

CHAPTER 3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1. Geographic location and size

Laikipia county is located in the central part of Kenya (0.29S°–0.86N° & 36.20°E–37.39°E), demarcated by Mt Kenya to the east and Southeast (5200 m asl), Aberdare Range to the south and Southwest (4000m asl), rift valley on the West (970m asl), Karisia Hills on the northwest (2580m asl), Mathews Ranges on the north (2688m asl), and the Samburu and Buffalo Springs National Reserve on the North East (900m asl). The size of Laikipia County is 9,508 km^2.

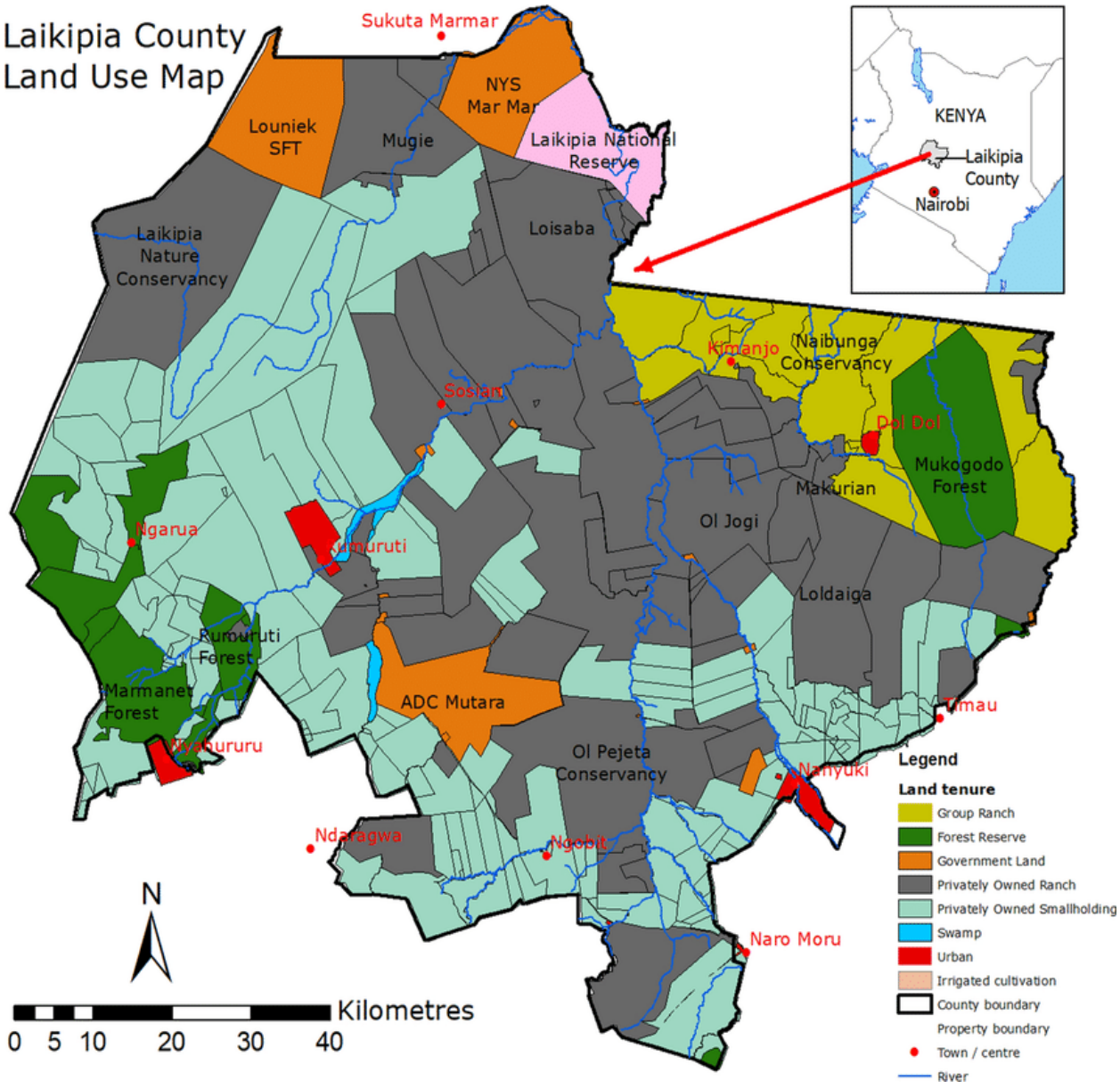


Figure 1.3: Location of Laikipia

Obtained from: https://www.researchgate.net/figure/Land-use-map-of-Laikipia-The-study-sites-were-Olpejetas-and-surrounding-areas-Loldaiga_fig1_350682392

3.1.2. Climate

The County has a mean annual temperature of 16^0 c. Nyahururu, located in the south West has the lowest mean temperature of 13^0 c (2300m asl), while Lekurruki Conservancy in the northeast

part has 24^0 c (962m asl). The mean annual rainfall is 55cm, where the north has 40cm and the southwest parts 120cm.

3.1.3. Topography and soil

The Lowest part of the County is 962m asl around the Lekurruki Conservancy. The highest point is Rugongo, located in the southwest part of Nyahururu. The altitude ranges at 1649m asl. The area consists of mainly flat grounds, rolling hills, granitic inselbergs, and undulating plains. The more significant part of the County has black county soil while other regions have red sand.

3.1.4. Hydrology and drainage system

The County consists of several perennial and seasonal rivers. The largest river is Ewaso Nyiro, and the water cover is approximately 22 km2 or 0.002 per cent of the total area.

3.1.5. Population

According to the 2019 census, the County has 519000 people, and 75 per cent of the population dwells in rural areas. However, projections affirm that the number will increase to 600000 people by 2030. There is an average of 55 people per $km^{2.}$

3.1.6. Land use

In Laikipia county, 90 per cent of the total Land is dry, limiting agriculture, 0.03 per cent (234 km^2) in urban areas, and 0.002 per cent (22km^2) is covered by water. 65 per cent (5820 km^2) are set for wildlife habitats. Thirty-eight per cent (3650 km^2) possess natural habitats and are relatively intact. Recent studies affirm that cultivation negatively impacts environmental welfare and people's health. Climate change leading to erratic rainfall and high temperatures will likely worsen the situation.

3.2. Data Sources

To attain the objectives of the research, two types of datasets were collected they incorporate satellite and ancillary data.

3.2.1. Satellite Data

Landsat satellite data was obtained from USGS earth explorer (https://earthexplorer.usgs.gov), a user interface for getting Landsat data. The downloaded images are for 1990, 2000, 2010, and 2020.

Table 1.1: Landsat Data and Specification

Year	Sensor	Bands	Display
1990	Landsat 4 (TM)	1234	Natural colour False-color for vegetation
2000	Landsat 7 (ETM)	1234	Natural colour False-color for vegetation
2010	Landsat 5 (seven had some radiometric problems during this time. The scan line corrector failed)	1234	Natural colour False-color for vegetation
2020	Landsat 8 OLI (Operational Land Imager) & TIRS (Thermal Infrared Sensor)	2345	Natural colour False-color for vegetation

3.2.2. Ancillary Data

Ancillary data refers to other data sources apart from remote sensing that help classify and analyse the metadata. In our study, the remote sensing data is the satellite information that can be used independently; thus, we need to incorporate ancillary information to produce detailed results. Ancillary data in the research included GPS points based on ground truthing, topographic Data, county shape files, and aerial images.

3.3. Methods of data analysis

The data analysis followed a systematic approach that incorporated pre-processing, data classification, post-processing, validation of results, and LULC detection.

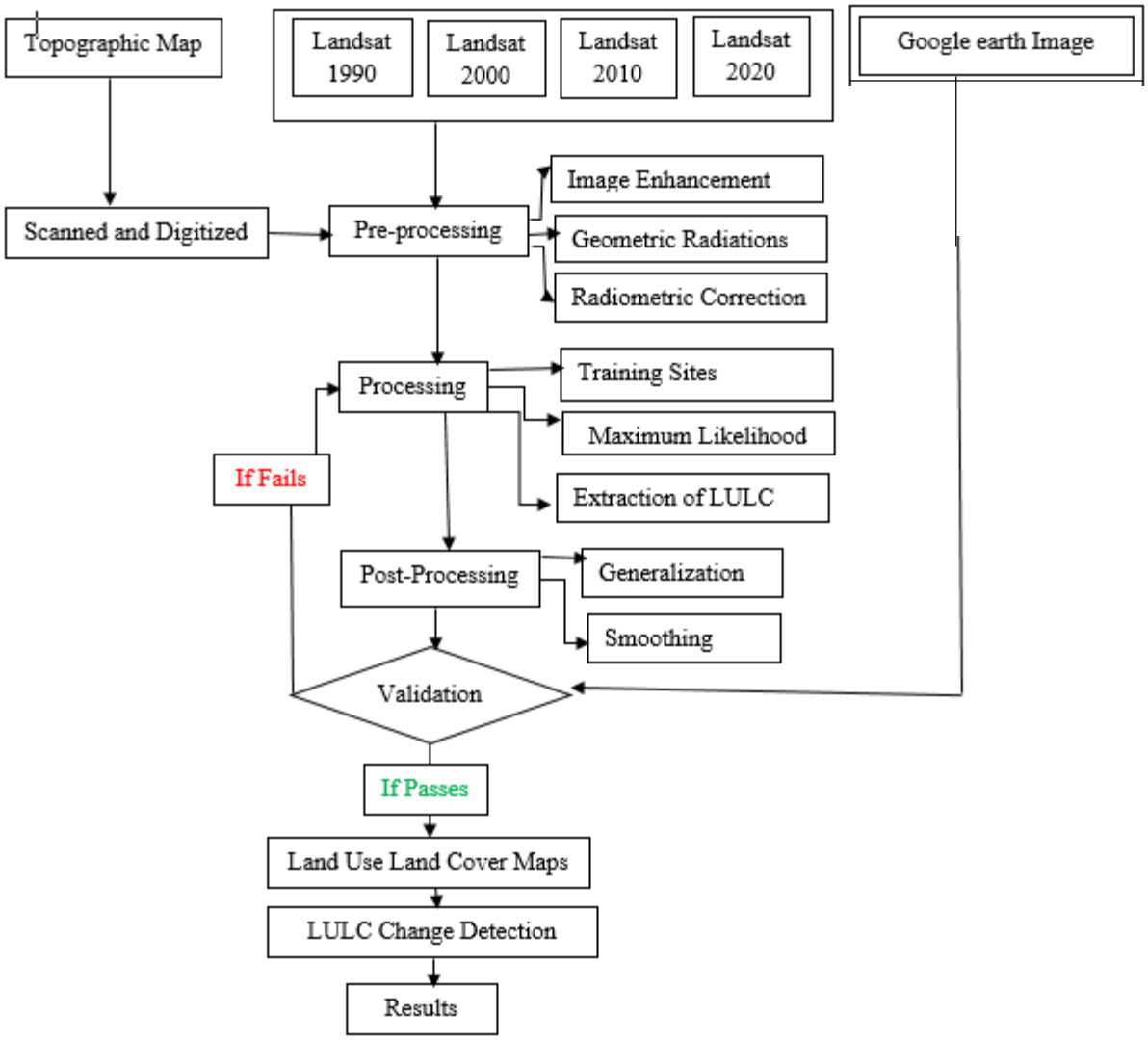


Figure 1.4: Methodology Work Flow

3.3.1. Data pre-processing

This stage incorporated the geo-referencing, extraction of data, and performing the radiometric and geometric corrections. The Landsat images were clipped to remove the unwanted parts and get the area of interest. The clipping process was essential as it helped to fasten the data processing time. Image enhancement was conducted by integrating the bands to produce a composite that eased visualization. The pan-sharpening procedure enhanced the composite resolution by applying the high-resolution panchromatic bar. The process was conducted on Landsat 7 and 8 images with a 15cm resolution panchromatic band 8.

3.3.2. Image classification and Analysis

The Study used the pixel-based classification approach to conduct the Analysis. Unsupervised and supervised classification tools in Arc GIS were applied. Supervised classification was used to process the satellite images in 1990, 2000, 2010, and 2020. The supervised classification needed preparation of the specific training sites. The research identified the everyday land use and land cover classes in Laikipia County and the corresponding description to create the training sites. They incorporated: agriculture, bare land, forest, Grassland, and urban development. The Study applied maximum likelihood to conduct the classification process.

3.3.3. Post Processing

The post-processing was conducted after classifying the satellite images to enhance the output quality. The process incorporated filtering, smoothing, and generalization of the classified output.

3.3.4. Validation of the results

Pixels are often misplaced or misclassified; therefore, the Study undertook the validation process to countercheck the output data and the referenced information on the actual ground. The Analysis was applied to the output data in 1990, 2000, 2010, and 2020. The process ensured that the classes represented what was on the ground. The validation process also helps the researcher compare the overall output and the referenced data. The research used three forms of reference information that is an aerial image for 2019, GPS points, and a google earth image. The Google earth image was the best fit solution as its photograph was available in the archives, and it covered part of the study period.

3.3.5. Change detection

This process helped identify the periodic changes that have occurred within the area.

3.3.6. Change Detection Technique

The research used the post-classification approach to conduct change detection. The method was the best fit as the satellite images for 1990, 2000, 2010, and 2020 were classified independently. Thematic maps were created from the classification process in the three epochs, and corresponding themes were used to identify the changes that have occurred in the past 30 years.

The process was suitable because it helped reduce atmospheric, sensor, and environmental variations as the images were classified differently. Mishra et al. (2017), the approach is ideal for land use land cover classification as it is used to measure urban development and other application.

CHAPTER 4: RESULTS AND DISCUSSIONS

RESULTS

4.1. Land Use Land Cover Classification

The Landsat image processing and ancillary data, such as the aerial images, helped create the LULC classes incorporating agriculture, Bare land, Forest, Grassland, and Urban Development.

4.1.1. Agriculture

The Study used agriculture as a training site by interpreting the aspects of the visual image, such as the shape, tone, pattern, and distinct spectral reflectance. Notably, healthy vegetation often has higher reflectance in the near-infrared region between the wavelengths 0.7 and 1.3 μm. Green vegetation absorbs energy in the visible areas because chlorophyll absorbs light near the 0.45 to 0.67 μm wavelength. Therefore, it is crucial to gather satellite data when the crops in the region are grown and use the band combinations displayed in table 1.1.

4.1.2. Bare land

The bare land refers to the open fields where the people do not conduct agriculture and do not have any vegetation. The more significant part of Laikipia county lie on the arid and semi-arid part of the country and the region possess little to no vegetation. The areas are covered in light grass land its spectral reflectance vary from the crop land and forest land. The false colour used is brown. Figure 1.1 shows the band combination utilized in analyzing the LULC classes selected in the County.

4.1.3. Forest Land

The forested area are covered by trees which has a different spectral reflectance from crops. Notably, trees have a high spectral reflectance and it is in the near-infrared region and absorb more energy from the visible part. The false colour used to represent the forest is green and the band combinations are indicated in table 1.1.

4.1.4. Grassland

Grassland contain continuous layer of grass widespread in major parts of Laikipia. The common ranches in the County lie in the grass land regions. The pastoralists also take advantage of these

regions to graze their cattle and goats. The regions do not support the growth of trees as most places are arid and semi-arid. The false colour used to represent this class is light green and used the band combination indicated on the map. The class used the colour combination band represented in table 1.1

4.1.5. Urban Development

Urban development incorporates the growth of infrastructure for the market, street pavement, health, education, justice, and cultural heritage. Laikipia County is a developing county, and a large part of the County is remote. Significant urban development occurs in Nyahururu to the Southwest, and Nanyuki to the southeast. The false colour representing the class was red with a band combination as depicted in the table 1.1.

5.1 Land Use Land Cover Map of Laikipia County

Table 1.2: Laikipia County Land Use Land Cover Changes

Class Name	**Area in (Km^2) 1990**	**Area in %**	**Area in (Km^2) 2000**	**Area in %**	**Area in (Km^2) 2010**	**Area in %**	**Place in (Km^2) 2020**	**Areas in %**
Agriculture	2,230.92	23.51	977.99	10.31	1,667.19	17.57	2,600.53	27.41
Bareland	2,312.27	24.37	2,164.62	22.81	1,323.54	13.95	685.49	7.22
Forest	524.94	5.53	397.16	4.19	594.05	6.26	1,276.15	13.45
Grass	3,957.57	41.71	5,325.24	56.12	5,344.42	56.32	4,332.81	45.66
Urban Dev	462.99	4.88	623.66	6.57	559.53	5.90	593.74	6.26
Laikipia County	**9,488.69**	**100**	**9488.68**	**100**	**9,488.72**	**100**	**9,488.72**	**100**

To achieve the study's objective, an analysis was conducted on the Landsat images to create the LULC maps for the years 1990, 2000, 2010, and 2020. Table 1.2 indicates the land area coverage for each class and the percentage concerning the county's total area.

5.1.1. Land Use Land Cover Map for 1990

In 1990, the agricultural land in Laikipia county was 2230.92 $km^{2,}$ 23.51 per cent of the total area in the County. The bare land occupied 2312.27 km^2 which was 24.37 per cent of the land. The forest land occupied the smallest region in the County, which was 524.94 km^2 which was 5.53 per cent of the total area. The majority parts of Laikipia county are arid and semi-arid, thus, accounting for the large parts of Grassland that incorporated 3957.57 km^2 which was 41.71 per cent of the total land cover. Urban development was minimal, accounting for 462.99 km^2 which was 4.88 percent of the total land cover.

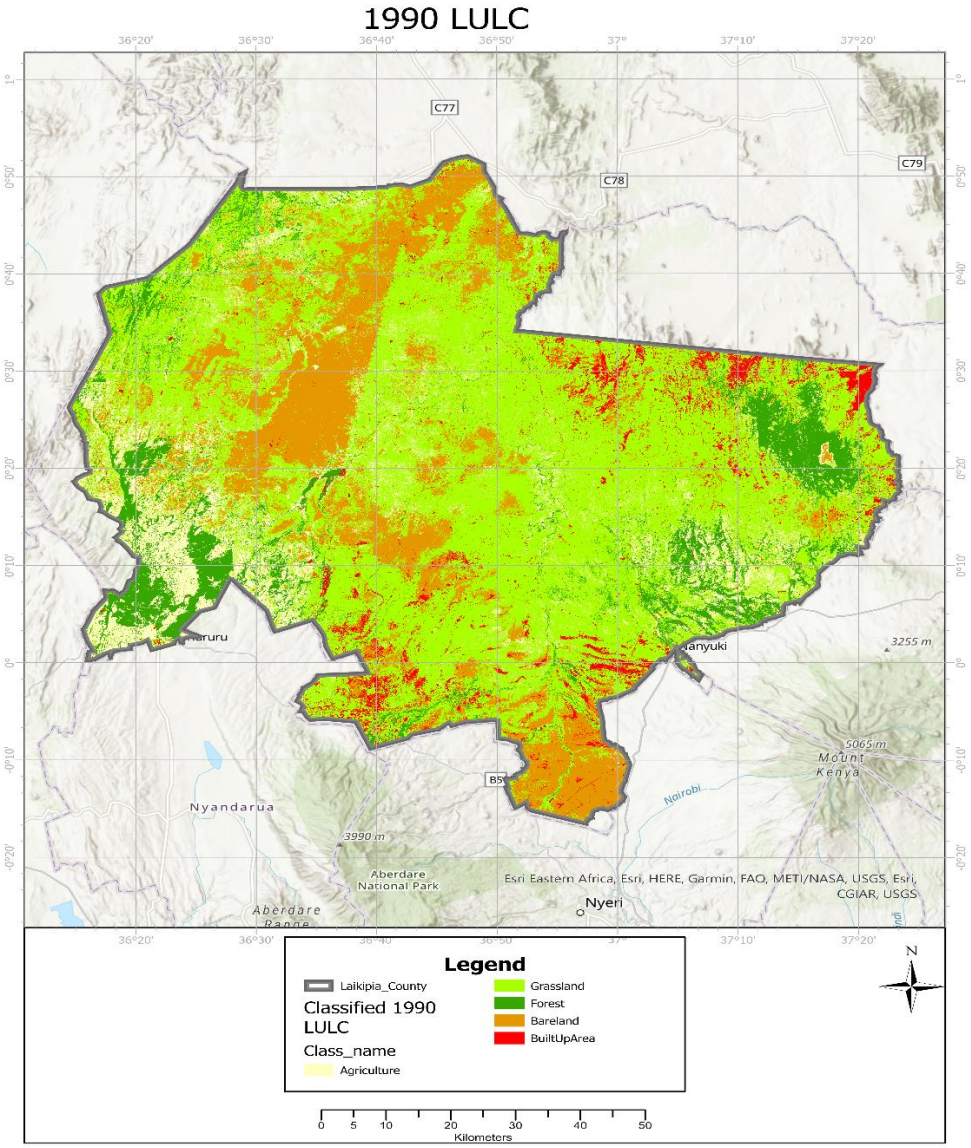


Figure 1.5: Land use land cover map for 1990

5.1.2. Land Use Land Cover Map for 2000

The agricultural land in 2000 occupied 977.99 km^2 which was 10.31 per cent of the total land. The Bare land covered 2164.62 km^2 which was 22.82 per cent of the land cover. The Forest land occupied 397.16 km^2 which was 4.19 of the total land cover. The Grassland covered 5325.25 km^2, which was 56.12 of the entire County. Finally, urban development covered 623.66 km^2, 6.57 percent of the total land cover.

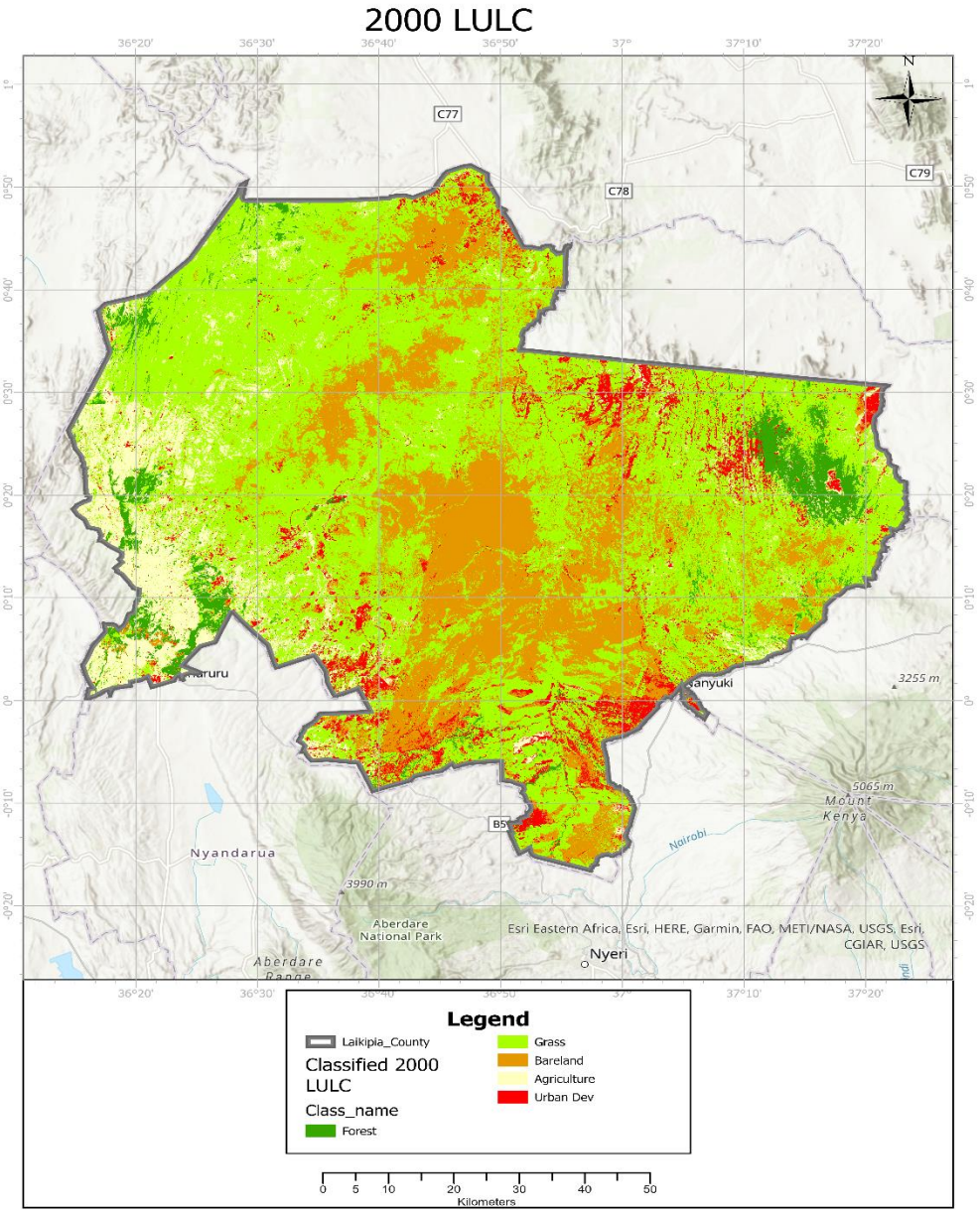


Figure 1.6: Land use land cover map for 2000

5.1.3. Land Use Land Cover Map for 2010

The agricultural land in 2010 was 1667.19 km^2 which was 17.57 percent of the total land cover. The Bare land was 1323.54 km^2 which was 13.95 percent of the total area. The forest land, Grass land, and Urban development was 594.5 km^2 (6.26 %), 5344.42 km^2 (56.32 %), and 559.53 km^2 (5.60 %) respectively.

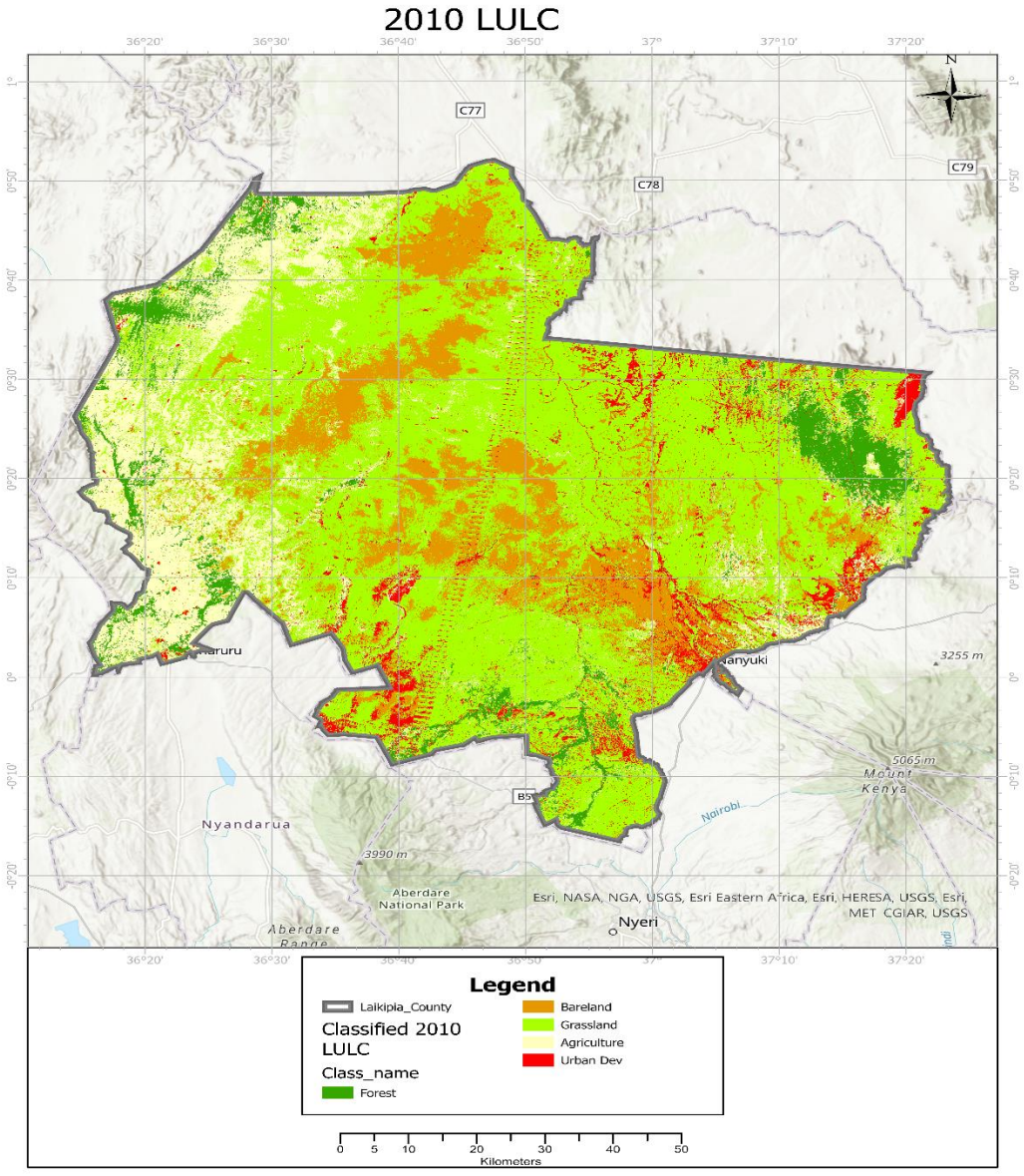


Figure 1.7: Land use land cover map for 2010

5.1.4. Land Use Land Cover Map for 2020

The agricultural land in 2020 was 2600.53 km^2 (27.41 %), the bare land was 685.49 km^2 (7.22 %), the forest land was 1276.15 km^2 (13.45 %), the grassland was 4332.81 km^2 (45.66 %), and the urban development land was 593.74 km^2 (6.26 %).

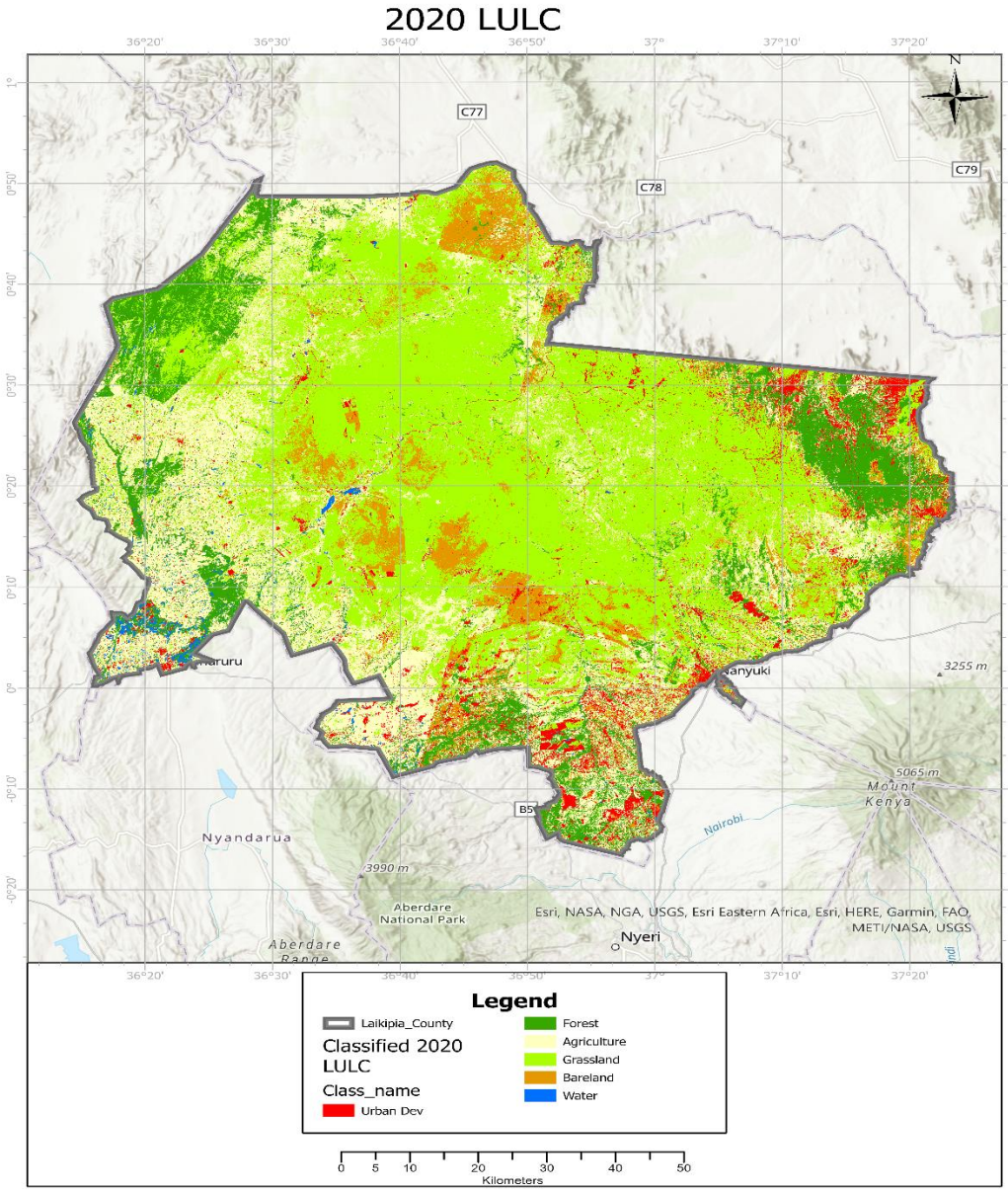


Figure 1.8: Land use land cover map for 2020

6.1. Change Detection Analysis

6.1.1. Land Use Land Cover Changes between 1990 and 2000

Table 1.3: Laikipia County Land Use Land Cover Changes

Class Name	Area in (Km^2) 1990	Area in %	Area in (Km^2) 2000	Area in %	Change in Area
Agriculture	2,230.92	23.51	977.99	10.31	-1252.93
Bareland	2,312.27	24.37	2,164.62	22.81	-147.65
Forest	524.94	5.53	397.16	4.19	-127.77
Grass	3,957.57	41.71	5,325.24	56.12	+1367.67
Urban Dev	462.99	4.88	623.66	6.57	+167.67
Laikipia County	**9,488.69**	**100**	**9488.68**	**100**	

The land cover in Laikipia county experienced significant changes between 1990 and 2000. The agricultural land was reduced by 1252.93 km^2, the bare ground reduces by 147.65 km^2, and the forest land reduced by 127.77 $km^{2,}$ but the Grassland and urban development increased by 1367.67 km^2 and 167.67 $km^{2,}$ respectively.

In the 1990s, pastoralists successively arrived in many parts of Laikipia, disrupting the agricultural practices of most small-hold farmers (Huho, 2011). As a result, the land was subdivided, creating approximately 85,000 subdivisions that rendered most of the land unusable as the resulting subdivided land was too small for viable farming activities, given that most of the part lies in the semi-arid region. This caused the agricultural land to reduce. As a result, the Grassland increased, facilitating the increase of ranches, national reserves, and pastoral activities.

The 10-year changes indicated that the forested areas would have been used to provide goods that would facilitate urban development. At this time, most activities relied on wood from constructing the metropolitan towns and other household activities, leaving unused space for Grassland to increase exponentially.

The changes are illustrated in the bar graph below and show that the agricultural land, bare land, and forest land reduced while urban development and Grassland increased.

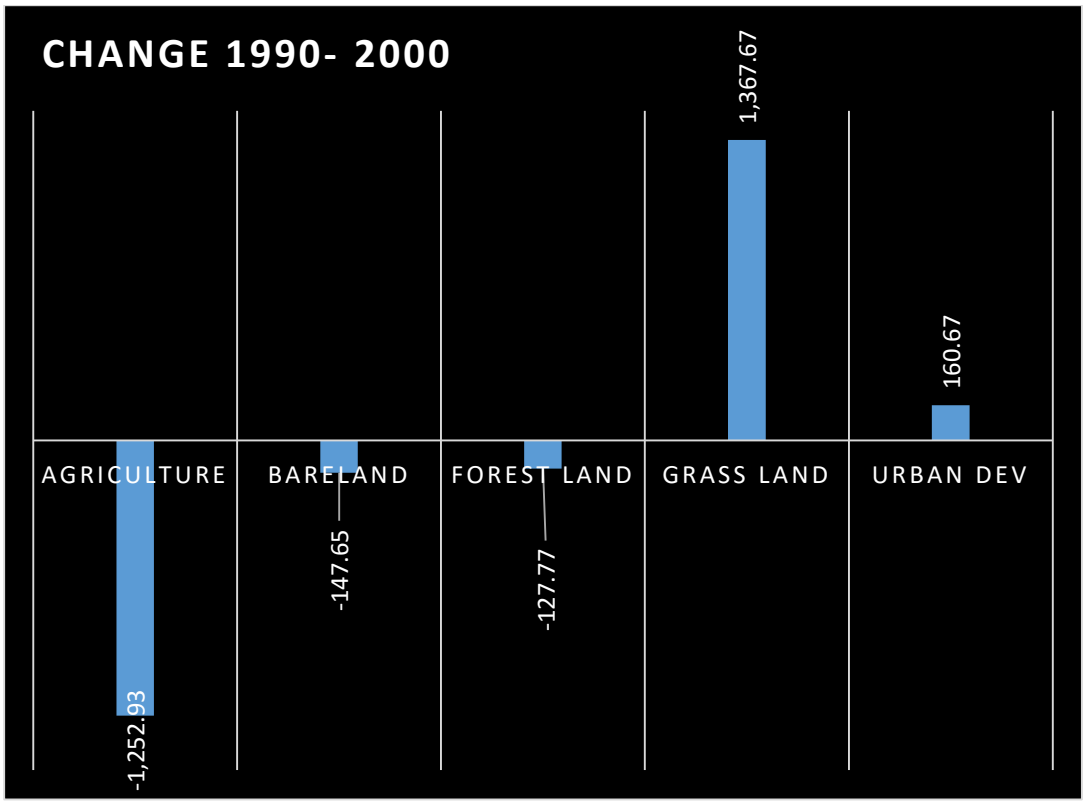


Figure 1.9: Bar graph for LULC in 1990-2000

6.1.2. Land Use Land Cover Changes between 2000 and 2010

Laikipia County experiences significant changes between 2000 and 2010. The agricultural land increased by 689.20 km^2, the bare land reduced by 638.05 km2, the forest land increased by 682.10 km^2, the Grassland reduced by 1011.61 km^2, and urban development increased by 34.21 km^2.

During this period, the Population in Laikipia was increasing steadily and required more land for agriculture. This resulted in the people utilizing the bare land and also rehabilitating some of the dry areas in the County. The national and local governments advised the farmers to perform agroforestry which would help curb climate change, conserve the soil, and improve crop yields while producing fuel wood. The ranchers also helped protect the primary forests as most people held large tracks of land.

Table 1.4: Laikipia County Land Use Land Cover Changes

Class Name	**Area in (km^2) 2000**	**Area in %**	**Area in (Km^2) 2010**	**Area in %**	**Change in Area**
Agriculture	977.99	10.31	1,667.19	17.57	+689.20
Bareland	2,164.62	22.81	1,323.54	13.95	-841.08
Forest	397.16	4.19	594.05	6.26	196.88
Grass	5,325.24	56.12	5,344.42	56.32	19.18
Urban Dev	623.66	6.57	559.53	5.90	-64.13
Laikipia County	**9488.68**	**100**	**9,488.72**	**100**	

The graph below provides a pictorial representation of the land use land cover changes in 10 years. The agricultural land increase occupied the bare land, whereas the forested increases are the changes in agroforestry and conflicts that disrupt the social and economic activities. However, comparing the results for the past 20 years, the grasslands have considerably reduced, emanating from the increase of the overall shoats and cattle migrating into Laikipia County. Urban development also reduced the reason the bandits would attack people in these urban areas, leaving most of the deserted regions.

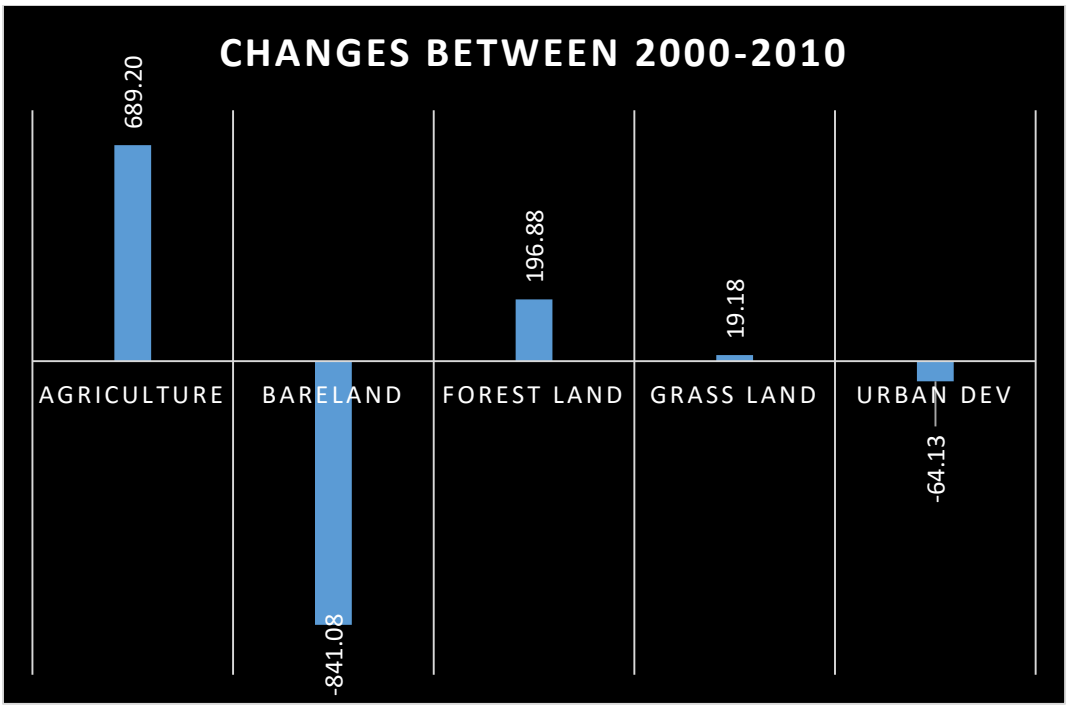


Figure 2.1: Bar graph for LULC in 2000-2010

6.1.3. Land Use Land Cover Changes between 2010 and 2020

Results from data analysis indicate that between 2010 and 2020, agricultural, forest, and urban development land increased by 933.34 km^2, 682.10 km^2, and 34.21 $km^{2,}$ respectively. The bare land and grassland reduce by 638.05 km^2 and 1011.61 $km^{2,}$ respectively.

According to the results presented in the table, the agricultural land continues to increase, and farmers are rehabilitation the bare land and grassland to produce food. The farmers are encroaching on the grasslands that are wildlife habitats creating conflicts and destruction of the farm produce.

Table 1.5: Laikipia County Land Use Land Cover Changes

Class Name	**Area in (Km^2) 2010**	**Area in %**	**Area in (Km^2) 2020**	**Areas in %**	**Change in Area**
Agriculture	1,667.19	17.57	2,600.53	27.41	+933.34
Bareland	1,323.54	13.95	685.49	7.22	-638.05

Forest	594.05	6.26	1,276.15	13.45	+682.10
Grass	5,344.42	56.32	4,332.81	45.66	-1011.61
Urban Dev	559.53	5.90	593.74	6.26	34.21
Laikipia County	**9,488.72**	**100**	**9,488.72**	**100**	

The graph below visualizes the increase and decrease of the predominant resources in the County. The communities also replanted trees in most bare lands to minimize soil erosion. Efforts by the local and international governments to plant fast-growing trees in the past 20 years have helped increase the forest land.

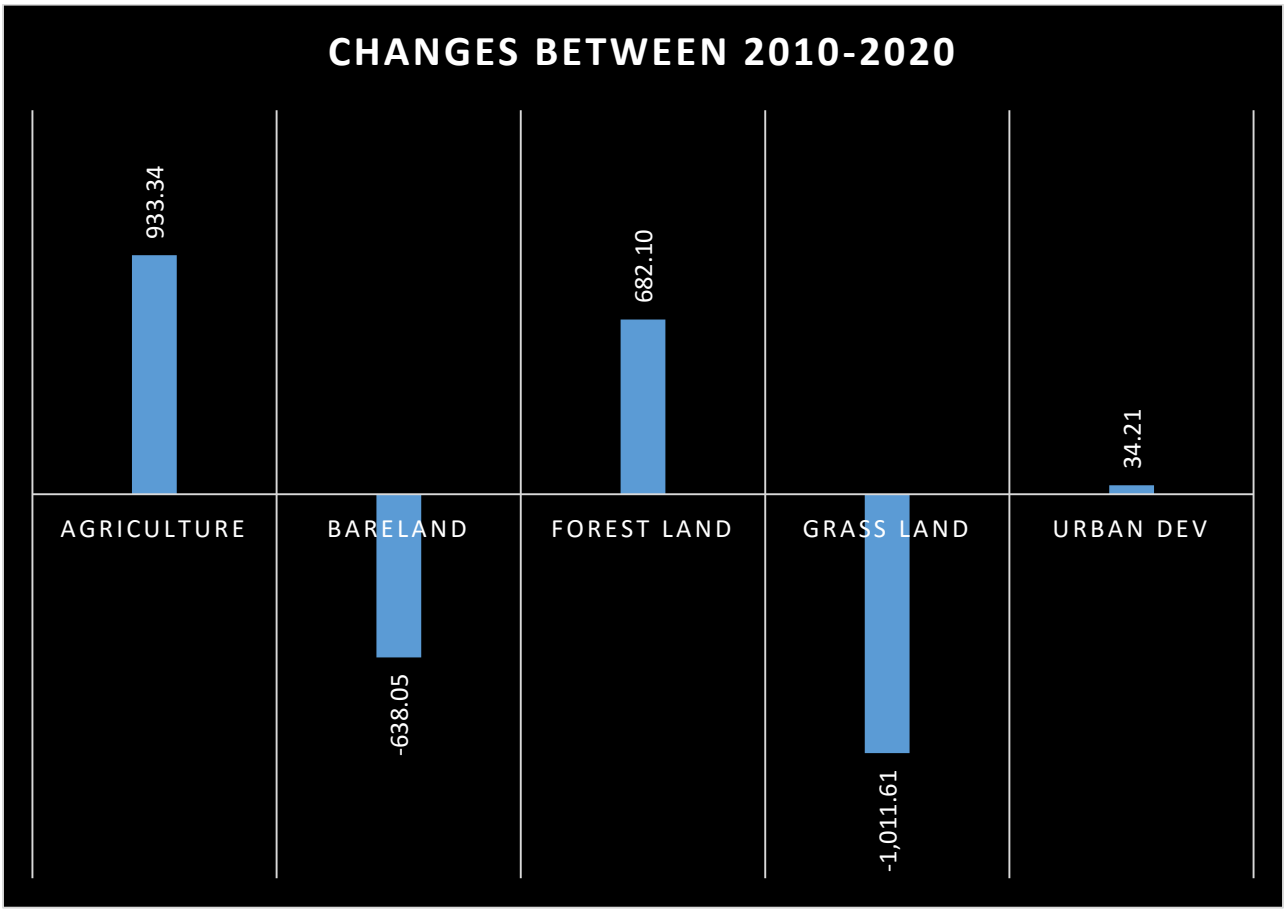


Figure 2.2: Bar graph for LULC in 2010-2020

DISCUSSION

7.1. Impact of Land Use Land Cover Changes on the environment in Laikipia County.

According to the result from the study, it is prudent that the LULC in Laikipia County through GIS and remote sensing has changed over the years. From table 1.4, in 2020, the agricultural land is increasing alongside the forested areas. The grasslands are reducing at the expense of agriculture and pastoral communities that live within the areas. The significant impacts that emanate from the changes in the land cover include increased agriculture, increased human-wildlife conflicts, and excessive soil erosion from overgrazing and overstocking.

7.1.1. Increased Agriculture

Laikipia County, just like other counties' economies, relies mainly on agricultural production, which often leads to the depletion of natural resources such as natural forests. The intense agriculture aid in producing commercial and Home used foods for the people. However, the current technology has helped improve agricultural practices such as low-cost farming agriculture (Letai, 2011). The United Nations Food and Agriculture sensitized the communities in the County to use Conservation agriculture which would help sustain productivity and increase food security and profits while protecting nature (Huho, 2011). As a result, farmers have continued to identify suitable agricultural fields hence expanding agriculture.

According to data presented in Tables 1.4 and 1.5, agriculture has improved as the communities have identified new farming approaches such as agroforestry and horticulture. The county Government of Laikipia affirmed that horticulture is an emerging trend in the region that promotes the growth of foods such as watermelons, potatoes, and vegetables. Farmers are also incorporating floriculture, generating an annual income of approximately Ksh. 1.3 billion (Bond, 2014). As a result, the farmers are taking advantage of any bare land, creating micro-climates through greenhouses and starting agriculture. The individuals sell produce locally and internationally gaining revenue for the country and the families that work on these farms. The primary greenhouses in the County incorporate AAA growers, Frigoken, and Home grown. The AAA growers (samba farms) occupy approximately 40 Km2 of land that was initially dry and non-productive. Mzuza et al. (2019) stipulate that agriculture is possible due to the available

empty spaces that individuals own. Therefore, the farmers can exploit the spaces and increase agriculture.

7.1.2. Increased wildlife and human conflicts

Over the past decades, the pastoral communities, ranchers, and residents have constantly fought. Park (2020) posits that Human-wildlife conflict occurs when animal behavior and needs negatively impact human beings or when human activities tend to interrupt the wellbeing of the wildlife. The resultant issues after conflicts are crop destruction, injury, killing, or threat to the domestic animals and the riparian communities. Park (2020) stipulates that such problems erupt when the communities move near and in the wildlife habitat.

Accordingly, results from tables 1.4 and 1.5 indicate that the Grassland is considerably reduced, which is home to many wild animals. For example, in 2010, the grassland was 5344.42 km2, and in 2020 it declined to 4332.81 km2. Agricultural activities are increasingly taking over the habitats, and as a form of retaliation, the animals attack or destroy their farm products (Waweru, Cornerli, & Okoba, 2013). As the Population and urban development increase, the need for natural resources increases, prone the people to encroach on land near the wildlife habitats to help meet their daily needs through growing food (Kibet et al., 2020). However, Human-wildlife conflicts vary with location, as most parts that experience the conflicts live near the resources. The government has not created co-existence measures to help reduce the disputes while sustaining food security as they encroach on the grassland and protected forests to perform agriculture.

7.1.3. Increased Soil erosion

Overgrazing and overstocking are significant problems in the County. Boles et al. (2019) affirm that most of the counties in Kenya experience overgrazing challenge that often leads to loose top, thus, soil erosion. The pastoral communities seek to store more herds of cows and flocks of goats and sheep without considering the predominant natural resources (Yurco, 2017). Notably, Laikipia communities mainly incorporate pastoralists and farmers. It also results in soil compaction through the rains and wind. This results in reduced ground cover and water penetration that leads to soil erosion. Deforestation also results in soil erosion in the river as the

roots of the tree help in holding the soil particles. The agricultural plants do not manage to hold the soil compared to trees increasing the likelihood of soil erosion.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

8.1 CONCLUSION

The study's main objective is to conduct a Land Use Land Cover analysis in Laikipia County and identify the impacts on the natural resources through GIS and Remote Sensing technology. The purpose of the research was to apply GIS and Remote Sensing technology to visually and graphical show the variations in the land uses and land cover for 30 years and investigate the implication of change to the environment and human beings. The main objectives were further subdivided into specific objectives.

The first objective was to map the Land uses and land cover changes in Laikipia County from 1990 to 2000, 2000-2010, and 2010-2020. The mapping process showed the existence of five major LULC classes incorporated: forest land, Grassland, bare land, Grassland, and urban development. The outputs are indicated in Figures 1.5, 1.6, 1.7, and 1.8. The results indicate that there have been immense changes in the land cover due to agricultural activities, increased pastoral activities, and population increase.

The second objective was to analyze the trends of the LULC changes in Laikipia County through mapping with the aid of GIS and remote sensing. The Analysis was applied to all three epochs and compared under a time difference of 10 years. Table 1.2 provide the summary of changes over the years, and it is prudent that agriculture has significantly increased, followed by the forest cover due to reforestation and agroforestry. On the contrary, the bare lands and grasslands reduce as most efforts are aimed at rehabilitating the land while farmers and pastoral communities

encroach on the grasslands.

The Study identified that the increase in Population and more food to sustain the growing Population prompted the individual to secure more land for agriculture. However, this resulted in human and wildlife conflicts, especially for families living within the habits that is the forests and grassland. Urbanization is still slow in the County as the ongoing human disputes over natural resources have resulted in people migrating to other towns and camps.

The third objective is to investigate the implication of LULC on the environment in the County. The study revealed that the grasslands and bare lands were most affected, where they reduced by 10.66% and 6.73%, respectively, between 2010 and 2020. The change is crucial as Laikipia is home to a variety of wildlife. The wildlife relies on natural habitats for survival. However, the issues are a double-edged sword as the growing Population depends on the lands to grow food hence curbing food insecurity. Over the past years, reports indicate that the pastoral communities are also scrambling to get grazing fields while their herd and flocks are increasing immensely regardless of the minimal resources.

8.2. RECOMMENDATIONS

According to the Study, society can appreciate the essence of GIS, and Remote Sensing as the technology can be applied to conduct land use and land cover change analysis. The various authorities in the local and national governments need to utilize such technologies to analyze the spatial changes and unravel the interconnection of land use and land cover over time which helps the resource planners to make informed decisions.

The Landsat images are reliable, cheap, and easily accessible are depicted in the Study. However, it is challenging to distinguish the signature of some LULC features, for example, livestock pasture, Grassland, and bare land. Therefore, government organizations need to get high-quality satellite images that help improve the quality of future studies.

To achieve temporal accuracy, it is essential for future researchers to obtain Landsat image data for a similar period, for example, the same month, to help produce accurate output.

To improve environmental sustainability, the people and government facilities need to apply GIS and remote sensing technology to help predict the future areas likely to experience habitat loss and implement preventative measures to prevent the continued human and wildlife conflicts.

To minimize soil erosion, researchers can use GIS and Remote Sensing, which is an essential tools in mapping soil erosion and will provide information to the resource managers on areas that are susceptible to soil erosion, thus, instilling the proper precautionary measures.

9.1. AREAS OF FURTHER RESEARCH

Areas of further Study should focus on examining the relationship between land use land cover changes and climate change in the County, as most of the problems that the County is experiencing may also emanate from climate change. Future areas should explore the impact of land cover changes on the hydrology system for a certain period on local and global scale.

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