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ASSESSMENT OF ANTHROPOGENIC ACTIVITIES AND THEIR IMPACT ON NGONG HILLS FOREST, KAJIADO COUNTY: A REMOTE SENSING APPROACH

BY

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A Project Report submitted in partial fulfilment 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 2019

This Project is submitted with my approval as University supervisor:

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DECLARATION

I, Hilda Simiyu Machuma, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other university.

Hilda Simiyu Machuma
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This project has been submitted for examination with my approval as university supervisor

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Turn it in report summary

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DEDICATION

I dedicate this work to my dear parents Mr. Jacob Simiyu Nalianya and Mrs. Victoria Simiyu Nasimiyu for being my greatest cheer leaders, my dear husband Dr. Duncan Sangura for spearheading my M.Sc. and supporting me in every stage financially, emotionally and spiritually and my wonderful kids Danette Kayla and Nolan Sangura for giving me the best smiles when am overwhelmed and giving me the reason to pursue harder.

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My sincere and humble gratitude goes to God for strength, good health and protection throughout my studies. I wish to thank my supervisor Mr. B. M. Okumu for his unending guidance and also wish to acknowledge the assistance tirelessly given to me by, Dr. F. Karanja and Dr. D. Siriba. I as well appreciate my family for the understanding and support accorded to me during my research period. Appreciation goes to my fellow colleagues for the unending assistance throughout the project. Finally, I wish to pass my sincere gratitude to Higher Education Loans Board for considering me for the scholarship that has aided my studies up to this point.

ABSTRACT

Monitoring of the forest ecosystem is mandatory in detecting any changes in the ecosystem. Human beings are dependent on forests for various livelihood needs and thus the development and conservation of forests around the world is vital. Forests offer a variety of benefits including ecological, social as well as economic benefits thus more reason to protect this ecosystem. Forest cover change detection gives an opportunity to track the productivity, health and the forest cover as well over the years so as to enable proper management, promote conservation and enhance functionality. Optical and radar remote sensors make it possible to monitor changes by the use of various analytical techniques which include visual interpretations.

The study reviewed on how remote sensing can be applied to detect change in forest ecosystem and to assess the rate of change of Ngong Hills Forest. This project is focused on determining whether anthropogenic activities are the major cause of the change in Ngong Hills Forest. Data from satellite images was analysed from 1984 to 2019 to identify the changes that occurred on the ecosystem. By achieving this, it will thus be possible for management agencies to enforce conservation because of the presence of reliable data. Landsat and Rapid-Eye images were used to inform on change detection and in this case, rapid eye data was found to be better than Landsat data in informing on change detection because of its high resolution thus high precision and better results. The changes depicted by the remotely sensed data were mapped for ease of analysis and visualization.

The research depicted a massive decrease in the forest cover despite the afforestation efforts by the KFS in the 1990’s. The forest has been depreciating massively from 1995 depicting greater deforestation rates between 2010 and 2019. This depreciation has been acknowledged by the KFS as it is said to be occurring due to the anthropogenic activities mainly settlement and logging.

The means of detecting change by use of remote sensing is thus able to identify the exact areas that change has occurred and thus providing insight to the Kenya Forest Service and other ecosystem protection bodies on the most affected areas and the extent of change. Once the study area is mapped, it is possible to calculate the areas that have decreased in vegetation quantity, areas where increase has occurred as well as the areas that have remained unchanged.

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List of Abbreviations

GPS	Global Positioning Systems
KFS	Kenya Forest Service
KFSB	Kenya Forest Service Board
WGS	World Geodetic System
UTM	Universal Transverse Mercator
USGS	United States Geological Survey
NFI	National Forest Inventory
FAO	Food and Agricultural Organization
CBD	Central Business District
SLMS	Satellite Land Monitoring System
NFI	National Forest Inventories
GDP	Gross Domestic Produce
NFMS	National Forest Monitoring Systems

CHAPTER ONE: INTRODUCTION

1.1: Background of the study

Anthropogenic activities have been on the rise globally creating a major concern. These are activities caused or influenced by humans such as cutting down of trees for charcoal, to create room for settlement or agriculture. Global efforts to ensure climate change as a key development factor is controlled and managed by all countries; has been widely accepted as a noble cause. During the 21st Conference of Parties to the United Nations Framework Convention on Climate Change in Paris in December 2015, for the first time, countries negotiated discussions on protected areas as climate change controlling strategy (UNFCC, 2015).

According to IUCN World Conservation Congress (2012), requested the Director General to promote activities for ecosystem resilience to climate change, including through: buffer zones and migratory corridors; ecosystem restoration, conservation of marine and coastal ecosystems; protection of species, and maintenance of forest quality.

The Africa Agenda 2063, the initial ten-year plan (2014-2023), its first Aspiration which is "*A Prosperous Africa based on inclusive Growth and Sustainable Development*" recognizes the need to conserve our biodiversity including forests.

These efforts adopted by many countries including Kenya, has promoted protection zones including forest covers recognizing their impact on climate change. The adoption of sustainable development goal 13 on Climate Action targets 1-3, are recognized in our Vision 2030 third Medium Term Development Plans (2018-2022).

Kenya has come up with a National Forest Program which runs from 2016-2030. Its main aim is to develop as well as coordinate development of forests with the aim of meeting the needs of its citizens in the next fifteen years. The ministry of Environment and Forestry is on the forefront to ensure that the program is up and running. The program is aimed at ensuring sustainable management of forests and develops as well as restore, manage, conserve and utilize Kenyan forests as well as the allied resources to ensure climate resilience and social economic growth. (Min. of Environment, 2018)

The natural resources sector contributes about 42% of the country's GDP and about 70% of the overall employment. The sectors related to natural resources include, mining, agriculture, forestry, mining, water supply, tourism and the energy sector. According to FAO's State of the Worlds Forest Report of 2014, the country's forest sector contributes about 3.65of the entire GDP. This estimate however excludes the contribution of forestry to the wood energy used in the households, the non-timber products provided by the forests as well as the ecosystem services.

The sector is a major contributor to the economy as it brings forth about 7 billion shillings to the Kenyan economy and creates an avenue for employment for over 350,000 people directly and indirectly (Ministry of Environment and Forestry, 2018). Forests are responsible for the provision of environmental services such as soil erosion reduction, ensure sufficient water quality and quantity as well as the creation of macro-climatic conditions which improve and maintain productivity of the ecosystem. Forests are one of the most effective sinks of greenhouse gases which are the major cause of climate change and thus are important in climate change mitigation. According to (FAO, 2012), forests contain approximately 80% of the biodiversity and are responsible for the provision of environmental services such as watershed management, soil conservation, provision of wood to be used for various purposes and protection against floods.

Deforestation has become a worrying factor globally and thus need to monitor the changes in the forest ecosystem and provide mechanisms that can be used to protect this ecosystem. At the moment, sustainable management of forest is the most urgent worldwide challenge as ecological processes are interfered by the activities of man. The forest managers to control the impacts caused by diseases, deforestation and wind throw, they need to put in place techniques that can be used to support updating and monitoring of forest information on a regular basis. Remote sensing techniques as well as forest inventories can be of great use in the detection and monitoring these changes.

Forest management presently necessitates that the data collected is continuously updated and very accurate. Vertical photos became available in the 1930's. Before then, the forest managers were totally dependent on resource information collected on the ground. The introduction aerial photography proved to be a very valuable asset. Remote sensing, among other techniques, has with no doubt proven its ability in the field of change detection. Landsat-1 was launched in 1972 marking the genesis of satellite remote sensing. It is very efficient and consistent especially when applied in large areas. It as well requires less input of manual labour and consumes less time.

Optical sensors are the major source of remote sensing data. Landsat is used frequently in mapping of forest cover and the changes that occur. Forest loss and gain has been mapped using Landsat data from 2000-2012 and has since been updated yearly.

Images acquired remotely from the Landsat satellites have spatial, spectral and temporal properties which are optimal for the identification of ecological changes on the landscapes. Since the Landsat images were made freely accessible by the public, there has been feasibility of automated temporal detection of forest disturbances (Woodcock *et al*, 2008).

Renewable natural resources for instance forest are exposed to continuous change. According to Milne, 1988, change is described as an alteration in the surface components of the vegetation cover" or can as well be described as "spatial/spectral movement of an entity of vegetation over a period of time" (Lund, 1983). The rate of change can either be abrupt or dramatic for instance tree logging; gradual and/or subtle, for instance growth of the forest standing volume. Forest cover modification can either be natural or human induced. The natural modification can be as a result of disease epidemics or insect invasion. Human-induced can be as a result of deforestation for purposes of land-use conversion

This study is meant to look at the ways in which remote sensing can be used to help monitor forest cover change caused by anthropogenic activities. Satellite data being the most preferred for timely and efficient monitoring of forest change will be employed in this case. This will enable continuous and repetitive coverage of the forest area. By use of this, the Kenya Forest service can maintain an inventory and thus find a better way to manage this ecosystem.

1.2: Ngong Forest Ecosystem

Ngong forest is located 6Km from Nairobi city. It was first gazetted in 1932 with coverage of over 2,900 hectares. Railway was a key means of transport back then and this forest supplied all timber and its products including fuel.

Following a series of legal excisions, this parcel of land was reduced drastically. Some of these illegal practices included land grabbing by private developers. Intense lobbying in the 1990s led by Trustees of Ngong Forest Road Sanctuary secured the forest with acreage of 1,224 hectares. In 2005, the Forest Act 2005 was ascended into law. It is at this point that the Kenya Forest Service was given the mandate to protect the forest. This Act has since been repealed by the Forest Conservation and Management Act 2016, to comply with the Constitution of Kenya 2010.

This forest is under the management of the Ngong Road Forest Sanctuary Trust. The sanctuary protects conserves and manages the forest of over 80 percent indigenous trees and the rest exotic eucalyptus plantations within the Ngong Road Forest Reserve. The forest is rich in biodiversity and is home to more than 35 mammals and numerous insects, 120 bird species, amphibians, and fish.

The goal of the Trust is to secure the natural environment and create a multifunctional and self-sustaining reserve which is meant to serve educational, social as well as the economic needs of the dependent communities.

1.3: Problem Statement

Forest ecosystems especially in Kenya face a lot of disturbance and fragmentation. This is majorly because of the increasing population, development and overdependence on forest products such as timber, and a variety of foodstuffs. The main cause of disturbance has been natural causes including fire and topography. This has contributed to diminishing forests over the years. Kenya being a third world country is majorly dependant on the natural ecosystem as a source of livelihood for both subsistence and export use.

The forest management agency such as the Kenya Forest Service has to ensure continuous monitoring of this ecosystem for them to effectively carry out their mandate. Inventories have been used for quite a long time to build national databases necessary for integrated monitoring of forests and are central to conservation. They give direction on the best management and conservation practices and have a great potential for the improvement of forest management strategies. As much as we appreciate the use of inventories in management of this ecosystem, the information it provides is hardly sufficient.

Management of forest is turning to be an urgent challenge worldwide. Forests are degrading at a very fast rate and thus posing socio-economic implications creating global concerns. This is due to an impact on the environment due to loss of biodiversity as well as climate change. There is a rising need for effective forest monitoring interventions due to the diversity of these ecosystems worldwide. Technological systems have been established to aid in effective and real time mapping and monitoring of ecosystem changes. For instance, the use of remote sensing to monitor forest ecosystem has been widely adopted in countries like Canada, Brazil and India.

The Department of Resource Surveys and Remote Sensing which is mandated to conduct forest monitoring to reduce conflict of interest where KFS was the monitoring unit and the overall lead in protection of forests. This study reviews previous reports and data since 2010 to 2018, to understand the ecosystem changes in Ngong Forest. These changes will be focused on land cover and biodiversity. The use of remote sensing technique in particular the Landsat will be used as it is cost effective, less time consuming and requires less manual labour. Landsat data is updated on a yearly basis and thus help speed up forest change detection.

1.4: Overall Objective

The overall 0bjective for this study was:

Assess the extent of anthropogenic activities disturbance and fragmentation to Ngong forest ecosystem using remote sensing.

1.4.1: Specific Objectives

The specific objectives were namely to:

1) Review how remote sensing can be applied to detect change in forest ecosystem
2) Identify suitable data that can be used to inform on change detection
3) Map the changes in Ngong Forest (land cover mapping)
4) Establish whether change is due to anthropogenic activities and

1.5: Justification for the Study

Ngong forest has been faced with a lot of disturbance and fragmentation largely contributed by man activities including; settlement, developments and transport systems like railway in the surrounding environments.

Forests are a source of livelihood for a large biodiversity. A lot of resource comes from them and are equally crucial for the climate change mitigation. Deforestation of these ecosystems poses a great risk as it translates to reduction of resources and adverse risk to climate change. Monitoring of the activities that lead to deforestation as well as assessing the amount of forest cover over a period of years will enable locals as well as the authorities to monitor and control deforestation; this will be through correct budget estimates, better strategies to enhance communal participation in conservation and management etc.

This study focuses on the anthropogenic activities that lead to disturbances and fragmentation as well as assessment of the Ngong forest cover and biodiversity for the period 1984 to 2019. This will help us understand the rate at which the forest is either decreasing or increasing and thus provide a basis for strategies that can be employed to maintain this ecosystem.

The Kenya Forest Service and Forest Service Board, as well as County departments may find this report useful as it will highlight possible strategies to better conserve natural resources. Scholars in the sector may find the study useful as it is an addition to the existing literature.

1.6: Scope of the study

Ngong forest is among the few natural forest in Kenya not to talk of in the capital city. It is located in Kajiado County and it is approximately 25 km from Nairobi's CBD. The forest is located in Ngong Hills accessible through Ngong road. The Ngong forest Sanctuaries manages the forest which is a home to a variety of wild animals as well as indigenous trees. The forest extends to the Rift Valley Province. It located on coordinate 1°18′59.12″S 36°44′30.13″E and covers approximately 3077.6 hectares of land.

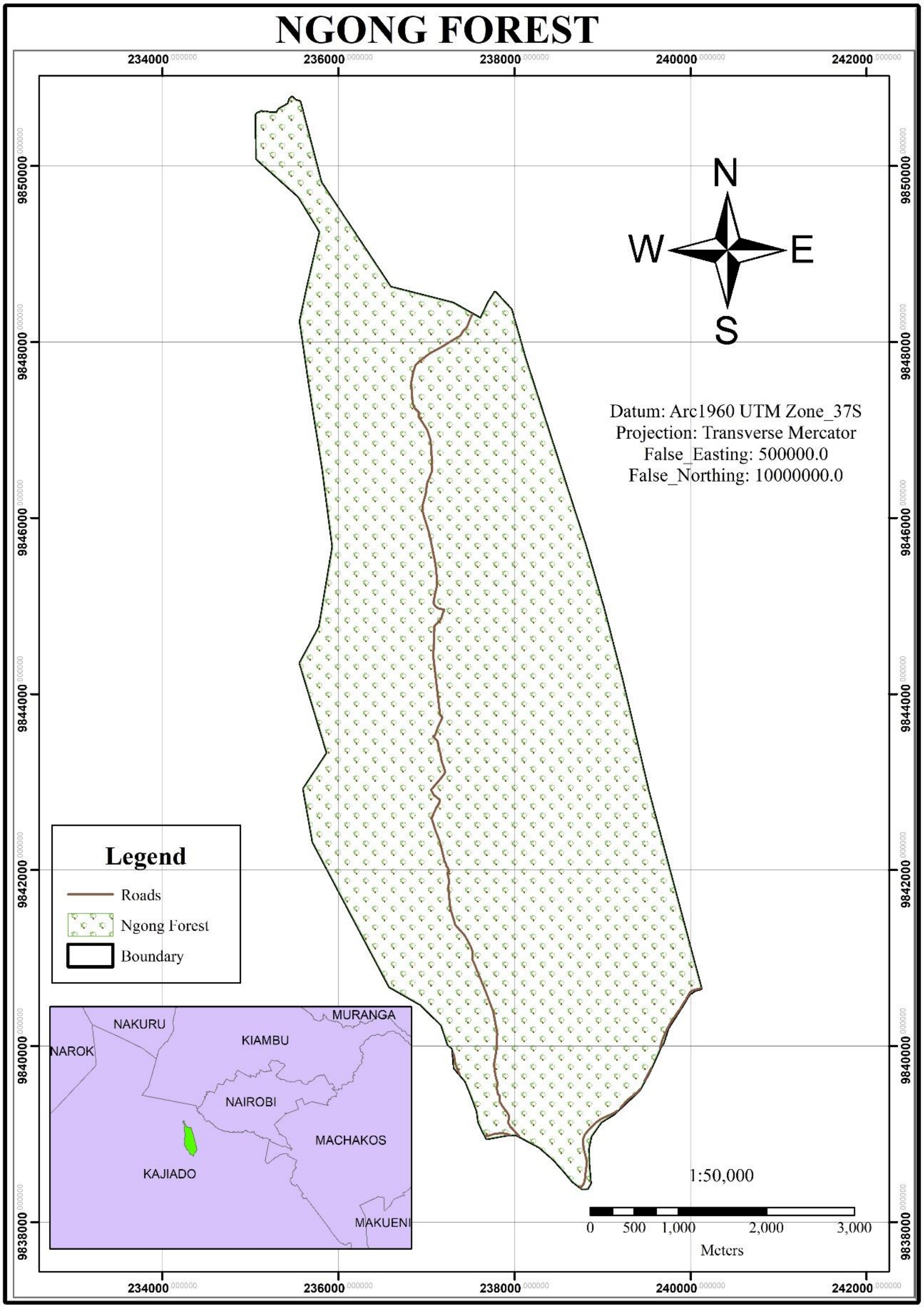


Figure 1.1: Map of the study area

1.7 Organization of the report

This research is organized into five chapters. The first chapter included the background of the study where the current status of the forest ecosystem in the country is reviewed as well as the measures that have been put in place by the government and conservation agencies in order to ensure protection of this very critical ecosystem. A closer look at the Ngong Hills Forest ecosystem is also done so as to better understand the study area and the problem at hand which highlighted the limited use of remote sensing on informing the change of the ecosystem. The objectives were then formulated so as to give a guidance on the way the project was to be carried out.

The second chapter is the literature review which reviewed similar work that has been carried out by other researchers especially in the developed countries where remote sensing is used on a large scale. Other factors causing forest change apart from anthropogenic activities were also discussed including invasive species and climate change. The techniques for forest change detection were also discussed in details as well as the knowledge gaps.

Chapter three is the materials and methods where the research design was discussed coupled with the flow chart to be followed as guidance to the accomplishment of the objectives stated. The materials are indicated as remote sensing data and softwares (Erdas Imagine and ArcGIS) and reference data which is the data collected from the Kenya forest service. Data collection procedures and analysis are as well indicated. The methodology part includes the methods that were used to accomplish the work from the initial stage up to the end. These include layer stacking of the satellite images (Landsat data), mosaicking (Rapid-Eye data) and finally clipping.

Chapter four involves the results and discussions that were drawn from the methodology formulated. The final results were mapped and also represented in tabular and graphical form. Chapter five represents the conclusions and recommendations based on the results acquired.

CHAPTER TWO: LITERATURE REVIEW

2.0: Introduction

This chapter will cover the related literature including empirical review and theoretical review, research gaps and the conceptual framework for the study.

2.1. Change detection

By use of remote sensing data for change detection means the changes in the land cover will definitely lead to the changes in the radiance values as well as changes in the radiance. According to (Ingram et al. 1981), the changes in radiance caused by changes in land cover have to be large with respect to the changes in radiance which are caused by other factors such as the differences in the sun angel, changes in the atmospheric conditions and soil moisture differences. The effect caused by these factors can however be reduced by selection of the appropriate data. For instance, Landsat data which belongs to the same time of the year for instance February 1995 and February 1996 lead to reduction of the problems from Vegetation phenology changes and sun angle differences.

2.2. Anthropogenic Activities

The drivers of forest biodiversity loss can be categorized as either primary or secondary drivers. The primary drivers include human activities which include fragmentation and destruction or change of land use, over-exploitation, invasive species and the indirect human activities as well which in the long run lead to climate change (Millennium Ecosystem Assessment, 2005). According to Barlow & Peres (2004), the primary drivers can induce the secondary effects such as altered disturbance dynamics. In this paper, I will focus on the four major anthropogenic activities which cause biodiversity loss.

2.2.1 Fragmentation and deforestation

Change of land-use greatly affects forest biodiversity (Sala *et al*, 2000). The clearance of forests destroys the ecosystem and leads to a decline in forest diversity and species. Due to deforestation, the new plants and animals will be the determinant of the biodiversity. For instance, after the primary forest has been cleared and there is a regeneration of the secondary forests, they might never get to the same composition and species richness as with the primary forest (Chazdon, 2008). Apart from destruction of the habitat, the clearance of forest might lead to the fragmentation of the remaining part of the forest thus leaving the parts that are way too small for species to live comfortably or survive (Fahrig, 2003).

2.2.2 Over-exploitation

The over-exploitation of species can result in their extinction in the long run. According to (Milner *et al*, 2003), the most common form of exploitation of species is whereby the large mammals are exploited for bush-meat and the harvesting of hardwood for timber (Asner *et al*, 2005). The risk exists when over reliance on these species is inevitable; as such strategies have been adopted in ensuring conservation and management of forests is a collective communal responsibility. However, observations indicate that these factors are largely driven by economic demands over social behaviours.

2.2.3: Kenya Legal Frameworks on Forest Conservation

Kenya Forest Conservation and Management Act, 2016 provides for, "the protection, rehabilitation and maintenance of forest ecosystem. This is meant to benefit each and every citizen by making sure there are sustainable utilization, exploitation, management and conservation of the natural resources while making sure the 10% forest cover is maintained. Every individual thus has a duty to conserve and protect forests.

The Constitution of Kenya, 2010 in article 69, "provides for the development and sustainable management, including conservation and rational utilization of all forest resources for the socio-economic development of the country and other connected purposes".

This Act has established a number of monitoring units in charge of forest covers; this includes the KFSB, whose role is to develop the annual forest resource assessment report and a forest status report every two years. The Act also provides that County governments should adopt the Act and protect the forest covers within their jurisdiction; to ensure participatory development of regulations and policies.

2.2.4: Invasive species

Invasive species are species which are established away from their natural range. Introduced species on the other hand are ones that have been established away from their natural range mainly by natural actions. According to Bradshaw *et al*, 2009), both the introduced and invasive species can alter the Abiotic environments, cause extinction, introduce diseases or become pests. These species in most cases target species possessing lower reproductive potential. For instance, in the island of Guam, the introduction of the brown snake has led to the extinction of 12 native birds (Wiles *et al*. 2003). Thus, invasive species might be the lead cause of native species loss or might be enjoying the benefits of habitat modifications. According to Denslow & Walt, 2008), intact forests are resistant to invasion majorly because of the high number of species, exclusion rates that are highly competitive and functional group richness. Invasive species however, can take advantage of the disturbed forests and cause a great impact to their recovery.

2.2.5: Climate change

Climate change rivals land-use change as it impacts forest biodiversity greatly. Many studies have revealed that climate change causes the plant and animal species to shift to higher elevations and latitudes as these species expands to the areas that fit them climatically and contracts in the areas that pose to be warm (Wilson *et al*, 2007). Climate change also leads to mismatches between the species that interact for instance mismatch between the pollinators and the plants (Stenseth & Mysterud, 2002). The change affects species indirectly by causing a reduction in the availability and the amount of habitation environment. However, it is quite hard to create a link between changes in species richness and climate change because of several other variables that are involved.

2.3 Forest Ecosystem Changes Monitoring System

Over 40 countries are under the support of FAO which assists them in developing their NFMS as well as carrying out assessments. It aims at developing efficient forest resource information which can be beneficial in the creation of reliable national forest policies and achieve sustainable development. Forest monitoring systems comprises of measuring, reporting and verification also known as (MRV) functions and it is aimed at the production of high quality data on forests. The components of NFMS include: SLMS and NFI.

2.3.1: Satellite land Monitoring systems

FAO is at the fore front in helping countries in the identification and collection of activity data for each country's REDD+ activities. For instance, data on afforestation and deforestation is collected from satellite data. SLMS can be used to monitor changes. FAO facilitates and supports the country’s processes to put in place the capacities to design, conceptualize as well as implement a functional SLMS as well as monitor forest changes.

2.3.2: National Forest Inventory

The NFI is designed to monitor the macro-changes of forest resources at every 5 years on a continuing basis in terms of forest, quality, quantity and functions. NFI is aimed at is to identifying forest volume, extent, consumption, growth, function as well as their dynamics during the interval of NFIs (FAO, 2007). In addition, the brief on national inventory in India states that NFIs provide basic statistics to help in providing guidance for forest management, making forest policy, and development of plans for forestry development and ecological conservation (2007).

2.4: Techniques for Change Detection

Remote sensing is the acquisition of information about an object or phenomenon without physical contact with the object. It is useful in monitoring forest activities including deforestation processes using visual and digital analysis.

Satellite images are valuable tools for easy and fast access to areas that face some ecological disasters or protected areas. They have an advantage of covering a wide area, the ability to view quickly an area and evaluate their situation, where the consequences of the calamity hinder the other types of approach, are key factors in management of the recovery actions after the event.

2.4.1: Univariate image differencing

This technique subtracts spatially registered images of different time periods for instance T1 an T2, pixel by pixel in order to come up with a new image which is a representation of the change between the two time periods. A difference distribution is yielded for each band in this procedure. According to Stauffer & McKinney (1978), pixels showing radiance change in this distribution are located in the tails of the said distribution while the pixels which show no change in the radiance are grouped at the mean.

2.4.2: Image regression

In this method, assumption is made that T1 pixels are a linear function of the pixels at T2. The regression techniques makes accounts for the differences that occur in the mean as well as the variance between the pixel values for the different dates so as to reduce the adverse effects from differences in sun angles and atmospheric conditions.

2.4.2. Image Rationing

It is considered as one of the fastest means of depicting change (Howarth & Wickware, 1981). Two registered images having different dates and either one or more bands in one image are rationed band by band. The data are then compared on a pixel basis. In areas where change has occurred, the ratio value should be greater or less than 1 this is depending on the nature of the changes that have occurred between the two dates.

2.4.3. Vegetation index differencing

Spectral radiance values as per what is recorded on a Landsat computer compatible tapes (CCTs) can be independently analyzed on a band to band basis or two or more bands can be combined. According to Curran 1981 & Tucker 1979, band rationing is the most commonly used band combination technique which is used in vegetation studies. Rationing two spectral bands normally negates the effect extraneous multiplicative factors might have on sensor data which act equally in all the wave bands used for analysis (Lillesand & Kieffer, 1979).

The difference in vegetation indices should be able give an avenue for checking whether the vegetation cover has been altered (Nelson, 1982)

2.4.4 Post-classification comparison

This is the most commonly used method of detecting change. It involves comparing independently produces classified images. By cording appropriately classification results for images of different times, the analyst is able to produce several change maps which shows the changes that have occurred. In addition, grouping of classes selectively into different classes allows the analyst to have a closer look to the changes which may be of interest. In post-classification comparison data from two dates are classified separately thus reducing the problem of normalization of sensor and atmospheric differences between the two selected dates.

If one however considers the land cover classification that is generated from a single date of Landsat data, it is quite easy to see that the change map product of multiplying the accuracies of each classification (Stow *et al.* 1980).

a) Satellite imagery

Supports: Landsat 4 and 5 Thematic Mapper ™, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Satellite pour l'Observation de la Terre 4 and 5 (SPOT), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Earth Observing-1 Advanced Land Imager (ALI), and the Moderate Resolution Imaging Spectrometer (MODIS) (Matthew et al, 2008).

According to the USGS website, satellite imagery especially the Landsat images have been used in various countries such as Canada to monitor forest cover changes. The Landsat data has been put in use for detection of these changes, identification of the year the changes occurred as well as the estimation of the change type such as wildfire or forest harvest. There was application of change detection approaches to the annual tine series data which has enabled the detection of abrupt changes such as fires as well as the gradual changes such as drought. These time series data can be used to detect the recovery of forests after a disturbance has occurred. By monitoring these changes, scientists are able to prepare for any future changes by use of trend model developments.

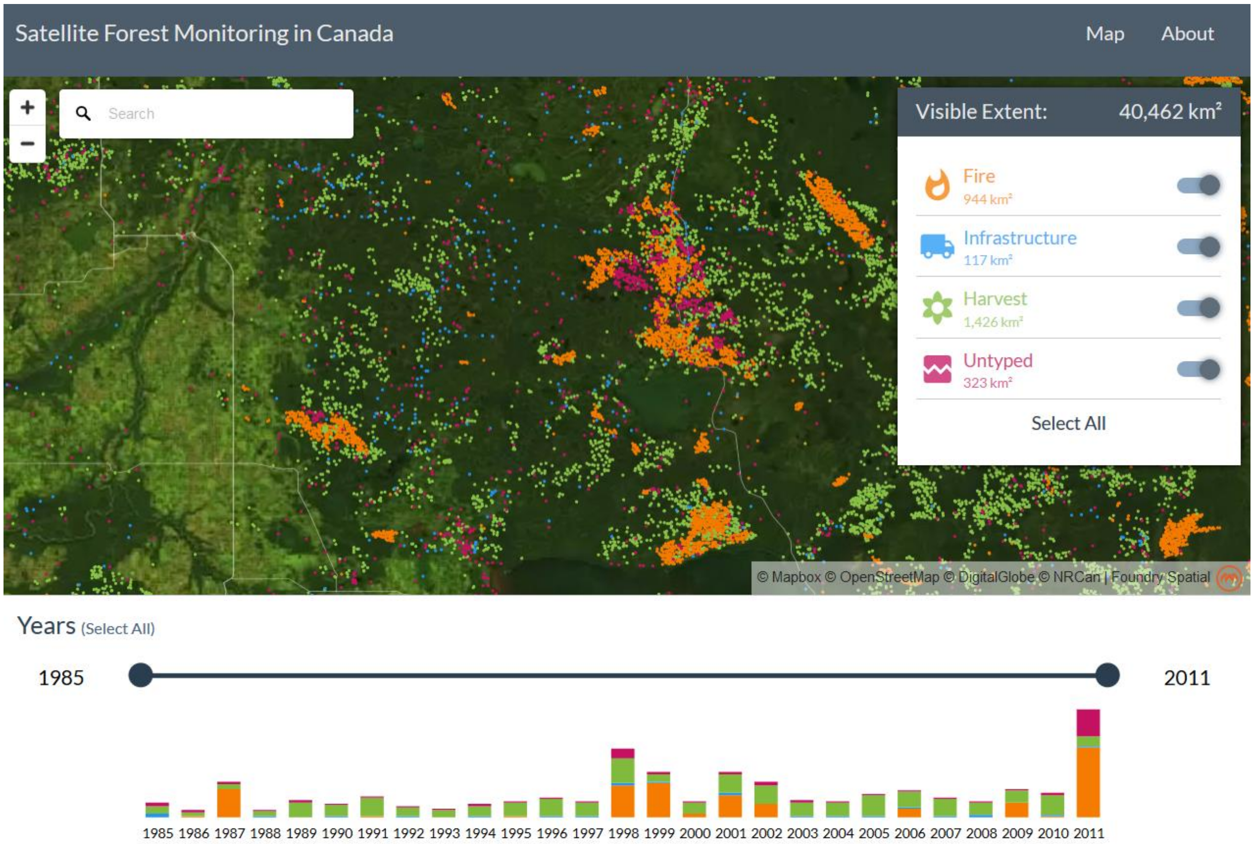


Figure 2.1: Satellite Image showing forest change detection in Canada

The above is a screenshot of an image acquired from the USGS website showing how Canada has incorporated forest monitoring in acquisition of data for change detection this is a section of central

Alberta and it depicts changes on the land surface by use of colored points. The scale shows the changes that have occurred over the years from 1985 to 2011 (USGS, 2017)

This study will use the Landsat images to analyze changes that have taken place since 2010-2018 this will give us a basis, as the Kenya Forest service reports give us the evaluative factors observed in the images.

2.4 Knowledge gaps

Scientific literature has come to a conclusion that digital change detection is not an easy task to accomplish. According to Edwards, (1990) an interpreter who analyzes aerial photography in large scale is most likely to produce accurate results with a higher precision degree. Remote sensing in particular Landsat data might also as well not be able to disclose 100% change detection. Aldrich, (1995) predicted that Landsat MSS scanner when combined and enhanced is able to disclose about 80-90% of the land use changes between the non-forest and forest categories.

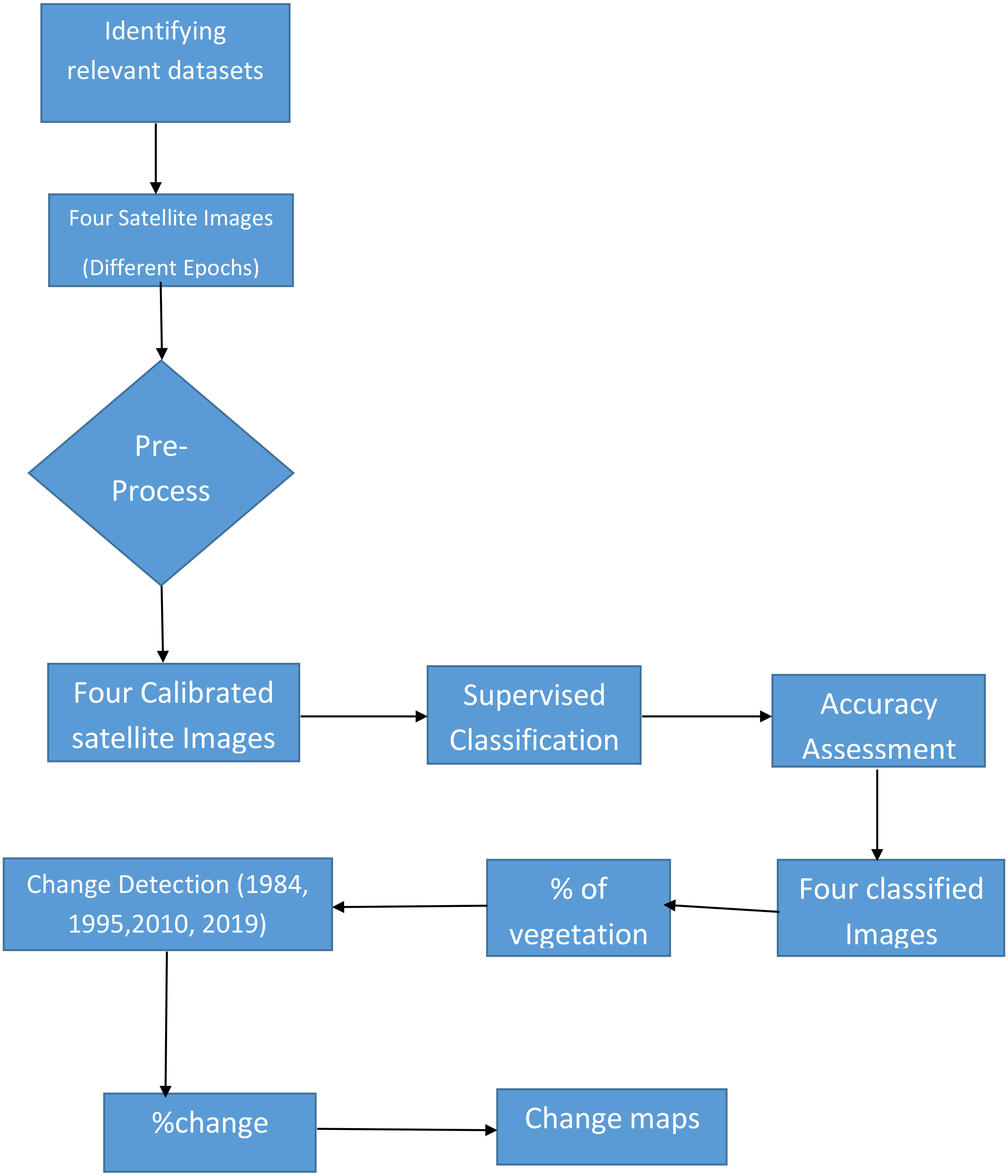
CHAPTER THREE: MATERIALS AND METHODS

3.1: Introduction

This chapter includes the methodology of study design, area, and data collection methods, sampling procedure, data analysis, confidentiality and ethical considerations.

3.2: Research Design

The study adopted a time series study design. This involved the collecting data for four epoch then analysing this data to assess whether there has been an increase or decrease in the vegetation cover. The study majorly involved three phases. These are; the preparatory phase, data collection phase and data analysis following the flow chart below:



Source: Researcher, 2019

3.2.1: Preparatory phase

This involved the selection of the study area, identification of the problem then formulating the research proposal. The project specific and overall objectives as well as the hypothesis were identified.

3.3: Materials

3.3.1: Remote Sensing data and software

Satellite images for the year 1984 and 1995 were downloaded from the USGS website. High resolution images from Rapid eye were downloaded from planet labs. The software used for analysis of these data was ERDAS Imagine and ARC GIS was used in map creation.

3.3.2: Reference Data

GPS points were collected from KFS. These points were for the years 1984, 1995, 2010 and 2019.

3.4: Data Confidentiality

Data obtained will be purposive and for the study purpose only. Information shared by individuals in the sector will be kept confidential and shall inform the study discussions.

3.5: Data Collection

Primary data was collected through unstructured interviews which were carried out to the KFS personnel so as to determine the cause of the degradation of the forest and also to gain insight on the measures that have been put in place to ensure restoration of the forest. Secondary information was collected from the free published and unpublished journals, articles, reports and satellite images.

3.6: Data Analysis

Satellite images downloaded were then fed into remote sensing software (ERDAS). The images for 1984 and 1995 were layer stacked in order to combine the different bands. The 2010 and 2019 images acquired from rapid eye were already layer stacked upon downloading and thus required mosaicking since there were two scenes. Mosaicking was done in order to combine two scenes to cover the study area fully. The four images were then clipped to cover the study area. Training sets were created and supervised classification was done on the four images. Change detection was done as the final step so as to identify the change that has occurred over the years.

3.7: Methodology

3.7.1: Layer stacking

The images for 1995 and 1984 acquired from Landsat 5 were layer stacked so as to combine the 7 bands.

3.7.2: Mosaicking

2010 and 2019 images acquired from rapid eye required mosaicking since it provided two scenes for the study area.

3.7.3: Clipping

Clipping was done by use of the shapefile provided by KFS. This was done purposely to remain with the study area (Ngong Hills Forest). The clipped images for each year are as shown in the figures 3.2, 3.3, 3.4, 3.5 ;

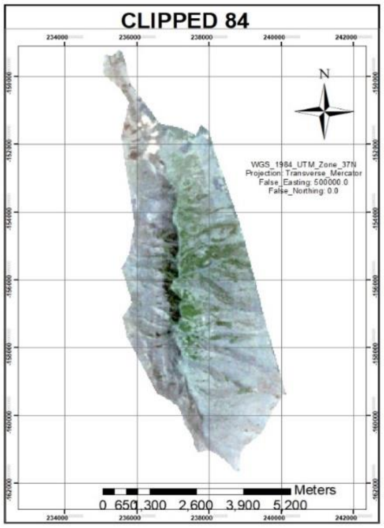


Figure 3.1: 1984 Clipped Image

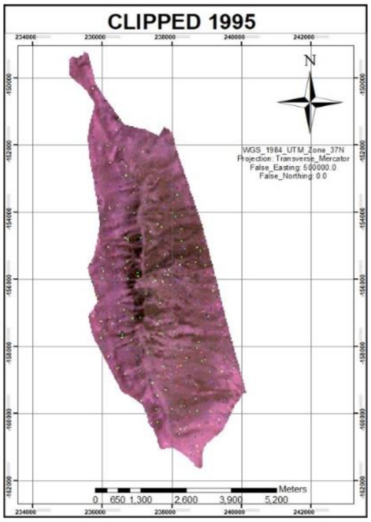
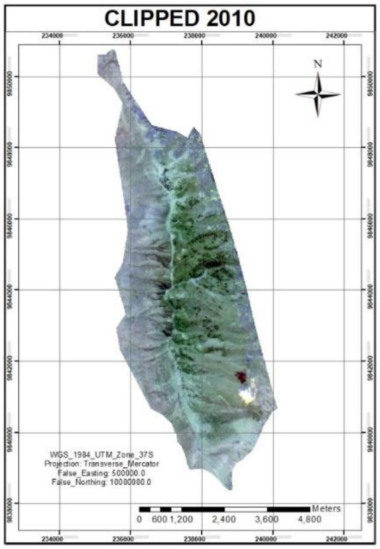


Figure 1.2: 1995 Clipped Image



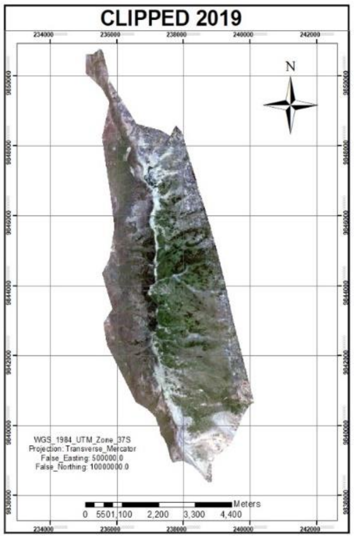


Figure 3.3: 2010 Clipped Image

Figure 3.4: 2019 Clipped Image

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1: RESULTS

4.1.1: Supervised Classification

Supervised classification was carried out on all the four images through the creation of training sets. The following three classes were extracted;

i. Dense
ii. Sparse
iii. Bare land and settlement

The area classified as sparse is composed of grassland, shrubs and bushes and trees that are scanty. Bare land was merged with settlement because most of the bare areas are populated and include roads to the populated areas as well. The following are maps depicting the supervised classification of the various years.

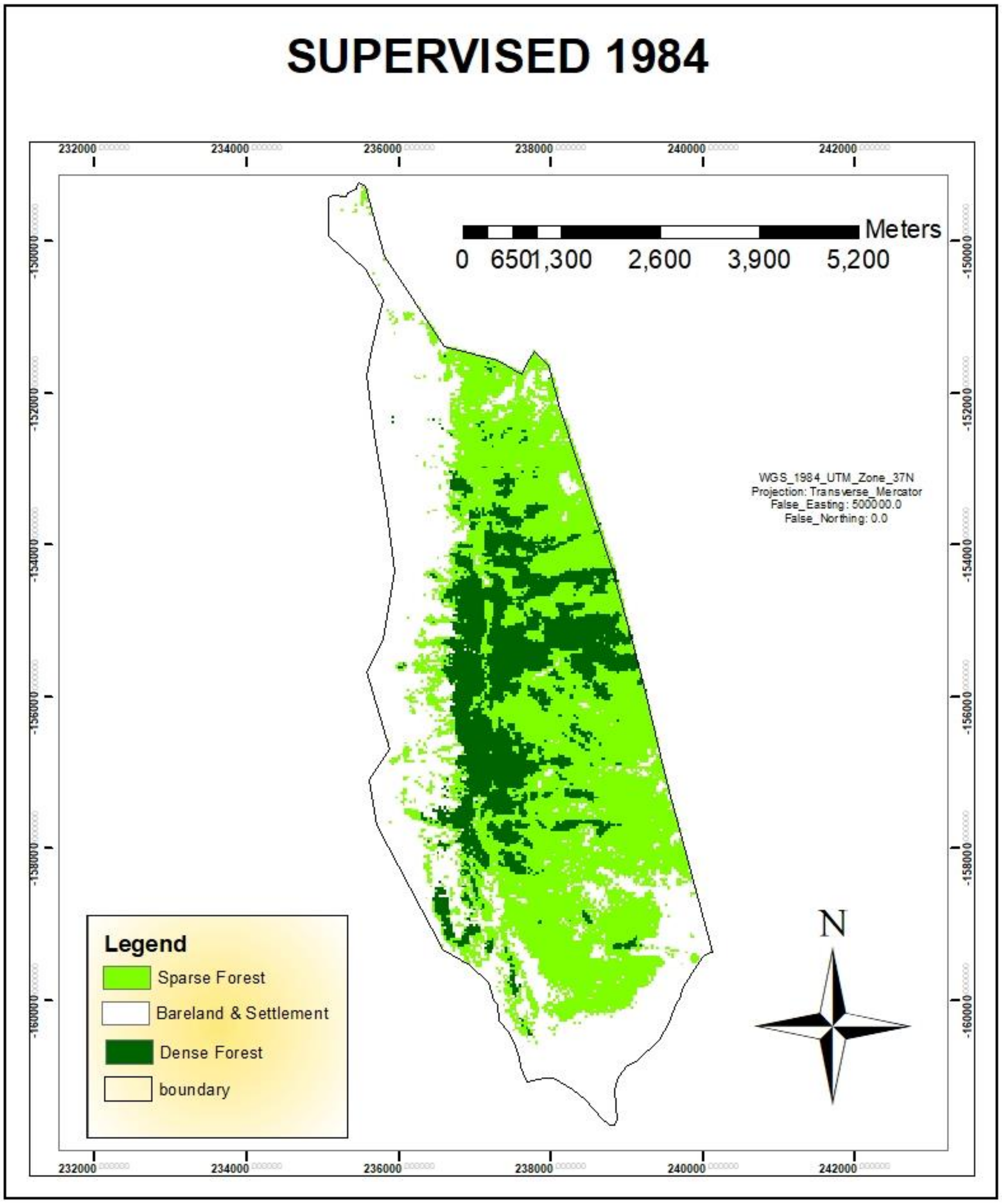


Figure 4.1: Supervised Classification 1984

Figure 4.1 depicts supervised classification for the year 1984 having the sparse at 21.70%, dense vegetation at 8.67% and Bareland and settlement at 18.79%.

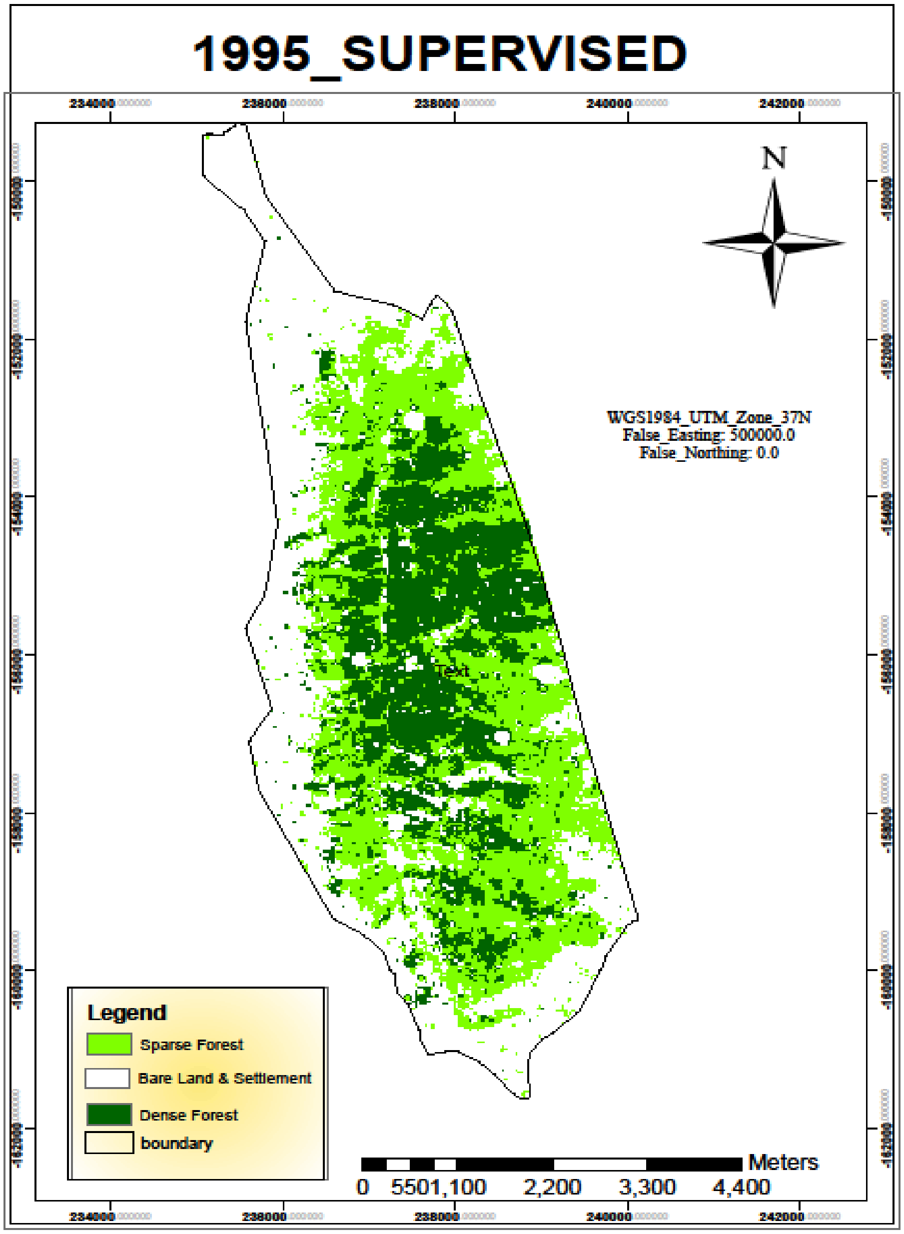


Figure 4.2: Supervised Classification 1995

Figure 4.2 shows the 1995 supervised classification map with bare land and settlement at 19.10%, Sparse 16.98% and Dense at 13.08%. This increase in the dense vegetation has been attributed to afforestation. The forested area increased by 4.41% due to afforestation efforts by KFS coupled with better rainfall experienced in the same year.

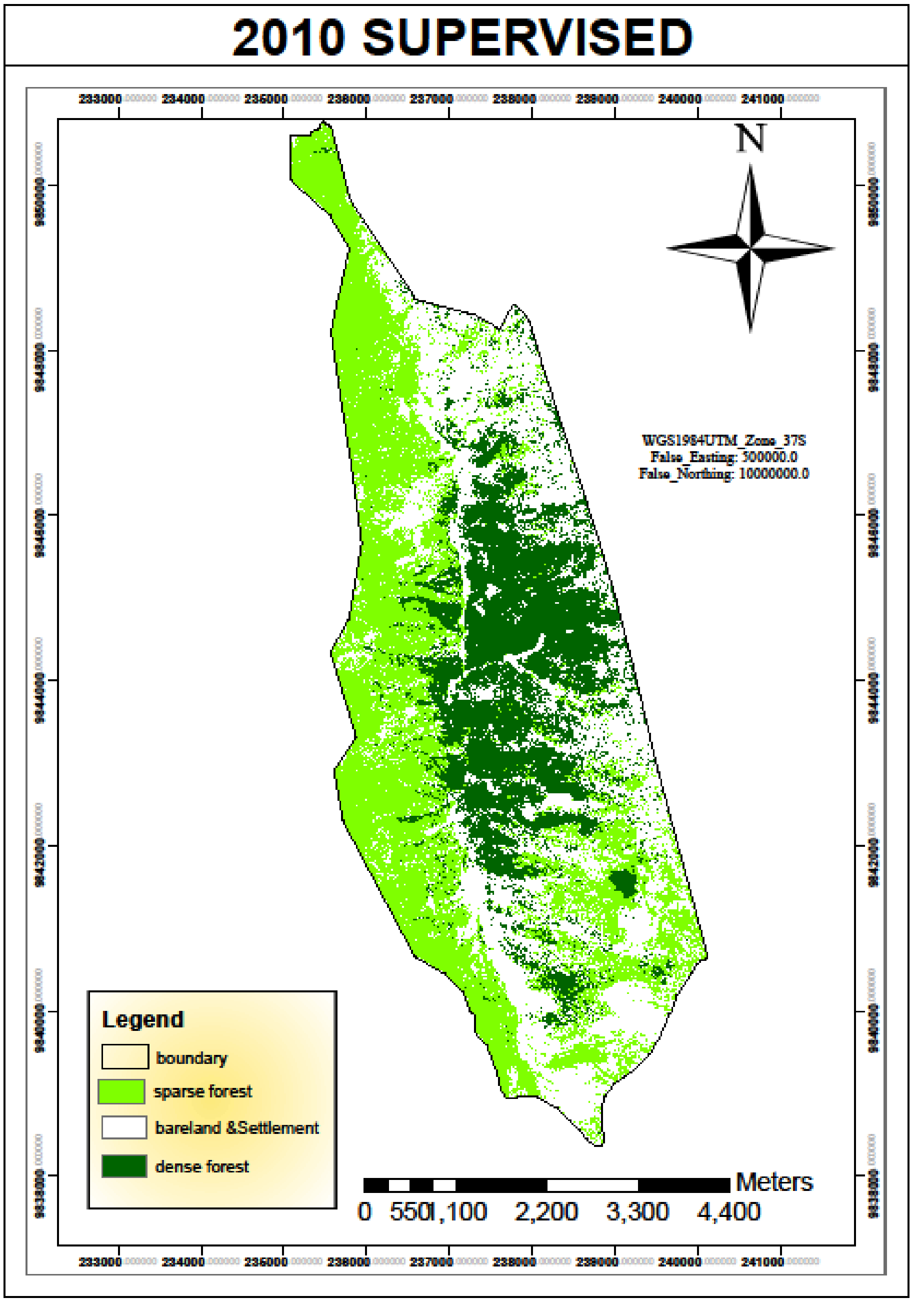


Figure 4.3: Supervised classification 2010

Figure 4.3 depicts supervised classification for 2010 with sparse vegetation at 19.11%, dense vegetation at 12.34% and finally bare land at 17.39%. The densely forested area is seen to have decreased by 0.74% as compared to the year 1995. This is attributed to logging.

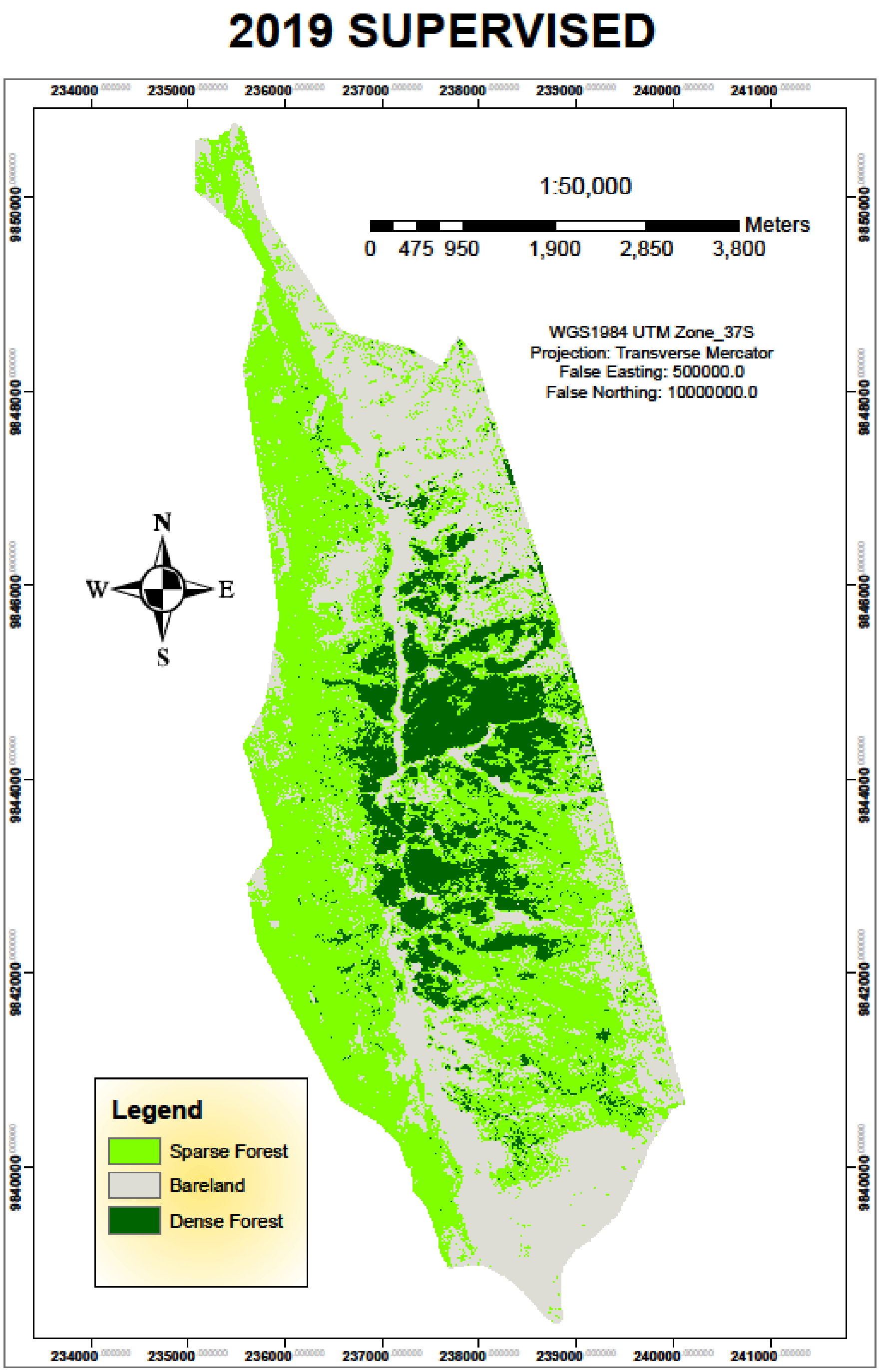


Figure 4.4: Supervised Classification 2019

Figure 4.4 shows supervised classification for the year 2019 showing sparse vegetation as 24.60%, Dense 7.25% bare land and settlement at 16.99%. There is 5.09% decrease in densely forested areas related to massive logging in the forest to pave way majorly for settlement.

After carrying out supervised classification, it was possible to compute the areas occupied by the three classes (Dense, Sparse, Bare land & settlement). Percentages of these were thus calculated by getting the total of the areas occupied by sparse, dense, bare land & settlement and the unclassified the dividing the specific areas with the total and multiplying by 100.

These percentages were computed by using the formula below:

$$\frac{Area}{Total\ Area} * 100\%$$

For instance, calculating the percentages for the year 2010 as in table 4.3 was done as shown below.

Total area = 6270.73 hectares

Sparse = 1198.07 hectares

$$\frac{Area}{Total\ Area} * 100\%$$

=1198.07/6270.73 *100= 19.1058

=19.11%

Dense = 773.678 hectares

=773.678/6270.73 *100 = 12.338

=12.34%

Bare land and settlement= 1090.74 hectares

=1090.74/6270.73 *100 =17.394

=17.39%

The same formula shown above was used for all the other years to come up with the percentages.

The total areas for 2010 and 2019 were similar standing at 6270.73 hectares while for 1984 and 1995 were different from the latter ones both having an area of 6296.94 hectares. These are the areas I worked with as the totals.

The results for all the epochs are as shown in the tables below which were computed by use of the formula and example shown above.

VEGETATION DENSITY

Table 4.1: Supervised classification for dense 1984

	Area	**Percentage**
Dense Forest	545.94	8.67%
Sparse Forest	1366.74	21.70%
Bare land	1183.05	18.79%
Unclassified	3201.21	50.84%

Table 4.2: supervised classification for dense 1995

	Area	**Percentage**
Dense Forest	823.86	13.08%
Sparse Forest	1069.02	16.98%
Bare Land	1202.85	19.10%
Unclassified	3201.21	50.84%

Table 4.3: Supervised classification for dense 2010

	Area	**Percentage**
dense forest	773.678	12.34%
sparse forest	1198.07	19.11%
Bare land	1090.74	17.39%
Unclassified	3208.24	51.16%

Table 1.4: Supervised classification for dense 2019

	Area	**Percentage**
Dense Forest	454.808	7.25%
Sparse Forest	1542.47	24.60%
Bare land	1065.21	16.99%
Unclassified	3208.24	51.16%

4.1.2 Ground truthing and accuracy assessment

After the percentages were computed, ground truthing was carried out on the 2019 image by collecting the GPS points in Ngong hills forest and inputting these points in ERDAS Imagine so as to do accuracy assessment. Accuracy assessment was also done for the other years by using GPS points provided by the Kenya forest service in form of shape files. The GPS points are provided in the appendices. The accuracy report provided for the various years are as follows;

Year	**Overall Classification Accuracy**
2019	92.00%
2010	92.31%
1995	85.71%
1984	84.62%

Class Ref Name	**Classified Totals**	**Number Totals**	**Producers Correct**	**Users Accuracy**	**Accuracy**
Unclassified	0	0	0	--	--
Sparse Forest	11	11	10	90.91%	90.91%
Bareland	14	14	13	92.86%	92.86%
Dense Forest	0	0	0	--	--
Totals	25	25	25		

Class Ref Name	**Classified Totals**	**Number Totals**	**Producers Correct**	**Users Accuracy**	**Accuracy**
Unclassified	0	0	0	--	--
Sparse Forest	16	14	14	87.50%	100.00%
Bareland	10	12	10	100.00%	83.33%
Dense Forest	0	0	0	--	--
Totals	26	26	24		

Class Ref Name	**Classified Totals**	**Number Totals**	**Producers Correct**	**Users Accuracy**	**Acuracy**
Unclassified	0	0	0	--	--
Sparse Forest	10	9	8	80.00%	88.89%
Bareland	11	12	10	90.91%	83.33%
Dense Forest	0	0	0	--	--
Totals	21	21	18		

Class Ref Name	**Classified Totals**	**Number Totals**	**Producers Correct**	**Users Accuracy**	**Accuracy**
Unclassified	0	0	0	--	--
Sparse Forest	13	13	11	84.62%	84.62%
Bareland	13	13	11	84.62%	84.62%
Dense Forest	0	0	0	--	--
Totals	26	26	22		

4.1.3: Change detection

After classification of the images and computation of accuracies, change detection was as well carried out by use of ERDAS Imagine to come up with the four images depicting the percentages of the decreased and increased areas. This process involves selection of two images from different years, selecting the output image and selecting the colours that will show either a decrease of increase in the phenomenon intended and in this case increase and decrease in forest cover. In this case, decrease in forest cover is depicted by red while increase is depicted by green as shown in maps below.

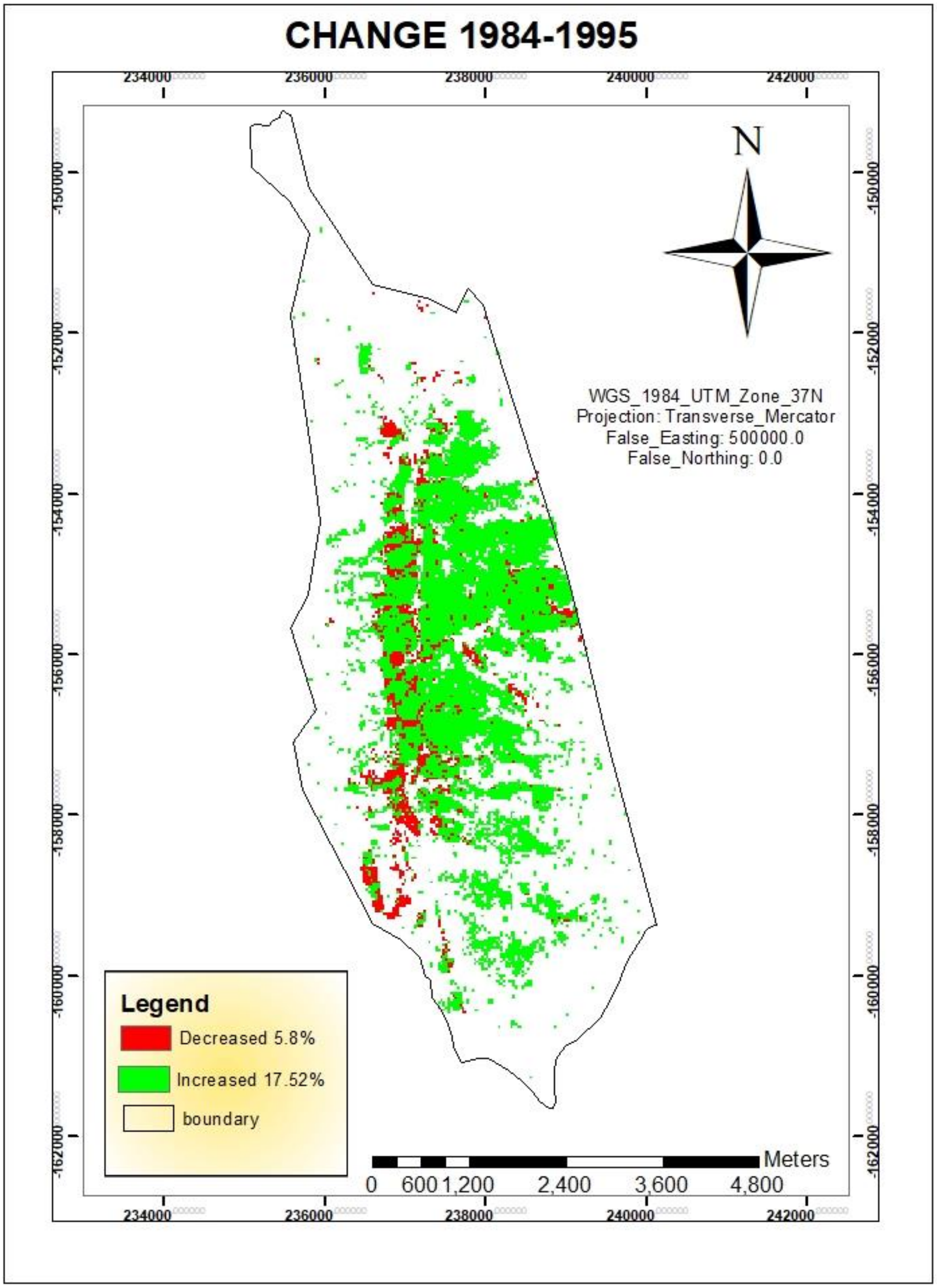


Figure 4.52: Change detection 1984-1995

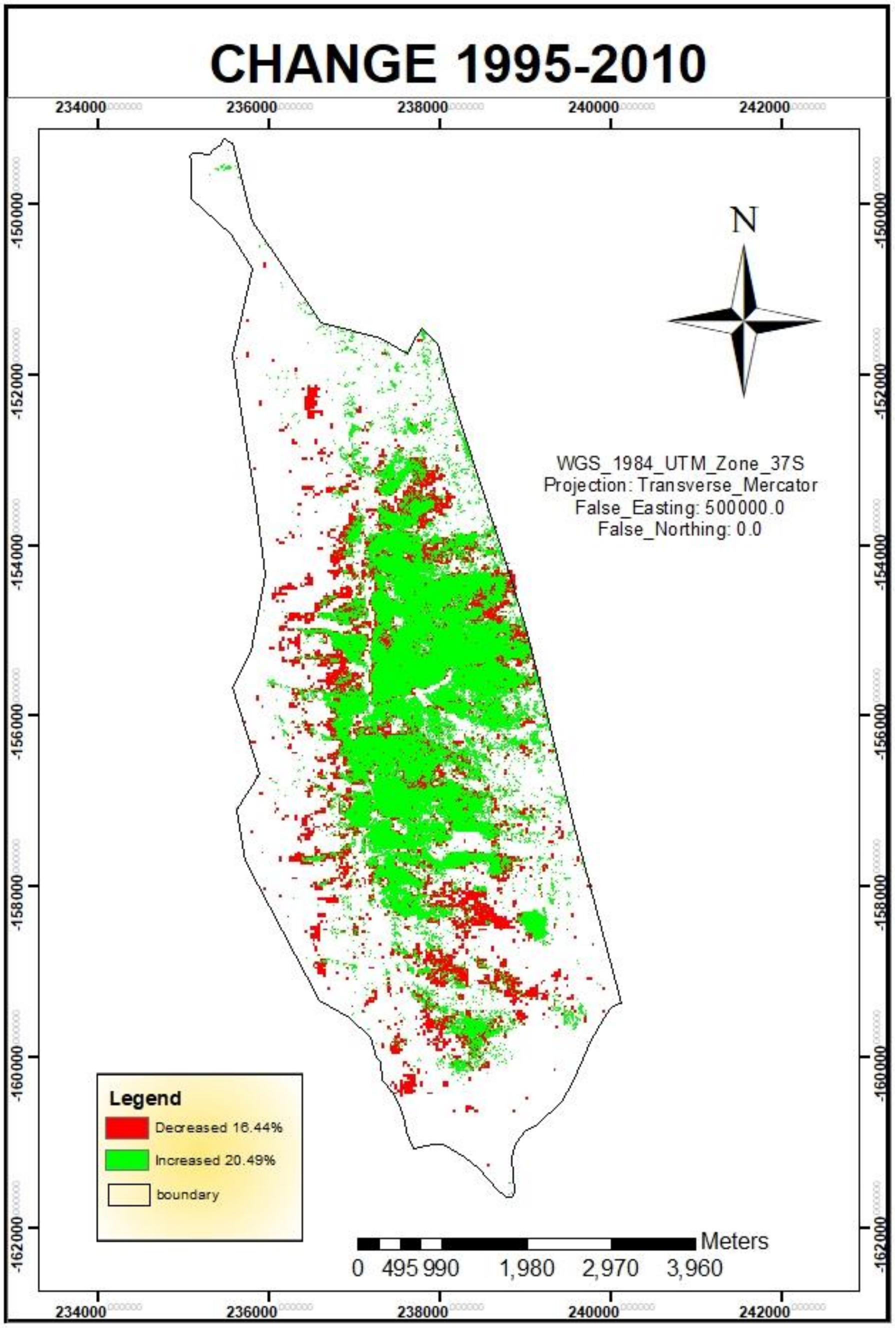


Figure 4.6 Change detection 1995-2010

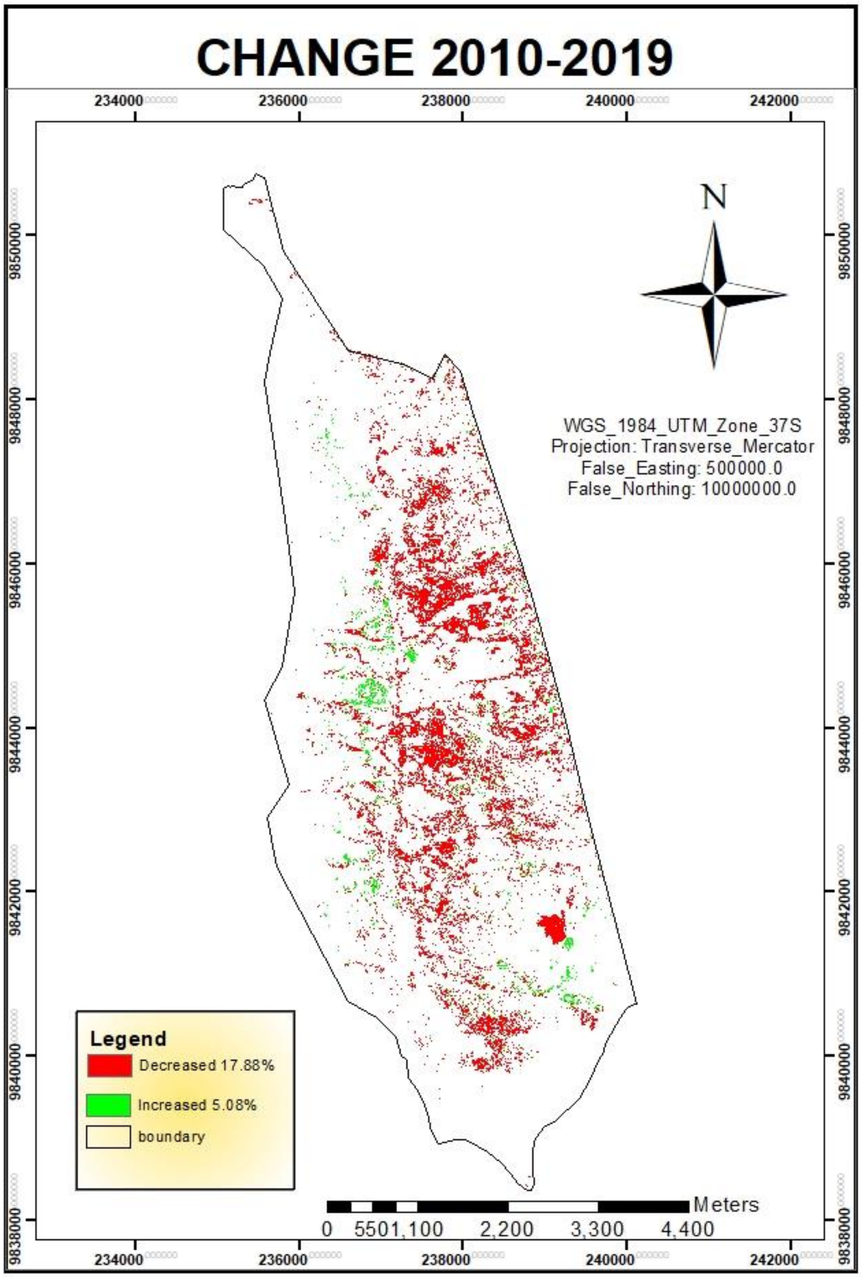


Figure 4.7: Change detection 2010-2019

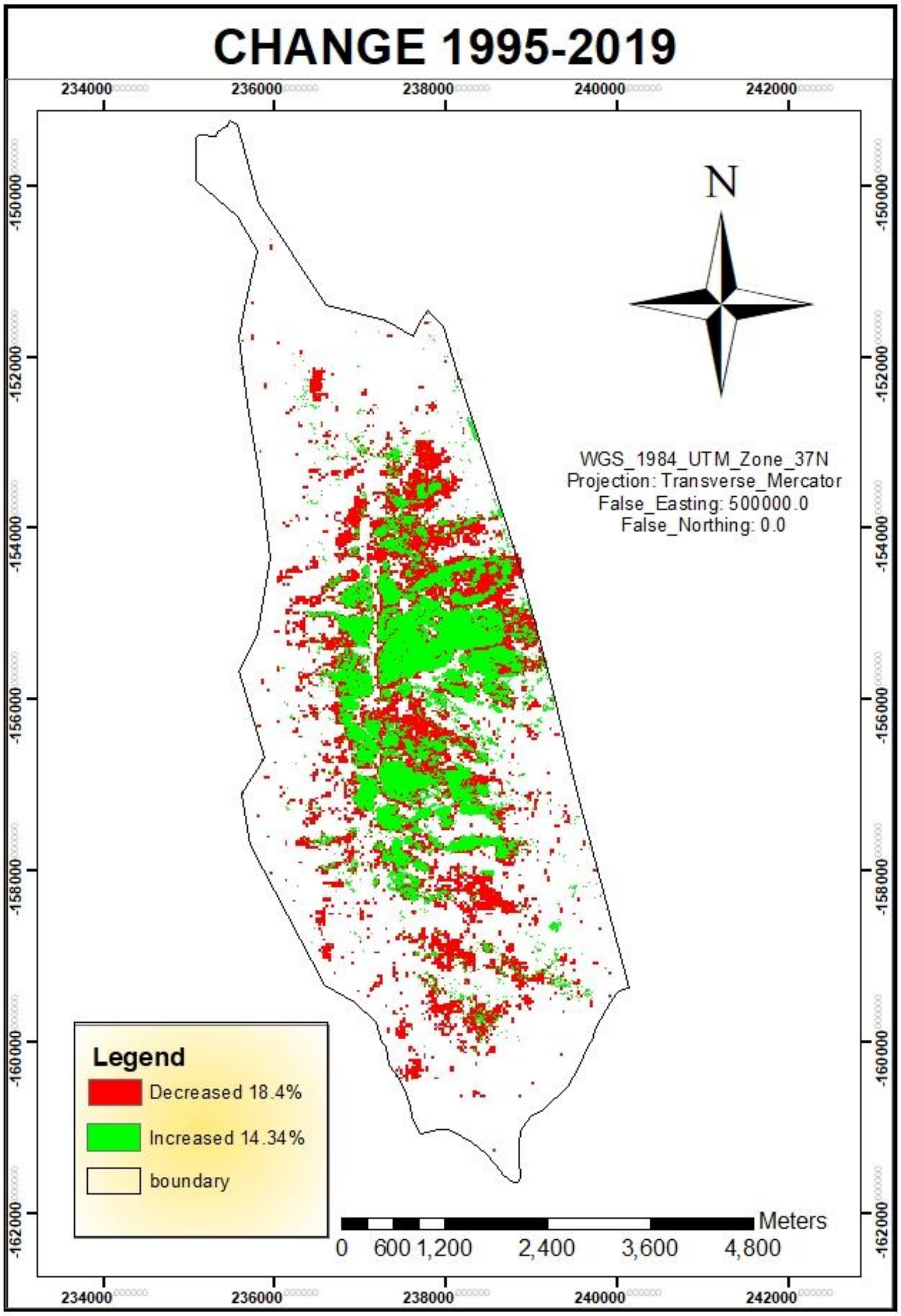


Figure 4.8: Change detection 1995-2019

The table below shows the increase decrease together with the unchanged ecosystem in Ngong hills forest. The percentages were computed using the formula;

$$\frac{Area}{Total\ Area} * 100\%$$

2010-2019 example

Total area= **6270.73 hectares**

Decreased= 1121.248 hectares

=1121.248/6270.73*100

=17.881

=17.88%

Unchanged= 4830.9 hectares

=4830.9/6270.73*100

=77.038

=77.04%

Increased= 318.5745

=318.5745/6270.73*100

=5.08%

Change detection area and percentages

Table 4.5: Change detection area 1984-1995

1984-1995	**Area**	**Percentage**
Decreased	365.31	5.8%
Unchanged	4827.96	76.67%
Increased	1103.67	17.52%

Table 4.6: Change detection 1995-2010

1995-2010	**Area**	**Percentage**
Decreased	1026.678	16.44%
Unchanged	3938.46	63.07%
Increased	1279.42	20.49%

Table 4.7: Change detection 2010-2019

2010-2019	**Area**	**Percentage**
Decreased	1121.248	17.88%
Unchanged	4830.9	77.04%
Increased	318.5745	5.08%

Table 4.8: Change detection 1995-2019

1995-2019	**Area**	**Percentage**
Decreased	1149.32	18.4%
Unchanged	4200.13	67.26%
Increased	895.112	14.34%

The histogram and the flow chart below show the percentage change of the increased, decreased and the unchanged.

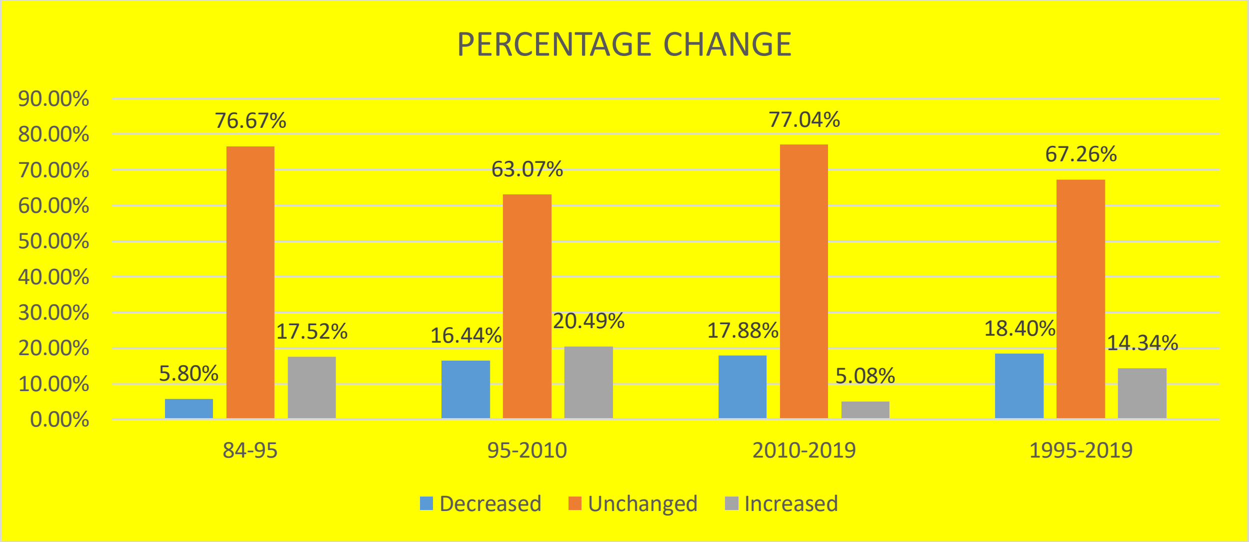


Figure 4.9: PERCENTAGE CHANGE IN DETECTED AREAS

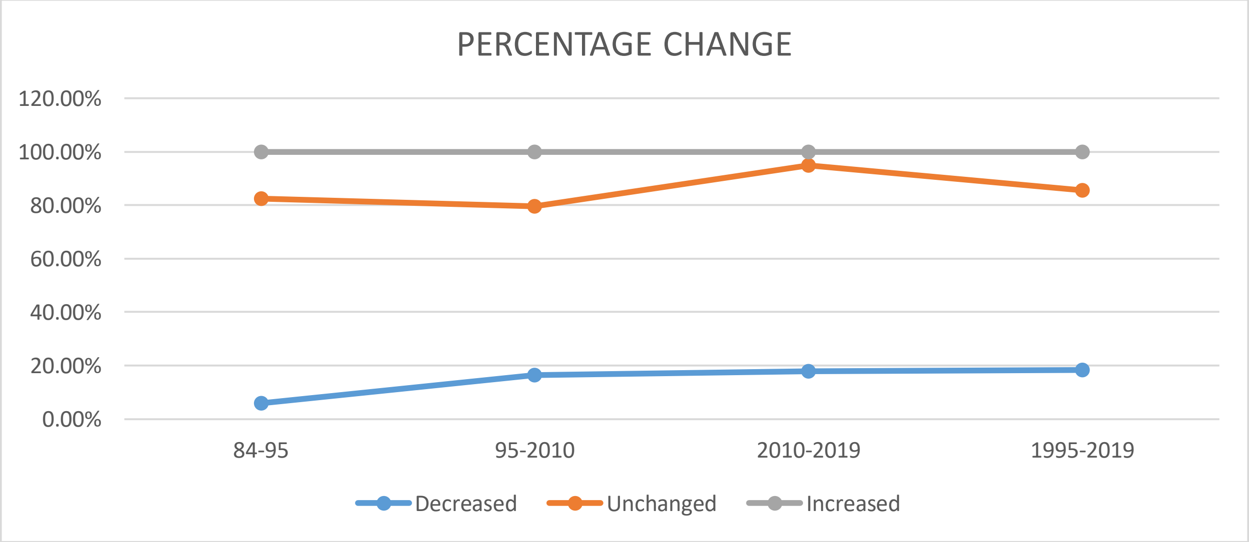


Figure 4.103: Percentage change

Indicated below is a zoomed in Rapid eye images for years 2010 and 2019. They are meant to further help in getting insight on the changes that have occurred in the forest. The 2010 image shows less settlement and bare land as compared to the 2019 image. Some vegetation has also reduced in 2019 as compared to 2010. This can be seen in figure 4.13 which show the areas that have changed with either increase or decrease between the two years. The areas shown in red is where reduction has occurred and the areas in green are areas where an increase has occurred.

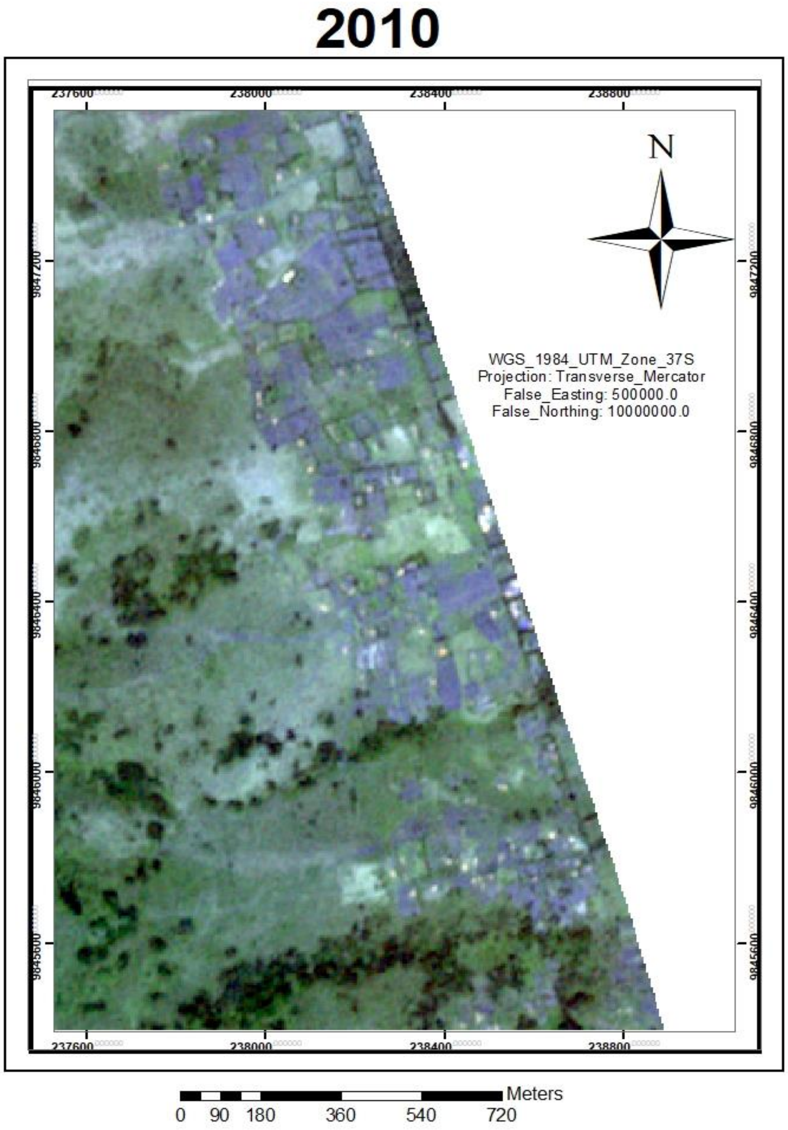


Figure 4: Zoomed in rapid eye 2010

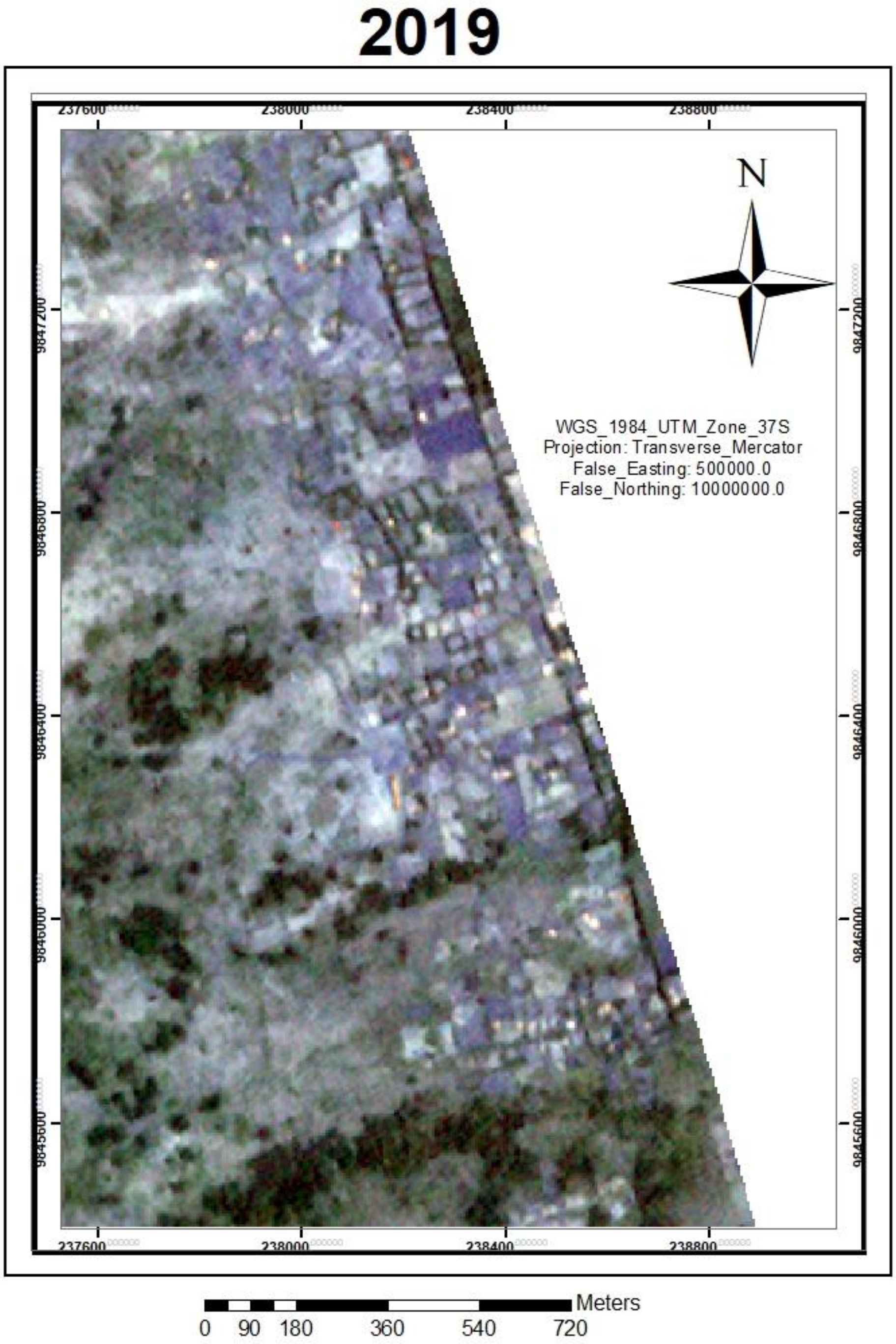


Figure 4.12: Zoomed in rapid eye 2019

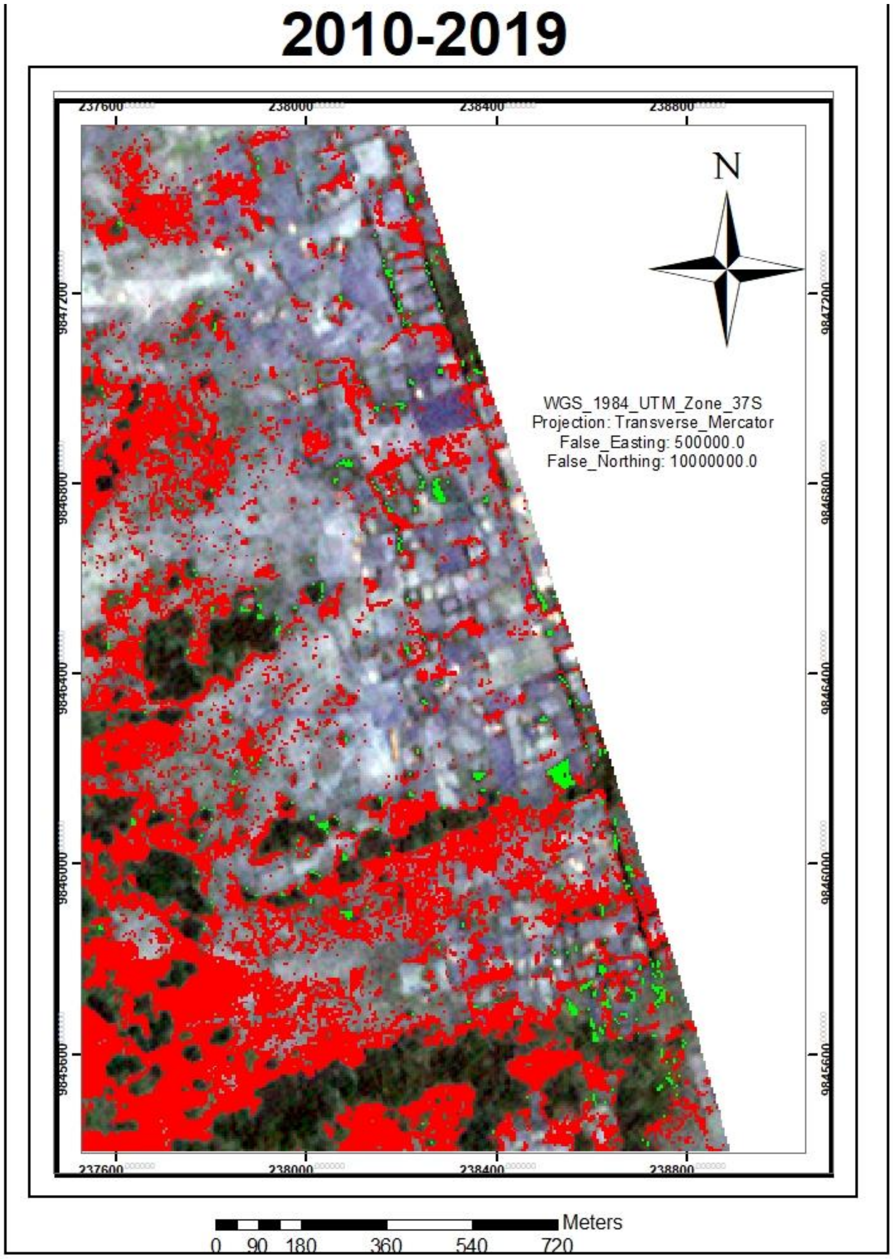


Figure 4.13: Zoomed in rapid eye 2010-2019

4.2: DISCUSSION OF RESULTS

The main objective of this research was to review on the ways in which satellite images are used to inform on change of forest cover over a period of time. In this case, the change is assessed for 35 years. This is from 1984, 1995, 2010 and 2019. Satellite images for these years were acquired and assessed by use of a remote sensing software; ERDAS.

As shown from the results, the forest cover in 1984 was at 8.67% for dense and the dense area increased to 13.08% in 1995 due to afforestation efforts from KWS. Since 1995, the forest cover has however been decreasing from the 13.08% to 12.34% in 2010 and lastly to 7.25% in 2019. As per the KFS, the decrease in Forest cover is as a result of logging and massive settlement in the forest.

This is further proved when change detection was done as the percentage decrease and increase were provided as seen in the tables depicting the % change. As from 1995 the change has been increasing constantly with a sharp increase between 2010 and 2019. The increase rate stands at 17.52% from 1984 to 1995 with an increase in the percentage from 1995 to 2010 with 20.49%. The increase however declined in 2010 to 2019 standing at 5.08%.

The main means of keeping track by the forest service in Kenya is mainly inventories and scanty use of remote sensing. As per the objectives that were stated earlier, it is very clear that remote sensing can be used to better inform on forest change. This has proven to be less costly and less time consuming. Remote sensing thus provides the best source of data to inform on change detection and is much better than inventories.

The specific objectives of this research were achieved and the findings are as well at per with what was done in previous studies. The change in Ngong hills forest was found to be caused majorly by human activities. This is majorly settlement and logging. As depicted by the 2019 high resolution image, it can be seen clearly that there is massive encroachment in the forest as people have settled deep inside the forest past the boundary.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1: CONCLUSIONS

The loss of trees as well as other vegetation can lead to desertification, climate change, fewer crops, soil erosion, increased greenhouse gasses, flooding and many more problems to the environment. Deforestation of the Ngong forest has occurred for a number of reasons. Logging is on the rise for material needs the most important one being timber for construction and for industrial purposes such as making of paper. Destruction of the forest for settlement has also been another factor. Trees are perennial resources and although this is true, many people do not understand that excessive exploitation of these resources makes its revival difficult.

With the use of remote sensing, it is thus very clear that the Kenya Forest Service as well as other forest protection agencies can implement this technology fully to help in monitoring the forest ecosystem as it provides timely information, up to date and cheap way to monitor the forest ecosystem. Remote sensing is seen to have been used world mostly in developed countries like Canada to monitor forest change. Most of the forest ecosystems occupy a very large area so keeping inventories may be tiresome, costly and might take a longer period of time to analyse these data so as to inform on change of the forest cover. As depicted, remote sensing can date to many years back and inform on the changes that have occurred as well as the areas that have been affected greatly.

Landsat data is what is largely used to inform on change detection. Some of the Landsat images used were for the years 1984 and 1995 since there wasn’t any high resolution images back then. However, for recent years, 2010 and 2019, high resolution images from Rapid eye were used and have been able to give more accurate results as compared to Landsat data.

Ngong forest was found to have evolved gradually for the past years attributed to mainly logging. Massive loss of the forest is mainly by anthropogenic activities as natural causes of forest loss in the forest is minimal. These changes can be clearly seen and analysed as per the maps that were generated.

5.2: RECOMMENDATIONS

As per the results obtained after the research was carried out it was evident that Ngong forest is at the verge of depletion. The following recommendations have thus been drawn;

i. Remote sensing works perfectly in depicting change as it can date back to many years and thus making it the most suitable data for informing on change detection
ii. Remote sensing data mainly from Rapid-eye is recommended to be used to inform on change detection mainly for its ability to produce high resolution images hence aid in better analysis.
iii. The changes in Ngong Hills Forest were mapped and thus making it easier to monitor change in pictorial form. It is thus advisable for the Kenya Forest Service to constantly map the changes that occur on this forest as it also aids to know the areas that are greatly affected.
iv. Anthropogenic activities have led a major change in the forest ecosystem. Settlements have encroached a big part of the forest as depicted. It is thus recommended that the Kenya forest service use remote sensing to find out the areas that have been largely affected by these activities and provide strict rules that will help in saving the forest from further destruction.

APPENDICES

Appendix A: 1984 GPS POINTS

EASTING	NORTHING	VALUES	EASTING	NORTHING	VALUE
237719	9840463	4	236107	9845941	1
239060	9841718	4	237215	9847103	1
236689	9841880	4	235949	9848102	1
238279	9846380	4	237413	9842306	1
238136	9847327	4	238748	9840145	3
237067	9847343	4	236498	9845889	3
238860	9839049	4	234943	9841989	3
239397	9845220	4	235066	9843983	3
239222	9846614	4	235221	9845395	3
236905	9844437	1	239100	9843569	3
237069	9845250	1	238957	9838269	3
237403	9844642	1	237858	9838159	3
238334	9842745	1	236455	9847016	2
236902	9843574	1	238858	9844184	2
236667	9846638	1	238729	9843566	2
237735	9846489	1	235869	9846841	2
236213	9844206	1	235969	9840461	2

Appendix B: 1995 GPS points

Eastings	Northings	Values	Easting	Northing	Values
238118	9838989	4	237492	9844128	1
239843	9841012	4	237837	9845477	1
238548	9846852	4	236335	9846392	2
237544	9847935	4	236404	9842133	2
238655	9839277	4	236924	9847764	2
237849	9847790	4	235694	9848413	2
239274	9840072	4	236268	9843550	2
237349	9841434	4	236198	9844610	2
237498	9844761	1	236189	9847133	2
236884	9844360	1	238913	9843484	2
237413	9846068	1	236780	9841291	2
237434	9843090	1	238167	9840645	3
237091	9843418	1	237319	9840236	3
236828	9845890	1	239217	9844174	3
238162	9844838	1	236656	9843191	3

Appendix C: 2010 GPS points

Easting	**Northings**	**Values**	**Easting**	**Northing**	**Values**
237052	9845818	4	237746	9844918	1
237968	9840821	4	238185	9843146	1
237828	9840200	4	237107	9843424	1
239322	9839966	4	237059	9846866	1
239232	9839165	4	237698	9845957	1
239424	9841895	4	237430	9845795	1
239021	9844371	4	236959	9845278	1
239163	9843225	4	236749	9845397	1
238408	9842559	4	236798	9844886	1
237067	9847913	4	236722	9844649	1
237953	9847356	4	236920	9843569	1
238247	9846662	4	236604	9842333	1
238157	9844721	1	237450	9842202	1
236980	9844849	1	237530	9841756	1
237391	9844298	1	239155	9840775	1
236965	9844180	1	238889	9840696	1

Appendix D: 2019 GPS points

Easting	Northings	Values	Easting	Northing	Values
239667	9840112	4	237301	9841360	4
236689	9846258	4	238166	9843108	2
236544	9845967	4	237502	9843117	2
238019	9839268	4	238279	9844791	2
238059	9839726	4	237478	9846104	2
237165	9844717	4	236996	9847383	2
237158	9845510	4	236872	9845185	2
236764	9840153	4	236933	9843587	2
238966	9839730	4	237120	9842939	2
239265	9839173	4	238417	9839935	2
239292	9839552	4	239483	9840508	2
239325	9839954	4	237703	9842043	2
239267	9843282	4	237431	9841923	2
238957	9838994	4	237450	9842228	2
237193	9846477	4	237967	9843932	2
238252	9846548	4	237342	9844590	2

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