University of Nairobi

School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

USING GEOSPATIAL TECHNOLOGIES TO ASSESS THE IMPACT OF HUMAN SETTLEMENT IN MT. ELGON FOREST

CHRYSTAL AMACHILANG

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DECLARATION

I, Chrystal Amachilang 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 institution of higher learning.

Chrystal Amachilang

………………………… ………………………….. …………………..

Name of student Signature Date

This project has been submitted for examination with my approval as University Supervisor.

Dr. David Siriba

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Name of supervisor Signature Date

DEDICATION

I dedicate this research study to God and my family.

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I acknowledge and greatly appreciate my classmates for the encouragement, assistance and support they've accorded me. I especially wish to acknowledge Mr. Edmond Kuto for his assistance throughout this project progress.

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ABSTRACT

The Mt. Elgon ecosystem is a gazetted forest reserve. Over decades of time, the forest ecosystem has experienced a surge in human population through the government-led Chepyuk settlement. Recently, there was a petition to degazette an extra 11,384 acres of the forest reserve for another resettlement programme. The matter is however still under debate in parliament whose members are divided over the petition. In addition to the legal excisions, illegal encroachment by communities into the forest has further compounded the effects of human activities into the forest reserve. This situation has led to a significant degradation of the forest cover and a shift in the forest structure. This project assessed the effects of human settlement on the forest reserve. The study assessed the changes in settlements, forest cover and forest structure over a period of 36 years using GIS and Remote Sensing technologies. The methods used was mainly classification of satellite imagery using ArcGIS software to determine the changes. Calculation of change in NDVI was employed to demonstrate a change in vegetation cover over the years. Analysis of the results showed a decline in the forest cover. The forest structure has also changed such that the area under mixed montane forest has declined while the area under Bamboo and grasslands has increased. Settlements within the forest ecosystem has increased. This study recommends that a repeat of the same or a similar study employs the use of sensors with high spatial resolution to better quantify the forest population. The study further recommends that policies around forest protection should protect the forest from the proposed excisions. Studies should be done to assess the status and number of the forest trees species in Mt. Elgon forest using geospatial technologies.

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DEFINITION OF TERMS

Forest cover: the land mass that is occupied by a forest.

Forest degradation: the decline of a forest in quality which renders it unable to provide its former roles (Serna, 1986).

Forest ecosystem: A community of flora, fauna and natural resources interacting as a system in the forest environent.

Forest encroachment: illegal settlements and activities such as farming and logging carried out by human beings in a forest.

Forest excision: a process that allows for the degazettements of forest reserves to facilitate exploitation of forests for purposes of farming, developments of infrastructure and settlements.

Forest structure: the horizontal layers of a forest which could consist of vegetation type, bare ground and shrubs.

Remote Sensing: A technique of obtaining information about objects through the analysis of data collected by sensors that are not in physical contact with the objects.

Settlement Schemes: programmes that involve relocating communities and people from one settlement area to a new location to enable them adapt to new social, physical and administrative environments (Kassahun, 2000).

LIST OF ACRONYMS

DRSRS	Department of Resource Surveys and Remote Sensing
GIS	Geographic Information Systems
KEFRI	Kenya Forestry Research Institute
NDVI	Normalized Difference Vegetation Index
NIR	Near Infrared
OSM	Openstreetmap
UNESCO	United Nations Educational, Scientific and Cultural Organization

CHAPTER 1: INTRODUCTION

1.1 Background

1.1.1 Mt. Elgon Forest Ecosystem

Mt. Elgon Forest is an ecosystem that makes up one of the five water towers in Kenya. The ecosystem serves as the catchment for three major rivers: River Nzoia, River Turkwell and River Malakisi. In addition, the ecosystem is a hotspot for diverse biodiversity. Because of these factors, Mt. Elgon ecosystem was named by UNESCO a Biosphere Reserve (2003). The ecosystem was gazetted as a forest reserve in 1932 (73,705Ha). It is also a national park hosting diverse animal (fauna) species as well as a nature reserve. Despite the forest being a gazetted forest reserve, the Elgonyi Dorobo Community dwells in the forest (Simiyu, 2008).

Over the decades, human population and activities have increased in the forest ecosystem as a result of encroachment, immigration and government settlements. These populations consist of small-scale farmers entirely depending on the forest resources for their livelihood and subsistence. As a result, the populations have encroached into the mixed montane forest and conducted their farming and logging activities thereby eating into the forest cover. These activities have resulted in significant forest disturbance which have affected the plant (floral), structure and composition of the forest. Human activities such as overgrazing has been noted in the forest, a factor that inhibits the natural regeneration of the forest. The mixed montane forest of the ecosystem has been degraded and encroached into for farming operations causing significant decrease of the montane forest. At the same time, logging activities by the forest dwelling communities in the forest ecosystem has caused a decrease of the sub alpine montane heath (KEFRI, 2018).

Mt. Elgon Forest consists of four distinct vegetation zones, namely: alpine moorland, sub-alpine montane heath, bamboo and low canopy forest and mixed montane forest. Each of the zones presents unique vegetation characteristics and structure. The structural distinction is as a result of change in climatic characteristics with the change in elevation. The mixed montane forest is found at the mountain slopes and stretches to about 2500m above the sea level (Mwaura, 2011). The bamboo zone stretches from an altitude of 2500m to 3000m above sea level. From an altitude of 3000m to 3500m above sea level comprises the sub alpine zone from where the alpine moorland zone stretches up to the peak of the mountain. According to Hinchley (2003), logging and encroachment into the forest have caused a 30% decrease of the mixed montane forest zone and a 25% decrease under the sub alpine montane heath region. This has resulted in changes in the vegetation structure of the forest, which has impacted in the biodiversity that depend on particular forest zone. The bamboo zone is stretching into the mixed montane zone and the lower sub alpine montane zone. The area under the alpine zone is also increasing. Human activities in the forest prevents the natural regeneration of vegetation.

This shift in land use and vegetation cover has also resulted in changes in the forest cover, forest structure and settlement patterns in the forest.

1.1.2 Chepyuk Settlement Scheme

Aside from the illegal encroachment into the forest, the government settlement programmes further compounds the situation of land use changes in the forest eco system. The government-led Chepyuk Settlement scheme is located in the Mt. Elgon forest reserve. The scheme was established in the year 1971 to resettle the Sabaot community who had been dispersed from their lands by the British settlers in the colonial era. Chepyuk Phase I of the resettlement process which begun in 1971 until 1974 where 950 families were allocated land totalling up to 5252 ha (Simiyu, 2008). The second phase of the resettlement process called Chepyuk Phase II begun in 1992 in which 5252 Ha of the forest was hived off. A total of 1735 families were allocated land with each family being allocated 15-50 acres depending on the family size. Population growth necessitated a third phase known as Chepyuk phase III which was implemented in 2011. (Table 1.1) As a matter of fact, the populations that have been settled into the forest reserve have gone ahead to encroach into the forest for crop cultivation and grazing activitie.

In 2018, a delegation consisting of community members and politicians from the Mt. Elgon region presented a petition to further degazette 11,384.127 acres of the forest reserve to facilitate another resettlement. This matter is still currently under debate in parliament as the members of parliament are divided over it. While a section of the legislators defended the petition, others are opposed to it asserting that settling people in the forest reserve is counterproductive to the environmental conservation efforts (Psirmol, 2018).

Table 1.1: Settlement Schemes in Mt. Elgon Forest Reserve (Source:(Simiyu, 2008))

Settlements	Year	Size of land
Chepyuk Phase I	1971-1974	-
Chepyuk Phase II	1989-1991	5252Ha
Chepyuk Phase III	2011	2865.42Ha

1.2 Problem Statement

Over the decades, human population and activities have increased in Mt. Elgon forest ecosystem as a result of encroachment, immigration and government settlements. This population consists of small-scale farmers who entirely depend on the forest resources for their livelihood and subsistence. As a result, the populations have encroached into the mixed montane forest and conducted their farming activities and logging thereby eating into the forest cover. These activities have resulted into significant forest disturbance which have affected the plant (floral), structure and composition of the forest.

Gazetted excisions of Mt. Elgon Forest reserve to faciliate Chepyuk Settlement Scheme by the government has eaten into the forest cover and endangered the forest cover and structure.

Several studies have been done in the past on Mt. Elgon Forest Reserve to attempt to characterize the environmental status of the forest reserve. The studies include establishment of the woody perennials population and diversity and bird species in the forest ecosystem by Katende et al. (1990), biodiversity survey and land use by van Heist (1994) and an assessment of resource use in the forest ecosystem by the forest communities by Scott (1994). These surveys focus mainly on the biodiversity status of the forest and have little to do with forest cover, forest structure and settlement changes. In addition, the studies previously conducted did not incorporate GIS and Remote Sensing Technology, which would provide an environment for spatial analysis of the forest reserve status.

1.3 Objectives

To assess the environmental impact of human settlement in Mt. Elgon forest reserve using geospatial technologies.

1.1.1 Specific Objectives

1. To analyse the forest cover change from 1984-2020.
2. To analyze the changes in the forest structure (vegetation zones) from 1984-2020.
3. To examine the change in settlement patterns in the forest reserve.

1.4 Significance of the Study

The findings established in this study will be cited as a guide to law makers in parliament who are still differing on whether or not to further degazette part of the forest reserve for resettlements.

The findings of this study will assist policy makers to design management strategies for Mt. Elgon forest ecosystem and other forest reserves in the country.

1.5 Scope of Work

Mount Elgon Forest Ecosystem is located on an extinct volcanic mountain whose elevation rises to 4,321m. The forest forms the catchment for Rivers Nzoia, River Turkwel and River Malakisi (Figure 1.1).

Although there are several environmental factors which can potentially be affected by forest settlements, this study seeks to exploit the forest cover and forest structure of the forest.

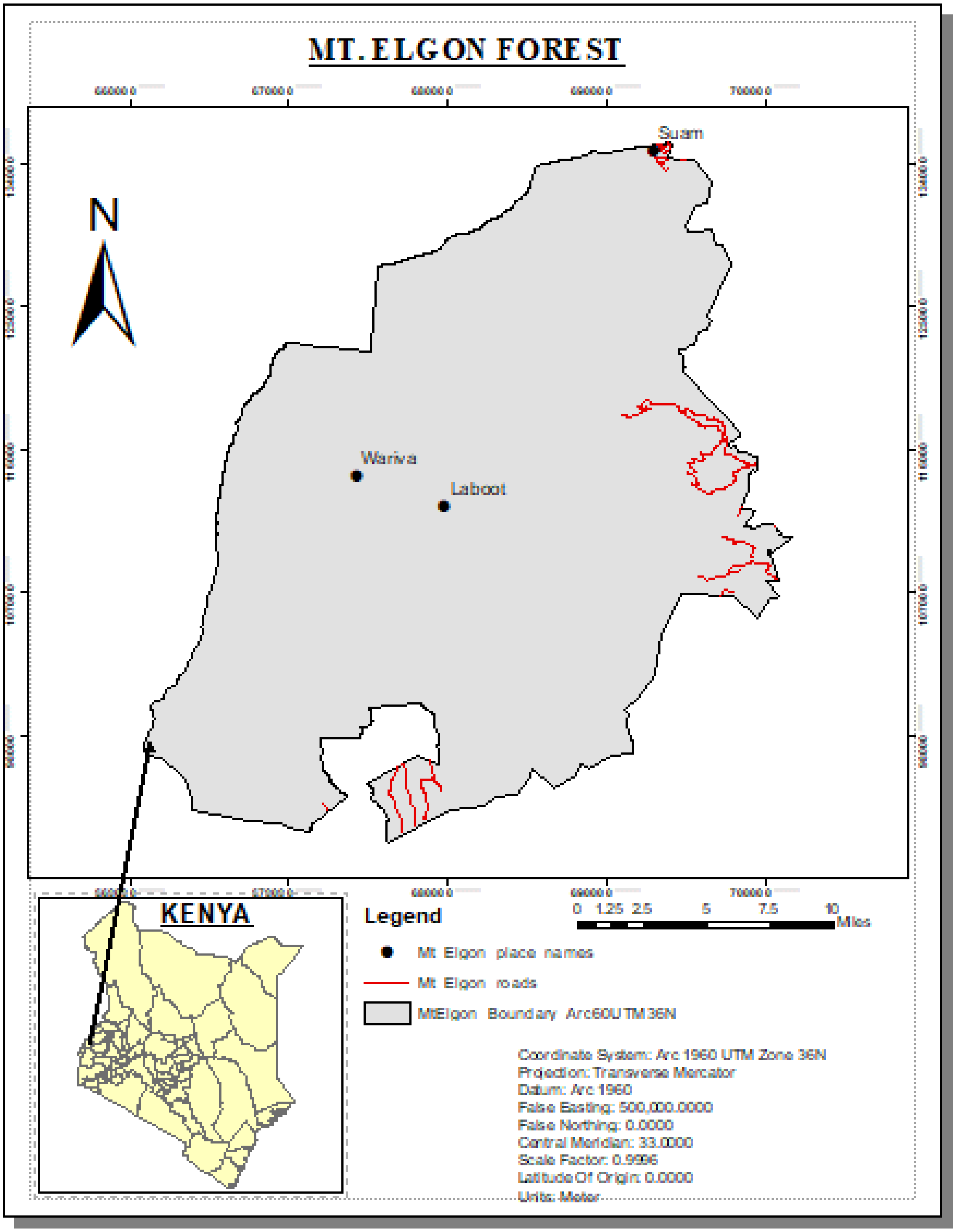

Figure 1:1 Mt. Elgon Forest (SOURCE: Kenya Forestry Service)

1.6 Research Matrix

Objective	Research question	Methodology	Data and Materials	Results/Output
1.To analyse the forest cover change from 1984-2020	Has the forest cover decreased in the period 1984-2020?	-Supervised classification of images to portray two classes: vegetative and the non-vegetative covers. Calculation of the Normalized Difference Vegetation Index (NDVI) values of images to demonstrate the change in forest cover.	-Satellite images (30m resolution).	-Maps showing changes in forest cover -Graphs showing change detection
2.To analyze the changes in the forest structure (vegetation zones) from 1980-2020.	Have the four vegetation covers changed?	-Classification of satellite imagery to portray four classes showing the four structures of the forest.	-Satellite images (30m resolution).	-Maps showing the changes in the four structures of the forest -Change detection graphs

3.To examine the change in settlement patterns in the forest reserve in a period of 40 years.	Has the settlement patterns increased in the forest reserve?	-Image classification by supervised classification to portray human settlement versus the forest cover to demonstrate how settlements affect the forest cover.	-Satellite imagery (30m resolution).	-Maps showing the extent of human settlements in the forest -Change detection graphs

CHAPTER 2: LITERATURE REVIEW

2.1 Settlement Schemes

Settlement scheme programmes involve relocating communities and people from one settlement area to a new location to enable them adapt to new social, physical and administrative environments (Kassahun, 2000). These new environments which are usually underdeveloped but have developmental potential can then experience socio-economic development through infrastructure and consequently, be beneficial to the community dwellers (ICMM, 2006).

Settlement scheme programs are designed with the overall objective of improving the socio-economic quality of humans particularly those that have been marginalized for one reason or another (Work, 2011). Settlement schemes are inspired by population pressure, natural resources degradation and economic growth (Mengitsu, 2005).

The settlement scheme concept was first done in Western Australia and Europe in the 1920s through a program called Group Settlement Scheme Programme (Gabbedy, 1988). The main objective of the scheme was to avail a labour force to open tracts of potential land for agriculture in an attempt to reduce dependence of the community on food imports.

The years following the second World War into the 1970s and 80s registered a steady rise in the settlement scheme programmes globally. The concept went on to become popular concept such that by the year 2000, 4500 settlement schemes had been established in more than 140 countries (Gabbedy, 1988).

The period after the 80s saw a decline in the development of settlement schemes in Europe and North America. This is because favourable sites for settlements were already developed.

The importance of settlement schemes includes providing needs for marginalized communities and in addition, they are sustainable and long-term programmes for such marginalized groups. They enable such communities to experience socio-economic empowerment, infrastructure projects and better livelihoods such as in Brazil (Canter, 2004) and in Asia and Africa, they have contributed to rural development (Chambers, 1983). The British colonial government deliberately formed settlement schemes in a bid to address land shortage dissatisfaction which was a growing issue. This is in addition to provide agricultural markets and also to meet raw materials demand for industries (Gann et al, 1983).

Settlement schemes in most parts of Africa were developed with the aim of redistributing land that had been created by the colonial government who had disinherited natives/locals. These programmes were meant to enable native Africans do their agricultural productions in the white settler farms. The settlement program was therefore meant to stimulate economic growth through agriculture (Gachagua & Wangu, 2007). Agricultural services such as extension services were availed to the settlement schemes to further expedite agricultural revolution.

Settlement schemes in Kenya were done the government post-colonial period in the year 1963 (Harbeson, 1971). The initial phase of land resettlement following the British rule was made to 5,000 experienced farmers with proven agricultural ability. These farmers had to cultivate the European farms with some financial grants from the World Bank, the British Government and the Commonwealth Development Corporation. The programme was meant to serve as a benevolent gesture by integrating the white highlands while developing those underdeveloped lands and at the same time establishing a market for those agricultural products.

Settlement schemes have served a positive end and assisted the government to realize many goals (Chambers, 1969). Some of these goals include, resettlement of populations from unproductive areas to productive areas hence realizing the economies of scale, solving the problem of landlessness, redistributing land that was taken by the colonialists and also community integration. The goals and objects vary from one settlement scheme program to another.

From the post colonial years upto the 1980s, the government of Kenya established settlement schemes in various parts of the country in a bid to solve the issue of landlessness and to improve the socio-economic status of the rural marginalized communities (Kandawire, 1985). These schemes were established in productive but idle lands. Agricultural extension services were embedded into the programmes to boost agricultural activities. Another goal of the settlement scheme was also to encourage inter ethnic cooperation and interaction (Kishindo, 1997).

2.2 Forest encroachment and degradation

Forest degradation refers to the decline of a forest in quality which renders it unable to provide its former roles (Serna, 1986). Degradation means that the essential process that sustains the forest ecosystems are impaired leading to a decline in the forest cover, forest structure and species composition. And the general environment of the forest. Degradation process is initiated by both biotic and abiotic factors (Laura, 2003). Man induces degradation of forests directly through encroachment into the forest to carry out human activities such as farming, logging and settlements.

The forests of Kenya are located in the regions with the highest agricultural potential. They also form the five water towers in Kenya. These forests host and support the livelihoods of the communities living adjacent to them. These forests serve numerous roles in addition to their importance as catchment areas. They are a host for Kenya's both floral and fauna biodiversity as they are a major wildlife and plant species habitat (DRSRS, 2006). The forest ecosystems store carbon from the atmosphere and regulate microclimates. Therefore, forest degradation leads to increased carbon concentration in the atmosphere (Laura, 2003). There are a number of factors that have contributed to a decline in the forest cover of Kenya's forests. Clearing of natural forests to pave way for plnatation farming has been a practice which has threatened indigenous natural forest (Obare, Wangwe, 2005).

Logging is another activity that has contributed to a decline in forest cover. Logging in the forests has been done in a way that is not systematic. There is no periodic cut that is permitted, similarly, there lacks a yield regulation to control the logging activities. Logging is often overeploited leaving behind little stock to allow for regeneration of the species.

Conversion of forests into farmlands through the shamba system has grossly contributed to a decline in the forest cover. The shamba system was imitated from the South America's Taungya system. The shamba system was established in the year 1943 in order to facilitate plantation farming. This was necessitated by the acute shortage of land faced by communities in the post colonial era. It was also prompted by the need to provide food security to communities. In the shamba system, farmers were incorporated in the forest department where they were allowed to clear and farm bush covers covering a specified area. The tree seedlings were grown on the same land together with annual food crops such as maize, beans and vegetables. This was an important and benevolent arrangement as it enhanced food security for the rural peasant communities. Population pressure which increased demand for the forest land result in discontinuation of the system in 1986. When the system was discontinued, forest dwelling communities encroached into and settled in the cleared areas which escalated forest degradation.

80% of Kenya is characterised as arid and semi-arid, therefore, 20% forms the productive area which is under agriculture and forests. Kenya is classified among countries that have a low forest cover of below 2% of the total lad cover (FAO, 1990). This declining forest cover poses a potentially adverse effects on the entire forest resource such as the biodiversity, rivers and streams, the climate and the populations that depend on the forest.

2.3 Forest Excisions

Forest excisions allow for the degazettements of forest reserves to facilitate exploitation of forests for purposes of farming, developments of infrastructure and settlements. Excisions are often made without involving stakeholders. Public participation and views of anybody who feels aggrieved by the excision process are hardly considered. A gazette notice is issued and an aggrieved party has 28 days to contest the process. The challenge is that very few people are usually aware of the gazette notice. The minister in charge can easily be subjective and apply decisions that do not meet the interest of the public. Excisions are often implemented after the forests have already been encroached into.

2.4 Forest Cover and Structure Change through Remote Sensing and GIS

GIS and Remote sensing technologies have been extensively employed for land use planning and management (Tickle et al., 2005). The technologies have been important in determining the structural characteristics of forests (Gemmell and Varjo, 1999), classifying forests to display vegetation characteristics and assessing the forest cover changes over a specified period of time (Qingmin et al., 2007). GIS technology is also useful in inaccessible forest sites (Hall et al., 1997). GIS technology has been used in forest fires management, mitigation and preparedness as well as data management of global forest changes(Laura, 2003). GIS and Remote sensing technologies can be used in detecting the species composition and concentration in a forest. Lillesand and Keifer (2002) observed that the reflectance of vegetation depends on the properties of the vegetation such as the orientation, the pigmentation, leaves' internal structure and the canopy structure. Plants absorb different colours. Chlorophyll which is absorbed at the wavelength band 0.45-0.67microns reflects the blue light while the red portions are absorbed. At the 0.7-1.3 microns wavelength band, leaves reflectance is at 50%. The density of green colour on land can be observed by determining the distinct wavelengths of near infrared and visible light reflected by the vegetation. When light strikes vegetation, chlorophyll absorbs visible light while the cell structure of the leaves will reflect the near infrared. If there is more reflected radiation in the NIR than in the visible wavelengths, it means that vegetation is dense in that pixel. On the flip side, if the difference in the NIR and visible wavelengths is minimal, it depicts sparse vegetation consisting of shrubs, grassland or a desert.

Normalized Differential Vegetation Index (NDVI) is used to determine the health of vegetation. used to calculate the forest cover for each image and then compare the changes in each image. NDVI is the value of Near Infrared (NIR) radiation minus visible radiation divided by NIR radiation plus visible radiation expressed as follows:

$$NDVI=(NIR-Visible)/(NIR+Visible)$$

NDVI value ranges from -1 to +1. A value close to zero indicates little green vegetation whereas a value close to +1 indicates dense green vegetation.

2.5 Empirical Review

Kinyanjui (2009), assessed the the effect of human encroachment on forest cover, composition and structure in the western blocks of the Mau forest complex. The study, which was conducted between the year 2003 and 2007, established that human encroachment has reduced the forest land cover thereby threatening its environmental, biological and socio-economic roles. The study further revealed that the degraded parts of the forest has lost its floristic composition, the basal area, species richness, soil nutrient content. The ability of the forest to recover has also been inhibited by the encroachment.

2.6 Conceptual Framework

The conceptual framework in Figure 2.1 shows the relationship between dependent and independent variables. Human settlements and activities into the forest facilitated by government excisions and illegal encroachment results in a decline in the forest cover and changes in the forest structure, where the lower mixed montane, and the alpine region faces a decline. Increase in human settlements, both legal and illegal, will no doubt translate into a visibly large patterns of settlements into the forest reserve.

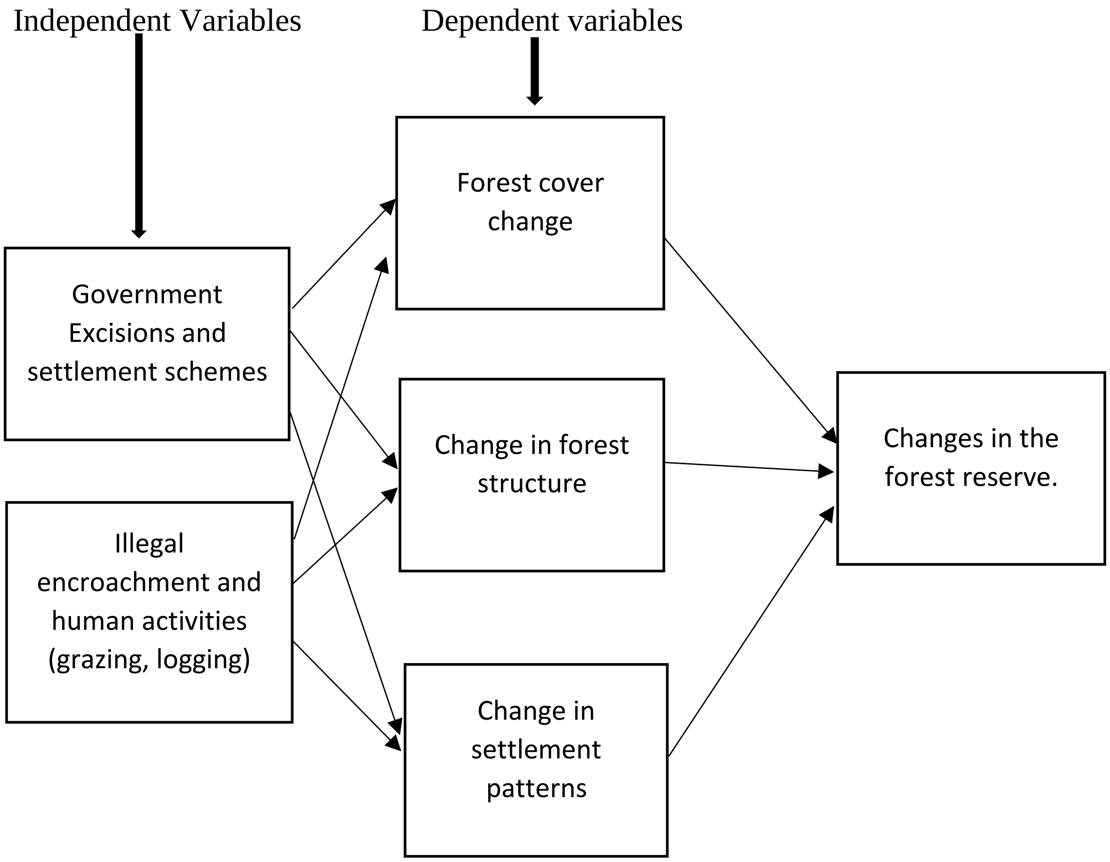

Figure 2.1: Conceptual framework

CHAPTER 3: METHODOLOGY

3.1 Change in vegetation cover by classification

3.1.1 Research Design

Landsat images were acquired for a period ranging thirty-six years, from the year 1984 up to 2020. 1984 was the baseline which would demonstrate the forest status as it had been before a series of continuous disturbances. The year 1984 was ten years after the first phase of the Chepyuk Settlement scheme and eight years before the second phase of Chepyuk Settlement Scheme. In this epoch, the forest had regenerated itself (Simiyu, 2008). The second image was acquired in 1995. This was to demonstrate the change in the forest status after the 1992 Chepyuk settlement scheme. The third image was acquired in the year 2009 to demonstrate the status of the forest fourteen years after the resettlement process. The next settlement process took place in the year 2011, which necessitates a study of the present-day status. The fourth image was thus acquired in 2020 which demonstrated the current status of the forest. Noteworthy is that the third objective which assessed the change in settlements in the forest, was done for a period between the years 2009 to 2020. In this period, modern housing is dominant in the forest.

The rationale for opting for Landsat data was that Landsat data are readily accessible and less costly, yet come with a spatial resolution of 30 meters which is good enough for spatial analysis. For regions with poor data resource in Africa and Asia, Landsat has provided remote sensing data for a wide range of analysis including in academic research.

3.1.2 Data Collection

Landsat Images were downloaded for the study area from USGS Earth Explorer portal (USGS Earth Explorer, n.d.) for the years 1984, 1995, 2009 and 2020. The table 3.1 is a description of the satellite images:

Table 3.1: Description of satellite images

	1984	**1995**	**2009**	**2020**
Source	Landsat 5	Landsat 5	Landsat 5	Landsat 8
Acquisition Dates	10/09/1984	02/04/1995	27/06/2009	01/01/2020
Bands	7	7	7	11
Cloud cover (%)	1	0	1	1.31
Spatial Resolution(m)	30	30	30	30 (15 pan sharpened)

The boundary for the Mt. Elgon Forest was sourced from the Kenya Forest Service. Roads and place names data was sourced from OSM.

3.1.3 Preparation of the Satellite Images

The satellite data folders were unzipped to obtain Tiff band images. The bands for each image were imported to ArcGIS software. The downloaded images are georeferenced. Bands one to band seven of images 1984, 1995, 2009 and band one to band eight for image 2020 were layer stacked using the composite band tool to form multispectral images of each of the four images. The resultant stacked images were then clipped using the Mt. Elgon forest boundary layer to generate the area under study.

The Landsat image of year 2020 was pan sharpened to generate a high-resolution image. The panchromatic band 8 comes with a higher spatial resolution of 15m, while the other bands come with a 30m spatial resolution. Pan sharpening fuses the multispectral bands with the panchromatic band which raised the spatial resolution of the resulting image to 15m. (Rose, 2018)

3.1.4 Classification

Supervised classification was used to determine the change in vegetation cover. This was done by creating two classes of the images to portray bare land vis a vis the vegetation cover. Training samples were created to assign two classes, that is, vegetation cover and non-vegetative zone, to the images. After creating signature files from the training samples, supervised classification was then performed using the maximum likelihood procedure. The maximum likelihood was used because it calculates the probability that a specific pixel belongs to a specific class.

The classified images of 1984, 1995, 2009 and 2020 were each converted from raster to polygon in which state, it's possible to perform mathematical calculations. The codes were dissolved and the Area for each class in each image was calculated to determine the land cover changes from 1984 to 2020.

3.1.5 Accuracy of Classification

To assess the accuracy of this classification, a confusion matrix was created in ArcMap. A high resolution image from Google earth was used. The image was captured by CNES Airbus satellite at a spatial resolution of 2.52m on 23rd September 2020. This was used to assess the accuracy of the classification of the year 2020 image. For years 2009, 1995 and 1984 images, the pre-classified landsat images were used to assess the accuracy of the classification. Rather than collecting samples from the ground, sample points were randomly collected from the Google Earth image. Collecting samples from the ground was not the best option for this study owing to limitations in terms of time and resources, while considering the nature of the study area which is a mountanous forest. Further compounding this problem was the existence of the Covid-19 pandemic at the time of the study, which necessitated the government to effect a lock-down that restricted movement of people.

The number of sample points considered were ten times the number of points for each class. Therefore, twenty sample points were collected for each of the two classes, making a total of fourty sample points. The number of sample points collected were ten times the number of points representing each class. This allows for improvement of accuracy assessment. The underlying land cover on the Google Earth image was then noted for each point and compared to the classified image.The points were randomly but evenly distributed across the study area.

The created random points were converted into reference pixels. The new raster layer was then combined with the classified image and the results displayed and analysed in a confusion matrix to reveal the user's and producer's accuracy, the error of commission, error of omission, the overall accuracy and the kappa coefficient. According to (McHugh, 2012), the logical interpretations of the Kappa statistics are as in table 3.2:

Table 3.2: Kappa Statistics interpretation

Kappa	Agreement
0-0.20	Poor
0.21-0.39	Fair
0.40-0.59	Moderate
0.60-0.79	Good
0.80-1	Very good

3.1.6 Change in the Normalized Differential Vegetation Index

The forest cover change was further assessed by calculating the Normalized Difference Vegetation Index (NDVI) for years 1984 and 1995, 1995 and 2009, 2009 and 2020. NDVI is an indicator used to measure and quantify healthy vegetation. The NDVI value ranges from -1 to +1; values close to +1 depict healthy vegetation. NDVI is used as an indicator for drough, in farming, it is applied in precision farming and in forestry, NDVI is used in forest degradation monitoring.

The pre-processed images were loaded into GIS software for calculation as the input data. The "Image Analysis" tool was activated and opened to facilitate calculation of the Normalized Difference Vegetation Index. The bands for the NDVI calculation were specified where for images 1984, 1995 and 2009, band 3 represents the red band whereas band 4 represents the Near Infrared band. For image 2020, band 4 represents the red band whereas band 5 represents the Near Infrared band. s

The NDVI value is calculated as follows:

NDVI = (NIR-RED) / (NIR+RED);

where the NIR is the near Infrared band while RED is the red band. These represent the reflectance captured in the near infrared and the red bands.A positive NDVI value indicates an improvement in the vegetation cover while a negative value represents a decline in vegetation cover. The average change in NDVI values between two subsequent periods of study was then calculated.

3.2 Change in Forest Structure by Classification

Supervised classification was used to determine the changes in the extent of the forest structure/vegetation types. Training samples were created to assign four classes of the forest structure. The four classes represented the Mixed Montane Forest, Bamboo and grasslands, Alpine and Sub Alpine Montane Heath and finally the Bare Ground constituting of rocks and bare soil. After creating signature files from the training samples, supervised classification was then performed using the maximum likelihood procedure.

The classified images of 1984, 1995, 2009 and 2020 were each converted from raster to polygon to enable mathematical computations of the various zones. The codes were dissolved and the Area for each class in each image was calculated to determine the area of each respective forest structure component.

A confusion matrix was created in ArcMap to assess the classification accuracy for each of the four separate classifications. For this assessment, it was not necessary to have an equal number of sample points for each class as the areas under Mixed Forest, Bamboo and Alpine/Sub-Alpine were significantly larger than the area under Settlements. The sample points were distributed among the classes as follows: Mixed Montane Forest 60 points; Bamboo and Grasslands 60 points; Alpine and Sub Alpine 60 points; Bare Ground 50 points; Settlements 20 points. These made a total of 250 sample points.

3.3 Change in Settlement patterns by classification.

Change in settlements for this study was determined between the years 2009 and 2020. In the section 3.2, a fifth class was identified during classification which represented the settlement patterns. The area under settlement was calculated to portray a change in the settlement patterns in the forest.

3.4 Ground Truthing

The slopes of Mt. Elgon Forest on the southern part of Kaberwa was identified for the field visit exercise. From classification, this area is heavily encroached into while the settlements border the mixed montane forests as demonstrated in classification. The field visit was done on 18th September 2020. A brief interview was conducted with the forest officials to establish the nature of encroachment. Observation was employed to study the nature of forest encroachment and photographs taken.

Kaberwa at Latitude 0.8701N; Longitude 34.7026E and elevation of 2163m was assessed. This area has significant settlements and borders a thick natural forest made up of mixed tree species with thick undergrowth (Figure 3.1 and 3.2). Also observed was tracts of man-made trees inside the Forest. A brief interview with the Forest Officers revealed that licensed people were allowed to grow trees in sections of the forest for commercial purposes. The interview further revealed that people were issued with licences for charcoal burning inside the forest. These observations and interview details reveal further the nature of encroachment into the forest (Appendices I and II).

Figure 3.1: Area showing farming bordering mixed montane forest at Kaberwa

Figure 3.2: Area of mixed montane forest at Kaberwa

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Change in Forest cover

4.1.1 Pre-processing Results

The image obtained for the year 1984 and 1995 (Figure 4.1 and 4.2) depicts vegetation and patches of non-vegetative zones comprising predominantly of bare ground. Most of the bare ground is visible at the area around the peak of the mountain. The vegetation cover comprises distinctively different types of vegetation. The deep green cover comprises the mixed montane forest, the medium green cover comprises bamboo and grasslands; the light green cover predominantly surrounding the peak of the mountain comprises the Alpine and Sub Alpine Montane Heath. The images obtained for the years 2009 and 2020 (Figure 4.3 and 4.4) have similar characteristics as the previous images, except in addition, settlements are clearly visible in these two images.

Figure 4.1: Pre-processed image of year 1984

Figure 4.2: Pre-processed image of year 1995

Figure 4.3: Pre-processed image of year 2009

Figure 4.4: Pre-processed image of year 2020

4.1.2 Results for change in Forest Cover by Classification

Figures 4.5, 4.6, 4.7 and 4.8 are classified images demonstrating the forest cover change.

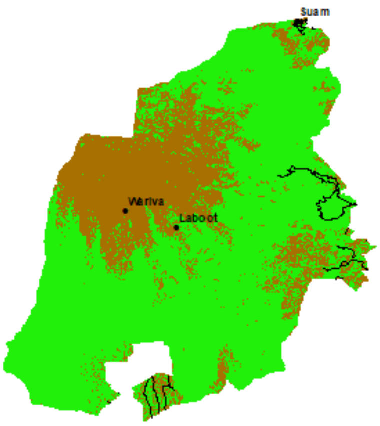

Figure 4.5: Forest cover 1984

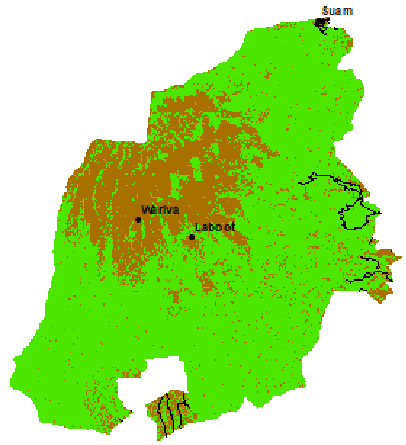

Figure 4.6: Forest cover 1995

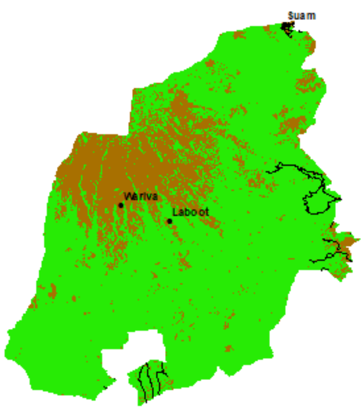

Figure 4.7: Forest cover 2009

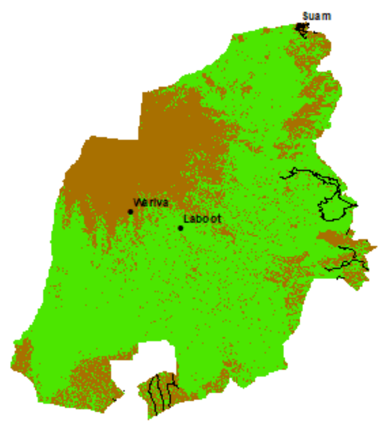

Figure 4.8: Forest cover 2020

An analysis of the classified images shows that, the forest vegetation cover has significantly decreased from 851 Sq Km in the year 1984 to 748 Sq Km in 2020 (Table 4.1). The forest cover declined by 17Sq Km between 1984 and 1995; 39 Sq Km decline between 1995 and 2009 and 17 Sq Km decline between 2009 and 2020. This trend shows a steadily declining vegetation cover of the forest. The non-vegetative cover consisting of settlements and bare ground demonstrate an exponential increase across the years from 215 Sq Km in 1984 to 317 Sq Km in the year 2020 (Table 4.1). The decline in the vegetation cover is due to human settlement as facilitated by the government excisions, as well as illegal encroachment into the forest by the forest dwelling communities. The gazette excision hived off 52.52Km Sq (7.13%) of the entire forest for the purpose of resettlement. However, population increase of the forest communities increases the demand of the communities for the forest resources, which led to further decline of the forest.

Table 4.1: Change in forest cover from year 1984 to 2020.

	Area (Square Kms)				**Difference (Sq Kms)**		
	1984	**1995**	**2009**	**2020**	**1984-1995**	**1995-2009**	**2009-2020**
Forest cover	851	834	795	748	-17	-39	-47
Non-forested	215	232	271	317	17	39	46
Total Area	1066	1066	1066	1066	0	0	-1

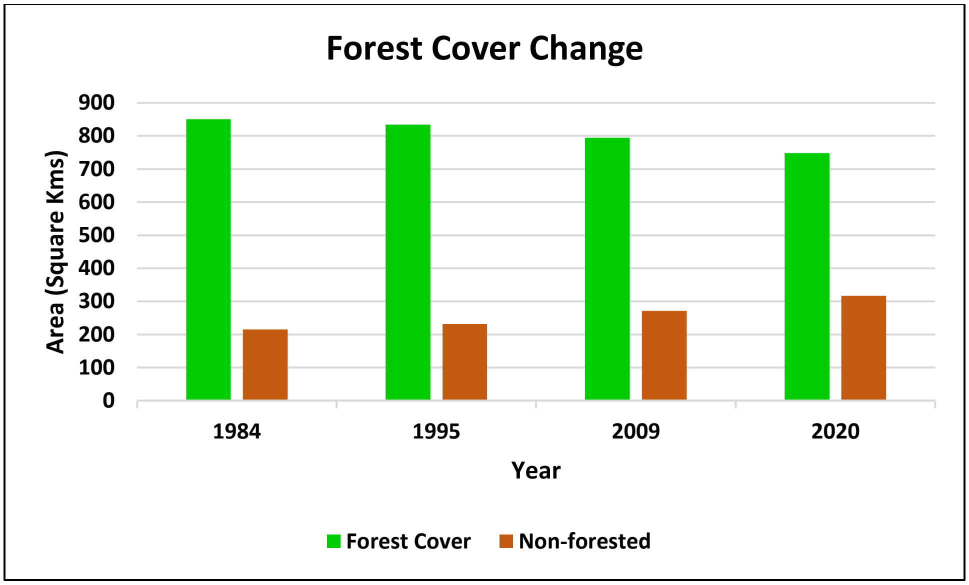

Figure 4.9: Forest cover from year 1984 to 2020.

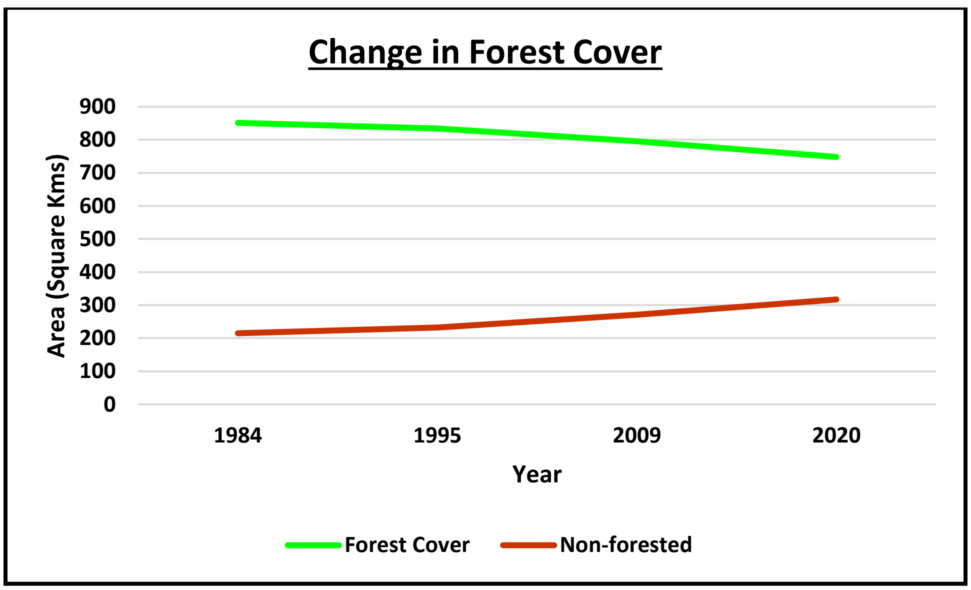

Figure 4.10: Change in forest cover from year 1984 to 2020.

4.1.3 Results for change in the Normalized Differential Vegetation Index

The mean difference of the NDVI values from year 1984 to 1995 is 0.2; -0.12 from 1995 to 2009 and -0.225639 from year 2009 to 2020.

The positive NDVI value between 1984 and 1995 demonstrates that the forest was still in good vegetative condition despite the forest resettlement processes in 1974 and 1992. The forest was able to regenerate after the first phase of Chepyuk resettlement. The second Phase which took place in 1992 caused disturbance as much as 52.52Sq Km of the forest was hived off. Any encroachment between that resettlement phase and the year 1995 was minimal because the population was hitherto under control.

The negative NDVI value between years 1995 and 2009 demonstrates that the forest cover was declining in that period. This is due to the long-term effects of the 1992 settlements. The resettled population grew in that period and depended entirely on the forest resource for their livelihood and hence, begun encroaching into the forest for crop cultivation, logging and grazing activities. Though forest land is excised to settle people, an increase in the population of the forest adjacent communities increases their demand for forest products due to their developmental needs (Sharma, 1992).

The negative NDVI value from year 2009 to 2020 demonstrates further decline of the forest cover across that period. This is attributed to the immediate and long-term effects of the 2011 resettlement process, migration and encroachment of the forest communities into the forest reserve.

4.2 Change in Forest structure (vegetation type)

Figures 4.11, 4.12, 4.13 and 4.14 are classified images demonstrating the change in the forest structure.

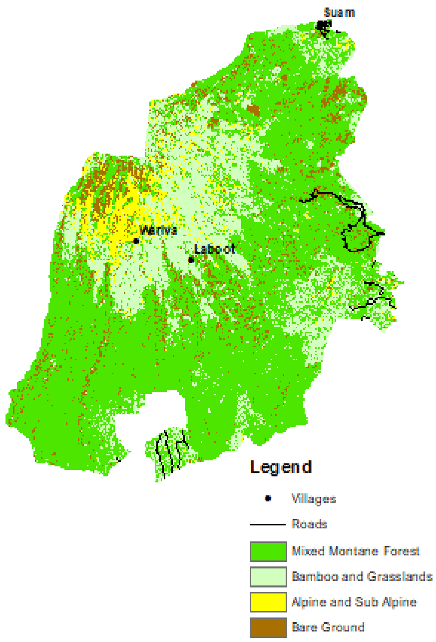

Figure 4.11: Forest Structure 1984

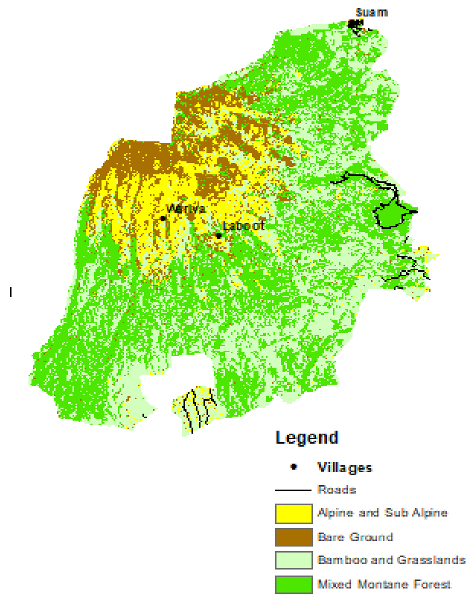

Figure 4.12: Forest structure 1995

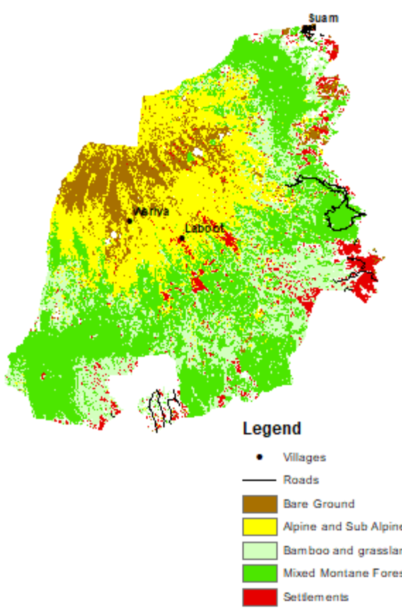

Figure 4.13: Forest structure 2009

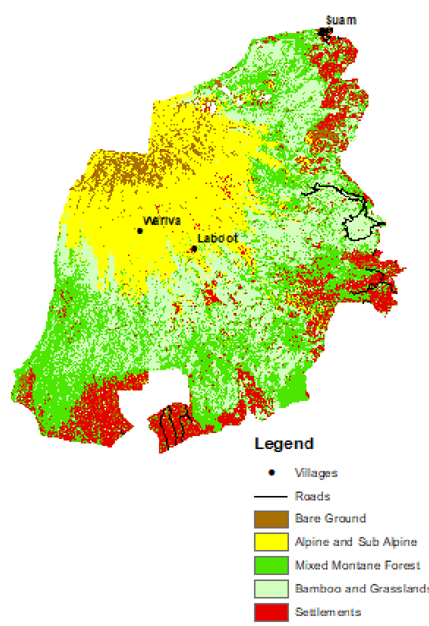

Figure 4.14: Forest Structure 2020

An analysis of the classified images to determine the changes in the extent of the forest structure/vegetation showed significant changes in the structure of the forest.

Table 4.2: Change in forest structure from year 1984 to 2020.

	Area (Square Kms)				**Difference (Sq Kms)**		
	1984	**1995**	**2009**	**2020**	**1984-1995**	**1995-2009**	**2009-2020**
Mixed Montane Forest	593	527	408	289	-66	-129	-119
Bamboo and Grasslands	247	305	325	336	58	30	11
Alpine and Sub Alpine	102	115	159	249	13	63	90
Bare Ground	123	117	95	61	44	-22	-34
Settlements	0	0	54	125	0	54	71
Totals	1065	1064	1041	1060	49	-58	-52

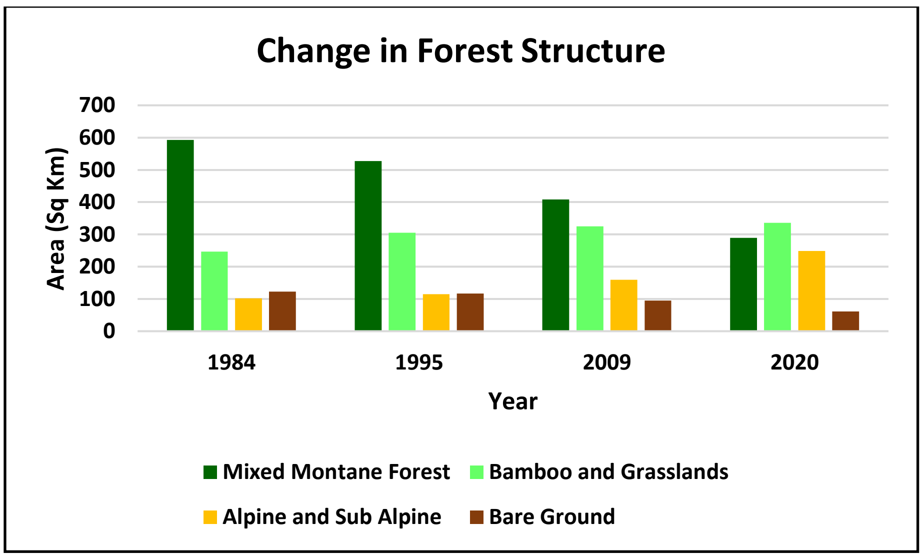

Figure 4.15: Forest structure

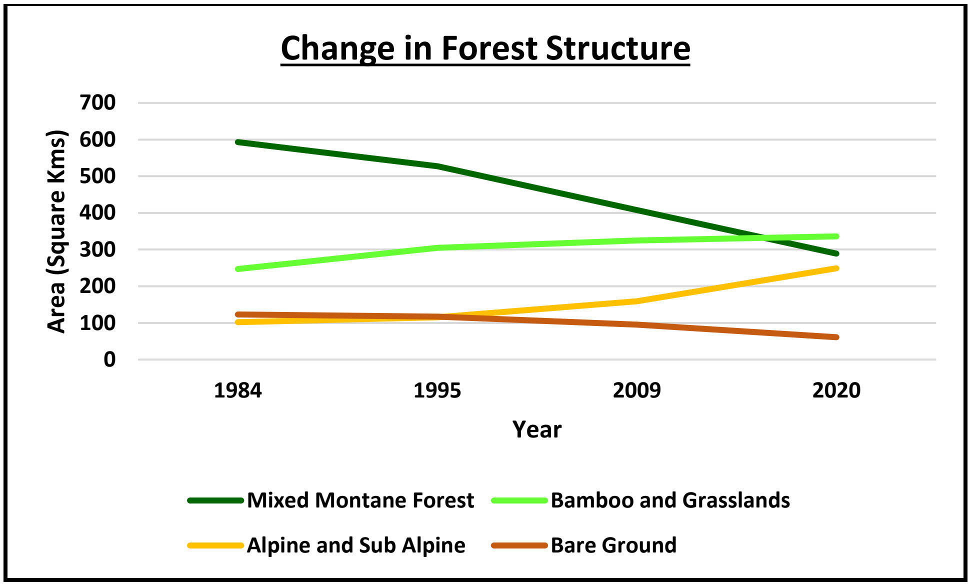

Figure 4.16: Change in forest structure from year 1984 to 2020.

The Mixed montane forest constituted the biggest vegetation portion of the forest (Table 4.2) It has been experiencing a steady decline from 1984 at 593 Sq Km; 1995 at 527 Sq Km; 2009 at 408 Sq Km to 2020 at 289 Sq Km. The mixed montane forest declined by 66Sq Km between 1984 and 1995 after 52.52 Sq Km of the forest was hived off to facilitate Chepyuk Settlement phase II in 1992. A total of 1735 families were allocated land with each family being allocated 15-50 acres depending on the family size. The forest communities continued to encroach into the forest for logging and farming activities, further destroying a significant portion of the mixed montane forest which is found at the sloped of Mt. Elgon. This saw a decline of the mixed montane by a further 129 Sq Km between 1995 and 2009. The mixed montane further declined by 119 Sq km between 2009 and 2020 owing to the third phase of Chepyuk Settlements in the year 2011. The fact that the mixed montane registered a lower decline between 1984 and 1995 demonstrates that the forest is capable of naturally regenerating itself under minimal disturbance. The high decline after 1995 demonstrates the impact of settling communities in the forest. The communities entirely depend on the forest as the source of their livelihood. Further, the community population is increasing. These two factors necessitate encroachment into the forest causing it to decline.

The bamboo zone has been increasing slightly from 247 Sq Km in 1984; 305 Sq Km in 1995; 325 Sq Km in 2009 to 336Sq Km in 2020. This zone is stretching into the mixed montane zone and the lower Alpine and Sub Alpine zones. This is attributed to the attempt of the forest at regenerating itself after disturbance of the mixed montane zone. The slow rate of the regeneration is attributed to the fact that sections of the Bamboo zones were equally felled off to facilitate resettlement process and human encroachment. In addition, human encroachment has been established to be in the form of tree planting for commercial purposes. Such man-made trees appear less dense than the mixed montane forest and are categorized under Bamboo and Grasslands zones. The Alpine and Sub Alpine zones are increasing at a slower rate. These zones face human disturbance at a slower rate due to their location at higher altitudes. The Bare ground is declining as the sections of bare earth are converted into settlement areas.

4.3 Change in Settlements

Change in settlements for this study was determined between the years 2009 and 2020 as shown in Table 4.2. The analysis reveals that the area under settlements in the forest increased from 54 Sq Km in 2009 to 125 Sq Km in 2020. This increase in settlement was occasioned by the third phase of the Chepyuk Settlement in the year 2011 in which 28.65 Sq Km was hived off. An increase in the forest dwelling population as well as migration further increased the settlements into the forest reserve. Increase in settlements within the forest causes the decline in the forest cover (Figure 4.18). Forest dwelling communities entirely depend on the forest resources for their livelihood, hence, they engage in logging and degrading the forest to create land for farming for their subsistence. Figure 4.17 shows changes in settlements.

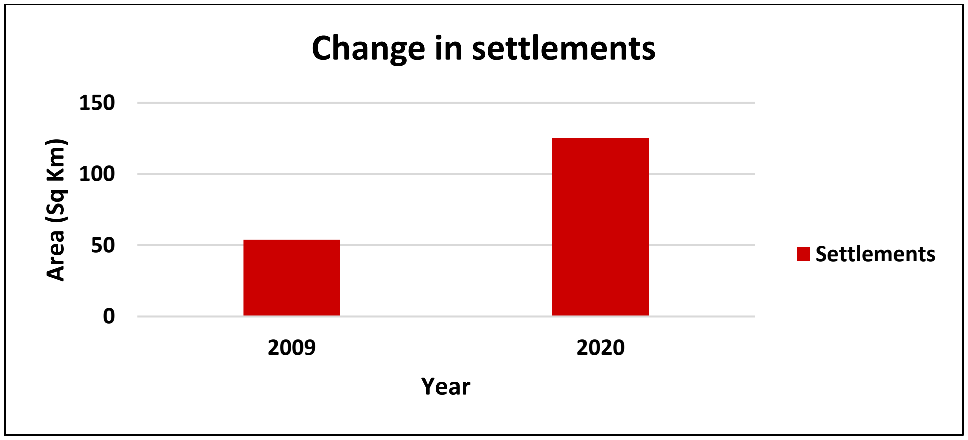

Figure 4.17: Change in settlements from year 2009 to 2020.

Table 4.3: Relationship between Forest Cover and Settlements

	Area (Square Kms)				Difference (Sq Kms)		
	1984	**1995**	**2009**	**2020**	**1984-1995**	**1995-2009**	**2009-2020**
Forest Cover	851	834	795	748	-17	-39	-47
Settlements	0	0	54	125	0	54	71
Total Area	851	834	849	873	-17	15	24

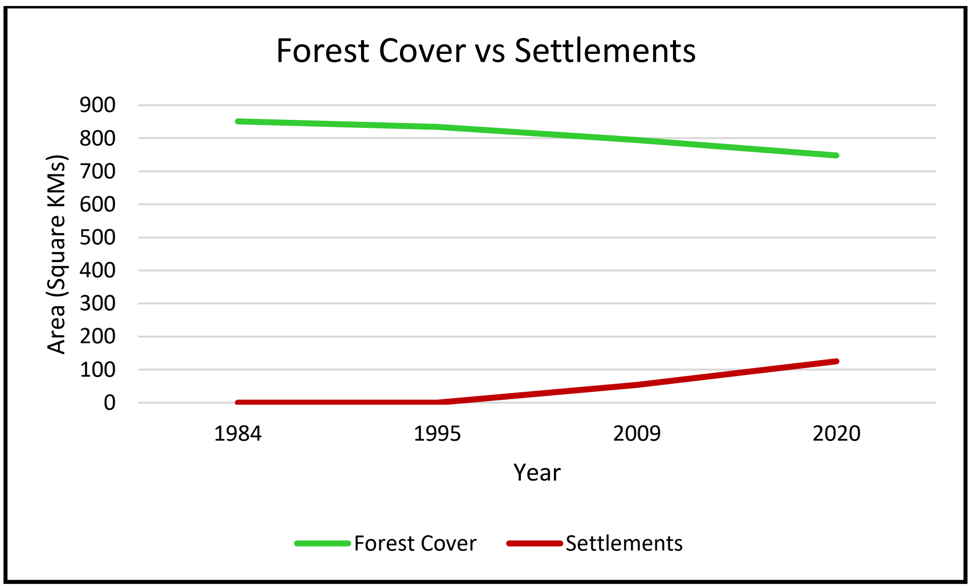

Figure 4.18: Relationship between Forest Cover change and Settlements

4.4 Accuracy Assessment of the Classification

The accuracy assessment of the classification revealed a “very good” rank as per the Kappa statistics interpretation (Table 3.2). This demonstrates that the classified images are usable and reliable for analysis and interpretation of the results of the study. The results of the accuracy assessments are summarized in the confusion matrices (Tables 4.3 and 4.4).

Table 4.4: Year 2020 Confusion Matrix for Forest Cover Classification

	Forested	Non-Forested	Total	Commission	User's Accuracy
Forested	20	0	20	0	1
Non-Forested	0	20	20	0	1
Total	20	20	40		
Omission	0	0			
Producer's Accuracy	1	1			
Overall Accuracy	1				
Kappa Coefficient	1				

Table 4.5: Year 2009 Confusion Matrix for Forest Cover Classification

	Forested	Non-forested	Total	Commission	User's Accuracy
Forested	17	3	20	0.15	0.85
Non-forested	0	20	20	0	1
Total	17	23	40		
Omission	0	0.13			
Producer's Accuracy	1	0.87			
Overall Accuracy	0.93				
Kappa Coefficient	0.85				

Table 4.7: Year 1995 Confusion Matrix for Forest Cover Classification

	Forested	Non-forested	Total	Commission	User's Accuracy
Forested	20	0	20	0	1
Non-forested	0	20	20	0	1
Total	20	20	40		
Omission	0	0			
Producer's Accuracy	1	1			
Overall Accuracy	1				
Kappa Coefficient	1				

Table 4.6: Year 1984 Confusion Matrix for Forest Cover Classification

	Forested	Non-forested	Total	Commission	User's Accuracy
Forested	20	0	20	0	1
Non-forested	0	20	20	0	1
Total	20	20	40		
Omission	0	0			
Producer's Accuracy	1	1			
Overall Accuracy	1				
Kappa Coefficient	1				

Table 4.8: Year 2020 Confusion Matrix for Forest Structure Classification

	Mixed Montane	Bamboo and Grasslands	Alpine and Sub Alpine	Bare Ground	Settlements	Total	Commission	User's Accuracy
Mixed Montane	57	3	0	0	0	60	0.05	0.95
Bamboo and Grasslands	4	49	4	1	2	60	0.13	0.87
Alpine and Sub Alpine	0	0	37	14	9	60	0.10	0.90
Bare Ground	0	0	7	38	5	50	0.14	0.86
Settlements	0	2	3	4	11	20	0.82	0.18
Total	61	54	51	57	27	250		
Omission	0.02	0.09	0.27	0.33	0.07			
Producer's Accuracy	0.98	0.91	0.73	0.67	0.93			
Overall Accuracy	0.768							
Kappa Coefficient	0.705							

Table 4.9: Year 2009 Confusion Matrix for Forest Structure Classification

	Mixed Montane	Bamboo and Grasslands	Alpine and Sub Alpine	Bare Ground	Settlements	Total	Commission	User's Accuracy
Mixed Montane	60	0	0	0	0	60	0	1
Bamboo and Grasslands	4	52	4	0	0	60	0.13	0.87
Alpine and Sub Alpine	0	0	37	14	9	60	0.10	0.90
Bare Ground	0	0	4	43	3	50	0.08	0.92
Settlements	0	0	0	4	16	20	0.25	0.75
Total	64	52	45	61	28	250		
Omission	0.02	0.00	0.18	0.30	0.00			
Producer's Accuracy	0.98	1.00	0.82	0.70	1.00			
Overall Accuracy	0.832							
Kappa Coefficient	0.786715							

Table 4.10: Year 1995 Confusion Matrix for Forest Structure Classification

	Mixed Montane	Bamboo and Grasslands	Alpine and Sub Alpine	Bare Ground	Total	Commission	User's Accuracy
Mixed Montane	40	0	0	0	40	0	1
Bamboo and Grasslands	1	36	3	0	40	0.13	0.87
Alpine and Sub Alpine	0	0	27	13	40	0.10	0.90
Bare Ground	0	0	8	32	40	0.2	0.80
Total	41	36	38	45	160		
Omission	0.02	0.00	0.29	0.29			
Producer's Accuracy	0.98	1.00	0.71	0.71			
Overall Accuracy	0.84375						
Kappa Coefficient	0.791667						

Table 4.11: Year 1984 Confusion Matrix for Forest Structure Classification

	Mixed Montane	Bamboo and Grasslands	Alpine and Sub Alpine	Bare Ground	Total	Commission	User's Accuracy
Mixed Montane	40	0	0	0	40	0	1
Bamboo and Grasslands	3	33	4	0	40	0.13	0.87
Alpine and Sub Alpine	0	0	24	16	40	0.10	0.90
Bare Ground	0	0	8	32	40	0.2	0.80
Total	43	33	36	48	160		
Omission	0.02	0.00	0.33	0.33			
Producer's Accuracy	0.98	1.00	0.67	0.67			
Overall Accuracy	0.80625						
Kappa Coefficient	0.741767						

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. The forest cover of Mt. Elgon Forest has declined over the years due to the threat of human activities in the forest. This decline in the area under the forest cover is threatening the essence of the forest as a biosphere zone and a water tower.

2. The forest has lost its original structure which is changing due to the effects of human encroachment and government settlements. The area under the mixed montane forest is thinning and declining over the years while the bamboo and grasslands zone is expanding.

3. Human settlements into the forest has increased. This shows that the resettlements of communities into forest reserves is a simple solution to a complex problem. The resettlement solves the issue of landlessness but opens the door to heavy encroachment and consequently forest disturbance.

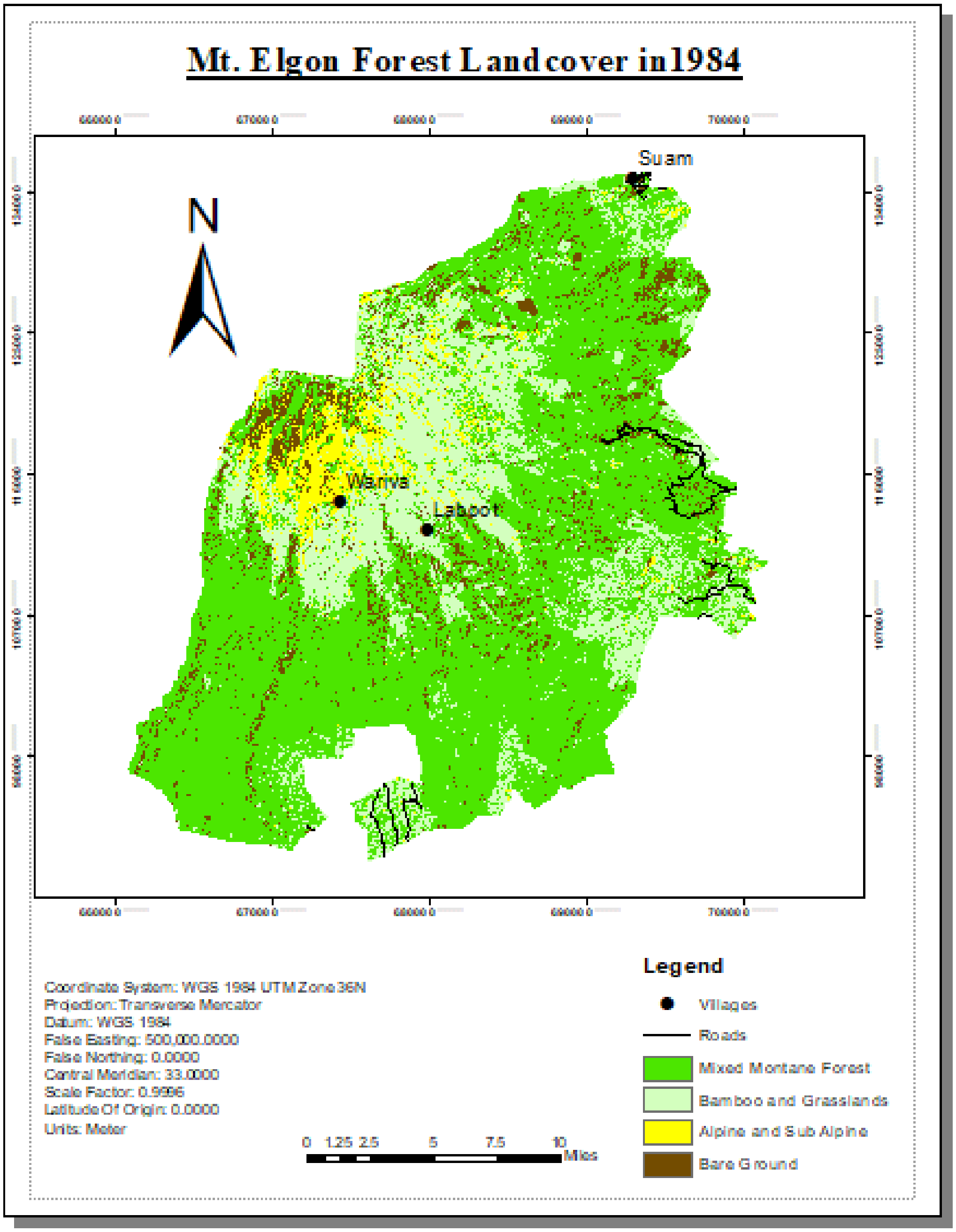

Figure 5.1: Landcover map of Mt. Elgon Forest in 1984

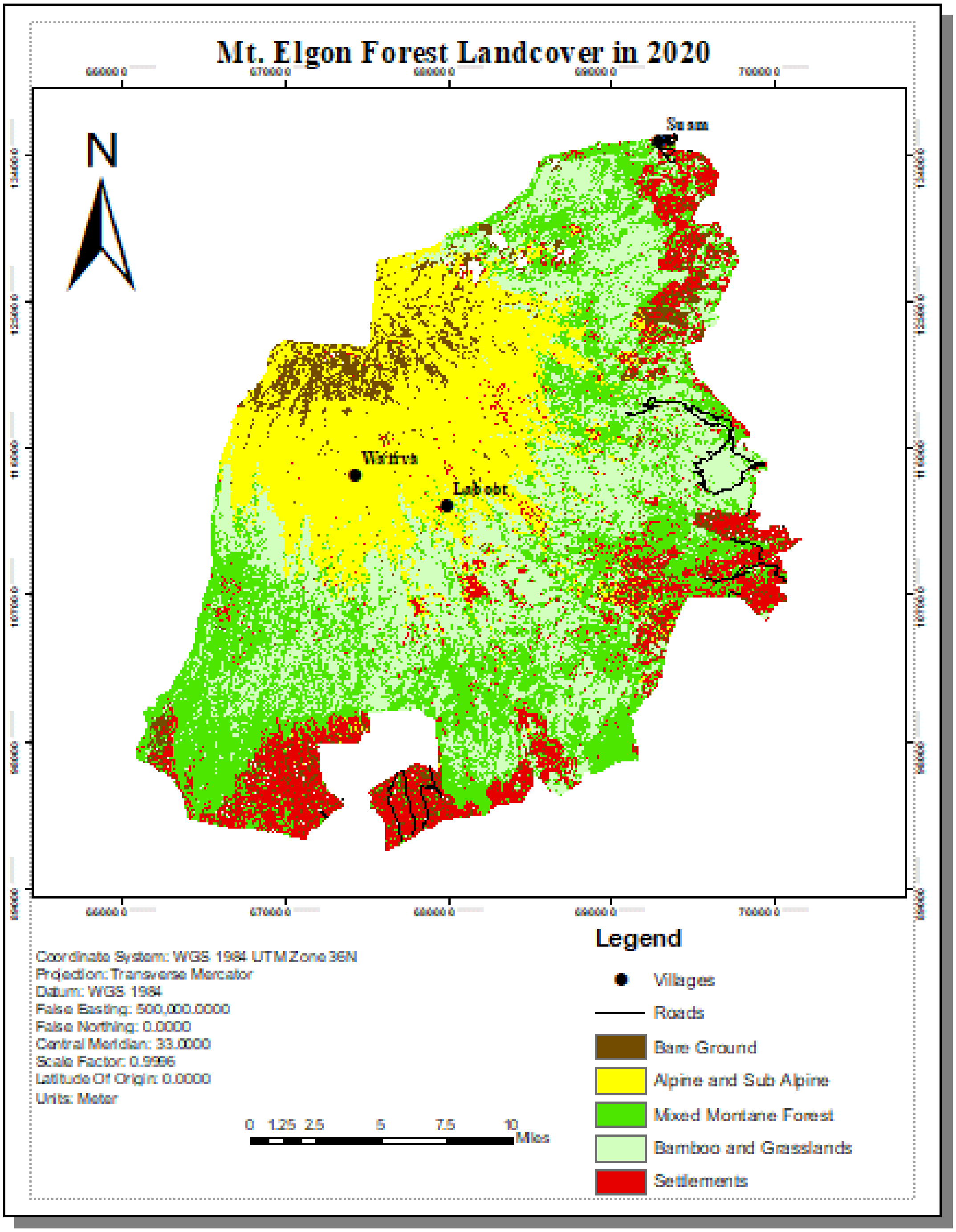

Figure 5.2: Landcover map of Mt. Elgon Forest in 2020

5.2 Recommendations

1. Carrying out this study has demonstrated the worrying decline of the forest. A repeat of this same study should consider the use of satellite images from sensors with higher spatial resolution such as the Quickbird and Geo-Eye sensor as well as real time land cover change monitoring. High resolution images would better characterize the forest ecosystem by capturing more details.

2. The Forest Conservation and Management Act (2016) ought to be fully implemented to protect Mt. Elgon forest from future excisions. The pending proposed excisions tabled by legislators should be revoked and new resettlement plans devised. Funding should be increased by the government and non-governmental sectors to facilitate research into different levels of the forest degradation. As a policy recommendation, Forest management studies should be made a compulsory subject in school curriculum as well as mainstreamed in all professional areas.

3. Studies should be done to assess the status and number of the forest trees species in Mt. Elgon forest using geospatial technologies. There is very little data regarding the status of the forest. Sufficient data ought to be generated through research to support policy and decision-making.

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APPENDICES

Appendix I: Extent of degradation from a point in Kaberwa

Appendix II: Extent of degradation in Kaberwa