Analyzing degradation of Southern Mau forest using GIS and remote sensing.

BY

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This is a project submitted to the Department of Geospatial and Space technology, in partial fulfillment of the requirement for the award of the degree of:

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DECLARATION.

The following masters' project report is prepared by Me. It is my original work and has not been presented for a degree in any other university.

NAME	SIGNATURE	DATE
GEORGE NJOROGE NDUNGU		27/07/2011

Supervisor declaration.

This project has been submitted for examination with our approval as university supervisors.

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ABSTRACT.

Forest Canopy density is a major factor in evaluation of forest status and is an important indicator of possible management interventions. Forest canopy cover, also known as canopy coverage or crown cover, is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns. Conventional remote sensing methods assess the forest status based on qualitative data analysis. Forest Canopy Density Model is one of the useful methods to detect and estimate the canopy density over large area in a time and cost effective manner. This model requires very less ground truths, just for accuracy check.

The main aim of the project is to assess the viability of using GIS and remote sensing in analyzing the forest depletion. Mainly to assess the effectiveness of analyzing forest cover with emphasis on Southern Mau forest.

Landsat maps 4 to 5 Thematic Mapper ™ and Enhanced Thematic Mapper (+ETM) with a mid resolution of 30 meters was selected, the maps were acquired from an authorized site (http://glovis.usgs.gov) this was due to its easy access and its swath width of 150km which covered the whole area.

Satellite images from the 28th Jan 1986, 27th Jan 2000 and 30th Jan 2010 were used and analyzed using the World Reference Systems (WRS) index path 169 row 060.
There were five main steps in the methodology of southern Mau canopy analysis which involve image pre-processing and land cover classification using Erdas software. A post classification was carried out using arcGIS and land cover detection and analysis using Erdas. Final maps and tables were done using arcGIS and Ms Excel.
The results indicate that the percentage depletion from 1986-2000 is about 7.55% and 32.71 between 1986 and 2010.

In conclusion GIS and remote sensing are important tools in assessing the depletion of forests. Further assessment indicates that application of the GIS and remote sensing can be used in forest management and monitoring systems.

DEDICATION.

This project is dedicated to my wife Regina and my children whom despite taking all the time I should spend with them were understanding and supportive.

ACKNOWLEDGEMT.

With all greatness my thanks to my committed and dedicated supervisor Mrs. Tabitha Njoroge who guided me through the stages of writing a project. Thanks for her patience and goodwill and may God bless you abundantly.

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AVI	Advance vegetable index.
BI	Bare soil
+ETM	Enhanced thematic map
FCC	False color composition.
FCD	Forest canopy density
GIS	Geographical information systems.
GPS	Global positioning system
IDW	Inverse distance weighted
IVI	important value index
LAI	Leaf area index
NDVI	Normalized difference value index
NR	Near Infra red
R	Reflectance
RS	Remote sensing
TI	Thermal index
TM	Thematic map.
SI	Shadow
VI	Vegetation index.
WGS	World reference systems.

CHAPTER 1

1.0 INTRODUCTION.

1.1 KENYA FOREST'S AND ECONOMIC AND SOCIAL PILLARS.

Forests cover only about 1.7 per cent of Kenya's land area, yet they provide crucial direct and indirect goods and services to its people and make a significant contribution to the national economy. About 70 per cent of Kenya's domestic energy comes from wood. In addition to providing a variety of wood and non-timber products, Kenya's forests provide the following ecosystem services: They trap and store rain water; regulate river flows and prevent flooding; help recharge ground-water tables; improve soil fertility; reduce soil erosion and sediment loads in river water; help regulate local climate conditions; and act as carbon reservoirs and sinks. Many forests serve as essential wildlife habitats, and are traditionally important for cultural ceremonies and as sacred sites to local communities. It is estimated that 530 000 forest-adjacent households (which amount to 2.9 million people living within five kilometers from forests) derive direct benefits from indigenous closed-canopy forests. This amounts to about eight per cent of Kenya's population. Estimates indicate that in some areas, the forestry sector contributes about 70 per cent of the cash income of forest adjacent households (Wass 1995). Forests play a critical role as water catchments. In addition to retaining and filtering water for human uses, forests contribute to the availability of water for hydro power, which supplies Kenya with close to 60 per cent of its electricity generation. Forests also help to reduce siltation in hydroelectric impoundments. There are different categories of forest in Kenya:-

State plantation forests: Large-scale industrial plantations, usually of exotic monocultures. Forest plantation coverage in Kenya had attained a peak of 165,000 ha by 1988, thereafter reduced by 45,000 ha through excisions of the estates in the late 90s and early 2000s. Today, 120,000 ha of forest plantation estates exist, of which an estimated 100,000 ha is stocked.

State indigenous forests:

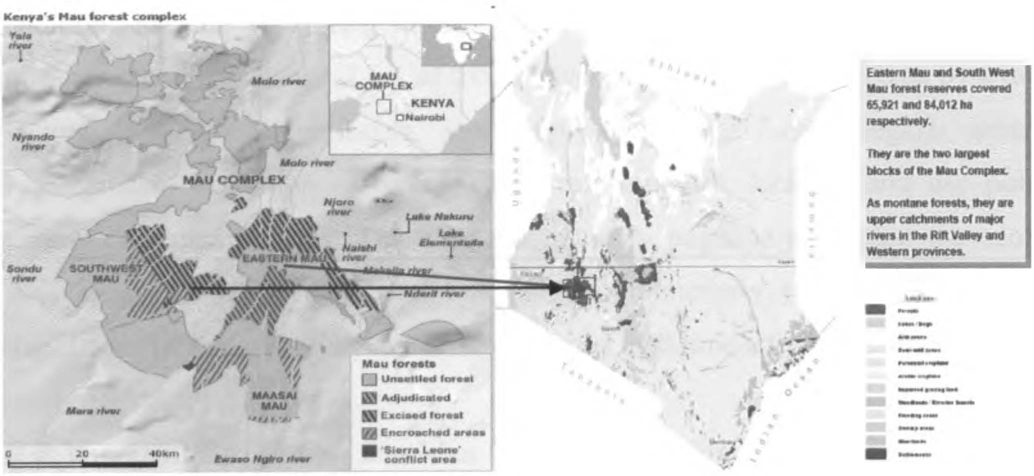
Gazetted reserves of naturally occurring indigenous forest on state land. Closed-canopy indigenous forests of variable quality cover 1.2 million ha. These forests contain 50% of Kenya's tree species, 40% of the larger mammals and 30% of the birds.

Farm forests and private forest:
There is no current estimate on the total size of farm forests, but statistics from KFS suggest that 690,000 to 800,000 ha of land is planted with *Eucalyptus* trees in western Kenya alone.

Local authority land (trust land): Dry land forests and other woodlands or scrublands on public land are usually under the control of the local authority. The Forest Act 2005 recognizes and promotes these areas as productive forest areas on which community and micro-enterprise should be supported, to contribute to people's livelihoods by providing fuel wood, charcoal, bee habitat and fodder.

1.2 MAU FOREST COMPLEX.

Location of Mau forest.



Source: Mau forest ecosystem page 25 and 26.

Fig. 1 Location of Mau forest.

The map above shows the location of the Mau forest and the areas that have been affected as a result of deforestation. As shown it shows that there is a high depletion level of east Mau and part of south west Mau due to high population growth which is usually exponential. The growth of small towns and the political handouts led to the high level of depletion.

The Mau Complex, the largest forest of Kenya, covers some 452, 007ha gazetted before the incision of 2001 which reduced the gazetted land to 416, 542 ha. It lies between 2,000 m and 2,600 m above the sea level, on the Western slope of the Mau Escarpment, and is situated approximately 250 km from Nairobi and border Kericho to the West, Nakuru to the North and Narok to the South. It comprises South West Mau, East Mau, Transmara, Mau Narok, Maasai Mau, Western Mau and Southern Mau. These seven forest blocks area merge to form the larger Mau forest Complex. The Mau Forest Complex forms the largest forest block in the country and forms the largest of the five “water towers” of Kenya., and the largest single block of closed-canopy forest in East Africa. Our natural environment not only provides us with the basic goods needed for sustenance, such as water, food, and fibre, but it also purifies the air and water, produces healthy soils, cycles nutrients, and regulates the climate. The forests are an important part of the water flow regulation, flood mitigation, water storage, ground water recharge, water purification, micro-climate regulation, and reduced soil erosion and siltation. The forest also provides other major environmental services, including nutrient cycling and soil formation. In addition, its role in storing carbon makes the Mau Forest globally important for mitigating climate change. Loss of forest cover in Kenya has been driven by a number of factors including: degradation, settlement (both legal and illegal), urbanization, unsustainable extraction of timber and forest products, lack of land use policy, and corruption, among others. This loss has not only negatively affected the ecological / ecosystems values of the forest but has also immensely contributed to diminishing livelihoods of many Kenyans caused by reduced land productivity, famine and drought.

It is important also to note that Mau forest is at its climax community with the highest primary productivity and maximum biomass. The degeneration of the Mau forest not only interferes with the ecological set up but it also influences the habitat diversity and species diversity. It also leads to either migration of the different species or alternatively adaptation to the new environment. This leads to the process of speciation or the extinct of some species. Beyond habitation for flora and fauna, it also houses the Agiek community who are hunters and gatherers. Therefore the interruption of the Mau forest leads to devastating effect on ecological complexity.

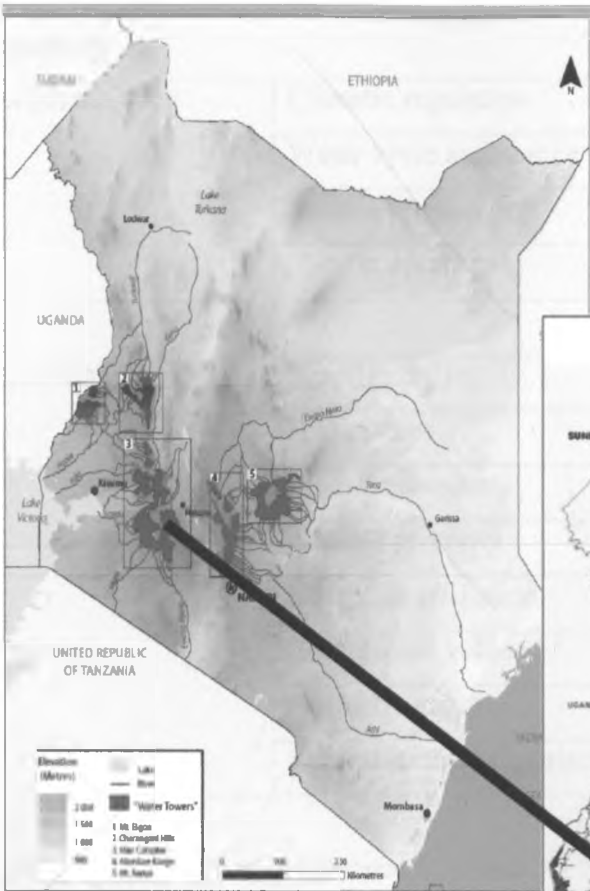
Continued destruction of the forests is leading to a water crisis: perennial rivers are becoming seasonal; storm flow and downstream flooding are increasing, in some places the aquifer has dropped by 100 meters while wells and springs are drying up. In addition there are global concerns resulting from loss of biodiversity, and increased carbon dioxide emissions as a result of forest cover loss. Poor soil and water resources conservation practices of the deforested land is causing soil erosion and decreasing crop yields in other areas as a result of change in humidity level/ climate change.
The estimated potential hydropower generation in the Mau Complex catchments is approx. 535 MW, representing 41 percent of the current total installed electricity

generation capacity in Kenya. In addition, the growing geothermal potential in the area is directly dependent on groundwater. If the water table declines, the geothermal potential diminishes correspondingly. Many of the high potential geothermal sites are around the Mau.

I.2.1 BIO- DIVERSITY OF THE MAU FOREST.

Mau forest has high bio diversity as a result of its complex nature as a Climax community. The diversity manifested by the countless kinds of genetic materials, varied species and ecosystem types has enormous value. The variety of distinct micro organisms, plant, animals and habitats can influence the productivity and services derived from the ecosystems. Biodiversity provides direct economic benefits in term of food, medicine and industrial raw materials, and supplies the functional ingredients for natural ecosystems to provide an array of essential services to man (photosynthesis, regulation of absorption and breakdown of the hydrologic cycle and climate, absorption and breakdown of pollutants and many others). Plants and animals, like human beings, have an established right to existence; therefore we should be concerned with their value and conserve their Diversity (Smitinand, 1994)

The map below shows the distribution of the state forests in Kenya. According to official statistics, the forest cover in Kenya has reduced drastically over recent decades and only 1.7% of Kenya is officially under forest cover. This figure is an estimate and includes only closed-canopy forest - forest of which the canopy covers at least 40% of the area.



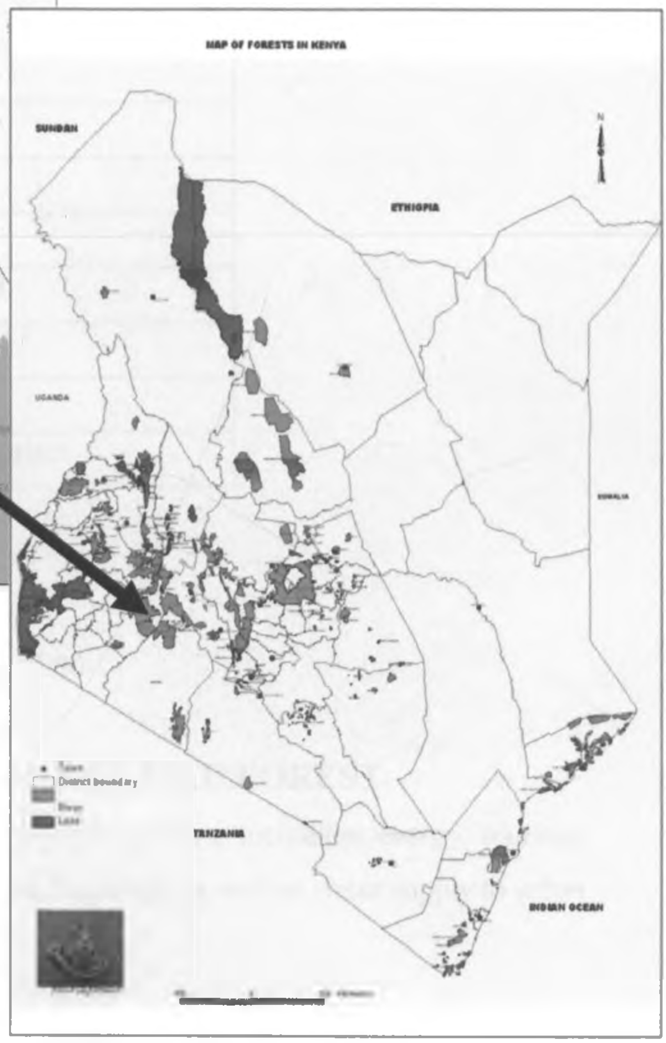


Fig.2 Drainage system supported by Mau forest.

Source: Session paper on rehabilitation of Mau forest 2010

Fig3: Distribution of the forest Kenya.

Ecosystem service category	Type of service
Regulating	Climatic regulation
	Water cycle and source
	Reduce erosion
	Habitat diversity
Provisions	Food
	Wood and fibre
	Fresh water
	Medicinal value
	Genetic diversity
Cultural	Religious affiliation
	Educational value
	Aesthetic value
	Recreational and tourism

Table 1: Summary of importance of forest.

Sources: Rehabilitation of Mau Forest page 19-20

1.3 ECOMOMIC SIGNIFICANT OF THE MAU FOREST.

The Mau Forests Complex supports key economic sectors, including: energy, tourism, agriculture (cash crops, subsistence crops, and livestock) as well as water supply to urban centre and industries.

Energy

The potential of hydropower generation on rivers that predominantly have their upper catchments in the Mau Complex has been estimated at 535 megawatts (MW), a potential that represents 41% of the total current installed capacity.

Tourism

In 2007, consolidated earnings from tourism amounted to KShs 65.4 billion (US$878million). It is also a major source of employment providing at least 400,000 jobs in the formal sector and over 600,000 in the informal sector.

Agriculture: Agriculture forms the backbone of our countries economy. There is high production of pyrethrum and tea around Mau forest.

Beyond economic activities there is other importance such as acting as catchments areas of major river systems regulate the carbon cycle and the hydrological cycle, used as habitat of hunters and gatherers and some of the trees has some medicinal value.

1.3.1 THREATS TO THE MAU COMPLEX

For along time very minimal discussions and research were done on Mau forest until recently when the effect of deforestation was felt especially in the provision of water. As indicated on the Photos below it shows that there is a high demand of forest product and the depletion if not checked will be disastrous.

PHOTOGRAPHS SHOWING THE DESTRUCION OF MAU FOREST OVER TIME.

Source: Session paper on Mau forest ecosystem.

Fig: 4

These are different aerial photos showing different levels of destructions and some of the social economic influence of the destruction. In reference to the photos1-4 above there is notable destruction of forest either as a result of settlement, logging, and agriculture or for charcoal and firewood.

The pace and severity of destruction and degradation of Kenya's forests has generated increasing publicity and concern over the past two decades. The main cause of this destruction is change of land-use from forest to agriculture, and change in ownership from public to private. During the past two decades, there has been extensive encroachment as well as irregular forest land allocation, exacerbating an already serious situation.

Some of the gravest impacts noted to date are related to water:

1. A main aquifer in Nakuru area has lowered by 100 metres in 10 years;

2. The Sondu River flow is more irregular making it impossible for Sondu-Miriu hydropower plant to run near full capacity in the dry seasons; 12 Including 54% (35,301 ha) of the Eastern Mau, 27% (22,797 ha) of South West Mau and 100% (902 ha) of Molo Forest reserve.

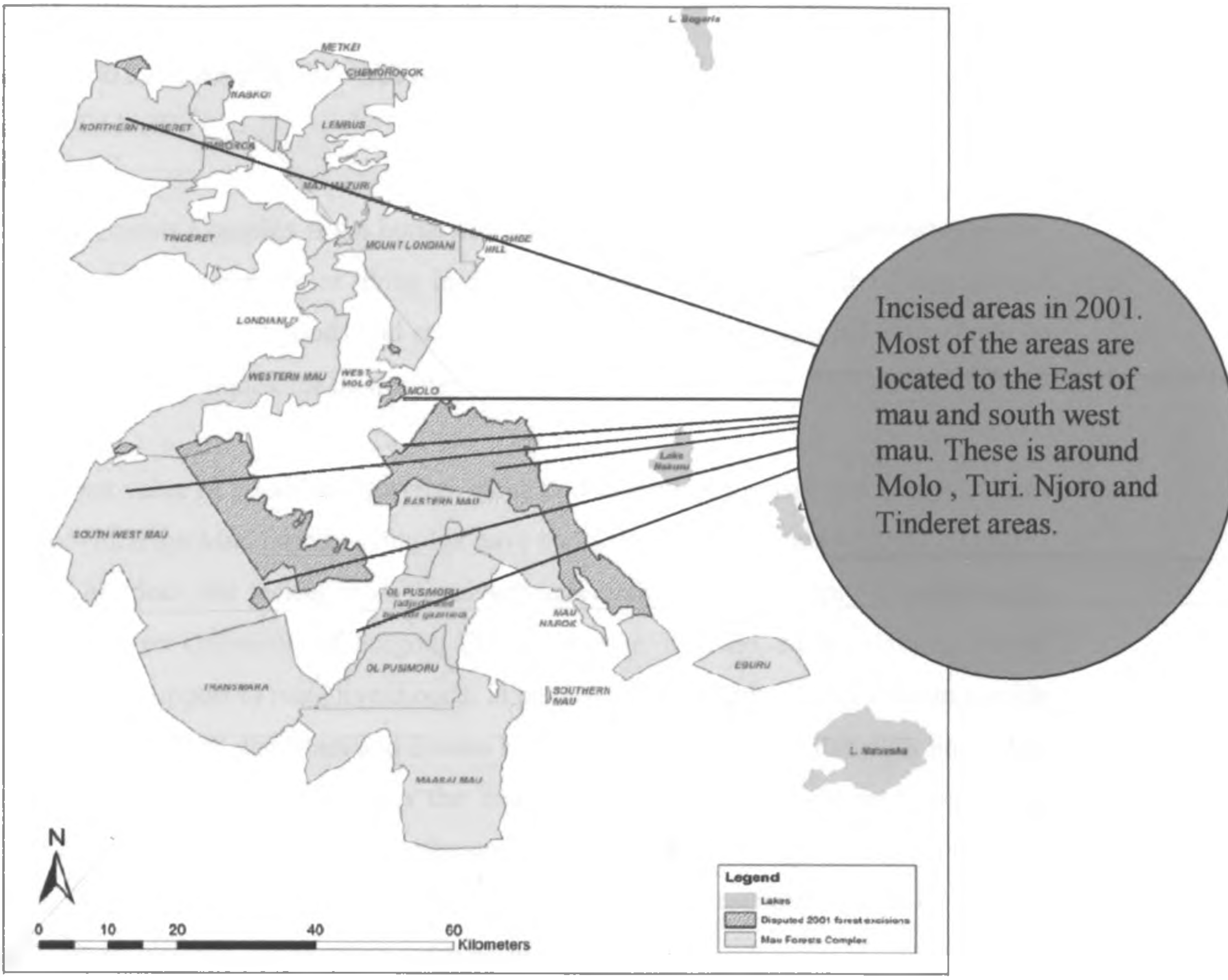
3. The four perennial rivers feeding Lake Nakuru are now seasonal;

4. The Mara River level in the dry season is very low, threatening the river-dependant wildlife in the Maasai Mara and Serengeti ecosystems; and,

5. Many streams in the Mau Forests Complex have their flows changed significantly or have driedup.

1.3.3 DEFORESTATION TREND IN MAU FOREST BETWEEN 1973- 2009.

Overall, as at 2009, the section of the Mau forest falling south of Londiani stood at 178,974 Ha - down from 226,064 Ha in 2000, 249,420 Ha in 1986 and 254,069 Ha in 1973. The total deforested land between 2000 and 2009 was 53,376 Ha, up from 28,828 Ha that was deforested between 1986 and 2000 and 10,635 Ha deforested between 1973-1986.



The Mau Forests Complex is critical to Kenya from two perspectives:

Fig 5 showing the incision of 2001.

The disputed incision is mainly in Eastern Mau and South west Mau. The red color indicates the areas that were degazetted by the government and given to private developers. The political polarization and ignorance and selfishness led to big chunks of land deforested and replaced either by tree crops such as tea or pyrethrum and subsistence farming.

1.3.4 NATURAL ASSET OF NATIONAL AND INTERNATIONAL IMPORTANCE.

The Mau Forests Complex is the home of a minority group of indigenous forest dwellers, the Ogiek. Many communities living in the immediate surrounding of the forest depend extensively on the forest goods and services. Urban dwellers also depend extensively on the Mau Forests Complex for their water supply.

The market value of goods and services generated in the tea, tourism and energy sectors alone to which the Mau Forests Complex have contributed, is in excess of Kshs 20 billion a year. This does not reflect provisional services such as water supply to urban areas (Bomet, Egerton University, Elburgon, Eldama Ravine, Kericho, Molo, Nakuru, Narok, and Njoro) or support to rural livelihoods, in particular in the Lake Victoria basin outside the tea growing areas, the Mara and Ewaso Ngiro basins. This figure also does not reflect potential economic development in the catchments of the Mau Forests Complex, in particular in the energy sector. The estimated potential hydropower generation in the Mau Forests Complex catchments is approx. 535 megawatts, representing 47 per cent of the total installed electricity generation capacity in Kenya.

Looking forward, environmental stability and secured provision of ecological goods and services, such as those provided by the Mau Forests Complex, will remain essential to attain sustainable development in Kenya. They are cross-cutting, underlying requirements to achieve the Vision 2030 - Kenya's development blueprint aiming at making the country a newly industrializing middle income nation, providing high quality of life for all the citizens in a secure and healthy environment.

1.4. STATEMENT OF THE PROBLEM

Depletion of major forest in Kenya has become an issue. The ever increasing demand for forest products and the exponential growth of population has lead to increasingly growth of forest depletion. The need for efficient monitoring and management of forest has lead to major discoveries in software's and hardware's that can be used in assessing and monitoring of canopy cover of forests. The chain effect of depletion of forest has necessitated the use of GIS and remote sensing in analyzing the forest cover. Analysing of forest canopy density is an important parameter in the planning and implementation of measures required to reduce the depletion.

1.5 OBJECTIVES

1.5.1 MAIN OBJECTIVES

Overall aim of this research was to explore the potential and constraints of the application of Geographic Information System (GIS) and remote sensing in analysis the level of forest degradation.

1.5.2 SPECIFIC OBJECTIVES.

(i) Assess the applications of GIS and remote sensing in forestry depletion in Mau forest with specific emphasis on southern Mau.

(ii) Analyzing the canopy cover of the Mau forest using GIS in Mau forest with specific emphasis on southern Mau.

iii. To investigate the extent at which the forest has been depleted using the landsat image maps of southern Mau from 1986- 2010 at interval of 10 years.

1.6 HYPOTHESES AND JUSTIFICATIONS.

GIS and remote sensing are tools to be used in assessing the degradation of forests. The analysis of satellites maps will give data on the extent to which the degradation has taken place. Gis and remote sensing are perfect in analyzing the species diversity, canopy cover and foliage. This can be done using the coloration difference on the green matter of the plants in cohort with analysis of the electromagnetic bands.

The forest is recovering from the bare patches into a more complex cover. This can be assessed by comparing the vegetation cover in the reforested areas and areas with indigenous vegetation. This can be identified through analysis of canopies, sizes of leaves and maturity of the trees through analyzing the diameter and sizes using clinometers to estimate the angles.

1.7 SCOPE AND LIMITATION.

Scope:

Mau forest is such a vast forest with very complex ecosystems. The scope of the study will be mainly on analyzing the canopy level by using NDVI to assess the patches within the Southern Mau forest. This will allow knowing whether the density of the forest has been interfered with especially when comparing the satellite images of 1986, 2000 and 2010. The analysis of the three satellite images to assess the change detection of the southern Mau forest.

Limitations.

As mentioned above Mau is complex and vast and this may not allow a thorough research which may minimize the representation of the whole forest. In some situations analyzing the canopy cover using arcGIS/EDRAS may be influenced by the quality of the landsat image depending on the time it was taken, the weather condition and the technology used. The changing types of trees especially the planted types may not give the same cover as the indigenous and may course some anomalies when analyzing the forage. Another limitation is the acquisition of high resolution satellite images which provide quality analysis. This leads to tedious processes of correction of the images.

1.8 REPORT ORGANISATION.

For this project, I carried out a comprehensive review of the theory, methods, and practice of existing forest monitoring and management system in respect to the Mau forest in Kenya. To address the objectives and hypotheses that I stated, I performed a review of the scientific and technical literature on forest and ecosystem management and monitoring, as well as on remote sensing technologies and their forestry applications as well as the GIS application and use of software's and hardware's. There is a high level of reference to literature review on a wide range of documents and reports from forest management, monitoring, and remote sensing programs.

This study of forest monitoring through remote sensing and GIS is not intended to be exhaustive; rather, the objective is to provide a brief overview of monitoring principles and practice and to highlight opportunities for that are available in analyzing the forest depletion.

The project involves doing some literature review of works that have been done by other scholars on forest management using GIS and remote sensing.

Some of the technical areas involved the process of data acquisition and processing through software's such as Arc GIS/ EDRAS.

Within the scope of the project there is also the results and analysis which gives a guideline on the trend and which tends to answer the hypothesis and my research questions. A thorough analysis of Southern Mau which is one of the most endangered areas has been analyzed using arcGIS and Edras software's. The canopy cover of Southern Mau is analyzed and the processes of capturing of the images through USGS were carried out using pathways 169 and low 060 landsat scene. Data processing was done using the mentioned software's and the results on deforestation rate were realized.

CHAPTER 2

2.0 LITERATURE REVIEW.

2.1 IMPORTANCE OF CLOSED CANAOPY.

With a high leaf area index, tropical forests are able to intercept all the water falling on the forest canopy and slowly channel the same to the forest floor and eventually to the ground aquifers. Natural forest reduces the erosive impact of rainfall. Leaf litter prevents erosion and forest soils provide the sponge for the entrapment of water. It has become clear in recent years that the continuous provision of water is directly related to the existence of the natural forest. Once the forest has gone, water infiltration is greatly reduced and aquifer level lowered causing springs to dry, and rivers to become highly seasonal. Increased runoff and storm flow frequency and amplitude causes soil erosion and downstream flooding. The social impacts are water shortage, infrastructural damage, poverty, ill health, conflict and regional insecurity. Forests trap radiation in their multi-layered canopies resulting in a net warming of the ecosystem. This warming generates more thermal turbulence above the forest, favoring the formation of clouds and rainfall over forest areas. During the day, transpiration of water through plants into the atmosphere cools the forest environment and increases air humidity in the near-surface atmospheric layer. Evapo-transpiration determines the availability of water vapour for the formation of clouds. Large trees gain access to soil water through their roots year-round, thus maintaining evapo-transpiration (hence favouring cloud formation) through the dry season.

Biodiversity has become increasingly imperative during the last decade (Wilson, 1988). Sustainable forest management is generally accepted as the only way to maintain this resource for the present and the future generation. In order to design meaningful biodiversity conservation strategies, comprehensive information on the distribution of species, as well as information on changes in distribution with time, is required. Biodiversity is defined “as the total variety of life and the major features of biodiversity can be distinguished into at least three conventional divisions, such as genetic diversity, species or taxonomic diversity, and ecosystem diversity" (Acharya, 1999).

The pace and severity of destruction and degradation of Kenya's forests has generated increasing publicity and concern over the past two decades.

The main cause of this destruction is change of land-use from forest to agriculture, and change in ownership from public to private. During the past two decades, there has been extensive encroachment as well as irregular forest land allocation, exacerbating an already serious situation. The Mau Complex is a particularly degraded catchments area in Kenya. Despite its critical role in sustaining current economic development, the Mau has been affected by widespread ill-planned settlements, encroachments and illegal extraction of forest resources. De-gazetting of forest reserves (excisions) and continuous widespread encroachments have led to the destruction of over 116,000 ha over the last two decades, representing over 27% of the Mau. Out of the approximately 416,542 ha of the protected forests, 61,587 ha were excised in 2001.

2.2 GIS TECHNOLOGY IN FOREST MANAGEMENT.

GIS Definitions

Various definitions of GIS have evolved in different areas and disciplines (Maguire *et al.* 1991) so it is difficult to select one definition that suits all the purposes and concepts of GIS applicable to this project. From the definitions in some people see GIS as a toolbox that has a number of different roles and capabilities, while others view GIS as a decision-support system for policy making, planning and management (Apan 1999; Maguire *et al.* 1991). The following definition was developed by consensus among 30 GIS specialists from various disciplines (Durker and Kjerne 1989, cited in Chrisman 2002 p.12).

"GIS is a system of hardware, software, data, people, organization, and institutional arrangement for collecting, storing, analysing, and disseminating information above areas of the earth."

"a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes" (Burrough and McDonnell 1998 p. 11).

"an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working /analysis with the data" (Star and Estes 1990 p. 2-3).

Geographical Information Systems (GIS) is an information technology that has been used in public policy-making for environmental and forest planning and decision-making over the past two decades (Bassole *et al.* 2001). GIS and related technologies provide foresters with powerful tools for record keeping, analysis and decision making. GIS can be established to provide crucial information about resources and can make planning and management of resources easier, e.g. recording and updating resource inventories, harvest estimation and planning, ecosystem management, and landscape and habitat planning. Nowadays, with improved access to computers and modern technologies, GIS is becoming increasingly popular for resource management.

Since foresters have to deal with numerous objectives from a single patch of forest (e.g., annual allowable cut, maintenance of biodiversity, conservation of soil and water) a wide variety of spatial information is required and sources of reliable data are a prerequisite for developing a GIS in forest management.

Reasons for the increasing trends towards GIS use by forestry professionals.

- Reduced cost of computer hardware and software
- Technological advances in computer hardware and software
- User friendliness of software
- Availability of trained manpower
- Save time and money, although initial set up cost may be higher
- Trustworthiness of technology

• Ease to update (forest is ever-changing).

(Ammerman 1997; Bettinger and Wing 2004; Jordan 1998; Korte 2001; Warnecke *et al.* 2002)

Efforts are now being made to upgrade these forest administration information systems and improve their efficiency, in order to implement an e-forestry management capability. Under these circumstances, positioning a forest geographical information system as one important element to accelerate the realization of e-forestly management is being contemplated.

2.3 GIS APPLICATION.

GIS has emerged as a very powerful tool in the management of spatial information and has become a topic of intense interest for many academic disciplines, government organizations, as well as commercial enterprises. Although GIS has existed since the 1960s (Delaney 1999), its applications have grown phenomenally during the last two decades (Apan 1999). The development of cheap and powerful personal computers and user friendly, readily available GIS software has increased the use of GIS technologies in almost every field (Apan 1999; Berry 1994; Burrough and McDonnell 1998; Chrisman 1997). Davis (2001) reports that GIS is a highly dynamic field, growing as the same very rapid pace as the change in information technology. Sound understanding of the capabilities of GIS by users, managers, and decision makers is crucial to the appropriate and effective use of the technology (Aronoff 1989).

2.3.1 BASIC COMPONENTS OF GIS

Maguire *et al.* (1991) state that the four main components of GIS are software, hardware, data and people, whereas ESRI (2001) includes 'method' as a fifth component. All the components need to be in balance, if the system is to function satisfactorily.

Data.

Types of data used in GIS.

GIS data can be categorized into three main sub-division namely;

a) Spatial

b) Temporal

c) Thematic.

- Spatial: The spatial dimension of data can be regarded as various character strings or symbols that convey to the user information about the location of the feature being observed

- Temporal: The temporal dimension provides a record of when the data were collected (or the record to which data applies)

- Thematic/attribute: The thematic dimension shows the characteristic of a real world feature to which the data refer. In GIS, thematic data are often referred as non-spatial, or attribute, data.

The above data types can only be represented in two format vector and raster as explain below.

Vector data

In the vector data model the world is represented as a mosaic of interconnecting lines and points representing the locations and boundaries of geographical entities (Aronoff 1989). In vector data simple points, line and polygon entities are essentially static representation of phenomena in terms of *X, Y* coordinates and supposed to be unchanging and do not contain information about temporal and spatial variability (Burrough and McDonnell 1998 p. 22). Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as forest stands and river catchments, can be stored as a closed loop of coordinates. The vector model is very useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for services (Davis 2001).

Raster data

The raster (or grid-cell) data model has developed from aerial and satellite-imaging technology, which represents geographical objects as grid-cell structures known as pixels. The location of geographic objects or conditions is defined by the row and column position of the cells they occupy. The area of each cell defines a spatial resolution [illegible] distributed cells, each of which can have a different value (Aronoff 1989). Both vector and raster data models have their merits and limitations, which are summarized in Table below.

Table 2. Relative merits and limitations of raster and vector data models table.

Raster data model	Vector data model
Limitations • spatial inaccuracies are common • less compact data structures that data comparison techniques can often overcome this problem • topological relationships are more difficult to represent • output of graphics is less aesthetically pleasing because boundaries tend to have blocky appearance rather than the smooth line of hand-drawn maps.	Limitations • more complex data structure than the simple raster • overlay operations are more difficult to implement • the representation of high spatial variability is inefficient • manipulation and enhancement of digital images cannot be effectively done in the vector domain.

Tools.

GIS tools can be categorized into software's and hardware's. And both are evolving very fast.

Software refers to computer programs that provide the functions and tools needed to store, analyze, and display geographic information. GIS vendors often advertise their products with special features (Chang 2002) and different GIS software packages can vary widely in cost, functionality and user friendliness (Delaney 1999). A wide range of GIS programs have been used by forestry and natural resource management professionals (Bettinger and Wing 2004). The selection of a

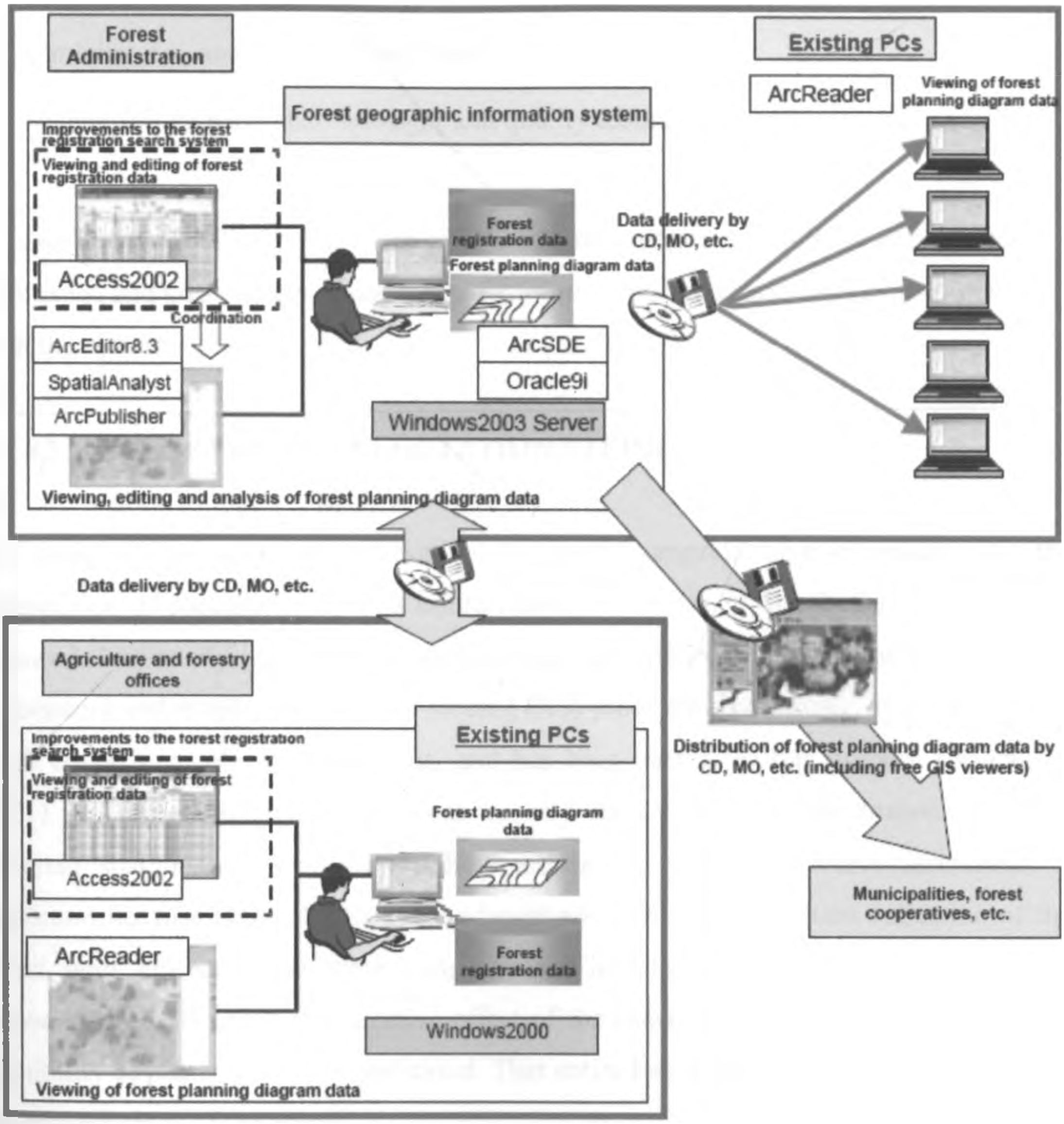
GIS software package for a particular project is usually based on criteria such as price, database availability and types, and the capability and flexibility of the software (Bettinger and Wing 2004).

Hardware refers to the computer components on which a GIS operates. The central processing unit (CPU) is the core part of computer hardware that performs all the data processing and analysis tasks. Today, GIS software runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations (Lo and Yeung 2002).

NB. The declining cost and increasing power of computer hardware made GIS affordable by many organizations.

The flow chart below shows a summary of software's and hardware's used in forest management and monitoring system

Fig 6. summary of software's and hardware's used in forest management systems



Manpower

GIS technology is of very limited value without skilled people to manage the system and develop plans for applying it to real-world problems (Congalton and Green 1992; Davis 2001). GIS users range from technical specialists who design and maintain the system, to those who use it to help them perform their everyday work. Juppenlatz and Tian (1996, p. 46) Different human resource categories required for GIS technology:

• Operational staff: end-user, cartographer, data capturer, and potential user

• Technical professional staff: analyst, system administrator, programmer, database administrator, and super-operator, and

• Management personnel: manager and quality assurance coordinator.

Lo and Yeung (2002) classified GIS users into three categories – GIS viewers, general GIS users, and GIS experts – based on their information needs and the way they interact with the system.

2.4 REMOTE SENSING IN VEGETATION STUDIES

For design of meaningful conservation strategies, comprehensive information on the distribution of species, as well as information on changes in distribution with time, is required. It is nearly impossible to acquire such information purely on the basis of field assessment and monitoring. Remote sensing (RS) provides a systematic, synoptic view of earth cover at regular time intervals, and has been useful for this purpose (Nagendra, 2001). The integration of these tools can increase the accuracy of forest analysis at different spatial scale. The use of these techniques in forest resource assessment is important because they offer us some advantages such as: information collection of the forest with low cost, few time consume and less human resources. However it is important to think about the negative effect of the shadow in that type of relief and the possibility of presence of haze and cloud. That entire factor makes a negative influence in the real accuracy of the work.

For the studies of species distribution using RS patterns researcher are using different ways according to their research. These ways may be categorized into three types:
1. Direct mapping of individual plants or associations of single species in relatively large, spatially continuous units.
2. Technique involves habitat mapping using remote sensed data and predictions of Species distribution based on habitat requirement.

3. Establishment of direct relationships between spectral values recorded from remote sensors and species distribution patterns recorded from field observation may assist in assessing species diversity.

Spatial forest structure can be quantified from measures of the composition and structure of landscape patches mapped from element obtained by remote sensing. For example, from classification forest type, leaf area index (LAI), or other defined elements of the surface, patch relationships that affect landscape dynamics, i.e., diversity, complexity, association and connectivity can be calculated. The variety and relative abundance of patch type are measures of composition and include patch richness, patch diversity and diversity index (Franklin, 1994). The purpose of this chapter is to review some important concepts of how to assess and monitor forest vegetation with remote sensing (RS).

DATA SOURCES

In order to gather a series of images with the largest possible time span, it is recommended to focus on the ones collected by the Landsat satellites first the MSS starting in 1972 and then the Thematic Mapper (TM) and finally Enhanced Thematic Mapper (ETM+). This combination is rarely used in published satellite time series analysis (Bruzzone and Smiths, 2002), however it remains the only one satellite system platform with wide time span. Spot image system does also has a good temporal span starting from **SPOT1** 1986 to date in **SPOT 5** (CNES, 2002). Other satellites platforms do not enjoy good temporal span and medium spatial resolution to qualify for this long term time series landuse stratification. Further data availability is limited to many satellites systems like SPOT, Quickbird, Ikonos, ASTER, among due to cost, however, Landsat satellites products are available in the public domain for the last two years for all 1973 to current date and can be downloaded free of charge via USGS Global Visualization Viewer (http://glovis.usgs.gov/ or http://glovis.usgs.gov)

With any time series satellite data acquired, one can adopt or modify any of the existing landuse stratification approaches and methods so far developed to provide time series landuse scenarios at landscape level (Lillesand & Kiefer, 1987; Sigh, 1989; Bruzzone and Smits, 2002; USGS 2001). The methods that come in the form of unsupervised and supervised image stratification can be undertaken solely on its own or with combination of other. It is on the bases of the above background that time series land use stratification protocol is formulated to select and avail basic land use stratification procedures within. The procedures represents methods, tools (software) , data (satellite images) and any form auxiliary information needed for land use stratification. The protocol will use supervised classification, under ENVI 4.7 with time series Land sat images for 1980, 1990 and 2010.modeling or machine learning systems., 2000.

Data capture and processing.

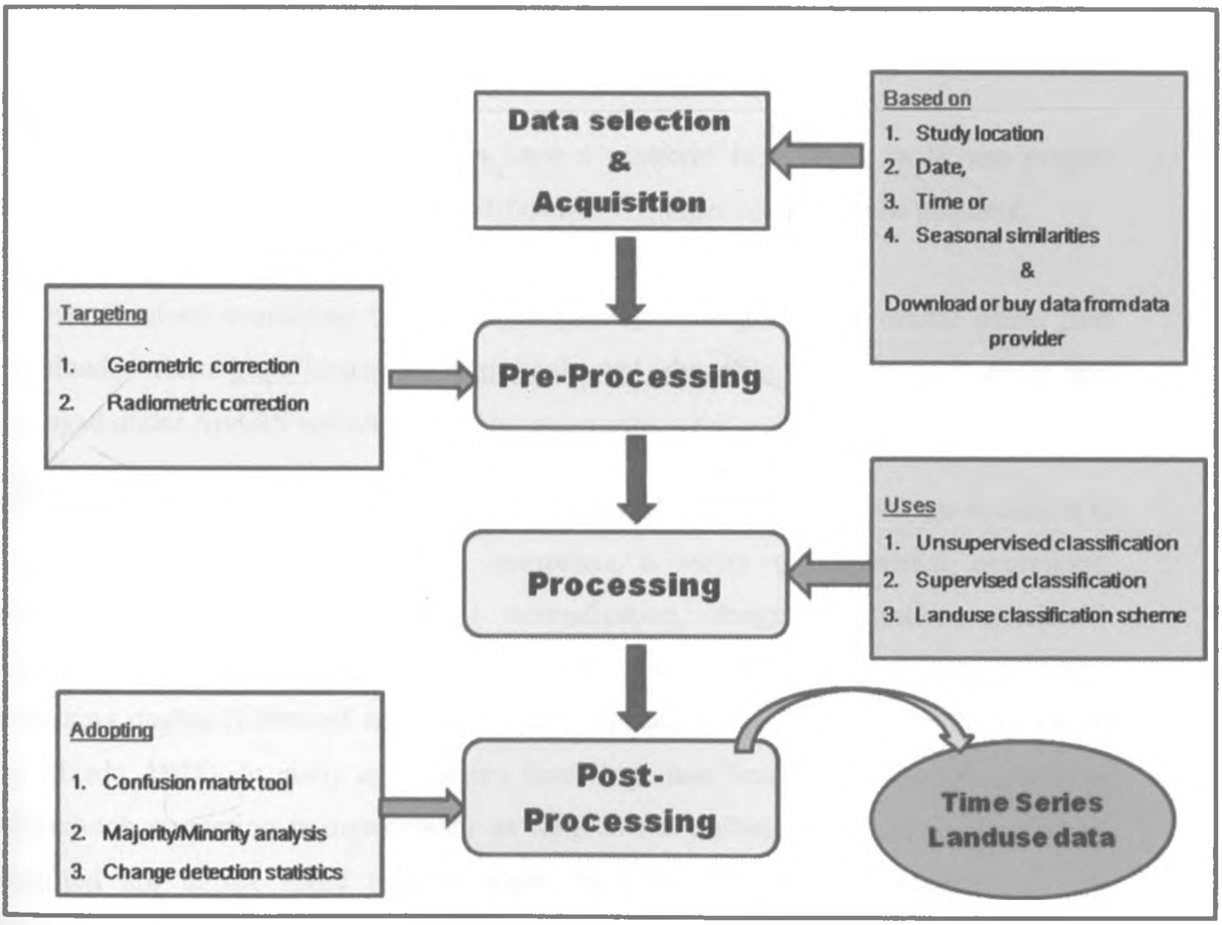


Fig 7. A summary flow chart of data acquisition and processing

Stages followed in data capture and processing.

i The overall choice of satellite platform is determined by long time span of data products already available in public domain either free or cheap to reduce the cost of satellite images for land use analysis.

ii. Satellite system was adopted due to its long history in capturing landscape data from 1972 using MSS to current date from ETM+, further, the Landsat satellite data are freely available and can be downloaded from these sites http://glovis.usgs.gov/ and http://landsat.usgs.gov/.

iii.The initial stages of data selection once a platform is isolated, is to use project boundary location or site to help in identification of images scene(s) to be acquired.

The pathways and rows are identified.

iv. This involved overlaying the country boundary to with satellite orbital shape files downloaded from http://landsat.usgs.gov/tools_wr1_shapefile.php, which is unzip and displayed under ArcGIS software.

v. Pre-processing of satellite images prior to image classification and change detection is essential. Pre-processing commonly comprises a series of sequential operations, including atmospheric correction or normalization, image registration, geometric correction, and masking (e.g., for clouds, water, irrelevant features) to impove image processing quality (Lillesand & Kiefer, 1987; Chander et al, 2010; USGS 2010; Murai and Maeda, 1978). In many applications involving classification and change detection, atmospheric correction is unnecessary as long as the training data and the data to be classified are in the same relative scale. In other circumstances, corrections are mandatory to put mutlitemporal data on the same radiometric scale in order to monitor terrestrial surfaces over time (Song et al., 2001).

vi. Geometric correction

It is included application of pre-defined models to reduce the effects of Earth rotation and application of a polynomial transformation function to correct further random and residual errors, resulting in a 'map-accurate' dataset. The parameters of this transformation function were derived from a spread of Ground Control Points (GCPs) located on asterisked topographic maps in ENVI 4.7 software and ARC GIS 10 (Use ENVI Map Menu to get all geometric correction tools). The Map Menu allows collecting several GCP for Image to Map, Image to Image registrations, where maps are scanned and geo-referenced satellite images of the same area. Most of the 2000 images were already ortho-corrected; the protocol uses these images as the source GCP for image rectification process.

vii Image Processing

Image processing is sometimes referred to as image classification. The intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or *"themes"*. This categorized data may then be used to produce thematic maps of the land cover present in an image. Normally, multispectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization (Lillesand and Kiefer, 1994). The objective of image classification is to identify and portray, as a unique gray level (or color), the features occurring in an image in terms of the object or type of land cover these features actually represent on the ground.

Viii **Image classification.** is perhaps the most important part of digital image analysis. It is very nice to have a *"pretty picture"* or an image, showing a magnitude of colors illustrating various features of the underlying terrain, but it is quite useless unless to know what the colors mean. Two main classification methods are *Supervised Classification* and *Unsupervised Classification.*

b. **Supervised classification** is a method where pixels in a dataset are clustered into classes corresponding to user-defined training classes.
c. **Unsupervised classification;** a large number of unknown pixels are divided into a number of classes based on natural groupings present in the image values. Unlike supervised classification, unsupervised classification does not require analyst-specified training data. The basic premise is that values within a given cover type should be close together in the measurement space (i.e. have similar

gray levels), whereas data in different classes should be comparatively well separated (i.e. have very different gray levels) (Lillesand and Kiefer, 1994; Acharya and Ray, 2005).

Summary of step for time for analyzing satellite images

- Selection of satellite platform with a good temporal span and cheaply available to reduce cost.
- Download satellite orbital shape file for the selected satellite systems and overlay this orbital shape with project boundary product.
- Determine with path and row of the satellite image to be downloaded from intersection of satellite orbital and project boundary
- Carry out both geometric and radiometric correction using tools available in Arc GIS Indris Kilimanjaro, ENVI or Erdas software
- Load each image at a time, use Indris Kilimanjaro/ENVI tools to capture training data for supervised classification process.
- Once capture, run maximum likelihood classification process and post process these data via combination of ENVI and ArcGIS

2.4.1 FORESTRY APPLICATION

Visual image interpretation provides a feasible means of monitoring forests. Visual image application includes tree species identification, studying harvested areas, assessment of fire, diseases and insect infestations.

The characteristics of shape, size, pattern, shadow, tone and texture in tree species identification. Individual tree species have their own characteristic crown shape and size. Some species have rounded crown, cone shaped crown and star shaped crown.

In dense stands, the arrangement of tree crown form a pattern that is distinct for many species. When trees are isolated, shadow often provides a profile of image of trees that is useful in species identification. Image tone depends on many factors such as correlated absolute tonal varies with individual tree species. Relative tones on a single image or a group of images may be of great value in delineating adjacent stands of different species. Variation of crown texture is important in species identification. Some species have a tufted appearance; others appear smooth and others billowy.

The extent to which tree species can be recognized on aerial photographs is largely dictated by the scale and quality of the image, as well as the arrangement of species on the image. The characteristics of tree forms such as crown shape and branching habit are heavily used for identification on large scale images. The interpretability of these images becomes less as the scale decreases. Eventually the characteristics of individual trees becomes so indistinct that they are replaced by overall stand characteristics in terms of image tone , texture and shadow pattern.

NB:

i. On large scales most of the characteristics of forest can be identified eg at a scale of 1; 600. Most species can be recognized on their morphological characteristics.

ii. At scale 1: 2400- 1: 3000 small and medium branches are still visible and individual characteristic can be identified unless on very dense forest.

iii. At 1: 15840 crown shape can still be determined from big tree shadows growing individually.

iv. 1:20000 individual trees cannot be identified and only the stand tone can be identified on satellite images.

Table 4 .AIR PHOTO INTEPRETATION KEY.

Characteristics	Type of tree to identify
1. Crowns compact, dense, large 2.crowns very symmetrical and very smooth, oblong or oval; trees form small portion of stand. 2. crown irregularly rounded(sometimes symmetrical) billowy, or tufted. 3. surface of crown not smooth but billowy 3. crowns rounded sometimes symmetrical, smooth surfaced 3. crown irregularly rounded or tufted	Basswood Oak Beech Yellow birch

1. Crowns small or, if large open or multiple. 6. Crown small, if large, open and irregular, revealing light-colored trunk. 7. Trunk chalk white trees tend to grow in clumps. 7. trunk light, but not white, undivided trunk reaching high into crown , generally not into crumps	 White birch aspen
6 Crown medium sized or large: trunk dark 8. Crown tufted or narrow and pointed. 9. Trunk often divided crown tufted 9.Undivided trunk, crown narrow	 Red maple Balsam poplar
8. Crowns flat topped or rounded. 10.crown medium sized, rounded, undivided trunk; branches Ascending. 10 crowns large, wide, trunk divided into big spreading Branches. 11. top of the crown appears pitted. 11.Top of the crown closed	 Ash Elm Silver maple

2.4.2 REFLECTANCE CHARACTERISTICS OF FORESTS.

When using remote sensing imagery it is always necessary to distinguish between the spectral class (based on reflectance of energy) and the information classes (based on human perception of what constitutes a community of plants) which will be used to create the patch / mosaic landscape (Franklin, 1994). The reflectance characteristic of vegetation depends on the properties of the leaves including the orientation and the structure of the leave canopy. The proportion of the radiation reflected in the different part of the spectrum depends on the leaf pigmentation, leaf thickness and composition (cell structure) and on the amount of water in the leaf tissue. In the visible portion of the spectrum, the reflection from the blue and red light is comparatively low since these portions are absorbed by the plant (mainly by chlorophyll) for photosynthesis and the vegetation reflects relatively more green light.

The reflectance in the near infrared is highest but the amount depends on the leaf development and the cell structure of the leaves. In the middle infrared the reflectance is mainly determined by free water in the result in less reflectance. They are therefore called water absorption band. When the leaves dry out, for an example during the harvest time of the crops, the plant may change the color. At this stage there is no photosynthesis, causing reflectance in the red portion of the spectrum to be higher. Also, the leave will be dry out resulting in higher reflectance in the middle infrared whereas the reflectance in the near infrared may decrease. As a result, optical RS data provide information about the type of plant and also about his health condition (Bakker, Janssen, & Weir, 2000).

Many feature types manifest combinations of digital numbers based on their inherent spectral reflectance characteristics in a remotely sensed image. Refer to graph below.

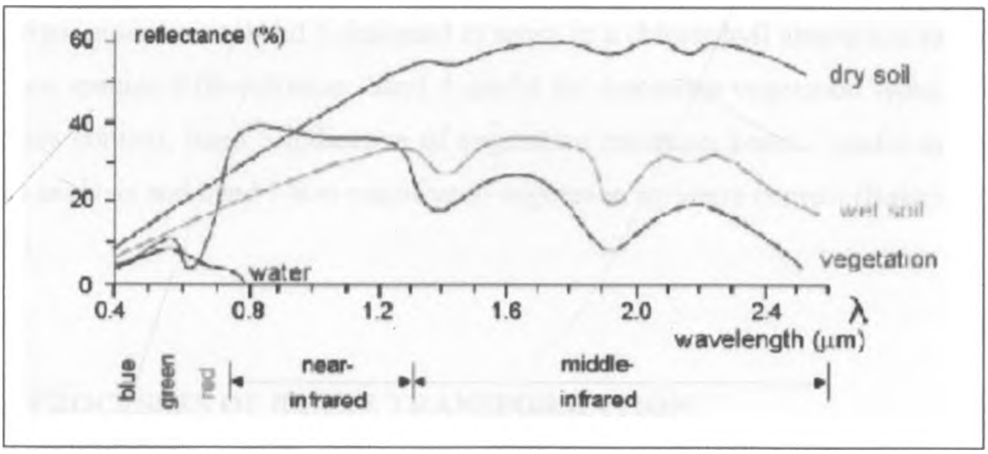


Fig 8. Reflectance level of vegetation.

Table 3. Application of wavelength radiation of vegetation.

Band	Wavelength (µm)	Principal Application
2	Green 0.52-0.60	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment.
3	Red 0.63- 0.69	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation.
4	NIR 0.76-0.90	Useful for determining vegetation types. vigour. and biomass content. for delineating water bodies. and for soil moisture discrimination.
5	MIR 1.55-1.75	Indicative of vegetation moisture content and soil moisture.
6	TIR 10.4-12.5	Useful in vegetation stress analysis. soil moisture discrimination. and thermal mapping applications.
7	MIR 2.08-2.35	Sensitive to vegetation moisture content.

The principal applications for vegetation assess of the Landsat7-TM are: band 2 is designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment; band 3 designed to sense in a chlorophyll absorption region aiding in plant species differentiation; band 4 useful for determine vegetation types, vigor, and biomass content; band 5 indicative of vegetation moisture; band 6 useful in vegetation stress analysis and band 7 also sensitive to vegetation moisture content (Bakker et al., 2000).

2.4.3 PROCESSES OF IMAGE TRANSFORMATION.

Normalized Difference vegetation index.

One of the most known RS method used to determine the vegetation index is NDVI (Normalized Vegetation Index); it is based on the spectral properties of green vegetation contrasting with its soil background. This index has been found a strong vegetation signal and good spectral contrast from most background materials (Tucker, Rushton, Sanderson, Martin, & Blaiklock, 1997). NDVI also strongly reduces the impact of varying illumination conditions and shadowing effects caused by variations in solar and viewing angle. NDVI is a measure derived by dividing the difference between near-infrared and red reflectance measurements by their sum (Seller, 1989):

NDVI=(NIR-R) / (NIR+R)

High positive values of NDVI correspond to dense vegetation cover that is actively growing, where negative values are usually associated with bare soil, snow, clouds or non-vegetated surfaces.

Forest canopy density.

Landsat7-TM however is an attractive data to study the forest condition for example;ITTO used this image during the project on " Rehabilitation of logged-over Forest in Asia-Pacific Region". In this methodology the forest status is assessed on the basis of forest canopy. The methodology is identified as " Forest Canopy Density Mapping Model or FCD Model".

The FCD model is based on the growth phenomenon of forest and the biophysical spectral response of the area. It is calculated in percentage for each pixel considering the physical feature like vegetation and soil, the relative feature like shadow of vegetation and heat radiated by vegetation and soil and the data derived from the biophysical feature of the ground. In this FCD model current forest status can be determined without incurring much cost and time in selecting training areas and accuracy check, but based purely on reflectance and expert knowledge to set threshold with histogram.

The FCD is a useful model analysis the forest cover, using LANSAT TM data. The components of this model are 4: vegetation index (VI), bare soil (BI), thermal (TI) and shadow (SI). Advance vegetation index AVI reacts sensitively for the vegetation quantity compare with NDVI. Shadow index increases as the forest density increases. Thermal index decrease as the vegetation quantity increases. Black colored soil area shows a high temperature. Bare soil index increases as the bare soil exposure degrees of ground increase. These index values are calculated for every pixel (FCD-Mapper, 1993).

Haze has an additive effect to the overall image, resulting in higher DN value, and as such, it is reducing the contrast. The haze contribution was estimate for each band, and subtracts value from all measurement pixels in the relevant band. This correction was necessary because of the haze visible in the area that is mainly influenced for the tropical climate in the region. By correction, we estimate for each band the haze contribution, and subtract this value from all measurements (pixels) in the relevant band.

False Color Composite (FCC)

With the objective of enhancing the vegetation in the image the FCC (band 4=red, band 3+green and band 2=blue) technique was selected. The result looks like similar to prints of color infrared photography (CIR). The most striking characteristic of false color composite is that vegetation appears in a red-purple color. In the visible part of the spectrum, plants reflect mostly green light, but their infrared reflection is even higher. Therefore, vegetation in a false color composite is shown as a combination of some blue but even redder, resulting in a reddish tint of purple (Bakker et al., 2000).

Topographic correction (shadow removal).

The topographic effect is defined as the variation in radiances from inclined surfaces as the variation in radiances from inclined surfaces compared to radiance from a horizontal surface as a function of the orientation of the surfaces relative to the light source and sensor position (Holben & Justice, 1980). In 1979 Holben and Justice measured the topographic effect on remotely sensed data and showed the effect to be most extreme at low solar elevations and greatest for slopes in the principal plane of the sun. They also showed by Landsat simulation study that the topographic effect can produce a considerable variation in radiances associated with a given cover types and may lead to poor cover classification results (Sah, 1996).

The reflectance varies as a function of slope and aspect and that such terrain variations complicated the task of discriminating woodland categories with remotely sensed data. Removal or reduction of the topographic effect before classification will reduce the variation associated with the radiance for a given cover type and thereby increase the likelihood that classes can be separated. There area various methods used for minimizing shadow effect from the satellite data, i.e., sum normalization, ratio image, NDVI etc.

Sum normalization is used to make the input data independent of the influence of external factors such as sun angle or relief. The addition or summation of input data is a representation of this influence. The ratio between the individual input bands and this sum (=Intensity) results in Intensity independent data. If the results are displayed they appear to be flat.

$Bi=(Bi/\Sigma Bi) *255$

Where B is a band, I=1 to N, ΣBi is (B1+B2+...+Bn) and 255 is a compensation factor. By dividing the digital number (DN) in one band by the corresponding DN in another band for each pixel, a ratio image can be produced. The resulting values of the ratio image are stretched and plotted as a new image. The ratio images minimize differences in illumination conditions, thus suppressing the expression of topography (Sah, 1996).

2.4.4 DIGITAL IMAGE RECTIFICATION AND ANALYSIS.

It involve the use of computer in the manipulation and interpretation of data.

Some of the processes involved:

a. Image rectification and restoration: Mainly mean to correct distorted or degraded image data to create a better representation. Mainly to eliminate noise, geometrical correction and radiometric corrections.
b. Image enhancement: involves enhancement of image visual distinctions. Involves:
   i. contrast of an image(level slicing and contrasting images)
   ii. spatial feature manipulation(spatial filtering, convolution, edge enhancement)
   iii. multiple spectral bands (spectral rationing, vegetation components, intensity hue saturation)
c. Data merging and GIS integration. involves combining data sets for a given geographical areas with other geographical referenced data sets for the same areas.
d. Biophysical modeling: relating the quantitatively the digital data recorded and remote sensed data.

Digital enhanced techniques.

a. Contrasting manipulation which includes: Gray level thresholding, level slicing and contrasting stretching.
b. Spatial feature manipulation: Spatial filtering, edge enhancements and fourier analysis.
c. Multi image manipulation. Multi band rationing and differences, vegetation components, intensity hue saturation color space transformations and decorrelation stretching.

CHAPTER 3

3.0 METHODOLOGY.

3.1 AREA OF STUDY.

Introduction

The study area is vast and complex. Mau forest covers over 416, 000 ha of land.
Mau Forest is a forest complex in the Rift valley of Kenya. It is the largest indigenous montane forest in East Africa and the largest water catchments area in Kenya. The forest area has some of the highest rainfall rates in Kenya with numerous rivers originating from the forest, including the Southern Ewaso Nyiro, Sondu River, Mara River and Njoro River. These rivers feed Lake Victoria, Lake Nakuru and Lake Natron.
The Mau Forest complex is considered to be of national importance but many areas of the complex have been deforested or degraded; much of the damage taking place during the past few decades.

Degazettement of the forest reserve and continuous widespread encroachment has led to the destruction of over 100,000 ha of forest. In 2001, approximately 61,000 ha of forest in the Mau Complex were excised including over half of Eastern Mau forest reserve. The Eastern Mau Forest is the catchment area of the Njoro river which drains its Eastern Slopes to Lake Nakuru. One quarter of South West Mau Forest (source of Sondu river) was excised and all of Molo forest reserve was excised.

Using mid resolution satellite imagery scenes at different time steps the forest degradation of the Mau complex can be well illustrated and the spatial extent of deforestation exemplified using image processing software's at the Eastern and South Western Mau, Transmara and Olipusimoru forest reserve. The ideal satellite image for this case study was landsat 4 to 5 Thematic Mapper (TM) and landsat 7 Enhanced Thematic Mapper (+ETM), this is because:

1. The orthorectified and georectified images are freely available online, through an authorised website (http://glovis.usgs.gov).
2. They have a large geographic extent; with a swath width of 150 km hence one scene can completely cover the study area.
3. Landsat imagery has a fairly good resolution of 30 meters and contains the red (band 3), infrarred (band 4) red and thermal wavelength band (band 5) that can discriminate vegetation types such as forest and land use types such as agriculture and urbanisation.

The study area comprises of four forest reserves (South Western Mau, Eastern Mau, TransMara and Ol-pusimoru) that capture most of the Southern Mau complex, montane forest. It covers an area of approximately 2220 sqkm between Kericho township to the West and Mau Narok centre to the East i.e. geographic coordinates of between 0.3^{0}S to 0.75^{0}S and 35.4^{0}E to 36.2^{0}E, *as shown below.*

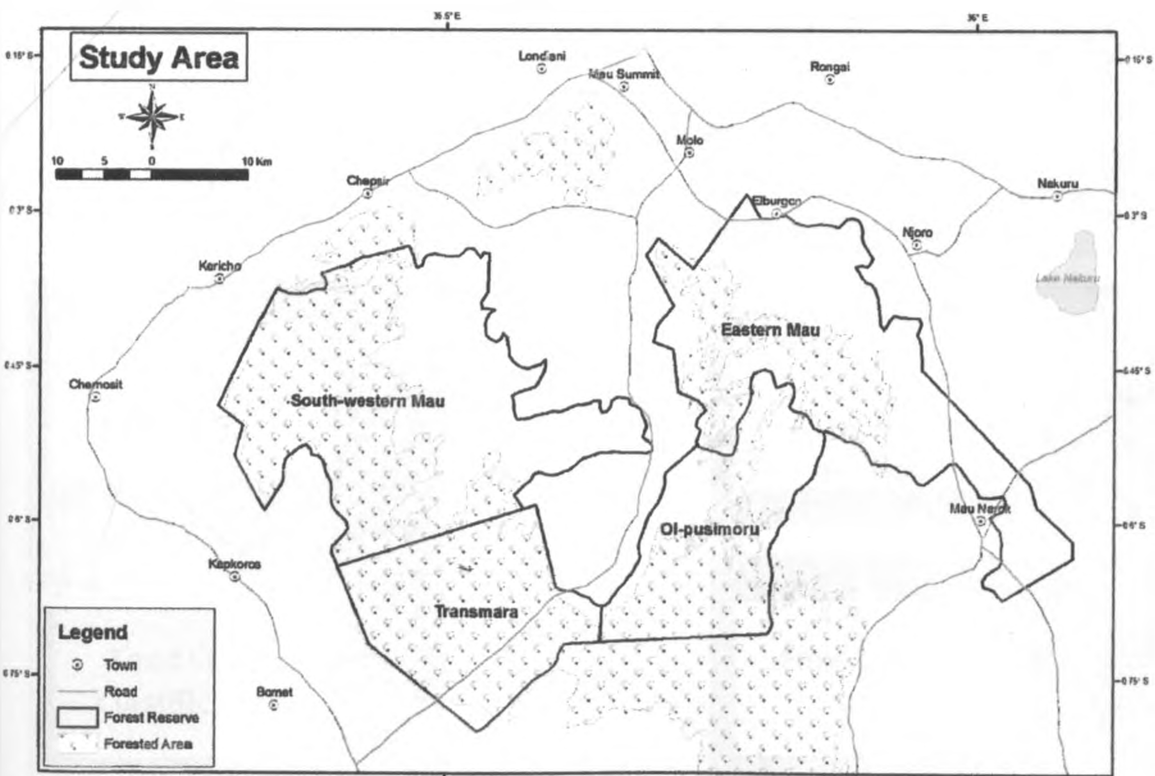


Fig 9 Map of southern Mau.

3.2 PROCEDURE IN DATA CAPTURE.

The time series analysis of forest cover was done in 5 main steps (*as shown in the methodological framework below*) using the World Reference System (WRS) index, path 169 row 060 landsat scenes that completely covered the study area. To enable the analysis 3 time step images were selected based on the availability of cloud free and high quality imagery from the USGS web portal (http://glovis.usgs.gov), these are:

1. 28th January 1986 landsat 4-5 Thematic Mapper (TM)
2. 27th January 2000 landsat 7 Enhenced Thematic Mapper (+ETM)
3. 30th January 2010 landsat 4-5 Thematic Mapper (TM)

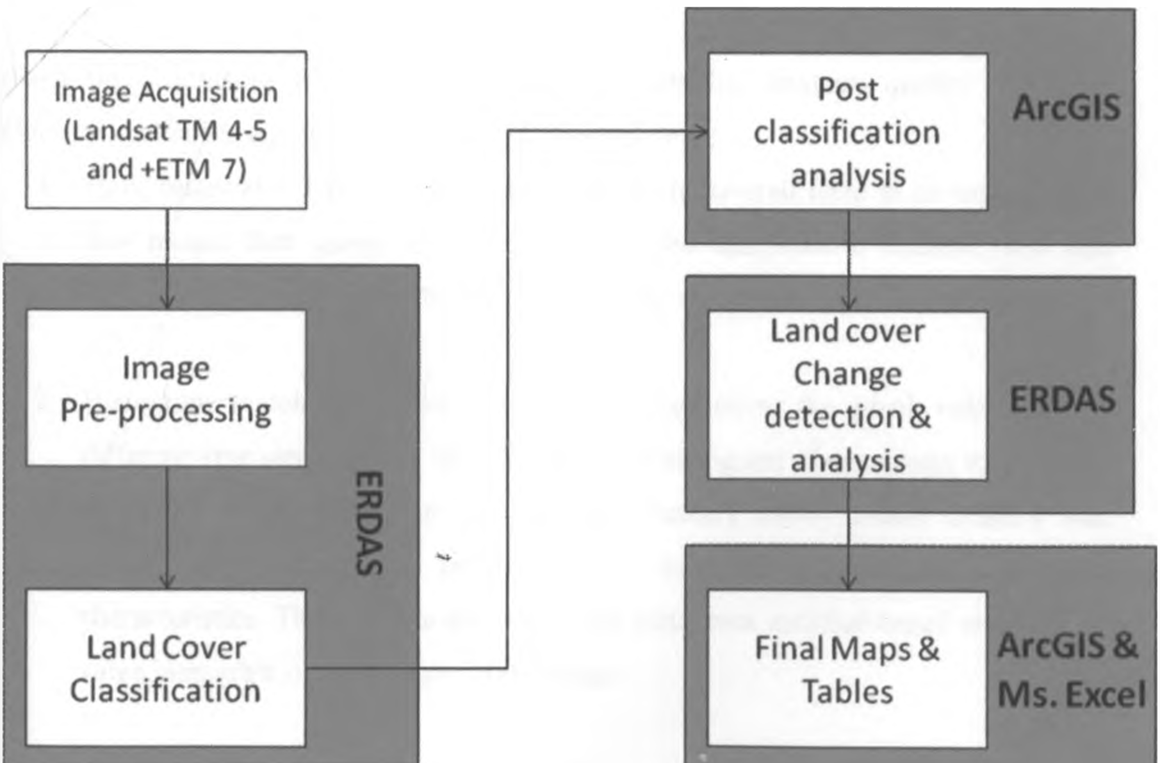


Fig 10. Procedure used to process images

3.2.1 IMAGE ACQUISITION.

The 3 landsat imagery mentioned above, from index p169r060 were downloaded from the USGS satellite imagery web portal. The imagery package consists of band 1 to band 7 for landsat TM and band 1 to band 8 for landsat +ETM.

Under the view of the electromagnetic spectrum: Band 1 represents the Blue wavelength band; Band 2 the Green wavelength band; Band 3, the Red wavelength band; Band 4, the Near Infrared (NIR) wavelength band; Band 5, the Middle Infrared (MIR) wavelength band; Band 6, thermal wavelength band; Band 7, the Microwave bands and band 8, the panchromatic (high resolution- 15 meters) band.

The bands usually used for land cover or vegetation classification are the red, NIR and MIR i.e. a composite combination of bands 3, 4 and 5 or individual bands of either.

3.2.2 IMAGE PRE-PROCESSING

Image pre-processing was used to enhance the satellite imagery quality to enable effective land cover classification analysis. These include;

1. Haze removal – This process was to reduce the overall haze in an input image, this means that image errors created by the atmospheric content, soil and vegetation moisture are completely or partially erased from the satellite imagery.

2. Histogram matching – This was used to harmonize the pixel values of the different time step imagery by converting the histogram of one image to resemble that of another image. For this case the January 2000 landsat imagery was considered the reference image due to its high quality and cloud free characteristics. The other images were then histogram matched based on the pixel value histogram of the January 2000 image.

3. Band stacking – In this process the different satellite bands are combined. For optimal land cover or vegetation classification analysis, band 3, 4 and 5 are

combined, but for this case using only band 3 gave the optimal result of what is forested and non-forested.

The image pre-processing was done using ERDAS imagine image processing software as indicated in the flow chart above.

3.2.3 LAND COVER CLASSIFICATION.

Land cover classification was carried out using unsupervised – isodata algorithm classification (The ISODATA (Iterative Self-Organizing Data Analysis Technique) algorithm calculates class means evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. Each iteration recalculates means and reclassifies pixels with respect to the new means. Iterative class splitting, merging, and deleting are done based on input threshold parameters. All pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, in which case some pixels may be unclassified if they do not meet the selected criteria. This process continues until the number of pixels in each class changes by less than the selected pixel unchanged threshold or the maximum number of iterations is reached).

To be able to effectively classify the land covers types and optimize the segregation of the forest land cover type 10 classes were established i.e. Class 1, Lakes, shadows, and river valleys; Class 2 Urban; Class 3, Grassland; Class 4, Forest; Class 5, Agriculture; Class 6, Cloud; Class 7, Woodland; Class 8, Bush land; Class 9, Bare land; and Class 10, Unclassified. The unchanged threshold was set to 0.95 with 7 model iterations.

3.2.4 POST CLASSIFICATION ANALYSIS.

Cloud removal

The January 1986 and January 2010 landsat 4-5 TM imagery had approximately 3 to 5% cloud cover, therefore blocking the surface land cover. To be able to deal with the cloud cover obscurity the clouds and shadows had to be first masked out through digitizing the clouds and then the nibble tools used to replace the blank/no data area with neighbouring land cover types (The nibble tool allows selected areas of a raster to be assigned the value of their nearest neighbour. This is useful for editing areas of a raster where the data is known to be erroneous. The tool determines all areas in the mask raster with the value NoData. The corresponding areas in raster will be nibbled. Secondly, the internal Euclidean allocation is performed to allocate values to the masked cells based on Euclidean distance. The values of cells of the input raster that correspond to the cells of NoData are then erased and replaced by the values of the nearest neighbor according to Euclidean distance).

Forest cover Isolation

The objective of the project is focused on forest cover (multi-canopy vegetation structure of trees). This in turn means that the captured forest cover class has to be isolated. To enable this forest isolation a process known as reclassification was used in the *ArcGIS reclass tool found in the spatial analyst tool set.* This process classifies the forest cover type as the only entity (class value 1) and the rest of the land cover types as non-entities (class value 0). This was done for all the 3 time step land cover maps i.e. January 1986, January 2000 and January 2010.

Clipping with the study area

The Forest cover change analysis was restricted to the study area extent. This was enabled by using the extract by mask function in ArcGIS Spatial Analyst, extraction tool. The study area was considered as the masking extent.

3.2.5 LAND COVER CHANGE ANALYSIS

To complete the objective of the project of spatially analyzing and visualizing the regions that have undergone forest degradation or deforestation, land cover (for this case forest cover) change analysis had to be carried out between the different time step image pairs i.e.

1. January 1986 and January 2000
2. January 2000 and January 2010

This analysis was carried out using the change detection tool (the tool enables differences between two images and to highlight changes that exceed a user-specified threshold- for the project case it was 10% of the total forest cover) in ERDAS imagine software. It is important to note that the change analysis was done using a spatial cross tab approach between the forest cover (class value 1) and non forest cover (class value 0) in order to spatially illustrate and analyze regions that have undergone deforestation from 1986 to 2000 and from 2000 to 2010.

CHAPTER 4

4.0 RESULTS AND ANALYSIS.

The final maps and tables produced using ArcGIS and Microsoft Excel is displayed on the result chapter.

Image Acquisition

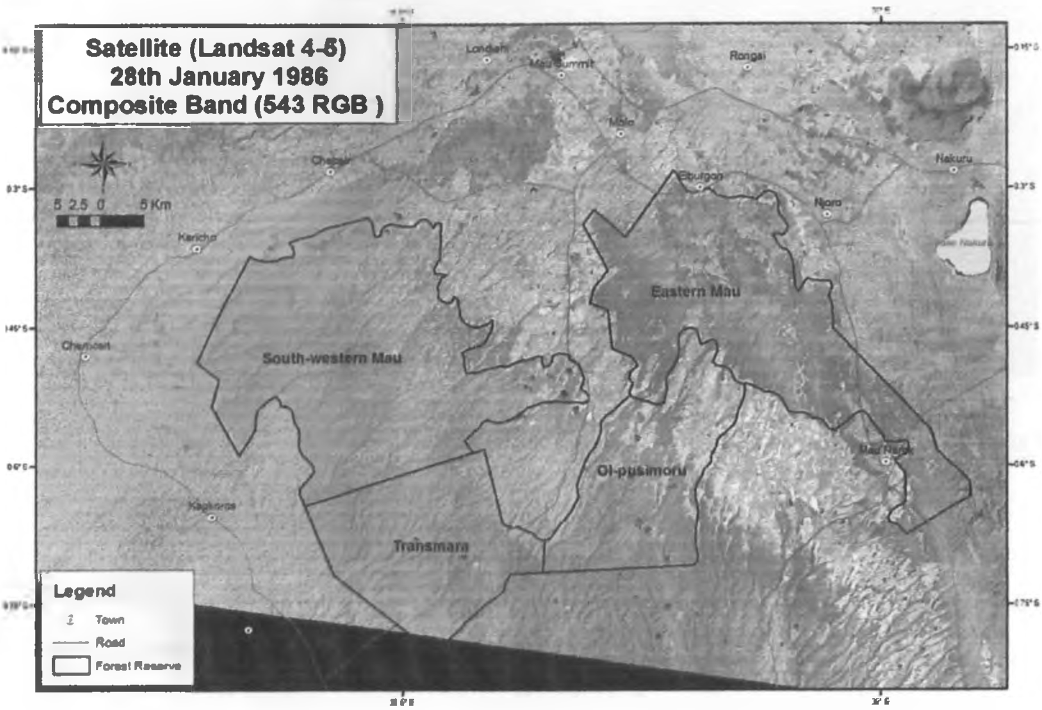


Fig11 Landsat 4-5 TM Satellite image composite of band 5 as Red, band 4 as Green and band 3 as Blue, captured on 28th January 1986.

The above satellite image was used as the base for analysis with the assumption that the destruction level by this time was minimal. As indicated the forest reserve is shown by the boundary shown on the Legend on the map. The green coloration is an indication of forest cover. During this time the buffer zones surrounding the forest reserve has not been interfered with and it shows that the buffer zone of 10km was almost intact. A part from some sides of the mountain which could be leeward side which does do show continues cover, most of the other areas have complete cover. Also the blue indicates patches of water. The image has mid resolution of 30 metres.

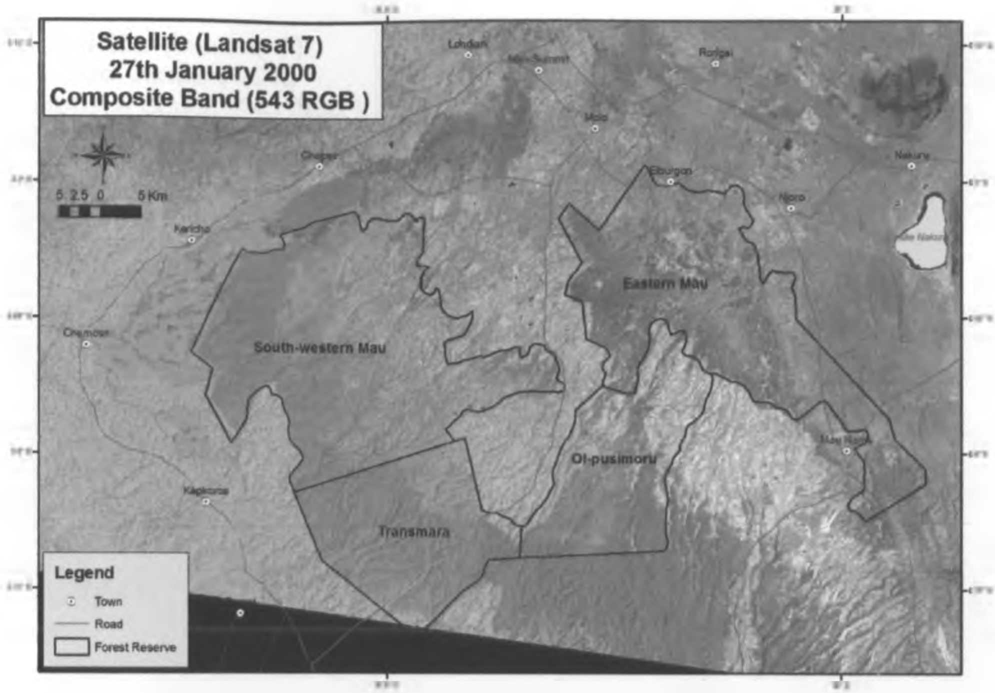
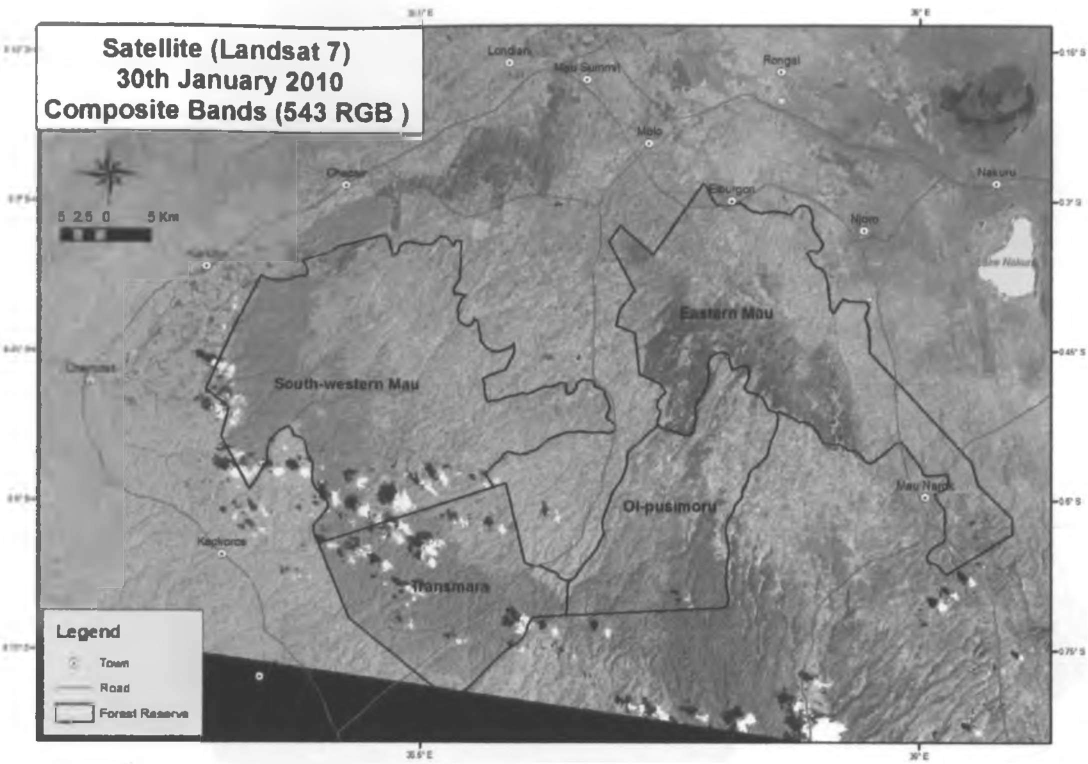


Fig 12. Landsat 7 +ETM Satellite image composite of band 5 as Red, band 4 as Green and band 3 as Blue, captured on 27th January 2000.

Though the 2000 image was the clearest image it can be seen that unlike 1986 the green coloration has reduced to the brown surface representing deforested areas. The image has a resolution of 30 metres which is usually okay for deforestation analysis. As indicated on the image composite most features captured are in band 3,4 and 5. Resolution of 30 metres.



f

Fig 13. *Landsat 4-5 TM Satellite image composite of band 5 as Red, band 4 as Green and band 3 as Blue, captured on 30^th^ January 2010.*

In the 2010 it shows a high level of deforestation. As indicated the white color are clouds and the black color are shadows of the clouds which will prevent a 100% cover analysis and as stated in the methodology to avoid the unnecessary shadow the areas were analyzed to the nearest class . Resolution of 30 metres.

Forest Cover Analysis

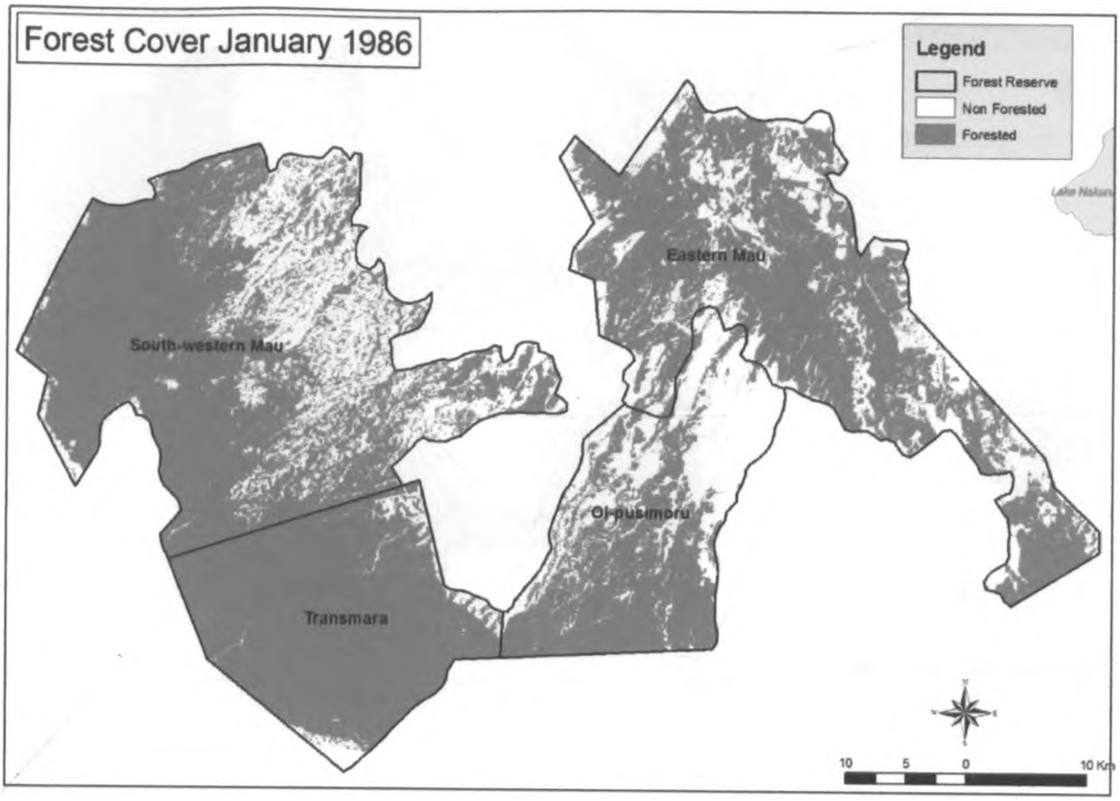


Fig. 14.

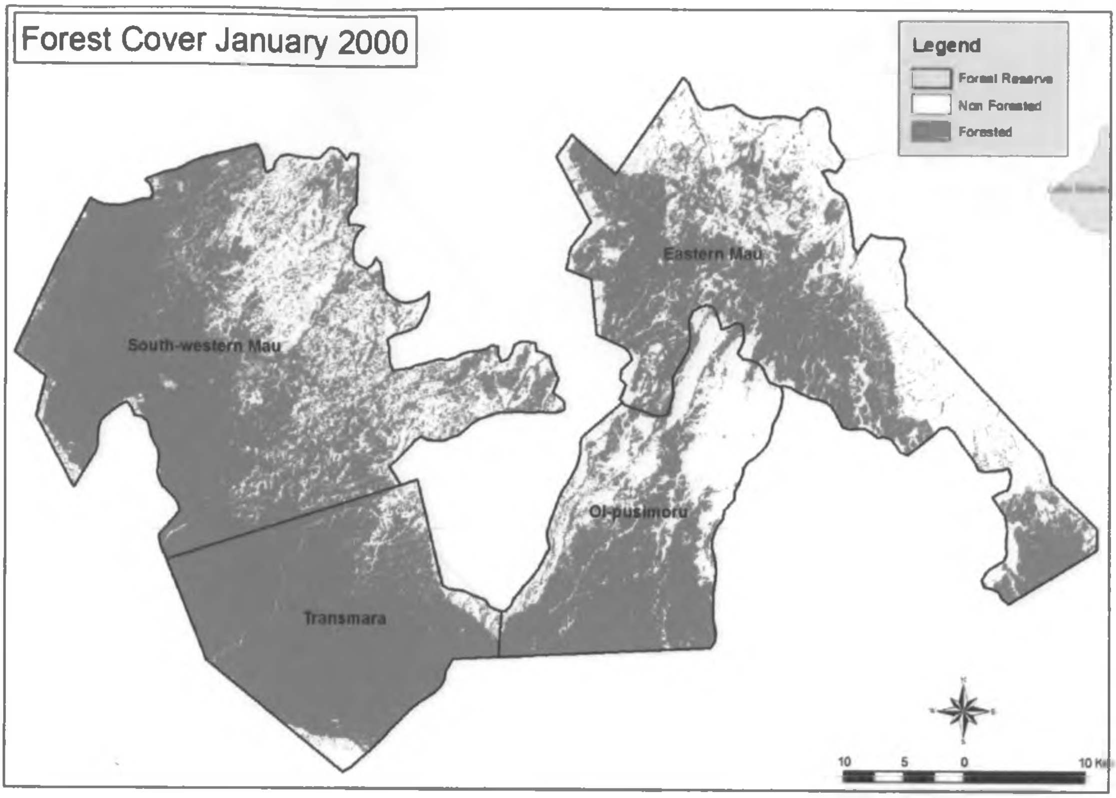

Forest Cover January 2000
Legend
Forest Reserve
Non Forested
Forested
South-western Mau
Eastern Mau
Ol-pusimoru
Transmara
10
5
0
10 Km

Fig 15.

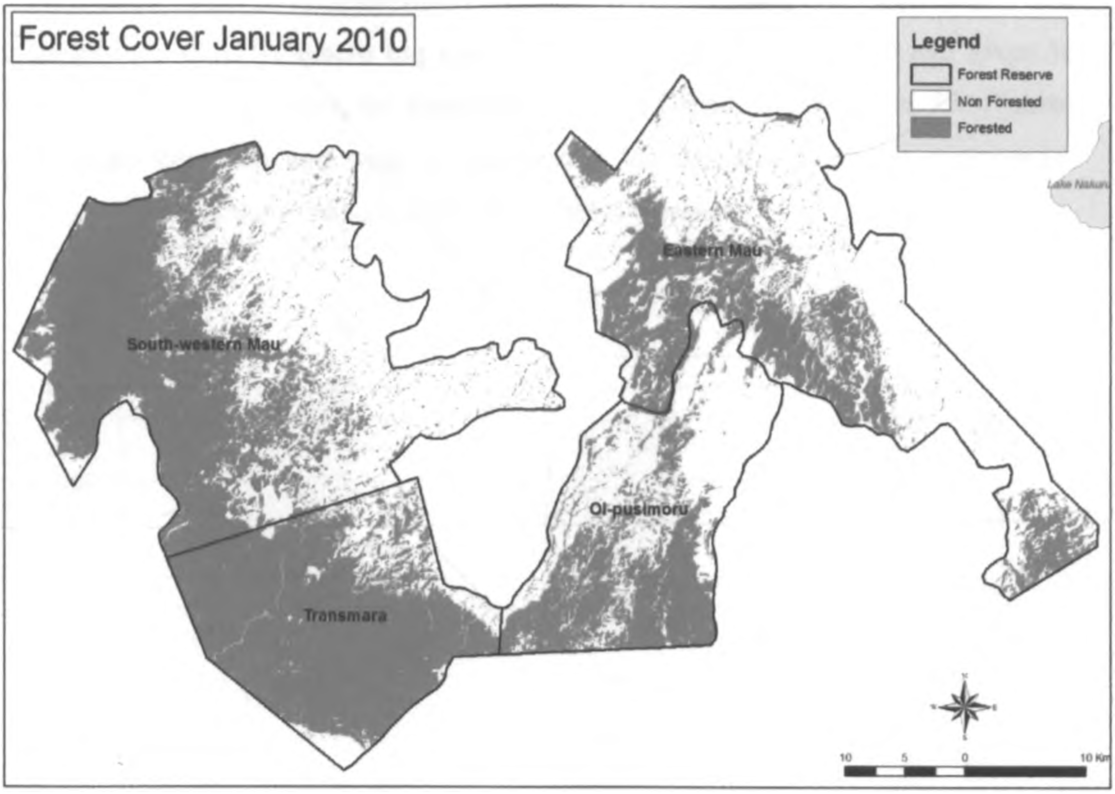


Fig 16

Year	Total Study Area (sqkm)	Total Study Area (ha)	Forest (sqkm)	Forest (ha)
1986	2218.5	221850	1550	155000
2000	2218.5	221850	1433	143300
2010	2218.5	221850	1043	104300

Table 7

The total area studied was 2218.5 was forms the forest reserve area. In 1986 it shows that 1550 kmsq was forested. As mentioned previously the 1986 satellite image was used as the base, there is a difference of about 61.5 km sq which could have been given out during the rift valley land rush of the 1970'S. The reduction between 1986 to 2000 shows that there was a reduction of 117 kmsq. The difference between 2000- 2010 was 507 km sq which indicates over 30% of the forest was depleted in 20 years. This was mainly as a result of incision of 2001 where big chunk of the forest was degazetted and given to private developers. In 34 years, the forest had lost 568.5kmsq, which shows that if there was no proper detection and ways of monitoring the forest. Due to the exponential depletion of the forest the forest can clear in less than 50 years.

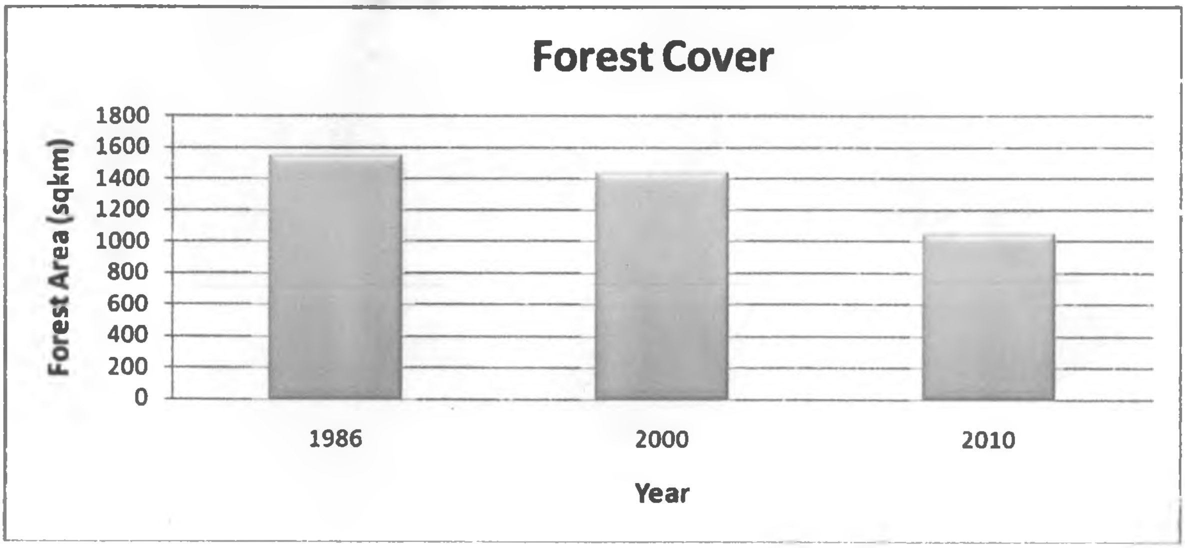


Fig 17. Graph showing forest cover change.

Forest Cover Change Analysis

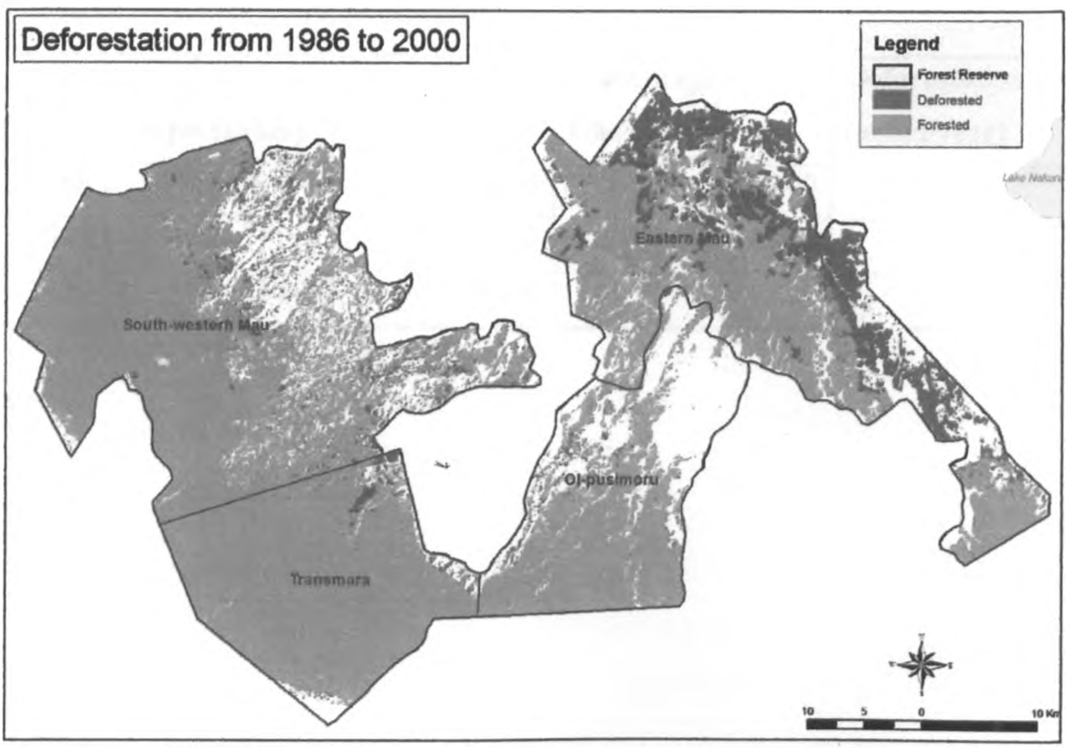


Fig 18

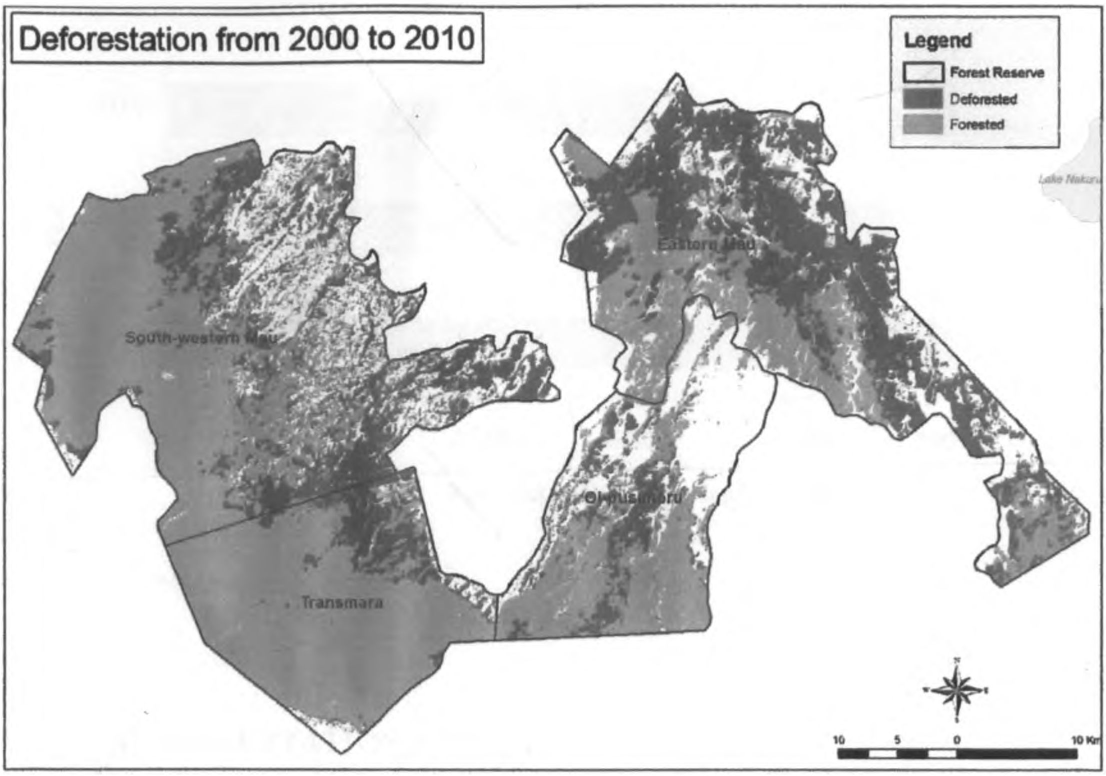


Fig 19

Year	**Forest (sqkm)**	**Forest (ha)**	**Percentage Change**	**Deforestation Rate (sqkm/year)**
1986	1550	155000	100.00	
2000	1433	143300	92.45	8.36
2010	1043	104300	67.29	39.00

Table 8.

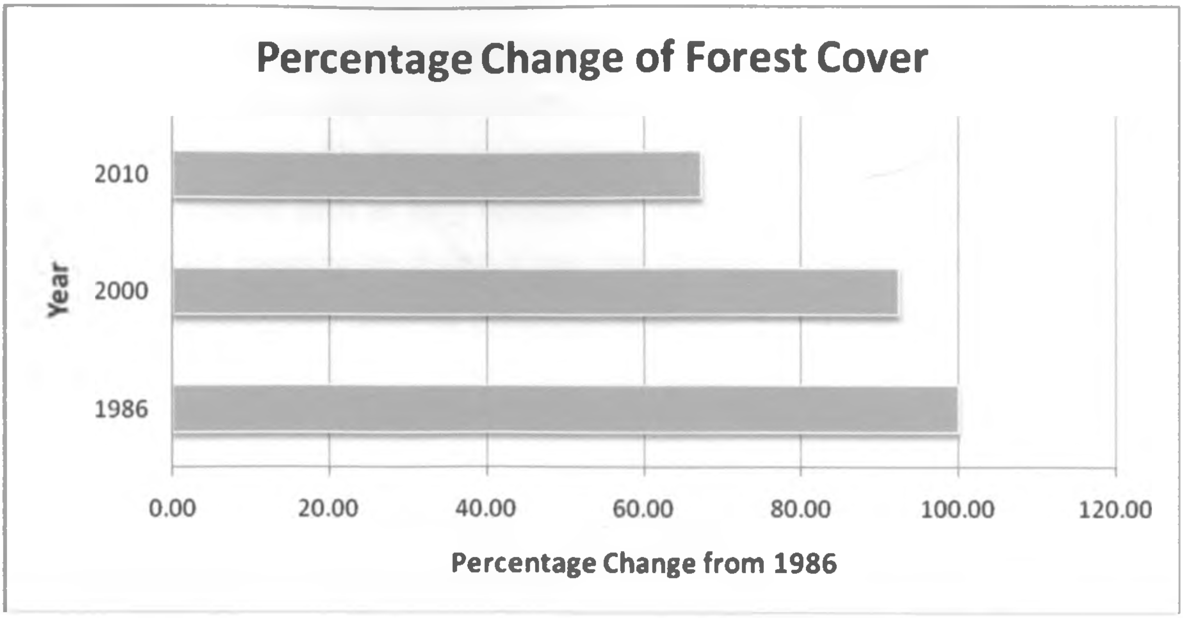


Fig 20 Percentage change.

4.1 DATA INTEPRETATION AND ANALYSIS.

Monitoring the Southern Mau using GIS and remote sensing shows some quantitative information which can be analyzed to allow a qualitative conclusions. As shown the table the assessment was on three satellite maps, 1986 being the assumed as the starting point and 2000 +ETM satellite map as a base of clear image with minimal noise. It serves as the benchmark for the other two thematic maps.

As shown the forested area studied in the same year 1986 was 1550 sq km which forms the base of the total area. From the 2000 image it shows a reduction to 1433 which is shows a difference of 117sqkm. This could have been as a result of the shamba system introduced by the government where the farmers were allowed to farm on the buffer zone which was set at 10 km around the forest. This was intended to safeguard the complex indigenous forest. At this moment the effect was not as much and minimal detection was noted with very few attempts to safe guard the forests. It was not noted because it was only 7.55% which compared to the vast forest cover was negligible.

Between 1986- 2010 there was a notable level of depletion which was 407 sq km which is about 32.71% depletion an indication that if the trend continues then another 50 years if no measures are taken to deplete the whole forest. This could take a short while as shown on the changes; the change is exponential just like the population growth.

With the new software's discoveries, the detection can be monitored closely and proper measures taken to sustainable reduce the depletion rate. Though there are a number of advantages as mention; such as easy detection of original boundaries using GIS and remote sensing and assessing the depletion rate, fast changing technology, and updating of software's frequently may make the venture more expensive than expected.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS.

In general my main objective has been confirmed that GIS and remote sensing are crucial in analyzing forest degradation. The ability of the software's to assess the level of depletion makes it easier for forest department to be able to plan and monitor forest depletion.

In the first specific objectives, the application of GIS and remote sensing is of paramount importance in the management and monitoring the depletion level. Both application are successful and are able to detect the levels along time series as well as the stratification of the forest cover. This will enable an assessment of the rate and magnitude of the depletion.

With the availability of maps on the USGS site at no cost and reducing cost of the soft wares, it becomes essay to monitor the canopy of the forest at a relatively less cost rather than deploy large number of human resource to manage the forest on the ground.

The rate at which the depletion of the forest is taking place can be detected easily using GIS and remote sensing as shown by the results of the project where the depletion detected between 1986- 2010 was 32.71%. This shows how effective this could be

It is concluded that satellite images seldom contain enough information to support the decision process in applied forestry. Although regional level applications may be useful, few successful and reliable applications for local forest inventory, planning or damage monitoring have evolved. Stratification for multi-stage sampling and monitoring of clear-cuts are areas in which satellite images have been shown to be feasible. However, it is doubtful whether the costs involved can be justified for such uses alone. A further conclusion is that many studies have adopted simplistic views of the information needs in the forestry planning process. These studies do not relate the analysis to management decisions, but instead assume that plain and approximate mapping of the forest has a great value. Present developments in the discipline involve complex modeling of reflectance, taking into consideration internal shading, topography and other features, yet without dramatic improvements compared with earlier studies. Structural features of forests can serve as useful indicators of forest condition and have the potential to be assessed with remotely sensed imagery, which can provide quantitative information on forest ecosystems at high temporal and spatial resolutions. Herein, we investigate the utility of remote sensing for assessing, predicting and mapping forest canopy of Mau . Normalized Difference Vegetation Index (NDVI) and radiance measurements in bands 3, 4, 5 and 7 from the Landsat Enhanced Thematic Mapper Plus (ETM+).

For better management of forest, changes of density should be considered. Forest canopy density is one of the most useful parameters to consider in the planning and implementation of rehabilitation program. It is possible that there isn't any change in the area of forest during the time but the density of forest canopy is changed.
Satellite based methods are conventional remote sensing method and biophysical response modeling. Conventional RS methodology, as generally applied in forestry is based on qualitative analysis. This has certain disadvantages in terms of the time and cost required for training area establishment, as well as to ensure a high accuracy. Unlike the conventional qualitative method, the FCD model indicates the growth phenomena of forests by means of qualitative analysis. FCD model is very useful for monitoring and management with less ground truth survey. This study investigated the suitability of high spatial resolution satellite images for preparing precise forest cover maps for Mau forest.. Based on a step-by-step analysis, this study suggested that segmentation, with color strongly weighted, was less sensitive to the scale parameter, leading to optimal forest cover segmentation and classification.

RECOMMENDATIONS.

- Though most of there is establishment of GIS laboratories in a number of institutions, the forestry departments should emphasize on setting more GIS laboratories in all forest department. This will empower them to be able to assess depletion regularly.
- In the establishment of GIS labs mainly there are very few qualified personnel and the government should embark on either organizing workshops or establish an online training centre.

- GIS and remote sensing can only detect the intensity and magnitude of the depletion but the measures can be decided by the people. This suggests that we should not just do the assessment and keep the records on the shelves rather recommendations should be given to the relevant authority.
- Satellite images contain enough information to support the decision process in applied forestry and should be taken as a substitute of ground research on depletion.
- Can provide quantitative information on forest ecosystems at high temporal and spatial resolutions enabling easy analyzing of the rate of depletion.

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