AN ASSESSMENT OF THE IMPACT OF LAND USE CHANGES ON HUMAN-ELEPHANT CONFLICT IN LAIKIPIA WEST DISTRICT, KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university or any other award.

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DEDICATION

My wife Eunice, children Anthony, Beatrice and Wilson for their perseverance during the study; my late mother Beatrice for self denial in support of my education

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ACRONYMS AND ABBREVIATIONS

ASAL	Arid and Semi Arid Lands
ANOVA	Analysis of Variance
CAMPFIRE	Communal Areas Management Programme For Indigenous Resources
DRSRS	Department of Resource Surveys and Remote Sensing
DNPWLM	Department of National Parks and Wild Life Management
ERDAS	Earth Resources Data Analysis System
ETM	Enhanced Thematic Mapper
ETM-SLC	Enhanced Thematic Mapper -Scan Line Collector
GOK	Government of Kenya
GIS	Geographic Information Systems
GPS	Geographic Positioning System
GEOVIS	Geographic Vector Interpretation System
GSM	Global System of Mobile Communication
KWS	Kenya Wildlife Service
KNBS	Kenya National Bureau of Statistics
KFS	Kenya Forest Service
LIRDP	Lungwa Integrated Rural Development Programme
MDG	Millennium Development Goals
MLC	Maximum Likelihood Classifier
MSS	Multi- Spectral Scanner
NEMA	National Environment Management Authority

NDVI	Normalized Difference Vegetation Index
TM	Thematic Mapper
UNDP	United Nations Development Programme
USGS	United States Geological Survey
UTM	Universal Traverse Marcitor
RUFORUM	Regional Universities FORUM for capacity building in Agriculture
SLC	Scan Line Collector
SPSS	Statistical Programme for Social Scientists

ABSTRACT

Farmers in Laikipia West district like many other farmers living in wildlife dispersal areas have continued to suffer huge losses resulting from wildlife menace without adequate compensation. Land use has been changing with time making the area prone to crop destruction by elephants. While it is known that land use change contributes to human -wildlife conflict, it has never been quantified over time for Laikipia West District. The objective of the study was to assess changes in land use/land cover between 1973 and 2008 in Laikipia West district of Kenya and their impact of human-elephant conflict. Land use and land cover mapping and change detection were done using satellite images of January 1973, January 1986, January 2000, March 2003 and April 2008. Supervised classification and on screen delineation approach were used for feature extraction. Geo-referencing and ground verification surveys were done after preliminary photo interpretation. Human-elephant conflict data was obtained from Kenya Wildlife Service (KWS). Study villages and farmers interviewed were selected using stratified random sampling and systemic sampling procedures respectively. Analysis of Variance (ANOVA), Spearson's Coefficient of Correlation and Chi square statistics were used to test data. Results showed an overall decrease in farms (-34.70%), settlements (-98.00%) and indigenous forests (-49.04%) while there was an increase in human population. Over the same period elephant's population and human-elephant conflicts were increasing. Analysis of Normalised Difference Vegetation Index (NDVI) between January 1973 and April 2008 showed that intensity of conflict was low when the level of vegetation was high. Human-elephant conflict was a major cause of increasing poverty levels and lowering of socio economic status of the community. The conflict was increasing as a result of land pressure arising from an increase in human population and increasing pressure on indigenous forests. Although there was establishment of plantation forests, they do not form a stable habitat for the elephants because there are times when they are cut down. Reduction in area of indigenous forest is a cause of the human-elephant conflict. There is, therefore, need to establish a migration corridor between Laikipia Ranch, Rumuruti forest, Lariak forest and Marmanet forest. The deforestation of remaining forests should be averted by involving the community through training and formation of community forestry associations. In addition, land use intensification such as agro forestry and soil fertility enhancement need to be promoted to reduce land degradation through a collaborative approach of lead agencies like Ministry of Agriculture, Kenya Forest Service (KFS), Ministry of Livestock Development, Ministry of Water and irrigation and National Environment Management Authority (NEMA). These efforts should be coupled with maintenance of the carrying capacity of elephant habitats. Declining socio economic status and increasing poverty levels of the community should be clearly addressed during implementation of policies to address the conflict problem.

CHAPTER 1: INTRODUCTION

1.1 Background to the problem

Globally, over the past 300 years, impact of land use change has increasingly assumed threatening proportions brought about by human agency. While human population has been on the increase, forests and grasslands have been on the decline (Grubbler, 1990). Mankind's presence on the earth and his modification of landscape has had profound effect upon the natural environment. The change could be beneficial or detrimental. Detrimental impacts are the chief cause of concern as they infringe on human well being and welfare especially conversion to crop land and forest clearance (Williams, 1990). Global land area converted to regular cropping has significantly increased in Africa, Asia and Latin America while there has been minimal change in Europe and USA mainly due to industrialization (Williams, 1990).

Land use and land cover change is gaining recognition as a key driver of environmental change (Riebsame et *al.*, 1994). Interest on land use change has a long history as there have been no instances in which people use land and its resources without causing harm. Magnitude of change varies with the time period being examined as well as the geographical area. Changes in area are difficult to assess unambiguously as they are haunted by definitional and data problems (Douglas 1994).

There is growing human population pressure on landscape as demands multiply for resources such as food, water, shelter and fuel. These factors dictate utilization of land regionally. Land use practices develop over longer periods of time under different

environmental, political, demographic and socio economic conditions. The conditions vary yet they have a direct impact on land use and land cover (Ojima, *et al.,* 1994).

When Kenya attained independence in 1963, one million acres were targeted to be achieved in settlement schemes in various districts across the country after the creation of the Ministry of Lands and Settlement. In Laikipia district, 35,000 families were settled under the government resettlement programme. The sessional Paper No. 1 of 1965 on African Socialism advocated for land buying companies and cooperative societies where some of these large scale farms formerly owned by European settler farmers were bought and converted to smallholder agriculture.

Tremendous land transformation in Laikipia District occurred in 1904 when former pastoral land was taken over for agriculture by European farmers. These farms were large scale managed as private or government ranches, communal ranches, private wildlife ranches or conservation conservancies. This was followed by land subdivision to create room for squatters which has been continuing since 1967/69. Land sizes varied from as low as two acres per share for the land buying companies to 15 acres per share for the settlement schemes. The first settlement schemes were Nyahururu and Laikipia West Settlement schemes which were started in 1968 followed by Oralabel in 1969. The farmers moved from high potential areas of Nyeri to the low potential areas of Laikipia and continue with the same type of farming system and lifestyle that is not suitable for these areas. This put a lot of pressure on environmental resources to unsustainable levels as a result of competition between human and wildlife. Consequently conflicts arise when the resources become scarce.

1.2 Statement of the problem

Human population in the Laikipia West District grew at a rate of 1.86% between 1979 2006. During the period from 2006 to 2007 average land holdings declined at a rate of 68.3% (KNBS, 2007). Declining land sizes with increase in population means more pressure is exerted on existing resources if it is not matched with land use intensification. Due to the demand for food supply and firewood, there has been continuous cropping on the same piece of land resulting in reduction in land cover and reduced crop and livestock output. As a result farmers turn to other means of survival like charcoal burning in the forest, forest grazing and clearance of forests to give way to crop farming. Over 530, 000 households that live within a distance of five kilometres from Rumuruti, Marmanet and Lariak forests depend directly on forest cultivation, collection of fuel wood, herbal medicine and other economic gains (GOK, 1995). This destroys the habitat for wildlife especially the elephants and lowers availability of browse and forage material. Reduction of land cover lowers the land carrying capacity and therefore there is less land available per Tropical Livestock Unit which cannot provide the food requirement for the elephants. Elephants therefore, move from their natural habitats to the surrounding farms in search of food and water. Increased settlement also interferes with the migration routes of the elephants.

According to Laikipia Wildlife Forum (1999), reports of elephants being shot in Laikipia in defense of crops date back to 1920. In 1978, a large-scale elephant drive tried unsuccessfully to push elephants out of the arable southern portion of Laikipia into Kenya's northern arid rangelands. Several attempts have been made to solve the problem.

In 1986, a district-wide elephant fence was proposed to separate areas inhabited by elephants from small scale farms where elephants pose a big danger to crops. Similar fencing 'solutions' were proposed in 1982, 1993, 1998 and 2002 by the Forum. In 2007, a 163 km fence was started along the edge of the ranches and forests to separate small scale farms from wildlife habitats in an attempt to solve the human-elephant conflict. Funds were availed and construction of the first phase started. This reduced the problem in areas where the fence was completed but increased the problem where construction had not started. Following these land subdivisions and the increase in human population, the consequences of the subsequent land use change on wildlife herbivore populations remain largely unknown. This study assesses the impact of these land use changes on the human elephant conflict in Laikipia West District, Kenya.

1.3 Research Objectives

The broad objective of this study was to assess the impact of land use changes on the human-elephant conflict in the Laikipia West district and recommend conservation and management systems to mitigate the problem.

The specific objectives of the study were to:

i. Assess changes in the land use/land cover between 1973, 1986, 2000, 2003 and 2008.
ii. Examine trends in human population, elephant population and human-elephant conflict.
iii. Establish the relationship between land use/land cover change and human elephant conflict.

1.4 Research questions

i. What are the land use/land cover changes in Laikipia West district between 1973, 1986, 2000, 2003 and 2008?

ii. What are the trends in human population, elephant population and human elephant conflict in Laikipia West district from 1998 to 2007?

iii. What is the relationship between land use/land cover change and human elephant conflict in Laikipia West district?

1.5 Research hypothesis

The study dwells on testing the following three hypotheses:

i. There were significant changes in land use/land cover in 1973, 1986, 2000, 2003 and 2008 in Laikipia West District of Kenya.

ii. Increase in human population is aggravating the human elephant conflict in Laikipia West district of Kenya.

iii. There is a relationship between land use/land cover change and human elephant conflict in Laikipia West district of Kenya.

1.6 Justification of the study

Viewing the earth from space has become essential to comprehend the cumulative influence of human activities on its natural resource base. Remote sensing and GIS provide tools for advanced ecosystem management. For example remote sensing and GIS was used in Taita Hills, South East Kenya by Pellika *et al.*, (2004) where they found striking changes in land use. There was an increase and decrease in sisal estates around

Mwatate and Voi respectively. Area and population of Voi town had increased rapidly invading abandoned sisal plantations while water reservoirs were declining near Mwatate due to siltation. However the study could not identify the change from secondary forests to agro forestry from satellite data. Campbell *et al.*, (2003) carried an investigation on drivers of land use change in Loitoktok area of Kajiado district between 1973 and 2000 using remote sensing data and aerial photos. The study identified that the overall policy towards the area did not encourage development of off farm livelihoods. A similar approach was used by Akotsi *et al*., *(*2005) in mapping land use/land cover changes in Kakamega forest (1975-2005). In Laikipia District, different land use systems have been evolving with time particularly in the new Laikipia West district. Grana (2007) observed that despite implementation of natural resource management programmes in Koija, Tiamamut and Kijabe group ranches in Laikipia, there was an increase of about 90% in human -wildlife conflict over a period of five years. The study found that land use change was a cause of the conflict but its impact was not quantified. The district was therefore selected for this study as it is home to 8% of wildlife herbivore populations in Kenya outside protected areas and has very dynamic land uses evolving over time. Elephants were selected for this study as they are the most prevalent and widely reported wild herbivores causing conflicts to the farming community in the study area. Land use change has profound effect on environment, wildlife and livelihoods and thus understanding these dynamics is important for development.

1.7 Significance of the study

This study will give information on land use/land cover changes and how they impart on elephants and therefore become a key driver of the conflict. Livelihood issues like increasing poverty levels amongst farmers and decreasing food security that arise from human-elephant conflict can be explained using the results of this study. It will suggest alternative opportunities and farming options for the farmers which when practiced can spread their risks and reduce incidences of human-elephant conflict. It will also suggest policy direction on how the problem can be mitigated. The study will also improve understanding of the human elephant conflict and generate some new knowledge on the area of study.

1.8 Scope of the study

The parameters investigated in the study are land use and land cover change, human populations trends and trends in human elephant conflicts in the conflict hot spots within the study area. The study area has dynamic land use patterns and high elephant populations which migrate from the Samburu to Mt Kenya forest migration corridor. The results of this study therefore can be replicated to other areas of Kenya with similar problems and conditions.

1.9 Limitations of the study

The study was limited to satellite images of Jan 1973, Jan 1986, Jan 2000, March 2000 March 2003 and April 2008 as these were the only images of the study area that were available at the Regional Center for Mapping Resources for Development (RCMRD).

These images were taken using different sensors and therefore had different spectral resolution which introduces an error during image classification. In addition, the classification was based on the spectral response of the land cover type. However, some land cover may give the same reflectance; for example, farms that have been cultivated but not planted may reflect the same way as bare ground. Seasonal variations have an influence on vegetation. However, all the months when the images were taken were generally dry. On screen classification of the 2008 image had some errors because of inability to manually distinguish between some of the colors. However the margin of error is below 10%.

The NDVI values computed from the satellite images are only a rough guide of the vigor and intensity of the vegetation for the years computed but may not account for vegetation that have similar reflectance values. Human elephant conflict data was limited to only the cases that were reported and recorded in the occurrence books of KWS. Data on total elephant counts was limited to only years when census was done as recorded in KWS census reports. Human population data was limited to the records available at the Kenya National Bureau of Statistics (KNBS) office at Nanyuki.

Collection of ground truth data was limited to the availability of resources.

1.10 Definition of operational terms as used in this study

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

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

Conflict: A situation where living organisms do not live harmoniously and compete for resources for their survival.

Indigenous forest: Forest that is native in a given area

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

Pixels: Smallest units of an image.

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

Geometric corrections: Correcting for geometric distortions due to sensor-earth geometry variations and conversion of the data to real world coordinates.

Geo referencing: Process of scaling, rotating, translating and de-skewing the image to match a particular size and position.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter deals with land use in the dry lands which are an important wildlife habitat, land use change and its relationship with human wildlife conflict, an understanding of elephant ecology and legal and policy issues affecting wildlife conservation and management in Kenya. The chapter concludes by looking at management options that can be used to mitigate the human elephant conflict.

2.2 Land use in the dry lands

Dry lands of the world comprise over 40% of the earth's surface. Over 1 billion people depend on them for their livelihood and are home for the world's poorest and marginalized people (UNDP, 2003). Surprisingly, a number of developed parts of the world are dry: Australia, Great plains of North America and major cities like New Delhi and Mexico. All over the world, the biggest challenge to development of the dry lands is land degradation. Land degradation in arid and dry sub humid areas resulting primarily from man-made activities and influenced by climatic variations is desertification. This is primarily caused by overgrazing, over drafting of ground water and diversion of water from rivers for human consumption and industrial use all of which are driven by over-population. The primary reasons of desertification are overgrazing, over-cultivation, increased fire frequency, water impoundment, deforestation, over drafting of ground water, increased soil salinity and global climate change (UNDP, 2003). To avert desertification, sustainable land use in the dry lands is critical. Any form of land use in the dry lands is sustainable if it can continue indefinitely. Sustainability, therefore,

depends on properties both of the resource and the way it is managed. The quality in a resource that renders its use sustainable is its resilience, but resilience can also only be defined for a particular form of use (a field that would be resilient if organically farmed might not be resilient if used for camel racing). Because of its dual nature (land use and environment), resilience is therefore, very variable from place to place and even from time to time. A good test of the resilience of a resource is its ability to recover from a shock, be it climatic or a change in land use. The bigger the shock absorbed, the greater the resilience (UNDP, 2003).

A recurrent shock in dry lands is drought, and it is usually drought that brings land degradation or desertification to notice. It is a common misconception that droughts themselves cause desertification. While drought is a contributing factor, the root causes are mans over-exploitation of the environment (Wilson, 2001).

Disturbance of the land through deforestation, urban sprawl, agriculture and other human influences substantially defragments our landscape and changes the global atmospheric concentration of carbon dioxide, the principal heat-trapping gas, as well as affect local, regional, and global climate by changing the energy balance on Earth's surface.

Current efforts to combat global warming focus on reducing the emission of heat-trapping gases, but do not fully address the substantial contribution of land use to climate change. Since even small changes of 100 square kilometers in urban development or deforestation can change local rainfall patterns and trigger other climate disruptions, science and public policy must evolve to factor in all of the components of human-

induced climate change. Reducing greenhouse gas emissions and minimizing the loss of forests and other ecosystems are measures we need to take to reduce global warming.

In Kenya, dry lands occupy over 80% of the country with over 60% of the population that live in these areas living below the poverty line (GOK, 2008). Predominant land uses in Kenya's dry lands are extensive livestock production, forestry and wildlife conservation. If a community is too poor to raise the capital needed for restoration of degraded land, then degradation is likely to continue and accelerate. This has been recognized in the United States for many years where it has been Federal policy for the state to provide the capital for restoration. It is now recognized by the World Bank to be a necessary policy in the Third World (Hopper 1988):

"Poor people cannot easily postpone immediate consumption for future returns. Nor will they ignore the pressing needs of the moment if these can be met from their limited resources, even if the use of these resources jeopardizes their longer term viability"

The 1992 ASAL policy for Kenya viewed pastoral production as environmentally destructive and advocated for the introduction and intensification of modern system like ranching and irrigation. Development of ASAL areas in Kenya has been lacking adequate attention for many years. For instance some of the communal ranches are being subdivided to create room for human settlement. A review of the ASAL policy in 2004 addressed subdivision of communal ranches but the policy was in draft form up to the time of writing this thesis. It is estimated that the costs of putting arid districts into other land uses in Kenya could be fifty times higher than supporting current land use systems (Pratt, 1999). The future of the ASALs, therefore, does not need to be bleak because these areas have enormous potential, to sustain themselves, and to contribute

substantially to the national economy. It is for this reason that the National Coalition government formed after the 2007 General Elections created a separate Ministry to address issues of the Northern Kenya dry lands. A proper understanding of the needs and potential of ASAL communities coupled with political commitment to adequately encourage investment is needed in order to provide an opportunity for communities to realize their development potential. A land use system for the dry lands should therefore, harness the existing potential like extensive livestock farming and wildlife ranching with sustainable utilization of the fragile environment.

2.3 Land use change and human-wildlife conflict

Crop damage caused by raiding wildlife is a prevalent form of human–wildlife conflict along protected area boundaries (Naughton *et al.*, 1998). However, in order to mitigate this form of human–wildlife conflict more effectively, it is first necessary to understand the temporal and spatial factors that predispose crop raiding. It is also necessary to identify correctly those species that cause the greatest amounts of crop damage, because farmers' perceptions of the most notorious crop pests may be influenced by factors other than crop damage (Naughton *et al.*, 1998; Siex *et al.*, 1999). To date, most research on crop damage by wildlife has been conducted in Africa (Hoare, 1999a; Naughton *et al.*, 1999; Hill *et al.*, 2002; Sitati *et al.*, 2005). Apart from studies of crop raiding by Asian elephants (Sukumar, 1989; Nyhus *et al.*, 2000), crop raiding by wildlife has been little studied in Asia (Sekhar, 1998; Rao *et al.*, 2002), particularly outside India. Yet, rural human population densities tend to be higher, and clearance of forest for agriculture is more extensive, in Asia than in Africa (Achard *et al.*, 2002). In turn, both these factors

are likely to lead to escalating incidents of crop raiding in the future. Furthermore, case-specific studies are needed from farmland bordering different habitat types, with different potential crop pests, as these may also influence crop raiding patterns and, therefore, the appropriate mitigation strategies (Sitati *et al*., 2003). Such studies offer an important insight into the capacity of wildlife to use agro forest landscapes, which will become increasingly common in Asia (Nyhus *et al.*, 2000).

Wildlife conservation was not known in pre-colonial African societies. The approach taken by most African countries to wildlife management was conservation through protected areas. This approach has been challenged on the basis of the presence of wildlife in areas occupied by humans and on the grounds that more enclosure of land for wildlife use would infringe on the rights of communities to use land in areas around or in close proximity to wildlife. Kenya's wildlife is under threat from population pressure and migration, land use changes, over harvesting of natural resources and climate changes (Olukoye *et al.*, 2004). Human population growth and wildlife numbers are inversely related (Kamande, 2008). In her study in Taita Taveta district, (Kamande, 2008) showed that wildlife numbers decreased with increase in population. A downward trend in wildlife numbers between 1970s and 1990s indicated that increase in human-wildlife conflicts was not triggered by increase in wildlife. She recommended a change in land use to one that is compatible with wildlife.

Research in land use change provides data necessary for analyzing the impacts of population growth and land use change. This information can be used to analyze the

causes of human migration patterns and loss of natural resources. Each of these impacts is linked to the extent of change in agricultural land, forest land and settlements. Planners use human population dynamics data to evaluate environmental impacts to develop land use zoning plans and to gauge future infrastructural development. Analysis of land cover change in Taita Taveta district in 1995 showed a loss of about 35% of original land cover to agricultural fields and sisal estates attributed to human population pressure, land tenure and water distribution (Kisoyan, 1995). In areas where there was no change in land cover, the elephants were associated with destruction of woody species while in areas of land cover change; the elephants were associated with destruction of crops.

Human-wildlife conflict a common malady of rural development is the result of rural growth, increase in human population density and increasing pressure on natural resources like browse and water. A study by Muoria, (2001) in Arabuko Sokoke forest found that there was a correlation between water availability, rainfall, food availability and crop raiding by elephants. Crop raiding by elephants occurred as a consequence of search for water. Elephants moved out of forest in search for water and in the process raided farms near water sources. Crop raiding intensity was negatively associated with rainfall, water availability, wild fruit availability and availability of cultivated crops on farms. Rainfall and water availability are low in the forest during the dry season and elephants search for water outside the forest. Wild fruit availability and farm food availability were also low during this period leading to a negative correlation between these two variables and crop raiding intensities. This agrees with Wandaka (2006) that human-wildlife conflicts intensified during the dry season, near the farms and permanent

water sources. To tolerate wildlife on farms and ranches, local communities need to be assured of economic gains (Kamande, 2008). Therefore there is need to have wildlife tolerance by local communities boosted by compensating them for losses incurred through destruction by wildlife. They should also receive tangible benefits from revenue accrued from wildlife which should also be combined with capacity building. Involvement of local communities in resource conservation has been emphasized not only for the Kenya government and Kenya Wildlife Service but also other countries (Wandaka, 2006). Involving local communities in any project gives them a sense of ownership. The high number of ranches and forests reserves in Laikipia provide useful habitat for elephants. However there is competition of browse material between elephants and livestock as 69.9% of households own livestock whose numbers exceed the land carrying capacity. In Laikipia this pressure is aggravated by the small size of agricultural land holdings whose mean is 1.9 acres (KNBS, 2007).

2.4 Elephant ecology

The African elephant that has an average body mass of 3550kg (Haternorth & Diller, 1980) and has high food intake to meet its metabolic requirements. In areas where there is scarcity of food it will feed for a long time to meet its energy requirements. When adequate feed is not available in the forest, it has to be supplemented with what is available in the farms. Leuthold (1970) suggested that African elephants by their behaviour avoid unnecessary depletion of food reserves. Habitat selection appears to coincide with seasonal changes and corresponding food availability. Seasonal use of habitat is probably an important mechanism for survival by reducing impact on dry

season habitats and allowing for food plant regeneration (Viljoen, 1989; Kabigumila, 1993). Elephants are also known to push over trees (Croze, 1974; Williams, 2002) thus gaining access to otherwise inaccessible browse. Removal of forest cover through such activities as firewood collection and charcoal burning thus reduces the availability of such browse. Differential use of habitat types and seasonal changes in the distribution of elephants (*Loxondota Africana)* has been well documented elsewhere in Africa (Caughley and Goddard, 1975; Eltringham, 1977; Short 1983; Merz, 1986; Tchamba, 1993).

For African elephant, Laws (1970) postulated that while grasses are probably essential to provide bulk cellulose for energy, the protein requirements of the elephant especially in dry seasons can only be met by herb and browse. Laws suggest that elephants browse more during the dry season because crude protein content of browse is higher than that of grass. Furthermore, grass tends to accumulate tannins and rapidly become fibrous thereby reducing its palatability during the dry season. This probably explains why the elephants prefer cereal crops compared to other food crops. Sikes (1971) and Short (1983) provided evidence that seasonal movement of rainforest elephants are largely a result of the distribution and fruiting patterns of fruit tree species. Merz (1986) and Tchamba and Seme (1993) attributed the differential use of habitat types by elephants to the distribution and variety of food resources, their abundance and permanence throughout the year and/or proximity to water sources. Viljoen (1989) defined the best available elephant habitat as the one in which elephants are observed more frequently and show the highest preference relative to their overall distribution and size of the various habitats. Elephants have the capacity for wide roaming opportunistic and flexible behavior

(Leuthold, 1977; Sukumar 1989); Williams, 2002). Elephants ranging patterns are, therefore, linked to their feeding ecology.

Elephant aggregation is an anti predation strategy (Laws *et al*, 1975). Moss and Poole (1983), believe that aggregation is more an association between family units than a mating strategy. Mating peaks are associated with high rainfall (Laws, 1969). Biometric studies done in Amboseli, Kenya, showed that elephants aggregate into large herds during the rainy season, which gradually break up during the dry season. This break up is probably to reduce intra group competition under conditions of food shortage (Hamilton, 1972). Prevailing land use practices in an area such as ranching and crop farming will, therefore have a direct bearing on elephant behavior and also on the human-elephant conflicts.

2.5 Management options of human-elephant conflict

In many parts of the world, wildlife is confined to National Parks and adjacent dispersal areas (Furnes, 1982). Many of these protected areas are found in developing countries and 426 of them are found in Africa where majority of the people eke their living (Kiss, 1990). Given that conservation issues are as political as they are historical or biological, management of wildlife should include humans as well as ecological dimensions and integrated human activities (GOK 1975; Omondi, 1994). Economic losses suffered from human-wildlife conflict can be relatively high in developing countries because farmers are poor and are rarely compensated for such losses (Sekhar 1998; Rao *et al*, 2002). Such losses can make communities antagonistic and in-tolerant towards wildlife which can

result to killing problem animals as well as undermining impending conservation strategies (Nyhus, *et al* 2000). To mitigate human-wildlife conflict more effectively, it is necessary to understand the effectiveness of current guarding strategies (Sitati *et al*, 2003).

Available options in the control of human wildlife conflict range from physical and vegetation barriers, culling, controlled shooting, translocation, guarding, hunting, scaring and monetary compensation for loss suffered (Mackinnon *et al* 1986; Ngure, 1992; Soorae, 1994; Lahm, 1996). Not all these methods can be used in Kenya to mitigate human-elephant conflict because either they have been banned or are not cost effective, inadequate scientific knowledge, negative ecological impacts or due to ethical considerations. When properly designed, electric fencing combined with translocation is effective but expensive. The first step in dealing with human-elephant conflict would be through consideration of ecological and anthropogenic factors leading to human-elephant conflict.

Studies done on management of human elephant conflict in Laikipia West District have developed simple and affordable tools for deterring elephants from small holder farms. In South West Laikipia, a tracking of elephants using Global System of Mobile Communication/Geographic Positioning System (GSM/GPS) collars has been developed with a view to generating information for conservation planning to mitigate future human elephant conflict (Graham *et al.*, 2008). However, during the study no farmer was found to use these deterring devices. Capacity building to communities to cope with the spite of

all these management options, non-interference with the elephant habitat can be a problem through poverty alleviation initiatives has also been tried in the study area. In cheap and sustainable way of managing the conflict although it has a high opportunity cost.

2.6 Legal and Policy issues on Human-Wildlife Conflicts

In various parts of Africa a protectionist approach to wildlife conservation has been used for many years. The colonial powers neglected the utility of indigenous resources virtually everywhere they went. Europeans saw little need to learn from indigenous people as they concentrated their efforts on husbanding crops and livestock that they had domesticated in Europe. After an exploitation phase, Africa's wildlife was to become regarded as exotic recreational goods (Crosby, 1986). Wildlife was displaced by exotic plants and animals on all the most productive land because the colonial elite had no experience of or productive use for it. In consequence, proprietorship of indigenous resources was formally removed from Africans and made State property, managed by Wildlife and Forestry departments.

This approach concentrated on wildlife conservation without involvement of local communities that live with the wildlife. This approach is not sustainable and has been reviewed in many countries. For example in the 1960's, Zimbabwe's Department of National Parks and Wild Life Management (DNPWLM) reviewed the country's colonial style wildlife policy, which process culminated in a radical shift of direction. The old protectionist approach was replaced by a pragmatic strategy which aimed to link protected areas with sustained utilization of wildlife on communal and commercial land.

Progressive conservationist thinking espoused the need for 'wise use' of natural resources. This perspective asserted the view that as long as wildlife remained the property of the State, no-one could invest in it as a resource. Consequently, management effort, on commercial and communal rangelands, was being put into domestic livestock. The protected wildlife areas were in danger of becoming isolated and vulnerable ecosystems. This conservation insight provided the rationale behind the 1975 Parks and Wildlife Act. The impact of this legislation is seen in Zimbabwe today in a thriving wildlife industry on private land and increasingly in the communal sector as well. The 1975 Act was primarily aimed at giving private commercial ranchers an economic rationale for conservation by promoting the possibility for investment into productive wildlife utilization. The Communal Areas Management Programme For Indigenous Resources (CAMPFIRE) was an attempt to make a social link with the economic and ecological objectives of the 1975 Act. Park's also had considerable management capability in its wardens and rangers who were able to carry out the management decisions of the ecologists such as capture, translocation and culling of large herbivores.

In Tanzania, the Maasai community had repeated conflicts with park authorities over land use in the Ngorongoro Conservation Area which originally was part of the Serengeti National Park created by the British in 1951. This led the British to evict them to the newly declared Ngorongoro Conservation Area in 1959. The Ngorongoro Conservation Area Authority which is the governing body that regulates use and access to the Ngorongoro Conservation Area has managed the area to the extent that it became a UNESCO World Heritage Site in 1979. Land in the conservation area is multi-use; it is unique in Tanzania as the only conservation area providing protection status for wildlife

whilst allowing human habitation. Land use is controlled to prevent negative effects on the wildlife population.

Other examples are Lungwa Integrated Rural Development Programme (LIRDP) in Zambia, Eco-partners in South Africa among others. However, they have not been successful due to lack of responsive and supportive legal and institutional framework (Emerton, 2001 and Virtema, 2003)

In many of the past policies for Kenya, there has always been an underlying desire to transform rangelands into "green" and agriculturally productive areas. This implied that the existing land use systems were perceived as not being appropriate and not as productive as expected (Sikunyi, 2008). The concern here was the need for ASALs to produce more crop based products in order to close the gap in cereals production. This does not provide the nutritional needs of the community which must be met by food aid as well as provision of mineral and vitamin supplements. Local demand can be met through irrigation but Sikunyi (2008) using simulation cycling around biomass needs with respect to milk and meat, pointed towards measures to increase forage production rather than water availability.

In the Kenya National Livestock Development Policy of 1980 (GOK, 1980), no declines in the land for grazing was anticipated in the ASALs because of the low likelihood for crop activities being undertaken on these lands. However in the draft National Livestock Development Policy of July 2003 (GOK, 2003), sustainable resource management in the ASALs compounded by drought, reduced forage and degradation is the biggest challenge for the sustainable development of the ASALs. This policy is however not clear on the

subdivision of ranches into uneconomical units and change in land use from livestock ranching to wildlife ranching without due consideration of the consequences of such change.

The Kenya ASAL policy of 1992 (GOK, 1992), failed to address the rising population and land tenure issues clearly. For instance some of these land uses typically tolerate elephants due to availability of browse material, while others do not. These issues have however, been addressed in the draft ASAL policy of 2004 (GOK, 2004). The draft land policy of 2006 (GOK,2006) however is silent on economic land units for the ASALs below which no further subdivision should occur if it has to support an average farm family.

The Kenya Wildlife Service Cap 376 of the Laws of Kenya addresses human wildlife conflict through a 'protectionist approach' (Mwakima, 2005). The control strategy concentrates on conflict prevention and land use planning through activities such as Community Based Forest Management and electric fencing. However it lacks a comprehensive conflict reduction mechanism where wildlife is viewed not as competitors with other human activities but complimentary. Mwakima suggests that equitable sharing of benefits from proceeds of wildlife conservation activities between the community and KWS needs to be put in place for the community to own up and fully participate in wildlife conservation activities. There is need, therefore, to put in place an ecotourism policy and guidelines to enable consumptive and non-consumptive use of wildlife resources. This has been tried in Golini- Mwaluganje community conservancy in Kwale District with limited success. (USAID/Kenya, 2003).

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

This chapter describes the study area and sources of information used in the study. It provides details of how information was extracted from the various sources and the methodology used to analyze the data obtained from the different sources.

3.2 Location of the Study Area

The study area is located on the semi arid plateau to the North West of Kenya. It comprises of the entire Laikipia West Constituency. The district was created in 2007 from the greater Laikipia District. In 2009 the district was further split into two to give way to Nyahururu district and Laikipia West district with the headquarters of the two districts in Nyahururu town and Rumuruti town respectively. The study area lies between 36^0 15'-$36^0$55'longitude and $0^0$00'-$0^0$50' latitude. It covers an area of 4937 km^2 comprising of Rumuruti, Nga'rua and Olmoran divisions. Nyahururu district comprises of the entire Nyahururu division. It borders Samburu East district to the North, Laikipia East district to the East, Baringo East and Subukia districts to the West and Nyandarua North district to the South. The Nyahururu - Mararal road traverses the study area. Figure 1 shows the location of the study area.

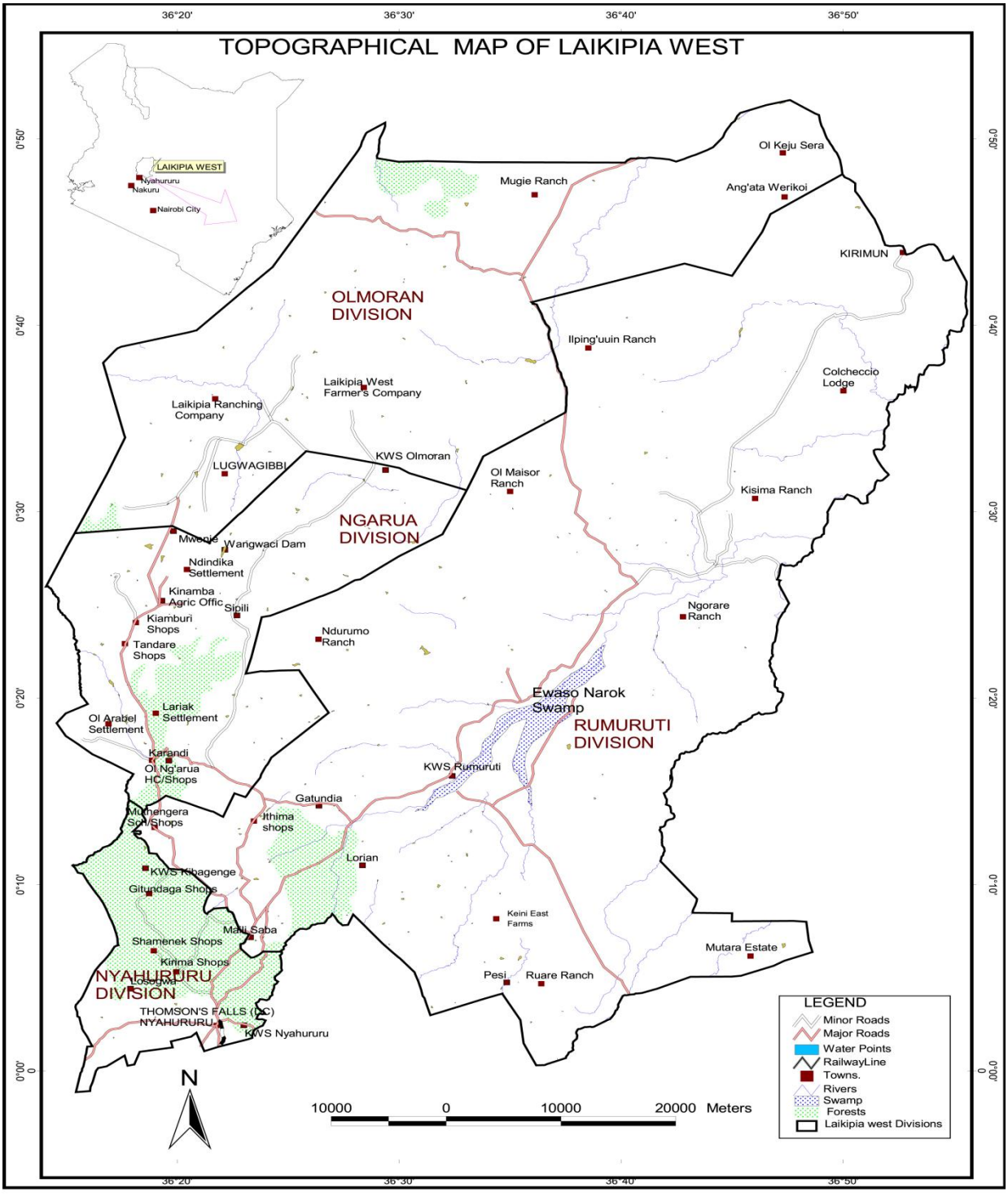

Figure 1: Location of Study area (Source RCMRD Nairobi 2007)

3.3 Environmental characteristics of the study area

Climate

Annual rainfall ranges from 900mm on the foot of the Nyandarua range to 500mm in the Western parts of the district. There are two rainy seasons; long rains fall in March- May while the short rains fall in October-November. Day temperatures range from 20-27^0 C while night temperatures range from 15-18^{0}C. January to March is the hottest months while June to July is the coldest months. Some areas are prone to frost around June when temperatures go to around 10^{0}C.

Geology and Soils

The geology of Laikipia is developed from volcanic materials mainly of pyroclastic rocks and ash. Red rocky friable soils dominate the sloping topographies. On the high central plateau soils of impeded drainage dominate especially the deep clay "black cotton" vertisols.

Vegetation

The dominant vegetation includes *Acacia drepanolopium* on heavy soils, *Acacia geriadii*, *Acacia tortolis* and *Acacia seyal* on the flat to the very gentle undulating soils. Grasses on the range include *Themeda triandra*, *Pennisetum stramionium*, *Pennisetum mezianum and Cynodon dactylon (*Wakhungu *et al.,* 2002).

3.4 Land utilization

Small scale maize and wheat farming, small scale livestock farming and extensive livestock ranching are the predominant farming activities engaged by 83.6% of the population (KNBS, 2007). Other crops like citrus, avocadoes, bananas, sugarcane, cassava and sweet potatoes are grown on a limited scale. The Ministry of Agriculture

annual reports showed that yields per unit area for these crops are lower than they were twenty years ago. Agro-forestry is gaining popularity due to declining yields, shortages of fuel wood and building materials which are becoming scarce. Limited irrigation activities occur along Ewaso Narok Swamp and Pesi in Rumuruti division. There are three gazetted forests namely Rumuruti, Marmanet and Lariak. These forests are surrounded by farms that block the migratory routes of the elephants making them ideal refuge places for the elephants at times when food in the forest is inadequate. Tourism is not an important economic activity as is the case in Laikipia East though Nyahururu town is in the central tourist circuit with Thomson Falls as the main tourist attraction. However it is an important conservation area for wildlife biodiversity.

3.5 Determination of land use/cover change

Landsat images taken between January 1973 and April 2008 and covering the study area were obtained i.e. MSS (P181r59 and P181r60 Jan 1973), TMs (P169r60 and P169r59 Jan 1986), ETM+ image of Jan 2000(P169r60 and P169r59), ETM+ (P169r60 March 2003) and ETM SLC off (P168r060 of 27th Feb. 2008, P169r059 of 6th April 2008 and P169r060 of 6th April 2008). These images cover an area larger than the study area and in some cases overlap. It was, therefore, necessary to geo-reference to obtain images covering area of interest which was then classified and studied to determine the land use and land cover change.

3.5.1 Geo-referencing

This process was carried out in order to obtain a scene of the study area for each of the years from the satellite image that was not distorted which when classified would give a true reflection of the actual situation on the ground of common features at the time the image was taken.

Using Geographical Vector Interpretation System (GEOVIS) software for geo-rectification, ETM+ image of Jan 2000(P169r60 and P169r59) was used as the true geo-referenced image(base image) to geo-reference the rest of the images i.e. MSS (P181r59 and P181r60 Jan 1973), TMs(P169r60 and P169r59 Jan 1986), ETM+(P169r60 March 2003) and ETM SLC off (P168r060 27th Feb 2008, P169r059 6th April 2008, P169r060 6th April 2008) where coordinates of common features in the image of 2000 and the other images were identified. There was a drought in April 2008 in the study area and therefore this image was as good as the one taken in February the same year. The coordinates of the 2000 image were adopted as follows:

Two windows within the software were used to display the un geo-referenced image bands especially band five (good for displaying rock formation) and the geo referenced one. Identification of common features in the two images was done and GCPs (Ground Control Points) specifying the coordinate of destination point were inserted. At least nine GCPs were inserted for each image.

Since Laikipia West district (area of interest) lies in the overlapping area between three images i.e. p168r60, p169r59 and p169r60, a mosaic of single bands was done for the

adjacent three images of the same year. Bands 1, 2,3,4,5 and 7 were mosaicked and Laikipia West District was clipped out from the mosaicked single bands. This kind of geo-rectification ensures features in the images are exactly one to one i.e. minimizing the errors during analysis. The images were projected to UTM zone 37n. The TM and ETM images were re-sampled to 28.5m pixel resolution while the MSS image was 57m to take care of the differences in the spectral resolutions of the two images. Single band images had uncombined (single) bands for each epoch i.e. the TM and ETM. Each epoch had 6 bands (1, 2, 3, 4, 5&7) while MSS had 4 bands (1, 2, 3&4). Composite images had combined bands for land cover/land use mapping i.e. band 2 as Blue and 3 as Green and band 4 as Red. For each epoch, the original image was enhanced i.e. the image was stretched in terms of color and light for clarity. The SLC -Off image was obtained from USGS without having been gap filled. Since all Landsat 7 SLC-off data are of the same high radiometric and geometric quality as data collected prior to the SLC failure, the image is equally good as the earlier ones but it was necessary to do gap filling. Gap filling was done by digitizing the SLC off image of 2008 and then overlaying on a previous image to confirm that the features are in the correct position. The final images used for land cover/use classification are as indicated in plates 1, 2, 3, 4 and 5.

Plate 1: January 1973

Legend

Image characteristics	**Interpretation category**
Dark brown/dark red with black mottles course texture	Natural forest
Dark brown /black shade with smooth texture occasionally separated with stripes of bluish greenish or purple	Plantation forest
Bluish or grayish shade with smooth texture	Bare soil/quarry/built area
Greenish shade with dense mottles of purple, rough texture or bluish shade light brown mottles medium texture	Farms
Bright red/light brown shade with smooth texture	River line vegetation
Dark blue shade with smooth texture	Open water body relatively unpolluted
Light blue shade with smooth texture	Polluted water body

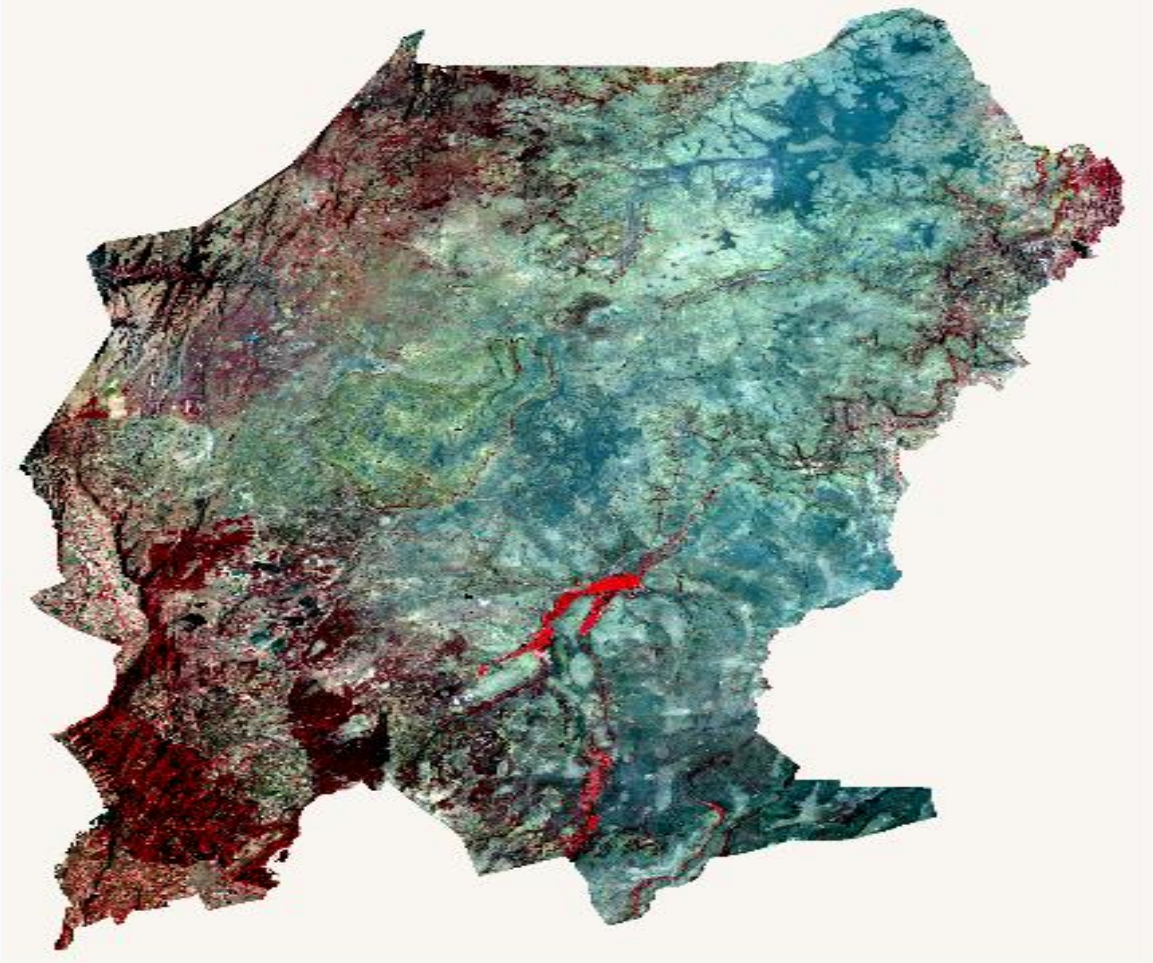

Plate2:January1986

Legend

Image characteristics	Interpretation category
Dark brown/dark red with black mottles course texture	Natural forest
Dark brown /black shade with smooth texture occasionally separated with stripes of bluish greenish or purple	Plantation forest
Bluish or grayish shade with smooth texture	Bare soil/quarry/built area
Greenish shade with dense mottles of purple, rough texture or bluish shade light brown mottles medium texture	Farms
Bright red/light brown shade with smooth texture	River line vegetation
Dark blue shade with smooth texture	Open water body relatively unpolluted
Light blue shade with smooth texture	Polluted water body

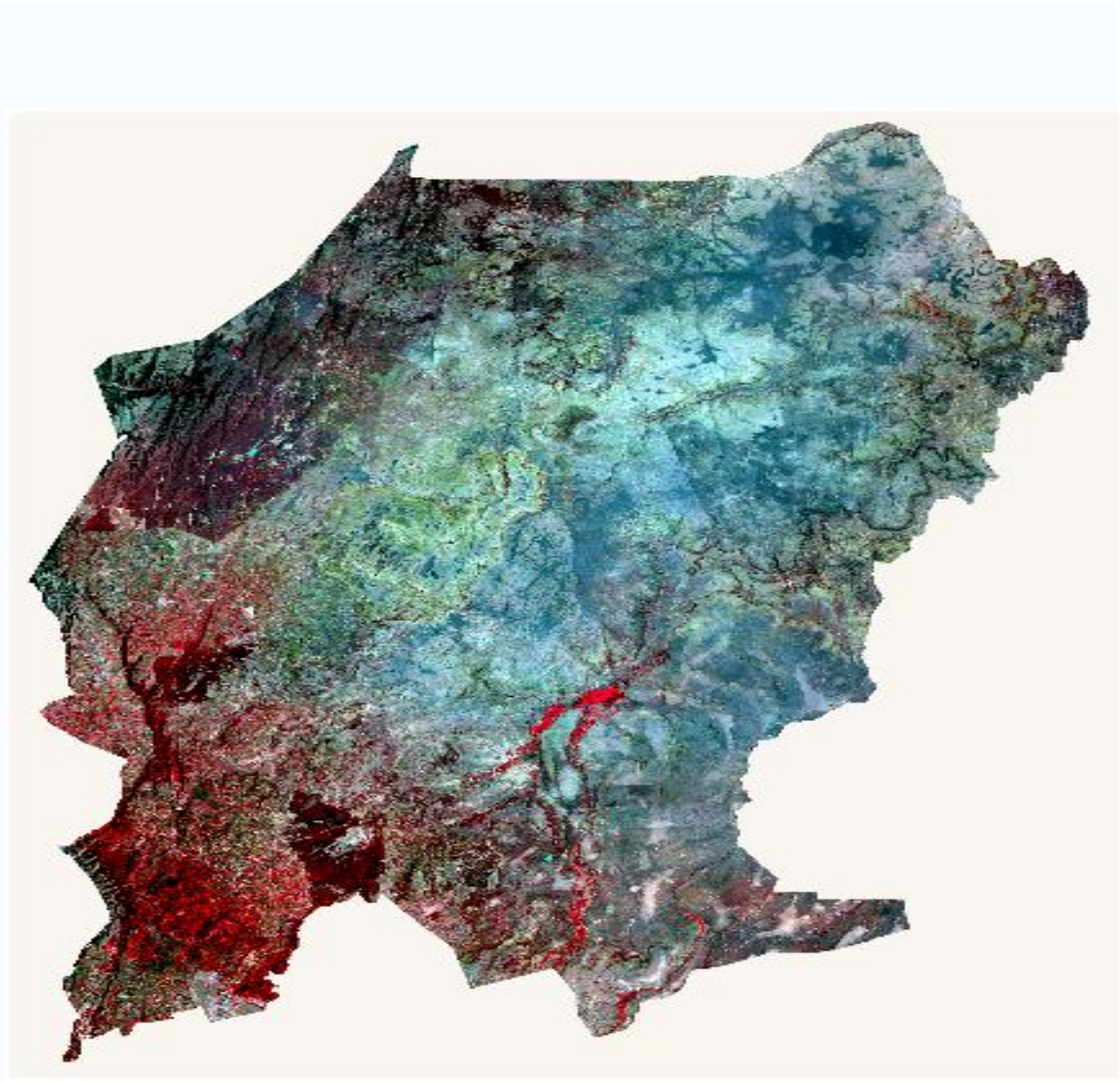

Plate 3: Year 2000

Legend

Image characteristics	**Interpretation category**
Dark brown/dark red with black mottles course texture	Natural forest
Dark brown /black shade with smooth texture occasionally separated with stripes of bluish greenish or purple	Plantation forest
Bluish or grayish shade with smooth texture	Bare soil/quarry/built area
Greenish shade with dense mottles of purple, rough texture or bluish shade light brown mottles medium texture	Farms
Bright red/light brown shade with smooth texture	River line vegetation
Dark blue shade with smooth texture	Open water body relatively unpolluted
Light blue shade with smooth texture	Polluted water body

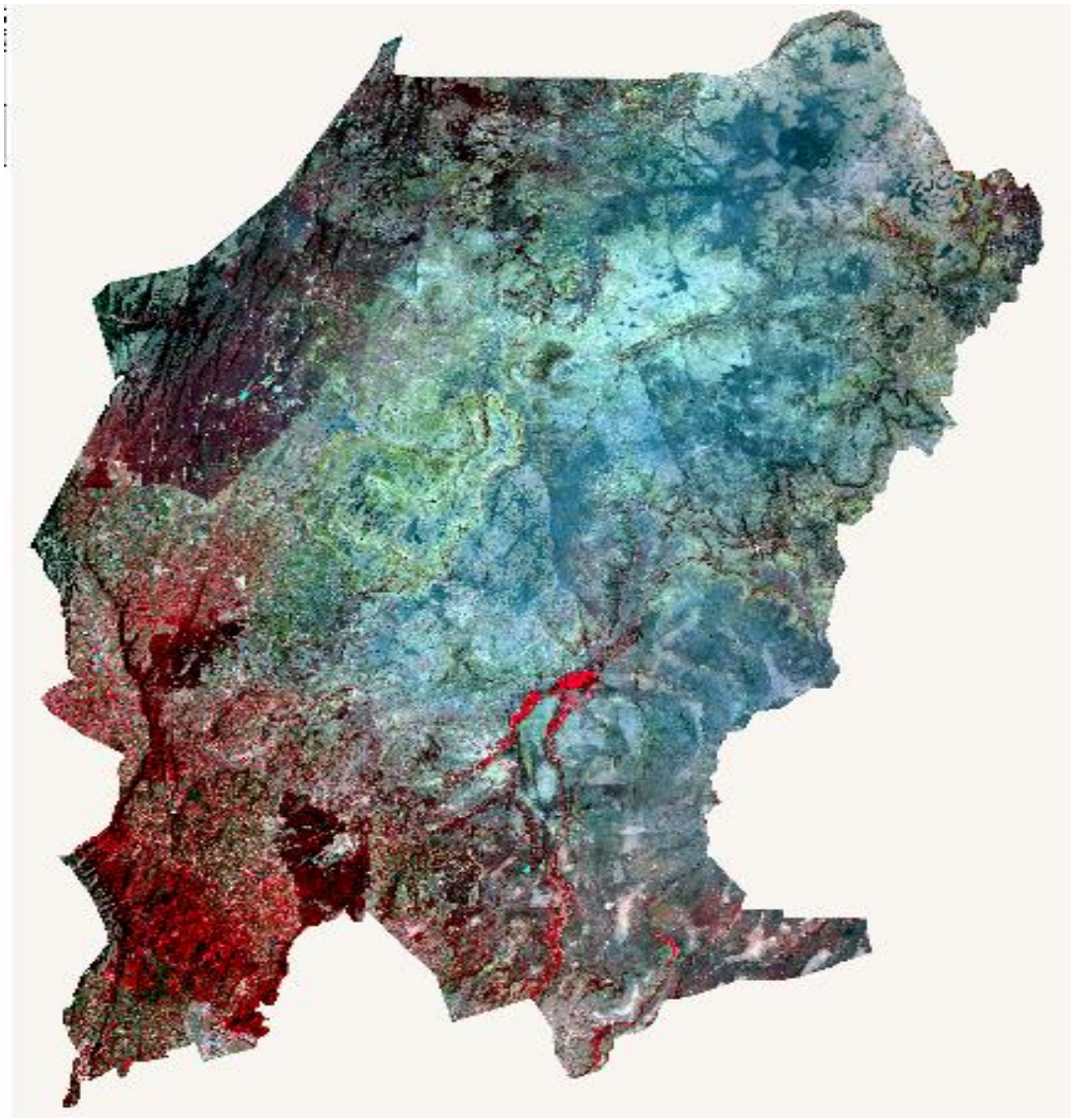

Plate 4: Year 2003

Legend

Image characteristics	**Interpretation category**
Dark brown/dark red with black mottles course texture	Natural forest
Dark brown /black shade with smooth texture occasionally separated with stripes of bluish greenish or purple	Plantation forest
Bluish or grayish shade with smooth texture	Bare soil/quarry/built area
Greenish shade with dense mottles of purple, rough texture or bluish shade light brown mottles medium texture	Farms
Bright red/light brown shade with smooth texture	River line vegetation
Dark blue shade with smooth texture	Open water body relatively unpolluted
Light blue shade with smooth texture	Polluted water body

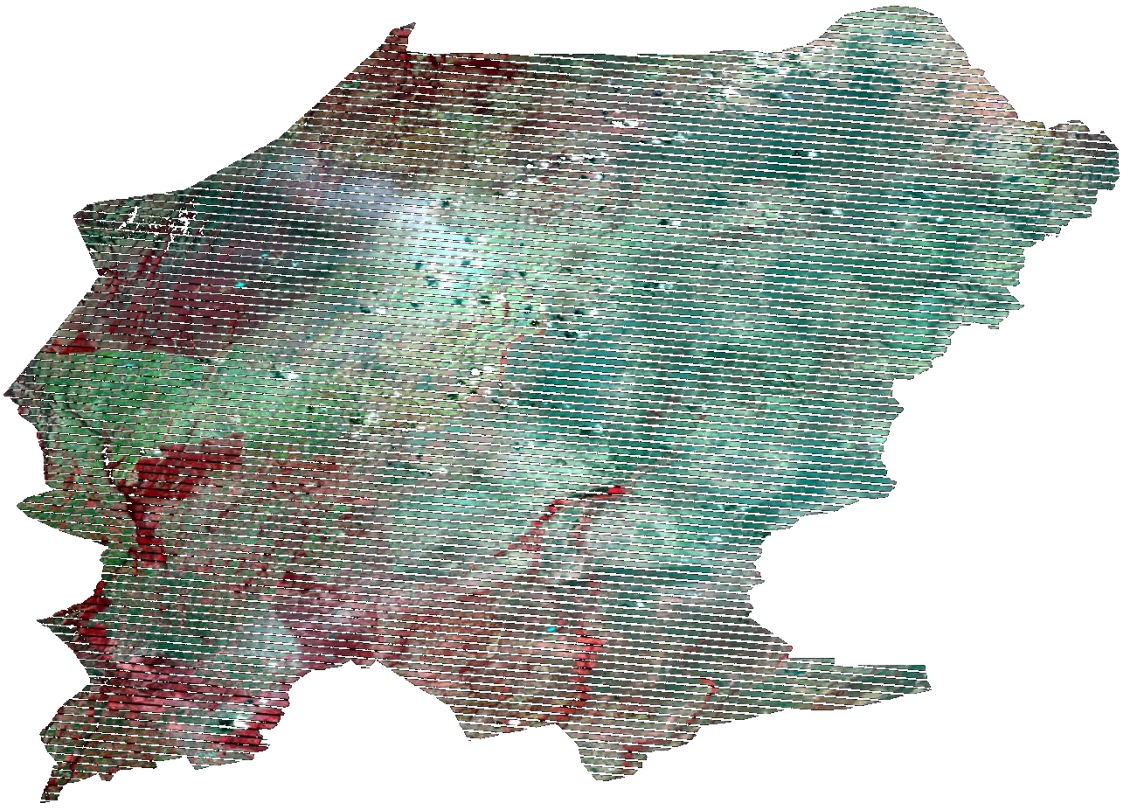

Plate 5: April 2008

Legend

Image characteristics	**Interpretation category**
Dark brown/dark red with black mottles course texture	Natural forest
Dark brown /black shade with smooth texture occasionally separated with stripes of bluish greenish or purple	Plantation forest
Bluish or grayish shade with smooth texture	Bare soil/quarry/built area
Greenish shade with dense mottles of purple, rough texture or bluish shade light brown mottles medium texture	Farms
Bright red/light brown shade with smooth texture	River line vegetation
Dark blue shade with smooth texture	Open water body relatively unpolluted
Light blue shade with smooth texture	Polluted water body

3.5.2 Classification of Images

Classification refers to the process of extracting information from remotely sensed images, which can then be developed into interpreted maps of various land use and land cover types. This information computed for different images taken over different time periods is subsequently used for change analysis. In supervised classification, one specifies the land cover classes by providing a statistical description of how the expected land cover classes look like in the imagery.

In this case, image classification began by creating areas of interest known as training sites and signature names for the various elements in the images used in the study. This involved the identification of the elements, for example indigenous forests, farms, plantations, settlements, grasslands and bare ground, dams and other water masses which were the land use and land cover classes. Small parts of each element were then digitized in order to come up with the training sites for which signature names were assigned. After this, supervised classification was carried out for the images of 1973, 1986, 2000 and 2003, by using a classifier called Maximum Likelihood Classifier (MLC).

3.5.3 Change analysis

A change analysis was carried out using the IDRISI Land Change Modeler (LCM), in which the change occurring for each land cover type was calculated. Feature extraction using on screen delineation to create GIS vector layers by using GEOVIS software was used for the 2008 image. The 2008 image was a low quality image in terms of spectral resolution as it was taken by ETM SLC Off which had to be gap filled. This software was the most ideal for on screen delineation of such an image as it was not possible to carry

out supervised classification for this image. However, similar land use classification was used in all the images.

3.5.4 Determination of vigor and intensity of vegetation (NDVI)

A quantative approach in Normalised Difference Vegetation Index (NDVI) analysis was used to detect incidences of drought for each of the satellite images of the study area taken between 1973 and 2008. This was done using GEOVIS and ERDAS Imagine software. The NDVI values were used to monitor vegetation changes between 1973 and 2008. Negative values show environmental stress while positive values show vegetation vigor. The smaller the negative NDVI value the higher the environmental stress and the higher the NDVI value the higher the vegetation vigor. A relationship between the vegetation vigor and environmental stress was then studied in relation to the level of human-elephant conflict by making comparisons between NDVI values and intensity of conflict.

3.6 Determination of trends in human-elephant conflict

3.6.1 Determination of human population trends

Population data in the study villages and for the whole district was collected (table 4) from KNBS office Nanyuki and analyzed using SPSS software.

The human population trend of the entire district was analyzed for significance using Pearsons bivariate correlation using census data for 1999 to 2008.

3.6.2 Determination of elephant population dynamics

Data on elephant populations was collected from KWS census reports for the Samburu Laikipia Ecosystem and the numbers for Laikipia district isolated. Total wildlife counts were done in the study area for the years 1996,1997,1999,2002 and 2008.

3.6.3 Human elephant conflict

Human-elephant conflict data for individual farmers affected by the conflict between January 1998 and November 2007 was collected from occurrence books located at KWS stations in Nyahururu, Rumuruti, Kibagenge, Mutitu, Olmoran and Pesi. The Warden in Nyahururu is in charge of Nyandarua district and the two out-posts located at Kibagenge and Mutitu which were transferred from Baringo District in 2003. For all the cases reported in these stations, only those cases that were reported from Laikipia West District were isolated. Incidences of conflict for individual farmers as reported were recorded, yearly totals obtained and an aggregate of all the years obtained which was used to rank the villages based on the intensity of conflict as shown in appendix 1. Conflict hot spots were then isolated on the basis of intensity of conflict. Eight conflict hot spots namely Siron, Losogwa, Gatundia, Salama, Mahianyu, Lobere, Wangwaci and Olmoran were selected for questionnaire administration. These were selected on the basis of agro ecological zones i.e. UH2 (Losogwa, Siron), LH3 (Lobere, Wangwaci), LH4 (Mahianyu, Olmoran) and UM5 (Gatundia, Salama) ensuring there was adequate coverage of the entire study area. Trends of human elephant conflict were analyzed for relationship with human population trends over the same period. This relationship was collated with NDVI

values which were computed for each of the landsat images to establish the levels of environmental stress.

Spearman's rank correlation was used to investigate the association between land use changes, human population and human elephant conflict. The tests were also used to determine whether a particular land use change was associated with human elephant conflict.

3.7 Collection of ground truth data

Selection of households

The total number of households in the study area was 8031. Out of these, 725 households reported conflict cases to KWS between Jan 1997 and November 2007 in the study area. The total number of households sampled was 160. Twenty households were interviewed in each village aiming at achieving 30% of the households in the study area.

Random sampling was used in selection of households for questionnaire administration. A household to be interviewed was selected after every five households. GPS positions of the villages plus some prominent features were taken to help in the interpretation of the images (appendix 2). These were taken using GPS Garmin Series 12X and the geo-positions are shown in table 6 and 7 in the appendix. The features and sites were marked in the study area map (figure 1).

Questionnaire administration

The questionnaire shown in appendix 3 was used to collect ground truth data from each selected household. The household head was interviewed or in his/her absence, an adult member of the household was interviewed.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the changes in various land cover/land use types between January 1973 and April 2008. It also presents and discusses relationships between land cover change, elephant population, human population and human-elephant conflict in Laikipia West District.

4.2 Change in area of the various land cover types

The results from the supervised classification of the images shown in Plate 6-10 indicate losses and gains in various land use and land cover types. From plates 7 and 8, it is apparent that the area covered by indigenous forest reduced drastically between 1973 and 1986; with an increase in plantations forest and bare land. The results from the 2000 and 2003 images indicate a loss of both indigenous and plantation forests. There was also a further decrease in the area covered by Ewaso Narok Swamp, which was replaced by farms as shown in table 1.

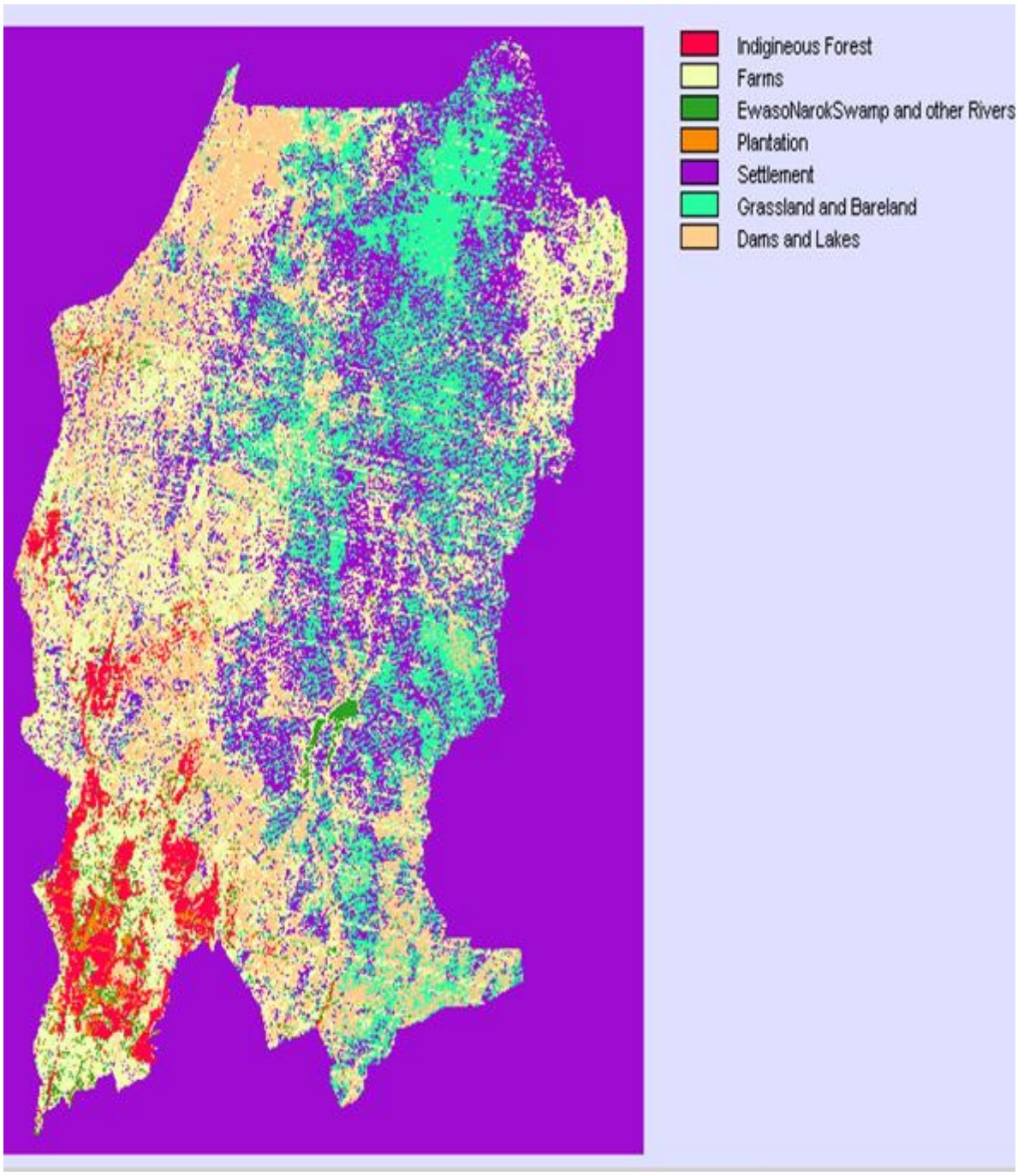

Plate 6: 1973 classified image

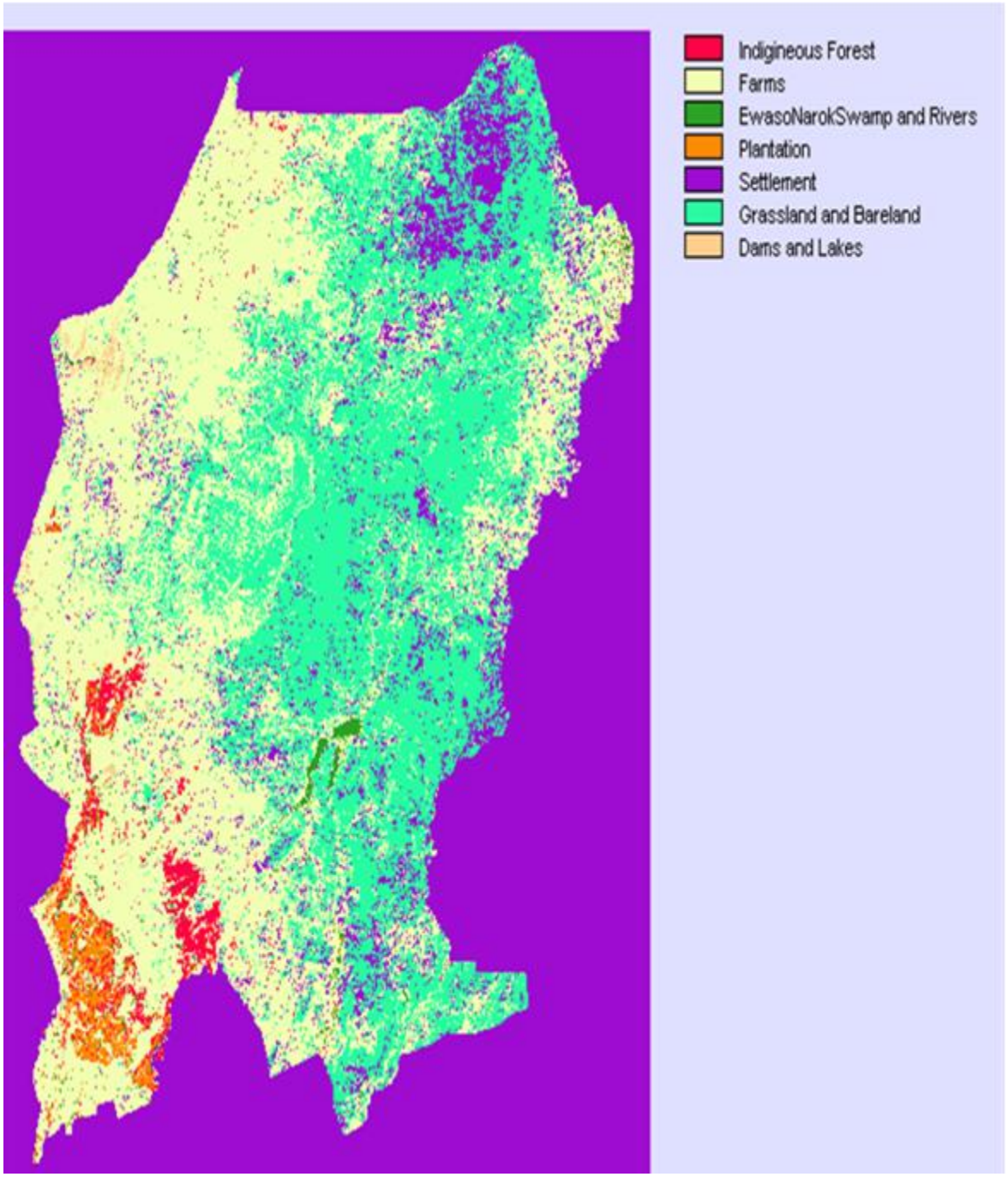

Plate 7:1986 classified image

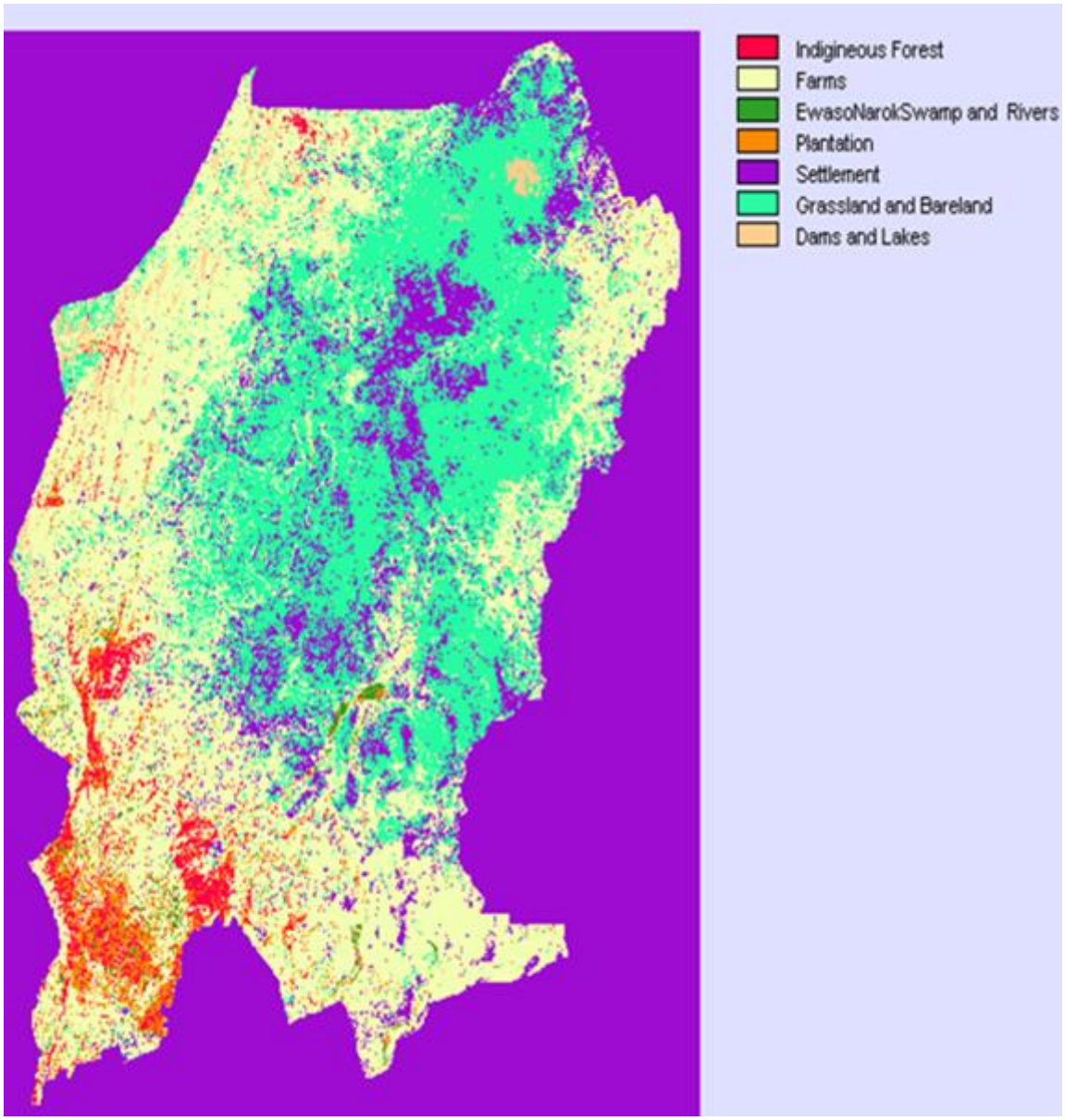

Plate 8 : 2000 classified image

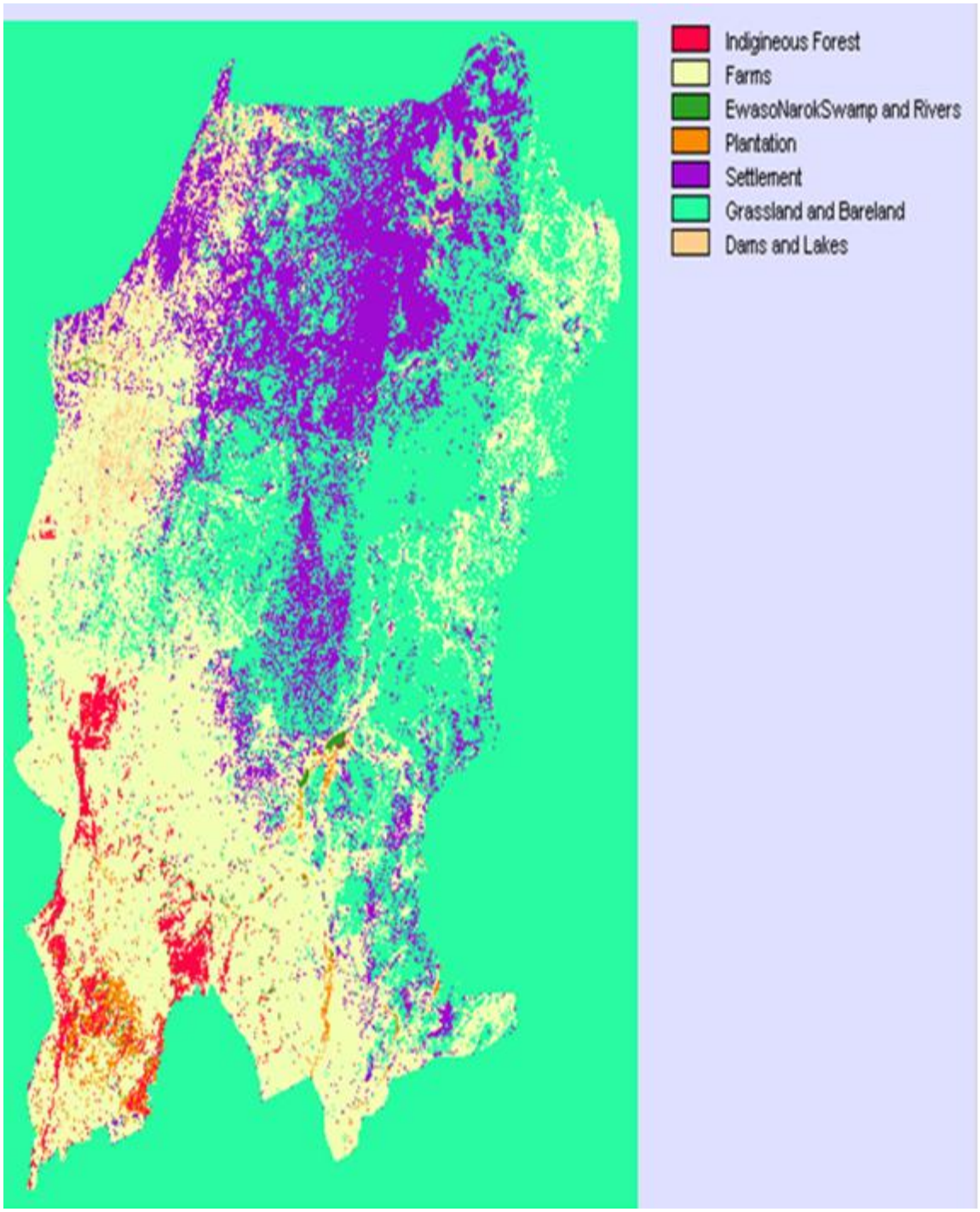

Plate 9: 2003 classified image

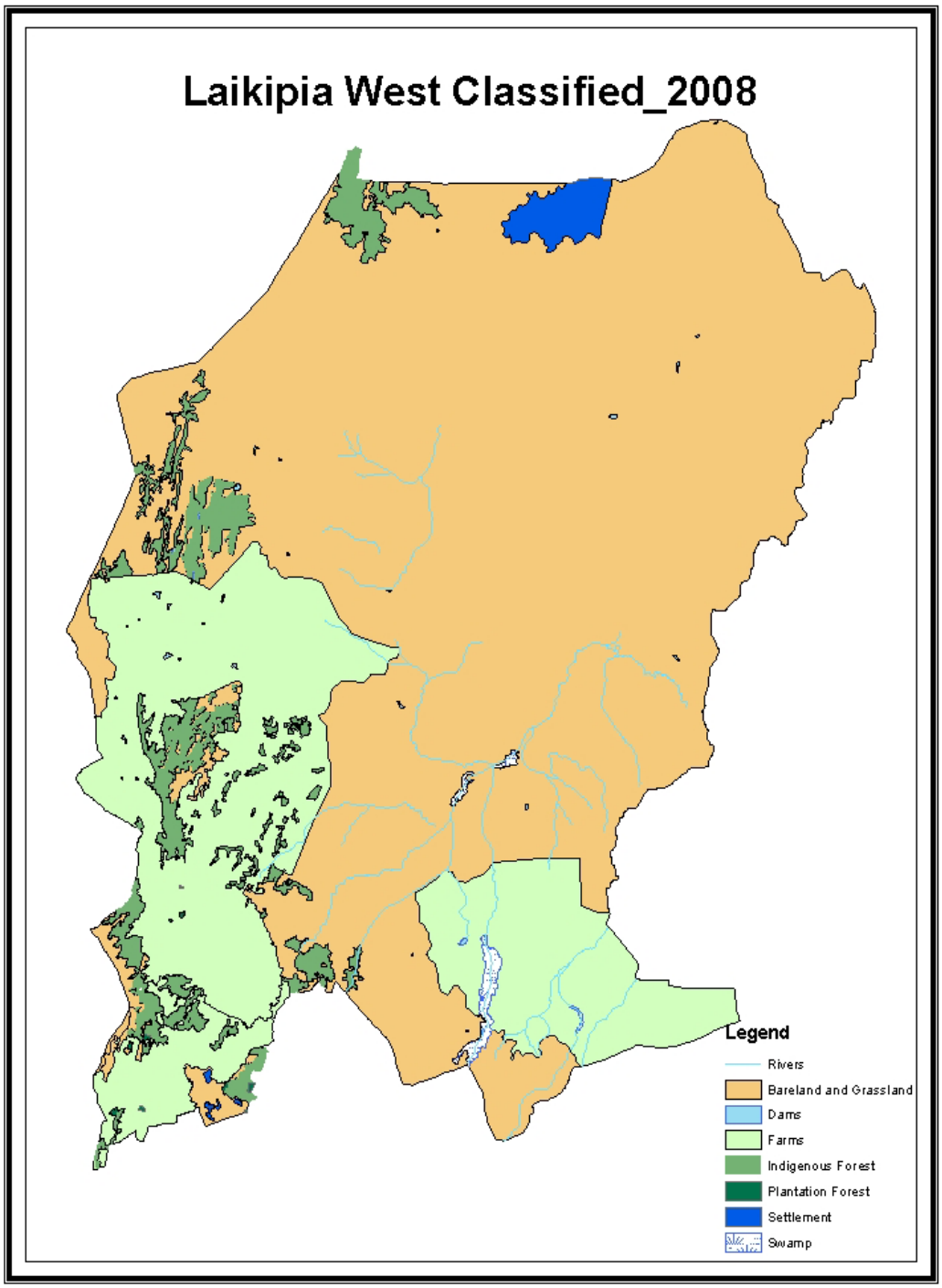

Plate 10: 2008 Classified image

Table 1: Change in area of land cover types

Land use/cover type	1973		1986		2000		2003		2008	
	Area in Km^2	Area as % of total area of district	Area in Km^2	Area as % of total area of district	Area in Km^2	Area as % of total area of district	Area in Km^2	Area as % of total area of district	Area in Km^2	Area as % of total area of district
Indigenous forest	209.5	4.2	104.9	2.1	148.3	3.0	120.5	2.4	106.7	2.4
Ewaso Narok Swamp and rivers	118.0	2.4	44.3	0.9	30.7	0.6	16.6	0.3	1.8	0.04
Grassland and bare land	1192.0	24.1	1802.8	36.5	1604.6	32.5	4890.1	99.1	3423.9	69.4
Dams and other water bodies	820.7	16.6	41.8	0.8	118.6	2.4	124.9	2.5	3.7	0.08
Farms	1621.1	32.8	2292.5	46.4	2161.2	43.8	1954.8	39.6	1058.7	21.4
Plantation forests	53.4	1.1	75.5	1.5	152.3	3.1	68.2	1.4	149.4	1.4
Settlements	4096.2	83.0	3748.9	75.9	3897.4	78.9	935.2	18.9	46.08	0.9

Table 2: Percentage change of land cover type

Land use/cover type	Percentage change				
	1973-1986	**1986-2000**	**2000-2003**	**2003-2008**	**Overall change 1973-2008**
Indigenous forest	-49.94	+41.40	-18.70	-11.46	-49.04
Ewaso Narok Swamp and rivers	-62.44	-30.00	-45.00	-89.00	-98.00
Grassland and bare land	+51.00	-10.00	+204.00	-29.00	+187.00
Dams and other water bodies	-94.00	+183.00	+5.00	-97.00	-99.00
Farms	+41.42	-5.73	-9.55	-45.84	-34.70
Plantation forests	+41.00	+101.00	-55.00	119.00	+55.00
Settlements	-8.00	+3.00	-76.00	-95.00	-98.00

(NB + denotes an increase while – denotes a decrease using 1973 as base year)

Table 3: Land use change matrix

Land use/Cover type	Year	1973	1986	2000	2003	2008
Indigenous Forest	Area (Km²)	209.5	104.9	148.3	120.5	106.7
	% Area to District Size	4.2	2.1	3	2.4	2.4
	Land area change (%)		-49.94	41.4	-18.7	-11.46
Ewaso Narok Swamp/Rivers	Area (Km²)	118	44.3	30.7	16.6	1.8
	% Area to District Size	2.4	0.9	0.6	0.3	1.8
	Land area change (%)		-62.44	-30	-45	-89
Grassland/Bare land	Area (Km²)	1192	1802.8	1604.6	4890.1	3423.9
	% Area to District Size	24.1	36.5	32.5	99.1	69.4
	Land area change (%)		51	-10	204	29
Dams/Other water bodies	Area (Km²)	820.7	41.8	118.6	124.9	3.7
	% Area to District Size	16.6	0.8	2.4	2.5	0.08
	Land area change (%)		-94	183	5	-97
Farms	Area (Km²)	1621.1	2292.5	2161.2	1954.8	1058.7
	% Area to District Size	32.8	46.4	43.8	39.6	21.4
	Land area change (%)		41.42	-5.73	-9.55	-45.84
Plantation Forests	Area (Km²)	53.4	75.5	152.3	68.2	149.4
	% Area to District Size	1.1	1.5	3.1	1.4	1.4
	Land area change (%)		41	101	-55	119
Settlements	Area (Km²)	4096.2	3748.9	3897.4	935.2	46.08
	% Area to District Size	83	75.9	78.9	18.9	0.9
	Land area change (%)		-8	3	-76	-95

Figures 2-8 show the trends in area of each land cover/land use type between 1973 and 2008.

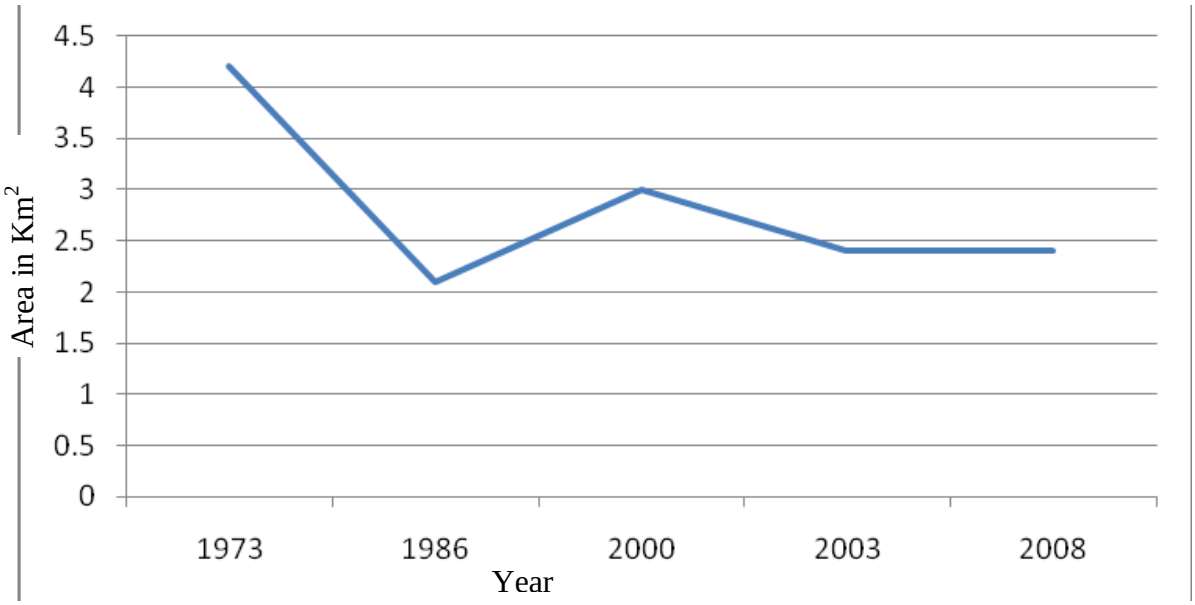

Figure 2: Trend in area of indigenous forest

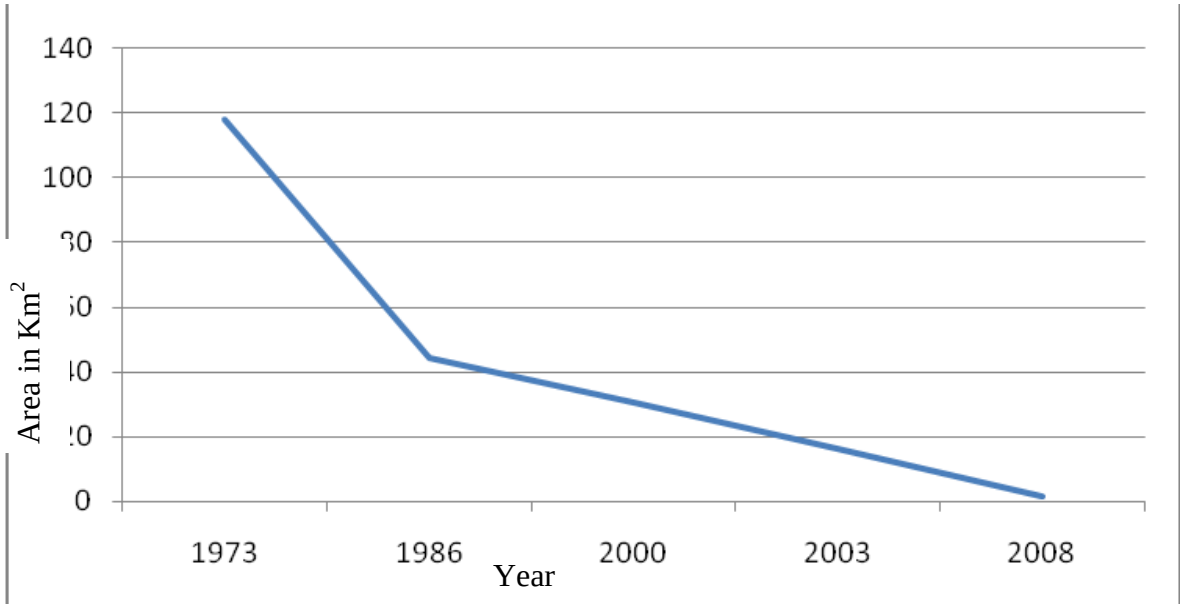

Figure 3: Trend in area of Ewaso Narok swamp and rivers

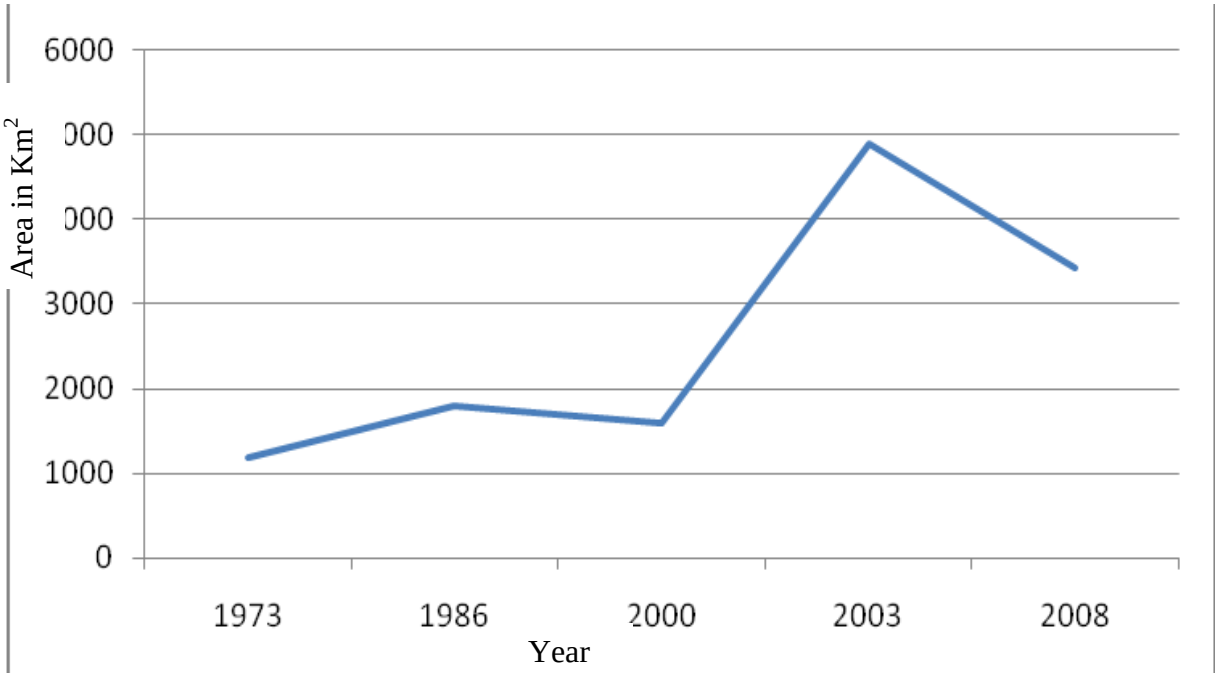

Figure 4: Trend in area of grassland and bare land

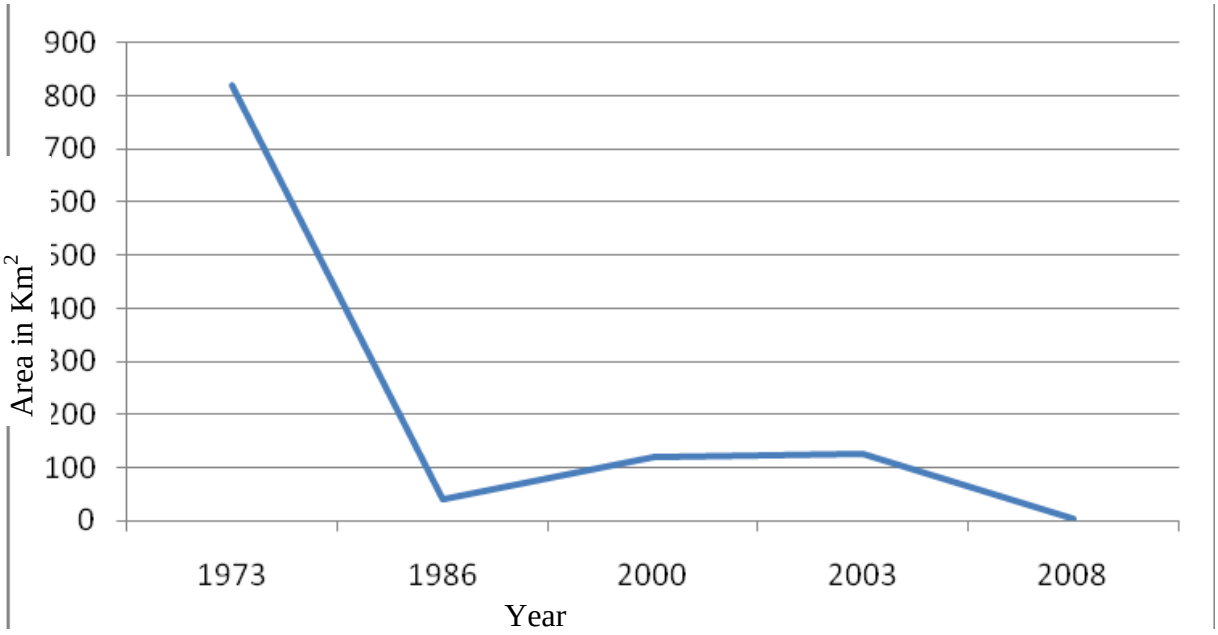

Figure 5: Trend in area of dams and other water bodies

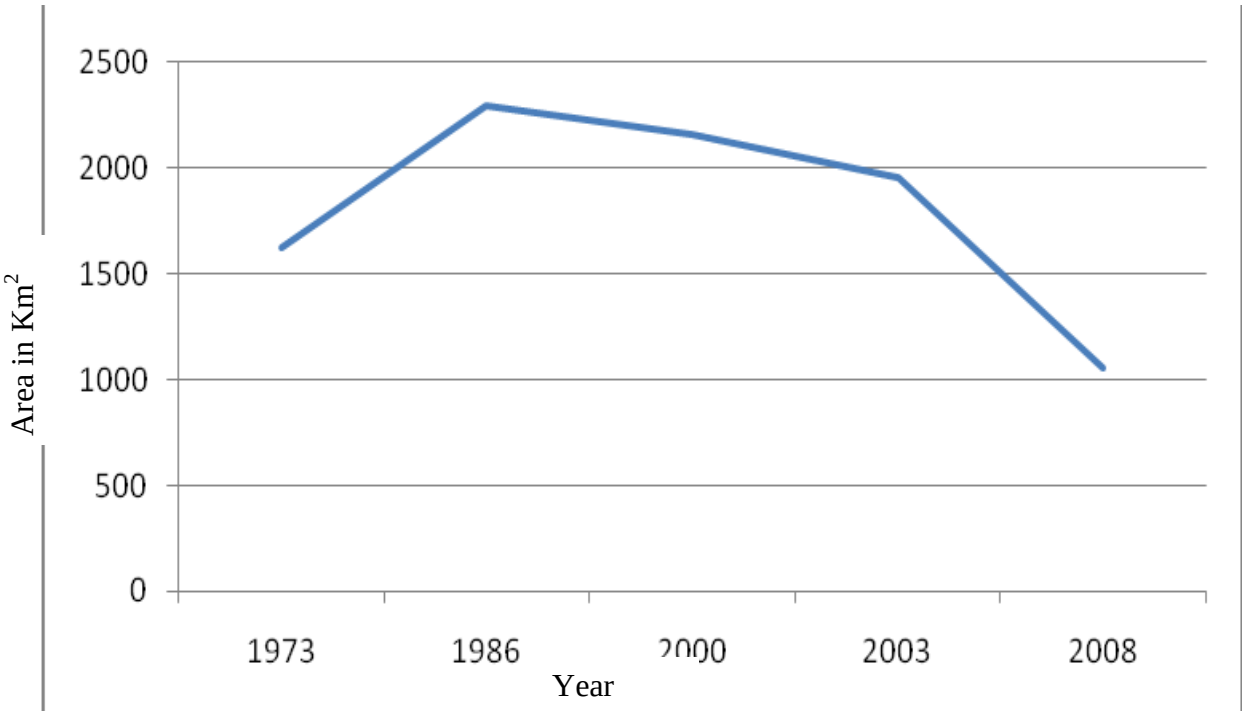

Figure 6: Trend in area of farms

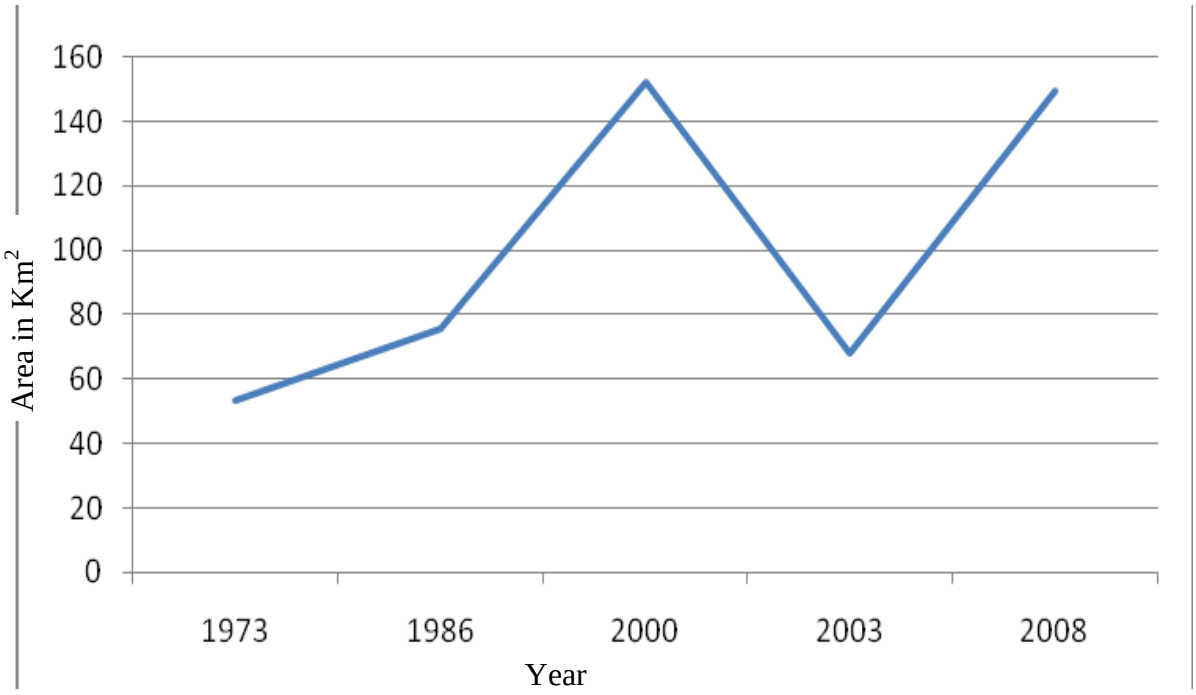

Figure 7: Trend in area of plantation forests

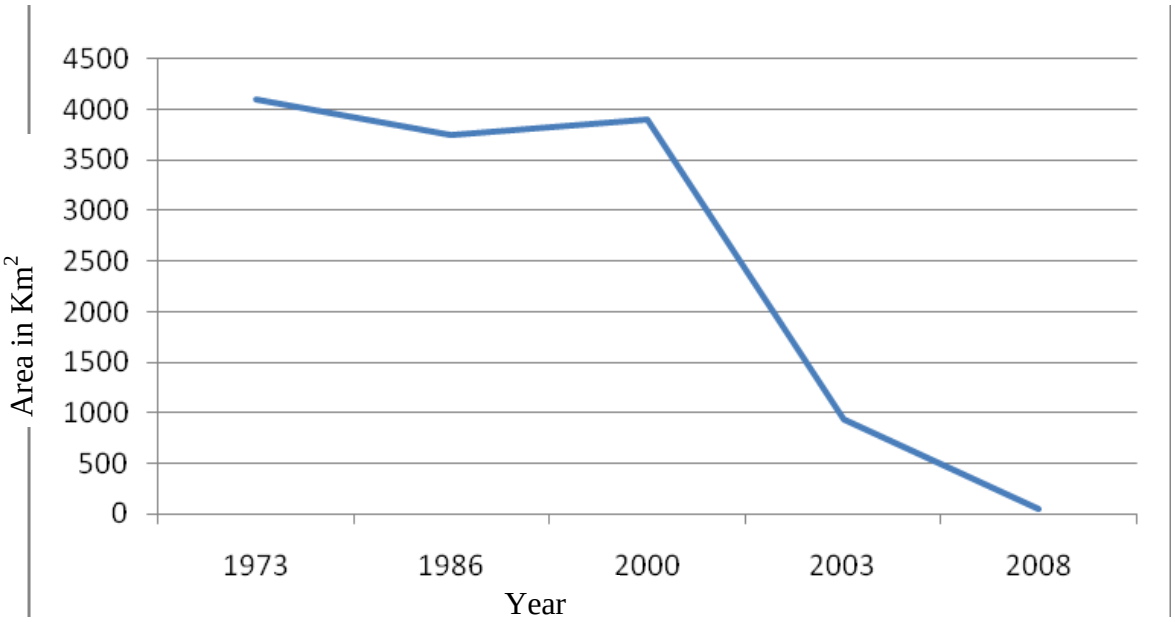

Figure 8: Trend in area of settlements

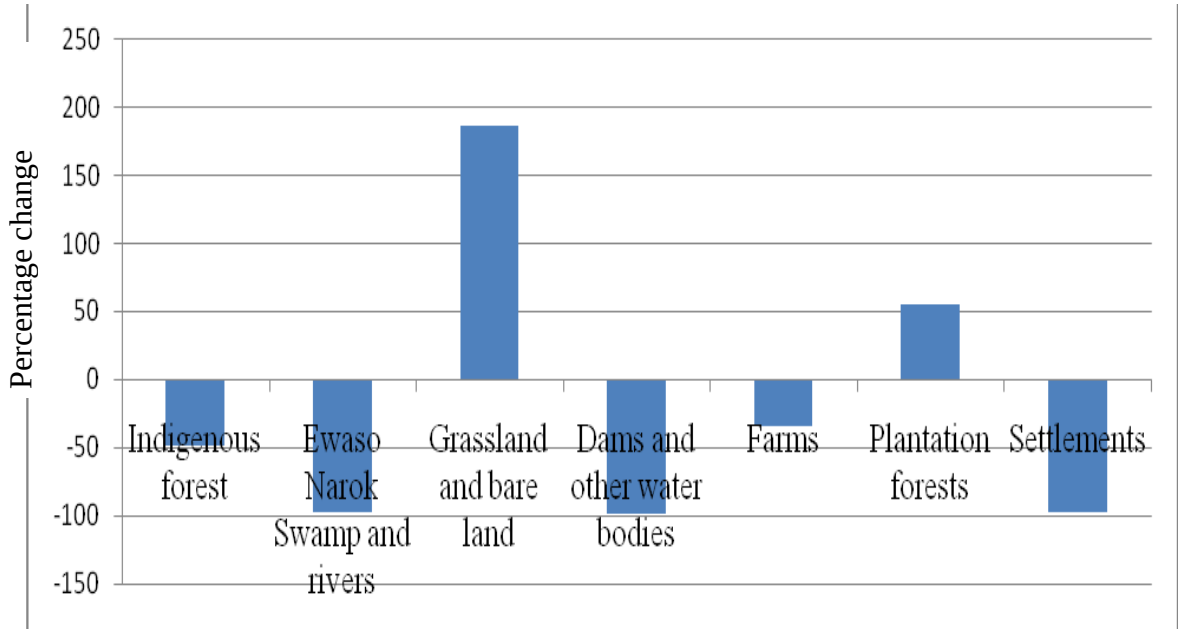

Figure 9: Percentage changes in land cover between 1973 and April 2008

From the estimates in tables 2 and 3, there has been a significant loss in the indigenous forest, whose area has shown decreasing trends {209.5 Km^2 (4.2%), 148.3 Km^2 (3.0%) and 120.5 Km^2 (2.4%) in 1973, 2000 and 2003 respectively}.There was an overall reduction of -49.04% between 1973 and 2008 in indigenous forests. A small increase in

the area of indigenous forest was noted in the year 2000 which later declined due to re-alignment of the boundary between the study area and Baringo district. There was increased settlement between 1986 and 2000 resulting in clearance of forests to pave way for farms. The need for fuel wood and construction materials was also expected to rise over the same period. The results also show a sharp decline in Ewaso Narok Swamp, with the area of the Ewaso Narok swamp and other rivers decreasing from 118.0 km^2 (2.4%) in 1973 to 30.7 km^2 (0.6%) in 2000, 16.6 km^2 (0.3%) in 2003 and 1.8 km^2 (0.04%) in April 2008 with an overall decline of 98%. This is a very sharp decline with the area reducing to about half between year 2000 and 2003 and about tenfold reduction between 2003 and April 2008. This can be attributed to the reduction in rainfall both in intensity and distribution coupled with deforestation and soil erosion and eventual silting of the swamp. This can be caused by continuous cropping on same piece of land and mono-cropping. The area of grassland and bare land however increased, with the area increasing from 1192 km^2 (24.1%) in 1973 to 1604.6 km^2 (32.5%) in 2000, 4890.1 km^2 (99.1%) in 2003 and 3423.9 km^2 (69.4%) in April 2008. From the classified images, some area of the forest and swamp has been modified to bare land. The area of plantations in 1973 was 53.4 km^2 (1.1%) while in 2000 it was 152.3 km^2 (3.1%) and 68.2 km^2 (1.4%) in 2003.

The area covered by plantations fluctuated, showing increases and decreases in different years with the decreases probably indicating periods when they have been cut down for commercial purposes. GIS cross tabulation procedures showed changes in areas of individual cover types between earlier and later years of interpretation. For example

between 1986 and 2003, Chi square statistics showed (p=0.000, X^2 = 94 666 25; df =159 at 0.01 level of significance two tail test. The results showed that there was correlation between land use change and human elephant conflict was significant at 0.005 level for indigenous forest (p = -1.000), farms (p= -1.000) and settlements (p = -1.000). The calculated chi square shows a figure greater than the tabulated figure and therefore the first null hypothesis is rejected. Following the rejection of the null hypothesis i.e. There were no significant changes in land use/land cover in 1973, 1986, 2000, 2003 and 2008 in Laikipia West district Kenya and the subsequent significance levels for forest, farms and settlements, then it follows that there were significant changes in land use/land cover in 1973, 1986, 2000, 2003 and 2008.

The calculated chi square statistics for human population showed (p= 0.794, N=160, d.f. =159) at 0.01 level of significance two tail test. The second null hypothesis is therefore not rejected i.e. Increase in human population is not aggravating the human elephant conflict in Laikipia West district, Kenya. Figure 2 shows there was a general decline in indigenous forests between 1973 and 2008. Similarly, there was a decline in available water resources as depicted in figures 3 and 5. Figure 4 depicts a general increase in the general area of grasslands and bare land while figure 6 depicts a decline in area under farms. Within the same period, there was a general increase in human elephant conflict cases as shown in figure 13. It was evident that the elephant niches have been interfered with through human activities. For example, the indigenous forest cover has been declining over the years allowing elephants to stray into farms. Similarly water resources for both human and elephants were declining. In spite of the area under farms and grasslands/bare ground increasing, these do not form suitable habitat for elephants.

Therefore the third null hypothesis is rejected i.e. There was no relationship between land use/land cover change and human elephant conflict in Laikipia West district Kenya. This implies therefore that there is a relationship between land use/land cover change and human elephant conflict in Laikipia West district, Kenya.

4.3 Changes in Land Use

Land use change arising from comparisons of landsat images taken between January 1973 and April 2008 show a decrease in the acreage of indigenous forests, farms and settlement. Human-elephant conflict in the study area over the same period was increasing. Increasing human population in Laikipia West district increases pressure on indigenous forests thus reducing browse material for the elephants. Reduction of browse material in forests means that elephants have to stray into farms in search of browse resulting in a decline in farms and therefore an increase in human-elephant conflict. In their migratory patterns, elephants are known to follow a particular route over the years. Settlements along the migratory routes of the elephants will therefore be destroyed resulting into a decline in settlements. Increase in population exerts pressure on indigenous forest due to increase in the demand on building materials and fuel wood. To meet their food requirements which would otherwise have been met by wild foods in the forest, elephants have to continuously feed on cultivated crops and remain in the farms. This is consistent with Iwamoto, (1988) who found out that cultivated crops have a higher nutritive value than wild foods. Animals with access to higher quality foods spend less time feeding and more time resting than those wholly dependent on wild foods (Forthman-Quick, 1986; Altman, 1998; Muruthi, 1989;). Animals with access to

cultivated crops therefore would be expected to adopt a strategy of raiding cultivated crops when availability of wild crops is low. This is consistent with Kisoyan, (1995) that in areas where there was no change in land cover, the elephants were associated with destruction of woody species while in areas of land cover change; the elephants were associated with destruction of crops.

Data collected during the study showed an increase in land subdivision with 44% of respondents having subdivided their land in the last ten years i.e. since 1997. Thirty nine percent (39%) of the subdivisions were below 5 acres. These are very small land parcels in an area that is 50-80% arid. Eighty seven percent (87%) of the respondents had lived on their farms for over 10 years. This land subdivision has contributed to land use change.

Ground truth data on land use between 2003 and 2007 in the land parcels of the respondents is as shown in figure 10. The predominant land utilization by the farmers was rain fed mixed crop and livestock farming/crop, livestock and woodlot (65%). Land use for crop growing alone has changed since the year 2003. There was a shift towards diversification with woodlots or livestock. Bare ground or grassland was observed to have increased by 5%. Crops are needed to meet the food demand and could not be fully abandoned but combined with other crops as a way of spreading risks. Livestock farming could not replace crops because of insecurity problems. Twenty three (23%) of the respondents cited wildlife conflict as the reasons for decreasing their crop enterprises.

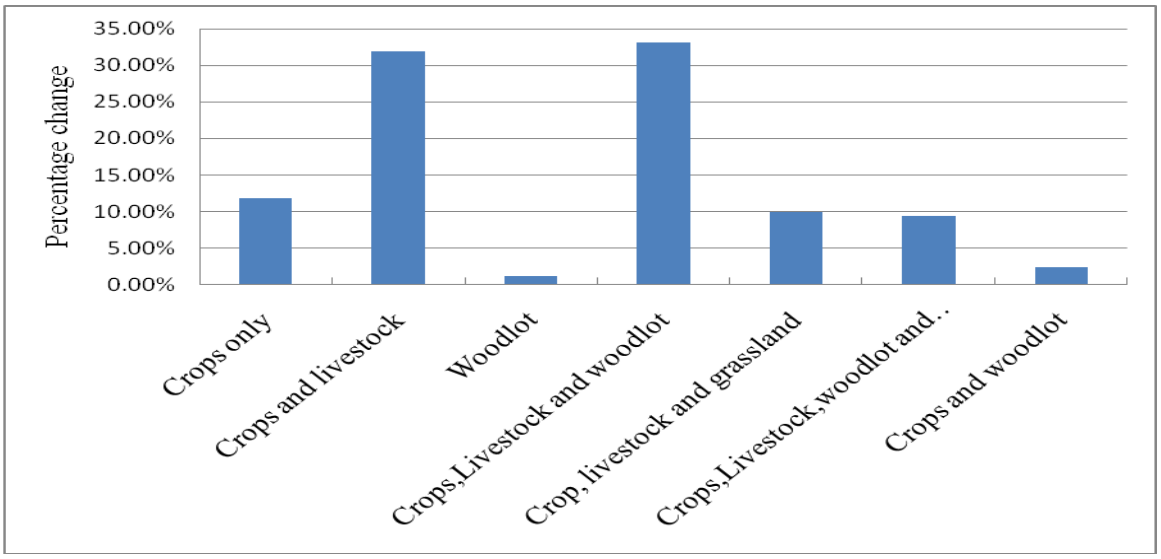

Figure 10: Change in land utilization by farmers from 2003 to 2007

4.4 Human population trends

Table 3 shows the human population in the study area between 1999 and 2008.

Table 4: Human Population in the Study Area

Year	Siron	Losogwa	Gatundia	Mahianyu	Salama	Lobere	Wangwaci	Olmoran	District Total
1999	7393	6209	6431	2404	3061	16927	5151	5031	193016
2006	9616	8076	8363	3126	3979	22017	6700	6543	251038
2007	9787	8220	3126	3182	4050	22409	6819	6659	255302
2008	9660	8365	3182	3238	4122	22806	6940	6777	259730

Source: Kenya National Bureau of Statistics Nanyuki, 2009

A decline in the population was noted for Gatundia in 2007 because of migration out of the area as the village was affected by post election violence in the same year. The trends are shown in figure 11a and 11b.

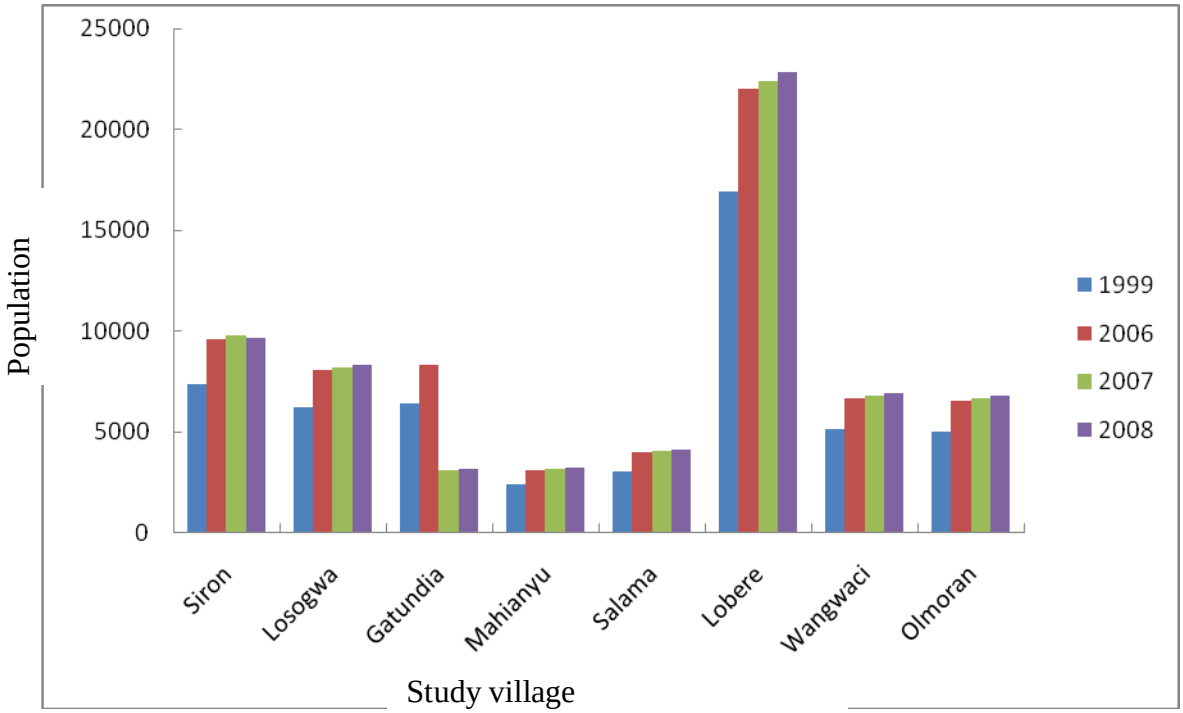

Figure 11a: Human population trends in the data collection sites between 1999 and 2008

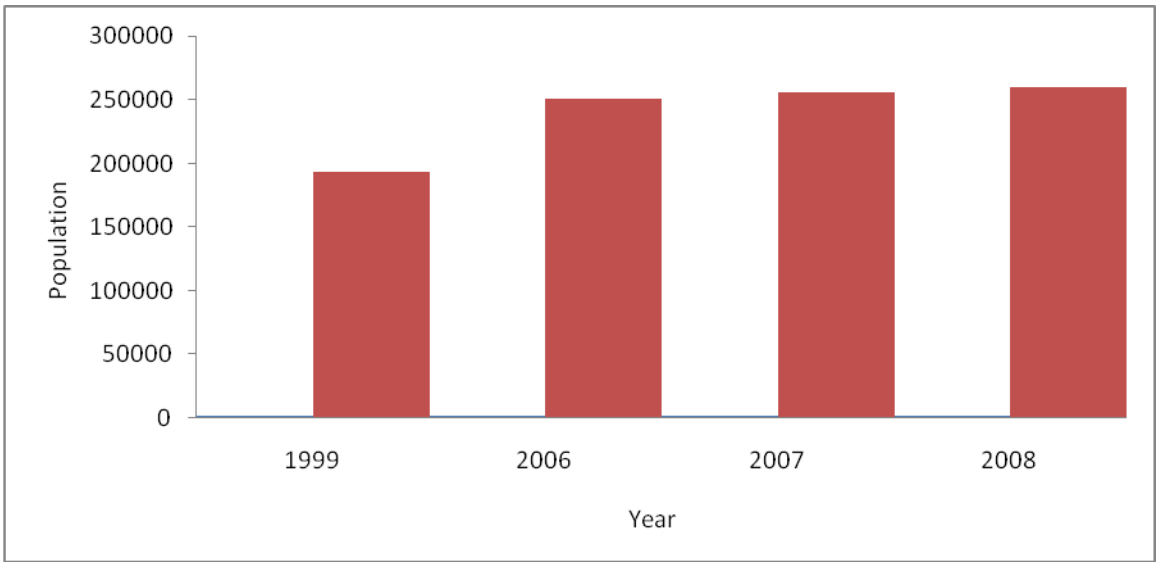

Figure 11b: Human population trends in the district between 1999 and 2008

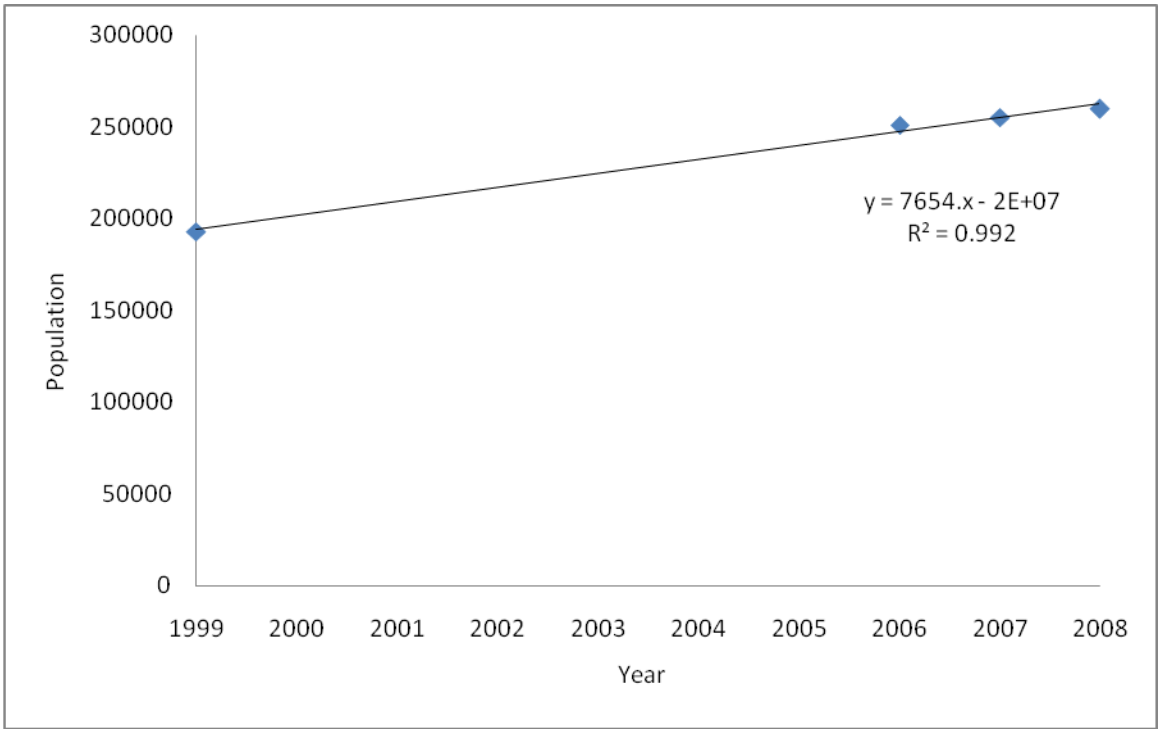

Figure 11c: Human population growth rate in the district between 1999 and 2008

Analysis of human population indicates an increase in the number of persons (Figure 11c) between 1999 and 2008 in the district showing a positive correlation between the population in the study villages and the district population ($p=0.555$, $N=8$, $df = 7$). There was a general increase in human population since the 1999 census which grew at a rate of 3% between 1999 and 2006 further increasing to 3.86% between 2006 and 2007 except for Gatundia where it reduced because migration out of the area following the post election violence that affected the area in 2007 (KNBS, 2007). The rate reduced to 1.15% between 2007 and 2008. This can be explained by migration into the district as evidenced by encroachment of forests and water bodies in search of farms and creation of settlement schemes like de-gazettement of Marmanet forest in Nyahururu division in the year 2000.

Plate 11 represents a typical use of this deforested area. There was no evidence of significant reduction in population growth rate.

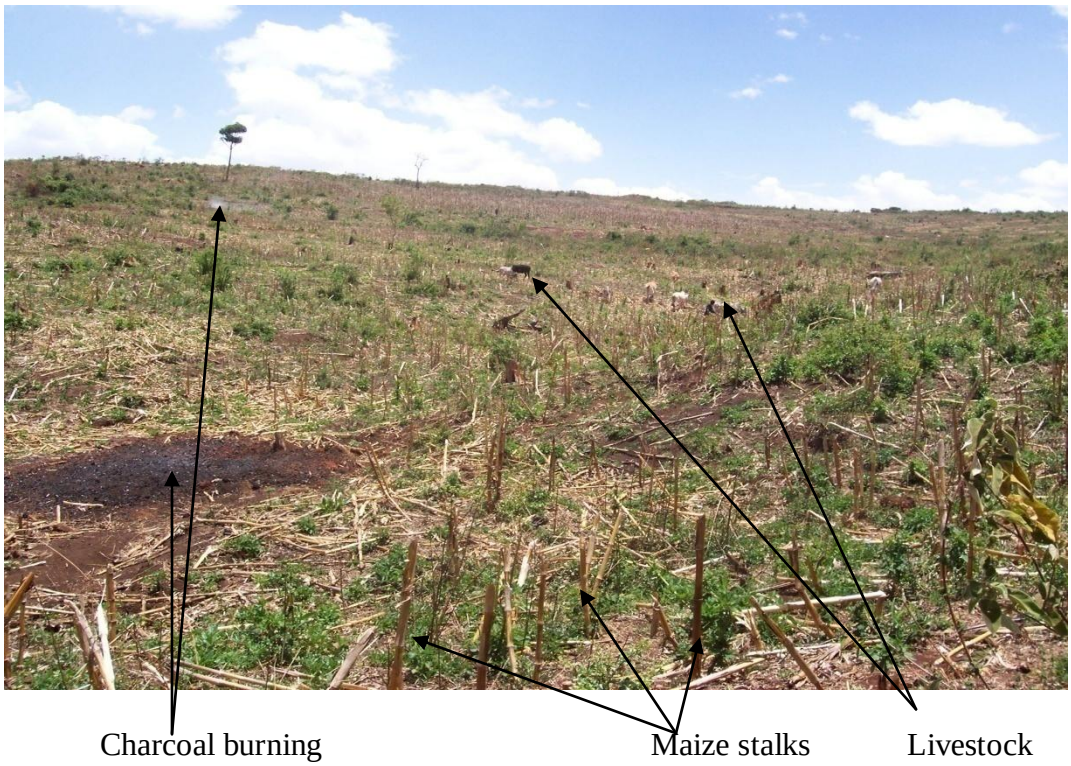

Plate 11: Land use in Marmanet settlement scheme created in 2002.

4.5 Trend in elephant population

Figure 9 shows the trend in elephant populations from 1990 to 2008. The numbers of elephants have been increasing since 1992 with a slight drop in 1999 after which there was a sharp increase up to 2008. This increase in elephant population exerts pressure on the vegetation which is already stressed by other environmental factors as shown in the NDVI analysis (see table 4). The increase could also be a result of seasonal movement of elephants in search of fruit, browse and water (Merz, 1986; Tchamba and Seme, 1993). Nationally the number of elephants has been increasing over the same period following

the ban on ivory trade in the country and the classification of elephants as an endangered species by the Kenya Wildlife Service which led to very close monitoring by wardens and game rangers.

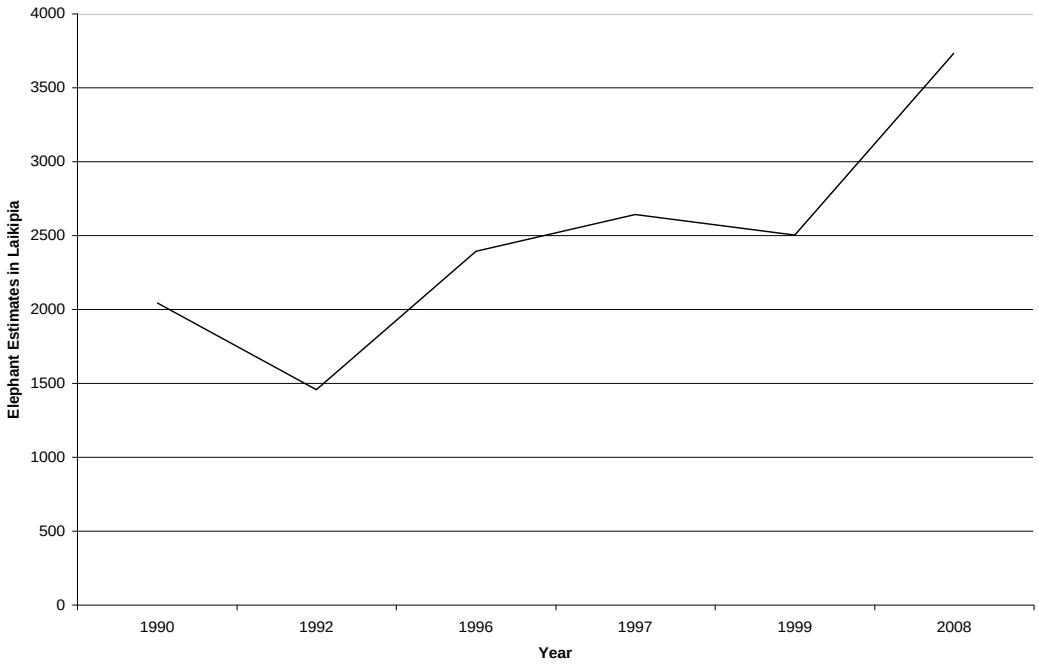

Figure 12: Trends in Elephant Populations

4.6 Human-elephant conflict in Laikipia West District

Figure 13 shows the trends in human conflict cases between Jan 1998 and Nov 2007.

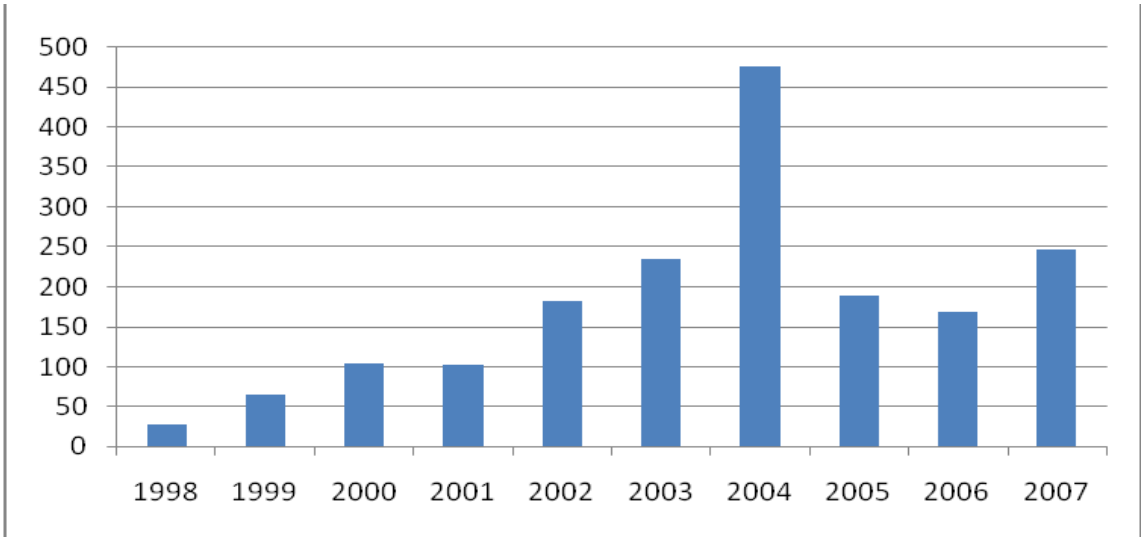

Figure 13: Trends in human conflict cases between Jan 1998 and Nov 2007

There was a steady increase in the number of conflict cases from the year 1998 to 2004 after which they declined sharply up to the year 2006 then they started rising. The year 2004 was exceptionally dry compared to all the other years. Figures for NDVI values were negative for year 2000, 2003 and 2008 as shown in table 4.

Table 5: NDVI data

Year	Class width	Mean	Actual Minimum	Actual Maximum	Primary Biomass Production Estimate in Kg/Ha	Standard deviation
Jan 1973	0.015	-0.024	-0.857	0.667	2496416	+ 0.056
Jan 1986	0.011	0.049	-0.44	0.65	9984951	+ 0.08
Jan 2000	0.014	-0.116	-0.886	0.49	9988488	- 0.122
Mar 2003	0.015	-0.061	-0.737	0.8	9984951	- 0.121
Apr 2008	0.012	-0.152	-0.724	0.71	5987637	- 0.104

The data gives an indication of the vigor and density of the vegetation for each year. The values range from positive to negative with dense vegetation having a higher value than sparse vegetation. NDVI values for year 2000, 2003 and 2008 were negative, indicating environmental stress. The lower the NDVI value, the higher the environmental stress. All the years show environmental stress although it was less severe in 1986 and 1973. The lower the NDVI value the lower the amount of rainfall and its distribution.

This shows an inverse relationship between the level of vegetation and human elephant conflict cases. Analysis of the trends in human population and human-elephant conflict showed that the two are 99% statistically not related at 0.01 confidence interval. This is consistent with the findings by Muoria (2001) in Arabuko Sokoke who found out that crop raiding intensity by elephants was negatively associated with wild fruit availability and availability of cultivated crops on farms. Land use/land cover is linked to human-elephant conflict. Intense land cover that provides browse materials for elephants reduces incidences of conflict and vice versa. Land use that reduces browse material like settlements increases conflict cases.

Ground truth data on wildlife conflict cases reported, 52.5% were reported to KWS while 30.6% are never reported. When reported, in 39.4% of the cases, no action is taken or takes 1-7days (20.6%). In 10.6% of the cases, time taken for action to be taken is over one week as the game rangers are either too far or come to the aid of the farmers too late. When cases are reported on the farms the only option is to scare which is mainly done by the farmers themselves. Shooting is only allowed for problem animals or when human

life is threatened. This leaves the farmers in a state of hopelessness and have to rely on own methods to cope with the problem.

Eighty three percent (83%) of respondents who live within 5km radius from forest or a wildlife conservation area cited problems with wildlife. Those who cited wildlife as a problem indicated that they have lived with it for over ten years but intensity of conflict had increased since the year 2003. The conflicts vary with the distance from the forest/conservation area. Those farmers near the forest/conservation area, reported higher intensity of conflict than those far from the forest. This is consistent with the findings of Linkie *et al* (2006) who found out that spatially crop raiding occurred near the edge of the forest and that local guarding strategies used around Kerinchi Seblat National Park, Sumatra were ineffective. Ninety four (94%) of the farmers rely on scaring while 3.75% have electric fences. Those with electric fences were financially stable and were located around Siron.

Soorae (1994) found that *opuntia exaltata* is a good game defense barrier in Laikipia where 80% of the farmers rated it as 'good'. This study is in contrast to findings by Soorae, (1994) as no farmer reported using this vegetation as a game defense barrier. Use of vegetation as a game defense barrier is not an option to manage the conflict in Laikipia West District. Eighty three percent (83%) of the farmers view electric fencing and translocation of the elephants as the most viable solution to manage the conflict.

The main losses arising from human-elephant conflicts in Laikipia West District include crops and fence damage with more than four incidences in a season as reported by 89%

of the farmers interviewed. Average loss incurred in a season was Ksh 15,000.00 per farmer. Other losses incurred include shelter destruction where an average loss of Ksh 25,000.00 per farmer was recorded.

4.7 Socio economic impact of wildlife conservation

Eighty seven percent (87%) of the farmers reported receiving no benefit from wildlife conservation initiatives while 12% indicated that they had benefited from projects done with cash from wildlife conservation. An example was a maternity block in Olmoran dispensary and a classroom in Ndindika and Nyakinyua Primary Schools. One farmer reported having received a bursary of Ksh 700.00 and Ksh 800.00 for her child from cash obtained from wildlife conservation. Those who had received such benefit were located around Olmoran and Mwenje. Fifty four percent (54%) of farmers indicated that there is no benefit from the forests/conservation area which form elephant habitat. Thirty six percent (36%) had received benefit in the form of either fuel wood, livestock grazing or building materials. While ownership of the forest is clear to the community, they did not visualize their role in the conservation of the forest. This is in contrast with the findings of Mwakima, (2005) in her study in IlNgwesi Community and Sweet Waters game Sanctuary in Laikipia District. She found out that, despite, the presence of human wildlife conflict in the two study areas, 98% of the respondents felt that the benefits received from wildlife far outweighed the losses caused by wildlife and that benefits had led them to appreciate wildlife better. However, findings of the study concur with Kamande (2008) who found out that in spite of Taita Taveta district being a major tourist region, average household income was Ksh 3,526.00 and absolute rural poverty was 66% making a

contribution of 1.26% to the national poverty index. In conclusion, human-elephant conflict is contributing to increasing poverty levels and food insecurity in Laikipia West District. This therefore means that you cannot increase food security and reduce poverty in the study area without addressing the human-elephant conflict.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The chapter presents a summary of the main conclusions and recommendations that can be made based on the findings of this study. Policy implications and areas for further research are also given.

5.2 Summary of findings

The broad objective of this study was to assess the impact of land use changes on the human- elephant conflict in Laikipia West district and recommend conservation and management systems to mitigate the problem. The study showed tremendous changes in land use/land cover between 1973 and 2008 in Laikipia West District. Indigenous forests, Ewaso Narok swamp and rivers, dams and other water bodies, farms and settlements all generally decreased during the period. Over the same time grasslands and bare land were increasing while plantation forests increased with sharp fluctuations over the same period. This meets the first objective of this study which was to assess change in land use/land cover between 1973 and 2008. Human population and human-elephant conflict were increasing between 1973 and 2008. Increasing human population was found to be the cause of these land use changes which meets the second objective of the study. Human elephant conflict in Laikipia West District is increasing as a result of land pressure arising from an increase in human population. Increase in human population results in an increase in farms and settlement which decreases the indigenous forests as shown in the assessment of changes in land use/cover between 1973 and 2008. With increase in human-elephant conflict cases, farms and settlements decline. Although there has been establishment of plantation forests, they do not form a stable habitat for the

elephants because there are times when they are cut down. This proves the hypotheses of this study that there are significant changes in land use/land cover between 1973 and 2008. Secondly, Land pressure due to increase in human population and changes in land use/land cover are aggravating the human elephant conflict in Laikipia West district of Kenya.

5.3 Conclusions

Human population and human-elephant conflicts have been shown to be on an increasing trend in Laikipia West District of Kenya. Increasing human population was found to be the cause of the land use changes. Human- elephant conflict in Laikipia West District is increasing as a result of land pressure arising from an increase in human population. Increase in human population results in an increase in farms and settlement which decreases the indigenous forests. With increase in human-elephant conflict cases, farms and settlements decline. Although there has been establishment of plantation forests, they do not form a stable habitat for the elephants because there are times when they are cut down. This demonstrates that land pressure due to increase in human population and changes in land use/land cover are aggravating the human elephant conflict in Laikipia West district of Kenya. It can, therefore, be concluded that the decline in area of indigenous forests is the cause of increase in human-elephant conflict cases in Laikipia West district Kenya.

5.4 Recommendations

From the findings of this research, it is recommended that there is need to establish a migration corridor between Laikipia Ranch, Rumuruti forest, Lariak forest and Marmanet forest. The deforestation of remaining forests should be averted by involving the community through training and formation of community forestry associations. In addition, land use intensification such as agro forestry and soil fertility enhancement need to be promoted to reduce land degradation through a collaborative approach of lead agencies like Ministry of Agriculture, Kenya Forest Service (KFS), Ministry of Livestock Development, Ministry of Water and irrigation and National Environment Management Authority (NEMA).

5.4 Policy implications

Any attempt to solve the human-elephant conflict problem in the district may not be successful without a comprehensive review and harmonization of Draft ASAL Policy 2004, Draft Land Policy 2004 and Draft National Livestock Development Policy 2003. These policies have remained in draft form for many years and may be enacted at different times which would pose problems with their implementation.

These policies should not contradict on land ownership, subdivision and registration of land in ASALs. The Land policy should be clear on where farming and settlement areas should be set aside as to avoid land pressure. Minimum land sizes in ASAL areas should clearly be addressed.

5.5 Areas for further research

1. There is need to carry out studies to establish whether there is any relationship between prevalence of crop damage by elephants the nutritive value of these crops.
2. There is need for further studies on why farmers are not using vegetation for fencing as a barrier to solving the problem considering also the risk of invasion e.g. opuntia, kei apple (*Doryalis caffra*).
3. Studies are necessary on the contribution of human-elephant conflict to rural poverty in Laikipia West District.
4. There is need to do further work using high resolution satellite images after ETM SLC off.

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APPENDICES

Appendix 1: Conflict cases by village Jan 1998- Nov 2007

Village	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Siron	11	23	10	11	26	24	31	21	21	16	197
Maili saba		1	39	6	31	13	23	18	27	6	164
Losogwa				17	47	13	14	3	11		105
Rwathia		5	5	5	16	10	4	9	19	21	98
Gatundia	3	3	3		2	15	39	9	8	9	91
Mahianyu		3	1	13	15	4	12	11	9	5	73
Salama	3	10	4	5	7	9	12	5	6	4	66
Lorian			8	1		10	24	7		6	56
Kwa Wanjiku		3	12	1	5	5	3	3	6	3	41
Thome							27	7		4	38
Shamanek	2		8	4		5	8	3	5	2	37
Marura						3	22	8		4	37
Marmanet	6	6	5	1	1	8	6	1			37
Maina			4	2	13	5	3			3	30
Kahuho							22	1		7	30
Igwamiti				10	8	1	10				29
Mutaro						4	9	3		12	28
Mwenje						11	15	1			27
Mackenzie	2	3	1	1	1	4		3	5	5	25
Wangwaci						3	12	4		4	23
Y-mungu				1		3	4	7	5		20
Kiriita						3			10	7	20
Ewaso Narok						3	6	5	4		20
Tangi nyeusi						9	2			5	16
New Mutaro							14	2			16

Village	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Mutamaiyo						2	9			5	16
Donyoloip						5	6			5	16
Pesi				1	2		7	1		1	15
Oljabet				2	3	4	1	1	1	1	15
Ndurumo							8			7	15
Mutara				5		3	4	2			15
Sosian						4	1	1		6	14
Muhotetu				3	2	2		3	3	1	14
Kiahiti				2		3	5	1	2		14
Karuga				4	1		2	2	3	2	14
Silale				1		6	2		1	2	12
Rumuruti							7		1		11
Mayu											
Demu ndune				2		4	4		1		11
Sipili							2	2		7	11
Simutwa						3	2	2	2		10
Muruku						1	5	1		3	10
Milango nne				1		4	3			1	10
Limunga						6	3			1	10
Gatero						1	5	2		2	10
Akorino					2	2	3	2	1		10
Survey						1	4			5	10
Magadi						1	2	1		5	9
Kiamariga						2	4	3			9
Kauka				2		1	2	1	3		9
Naigera						2		2	1	4	9
Kiandege										8	8
Aiyam									1	6	8
Ngare Narok							3	2		3	8

Village	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Kijabe							1	4		2	7
Kandorobo						3	2	2			7
Olmoran							7				7
Ng'arua						3	2	1			6
Mutitu							2		2	2	6
Muchungoi								2	2	2	6
Maundu meri				1				1	3	1	6
Matigari							4	2			6
Kiwanja						3		2		1	6
Scheme										6	6
OMC							2	1		2	5
Lonyek							5				5
Gituamba							4	1			5
Githima							1	1	3		5
Naibron							5				5
Kinamba										4	4
Karandi								3	1		4
Wamura								1	1	2	4
Nyahururu										3	3
Ndindika										3	3
Miharati							1			2	3
Mbombo							1			2	3
Kampi simba							2			1	3
Kahuruko						1				2	3
Wandeto							2				2
Ngare Mare							1			1	2
Nagum								2			2
Murichu							1	**1**		1	2
Mithuri							1				2

Village	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total
Marula Narok							2				2
Manguo							1			1	2
Laikipia campus										2	2
Kianugu							1			1	2
Kiambogo							1			1	2
Eighteen										2	2
North tetu										1	1
Narok						1					1
Mwireri							1				1
Mirigwiti										1	1
Merwa							1				1
Mathenge							1				1
Maili sita											1
Maili nne						1					1
Lobere							1				1
Lariakorok											1
Kona mbaya										1	1
Kiruki's farm											1
Kirimon							1				1
King'oris farm							1				1
Kifuko											1
Karungu											1
Karani farm							1				1
Karai							1				1
Jennings							1				1
Bondeni										1	1
Total	27	65	104	102	182	234	476	189	168	247	1794

Source: KWS occurrence books Laikipia West District

Appendix 2: GPS coordinates of various features in Laikipia West district

	North	East
Sipili	00 40709	036 37796
Maili Saba	00 11925	036 38810
KWS Rumuruti	00 26354	036 53973
KWS Olmoran	00 53714	036 48957
Wangwaci Dam	00 46575	036 36 891
Karandi	00 27725	036 32 683
Kinamba Agric Office	00 42028	036 32167
KWS Nyahururu	00 04072	036 38 314
KWS Mutitu	00 18092	036 30929
KWS Kibagenge	00 18091	036 30928
Gatundia	00 23681	036 43971
Olmoran	00 53684	036 49020
Mwenje	00 48236	036 33043
Losogwa	00 73436	03629812

Appendix 3: QUESTIONNAIRE

ASSESSMENT OF IMPACT OF LAND USE CHANGES ON HUMAN ELEPHANT CONFLICT IN LAIKIPIA WEST DISTRICT, KENYA

This questionnaire is designed and administered by Mumu Thomas Waithaka a Master of Environmental Science student of Kenyatta University as part of his research thesis titled as indicated above. Any information given will be treated confidentially and will not be used for any other purpose -February 2008.

Name of Household head……. Serial Number…….	
Gender of household head	1. Male 2. Female
Age of household head	(1) 35yrs and below (2) >35-55yrs (3) >55-70yrs (4) >71yrs
Village name	(1) Siron (2) Gatundia (3) Mahianyu (4) Salama (5) Losogwa(6) Wangwaci (7) Olmoran (8) Lobere
Acreage of farm	(1) 0-5 Acres(2)>5-10 Acres (3)>10-20Acres (4) >20-50 Acres(5)>50 acres
Number of years lived on the farm	(1) One year and below(2)>1-10 years (3) >10-20years (4)Over 20years
Have you subdivided your land?	(1)Yes (2)No

Indicate the sizes of subdivisions	(1) Below 2 acres (2)>2-5 acres (3) >5-10 acres (4)>10-20 acres (5)over 20 acres (6) Never subdivided
Land use/cover practice in the last 5 yrs on respondents farm	(1) Crops only (2)livestock only (3) crops and livestock(4) woodlot (5) Livestock and woodlot(6) crops and woodlot (7) Bare ground/grassland (8) Crops, livestock, bare ground/grassland (9) Crops, livestock, woodlot, bare ground (10) Crop, woodlot, bare ground/grassland(11) crop, livestock, woodlot, bare ground/grassland (12)Other -specify
Which of the land use/cover practices in (8) above has increased in size or production in the last five years?	(1) crops (2) livestock (3) crops and livestock (4) woodlot (5) Bare ground/grassland (6)None (7) Crop, woodlot (8) crop, livestock, woodlot(9) Other -specify
Reasons for the increase	(1) food demand (2) demand for cash (3) firewood/building materials (2) (4) wildlife conflict (5) price increase (6) Not applicable (7) Insecurity(8) Subdivision (9)demand for cash and firewood (10)Other- specify
Which of the land use/cover practices in (8) above has decreased in the last	(1) crops (2) livestock (3) crops and livestock (4) woodlot (5) Bare ground/grassland (6) Other -specify

five years?	
Reasons for the decrease	(1) food demand (2) demand for cash (3) firewood/building materials (4) wildlife conflict (5) price decrease (6) Subdivisions (7) Disease (8) Insecurity (9) Water logging (10)Not applicable (11) Demand for cash and disease(12) Other- specify
Magnitude of increase in %	(1) 0-25 (2) >25-50 (3) > 50-75 (4) >75-100 (5) no change
Magnitude of the decrease in %	(1) 0-25 (2) > 25-50 (3) > 50-75 (4) >75-100 (5) no change
Type of grazing	(1) freely on own farm (2)Forest (3)communal land (4)Zero grazing (5) not applicable (6)Other (specify)
Have you had a problem of wildlife on your farm?	(1)Yes (2)No
If yes specify the nature of problem	(1) Crop damage (2)Livestock damage (3)Human death (4) human injury (5) Shelter/store destruction (6) Crop damage and shelter destruction (7) crop destruction and human death (8) Not applicable (9) Other specify
What wildlife species was involved?	(1) Elephants (2)Buffaloes (3) Elands (4)Zebras (5) Elephants, zebra, eland (6) Porcupines, monkeys, wild pigs (7) not applicable (8) Other -specify
Which year(s) did this problem start?	(1) This year (2) >1-5 years ago (3) >5 – 10 years (4) Over ten years ago (5) never experienced the problem

Number of incidences the problem is experienced per year	(1) once (2) twice (3)thrice (4) four times (5) more than four times (6) never experienced the problem
How did you deal with the problem?	(1) scaring (2) Moats (3) electric fence (4) live fence (5) Not applicable (6) Other - specify
Where was the problem reported?	(1) Never reported (2)KWS (3)Police (4) provincial administration (5) Agric office (6) KWS police, Agric office (7) Laikipia Ranching Company (8) not applicable (9) Other - specify
How long did they take to act?	(1) One day (2) 1-7days (3) Over 1wk to month (4) over one month (5) no action taken (6) Not applicable
Which crops are mainly destroyed?	(1) Maize (2) Wheat (3) Fruit trees (4) Sugar cane (6) Maize, wheat, fruit trees, sugarcane (7)maize, fruit trees (8) Root crops (9) maize, fruit trees, sugarcane (10) none (11) Other - specify
Quantify the destruction in bags in 2007	(1) Below 5 bags (2) >5-10 bags (3) >10-20 bags(4) Above 20 bags (5) None
Quantify the destruction in acres in 2007	(1) below 1 acre (2) 1-2 acres (3) >2-5 acres (4) >5-10 acres (5) above 10 acres (6) Not applicable

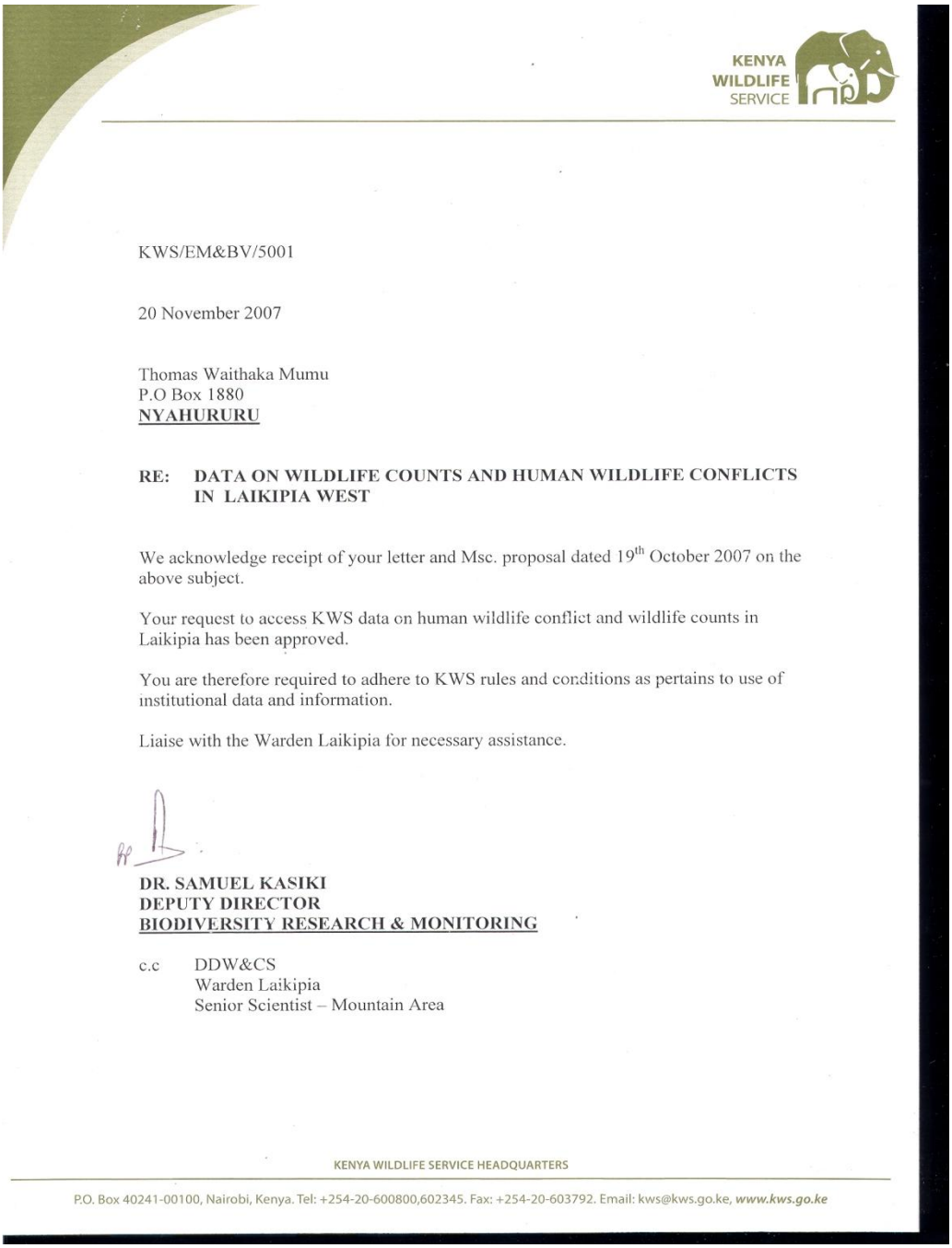
What was the unit price of produce destroyed?	(1) below ksh 500 (2) >ksh 500-750 (3)> ksh 750-1000 (4)> ksh 1,000-1,250 (5) Above ksh 1,250 (6) not applicable
Estimated total cost of destruction	(1) below ksh 5,000 (2) >ksh 5,000-10,000 (3) >ksh 10,000-15,000 (4) >ksh 15,000-20,000 (5) above ksh 20,000 (6) Not applicable
Estimated cost of store/ shelter destroyed if applicable?	(1) Below ksh 10,000 (2) >ksh 10,000-20,000 (3) >ksh 20,000-30,000 (4) >ksh 30,000-40,000 (5) Above ksh 40,000 (6) not applicable
What benefits do you get from wildlife?	(1) Cash (2)Projects done with cash from wildlife conservation(3)None (4) School bursary (5) Other (specify)
What in your view would you want done to wildlife so that you can reap maximum benefit from your farm?	(1) Community conservation (2)Translocation (3) Private ranching (4) Fencing of forest/Conservation area (5) Fencing and translocation (6) Fencing and community conservation (7) Fencing and compensation (8) other- specify
Is there a forest/conservation	(1) Yes (2) No

area nearby?	
If yes give the approximate distance	(1) Below 1 km (2) 1-5 km (3) Over 5 km (4) Not applicable
Who owns the forest/conservation area?	(1) Government (2) Public (3) Public/government (4) Individual(5) Don't know(6) not applicable
How do you benefit from the forest/conservation area?	(1) Fuel wood/charcoal (2)Poles/timber (3) Forest cultivation (4)Livestock grazing (5) None (6) Not applicable (7) Fuelwood and livestock grazing (8) Employment to local community (9) Other - Specify
What is the source of water for your household?	(1) Dam (2)Seasonal river (3) Permanent river (4) Spring (5)Shallow well(6) Dam, roof catchments (7) Shallow well, roof catchments (8) Tap water (9) Other-Specify
What is the approximate distance between your household and water source	(1) 1 km and below (2) Between 1km and 5 km (3) Over 5km
What observations if any have you made on water availability since	(1) Increase (2) Decrease (3) No change

you settled here?	
Suggest ways of solving the problem of human wild life conflict	(1) Translocation (2) Electric fencing (3) Translocation and electric fencing (4) Reduce numbers (5) fencing and reduce numbers (6) fencing and compensation (7) more game rangers (8) Afforestation (9) More game rangers and fencing (10) Moats and fencing (11) Community involvement in conservation (12) Afforestation and fencing (13) Other- specify

Thank you for taking your time to answer my questions and may God bless you.

Appendix 4: Authority to collect Data from KWS



KENYA WILDLIFE SERVICE

KWS/EM&BV/5001

20 November 2007

Thomas Waithaka Mumu
P.O Box 1880
NYAHURURU

RE: DATA ON WILDLIFE COUNTS AND HUMAN WILDLIFE CONFLICTS IN LAIKIPIA WEST

We acknowledge receipt of your letter and Msc. proposal dated 19th October 2007 on the above subject.

Your request to access KWS data on human wildlife conflict and wildlife counts in Laikipia has been approved.

You are therefore required to adhere to KWS rules and conditions as pertains to use of institutional data and information.

Liaise with the Warden Laikipia for necessary assistance.

DR. SAMUEL KASIKI
DEPUTY DIRECTOR
BIODIVERSITY RESEARCH & MONITORING

c.c DDW&CS
Warden Laikipia
Senior Scientist – Mountain Area

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