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Use of Geoinformation Technology in Assessing Nexus between Ecosystem Changes and Wildlife Distribution: A Case Study of Mt. Marsabit Forest

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Abstract: ***This study integrates Geospatial Information Technologies (GIT) in assessing the nexus between ecosystem changes and wildlife distribution. The objectives were therefore; to investigate the ecosystem changes and its impacts on wildlife distribution and to determine the drivers of changes. Ecosystem (Land use / land cover) changes were derived from classified Landsat TM images for 1990, 2000 and 2010 using six classes which were closed forest, open forest, shrub land, grassland, wetland and bare land. Impacts of ecosystem changes were determined by overlaying classified images on respective wildlife distribution data and then comparing the distributions for the three epocs. Structured questionnaires, interviews and focus group discussions were administered in determining change drivers. Results indicated immense changes of the ecosystem with degradation being evident. Wildlife (elephant) distribution was localised to open forests and shrub land. Therefore, degradation of closed forest indicated presence of elephants while further degradation of open forests and emergence of shrubs indicated an influx of elephants. Major threats identified included firewood collection, illegal logging, charcoal burning, water abstraction/ dependency, drought, and livestock incursion.***

Keywords: Ecosystem Changes, Wildlife Distribution, Drivers

1. Introduction

The distribution and abundance of animal populations can be influenced by various factors such as climate, food resources, water availability, predation, parasites and pathogens. In terrestrial herbivore populations, food availability and predation have the most influence (Sinclair, 2003) with forage availability impacting herbivore distribution (Fryxell, 1988; Pettorelli et al. 2002, 2003; Dussault et al. 2005).

Habitat loss and degradation contribute to the biggest single source of pressure on biodiversity including the elephants in the terrestrial ecosystem. Local changes in land-use/land cover are so pervasive that, when aggregated globally, may significantly affect central aspects of the Earth System functioning and thus life support functions and human livelihoods (Chhabra, A. et al. 2006).

The study area being a protected area is facing challenges arising from habitat loss and fragmentation due to infrastructural developments, illegal grazing and deforestation among others (Werth and Avissar, 2002). However, primary forests are lost or modified at a high rate due to selective logging or deforestation, and there is no indication that the rate is slowing (FAO, 2006).

Mt. Marsabit is a unique ecological system in Eastern Africa with the most developed and extensive upland forest on an extinct volcano within an arid setting. Vegetation ranges from evergreen forest to semi- deciduous bush land, deciduous shrub land and perennial grassland (Harlocker, 1979). Elephants are among the mammals in the protected area and feeds on *Bauhinia tomentosa, Phyllanthus sepialis, Glewia fallax, Acacia brevispica and Aspilia mossambicencis* (Githae *et al*., 2007). The forest is faced by numerous threats; firewood collection, deforestation, charcoal burning, illegal grazing, increasing human population in the surrounding, conversion of lands around the forest to other land uses and climate change.

This research therefore incorporates GIT in understanding the various ecosystem changes within a period of 30 years, the major drivers for the changes and how they impact on the distribution of wildlife (elephant) in the ecosystem.

2. Study Area and Methodology

2.1 Study Area

The study area is located between latitude 20 19' North (Lower left corner) and longitude 37º 59´ (upper right corner) and covers an area of 2100 km^2. It's an extinct volcano occurring in a semi arid region of Northern Kenya of Marsabit County. Rainfall is higher than the surrounding areas due to its high ground position. Temperatures are high ranging from 30^0 - 35^{0}C (February) and 22^0-25^{0}C in the months of March and July. Soils are volcanic with a high retention capacity on the lower slopes. Some areas have moderately deep clay loams while others are stony or rocky (Bake, 1983). Vegetation ranges from evergreen to semi deciduous bush land. Evergreen forest is dominated by *Cassipourea malosana*, *Olea lochstetten* and *Techlea simplicifolia*. Pastoralism is the main economic activity whereas crop cultivation is practiced in areas of good soils and sufficient rainfall. The common wildlife species are the elephants, buffaloes and gazelles.

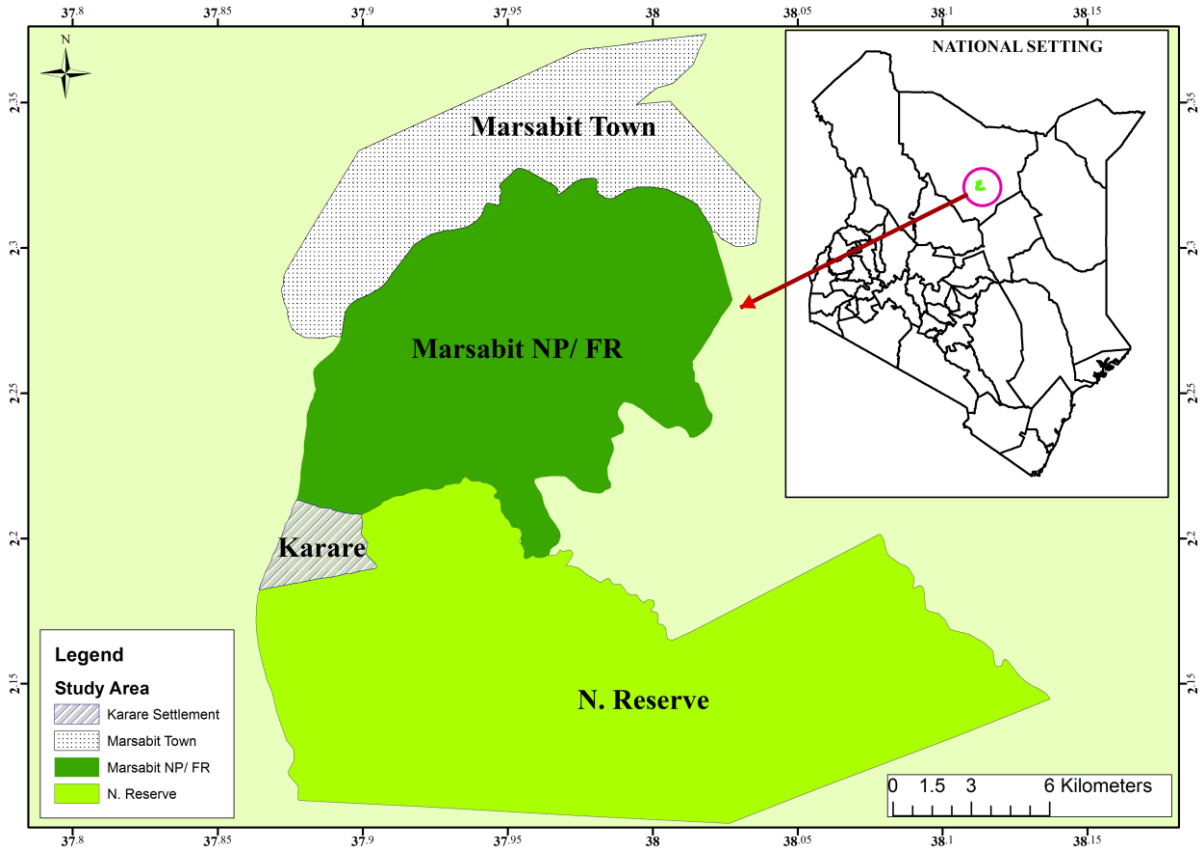

Figure 1: Map of the study area

2.2 Research Outline and Process

Ecosystem Changes and Wildlife Distribution

Multi-temporal Landsat 7 images of the study area were acquired covering periods of 1990, 2000 and 2010; and image pre- processing and processing procedures carried out. Unsupervised and supervised classifications (Maximum Likelihood Classifier) were carried out on each time period image to create required land use/ land cover classes using Land Cover Classification System (LCCS). Ground truthing was carried out by collecting more data in the field (GPS points and photographs) and re-classification performed. Comparison of Land use/ land cover and wildlife distribution was assessed by overlying the classified Land use / Land cover maps with respective elephant distribution data.

Drivers of Ecosystem Changes

Structured questionnaires, focus group discussions and key informant interviews were administered to collect data. Stratified sampling design was used to reduce bias in results and qualitative analysis of the results carried out.

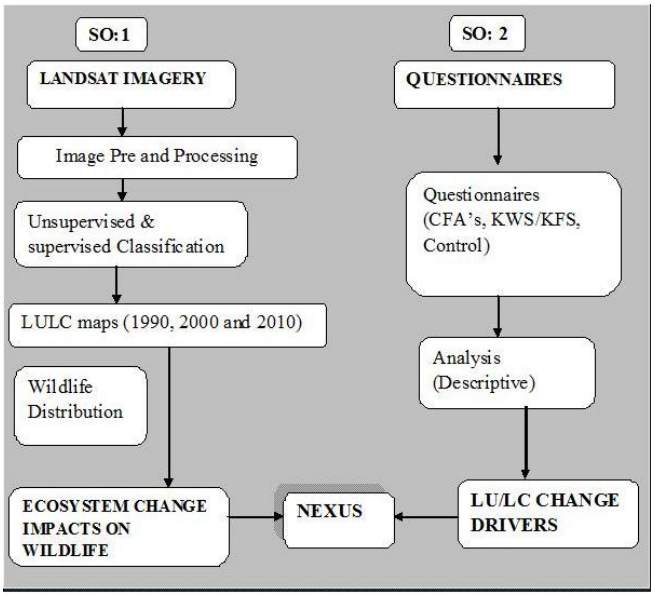

Figure 2: Summary of Research Process

2.2 Data Analysis and Presentation Techniques

Qualitative Analysis

Landsat imageries were classified using ERDAS 11 while further analysis was done in Arc GIS 10.0 to produce LULC maps for 1990, 2000 and 2010.

Quantitative Analysis

Statistics for the LULC maps were generated and presented in tables showing various LULC classes and their respective acreages for the study periods. Questionnaire data was

recorded and analysed in SPSS 17 while results were presented in tables, bar graphs and line graphs.

3. Results and Discussion

3.1 Study Area Analysis

Mt. Marsabit Forest is referred to as the "Green Island" since it is forested, receives a higher amount of rainfall and has lower temperatures than the surrounding areas. It experiences a bimodal rainfall pattern (Bake, 1983). The temperatures average at 30^0 - 35^0 C during the dry season and 22^0-25^0 C in the wet season. It has well developed volcanic soils. Pastoralism activities account for 80% of the economic activities of the region. However, crop cultivation is also practiced in areas of good soils and sufficient rainfall. Common wildlife species are the elephants, buffaloes and gazelles. Human population has been increasing at an alarming rate hence exerting pressure on the natural resources. This therefore necessitates an integrated conservation strategy towards sustainable utilisation of the forest.

3.2 Ecosystem Changes and Wildlife Distribution

Ecosystem Changes (LULC)

The study identified 6 major classes; closed forest, open forest, shrub land, grassland, wetland and bare land. There was a progressive decrease in closed forest cover to open forest. Open forests changed to grasslands and shrub land whereas bare ground increased (fig, 3, 4, 5).

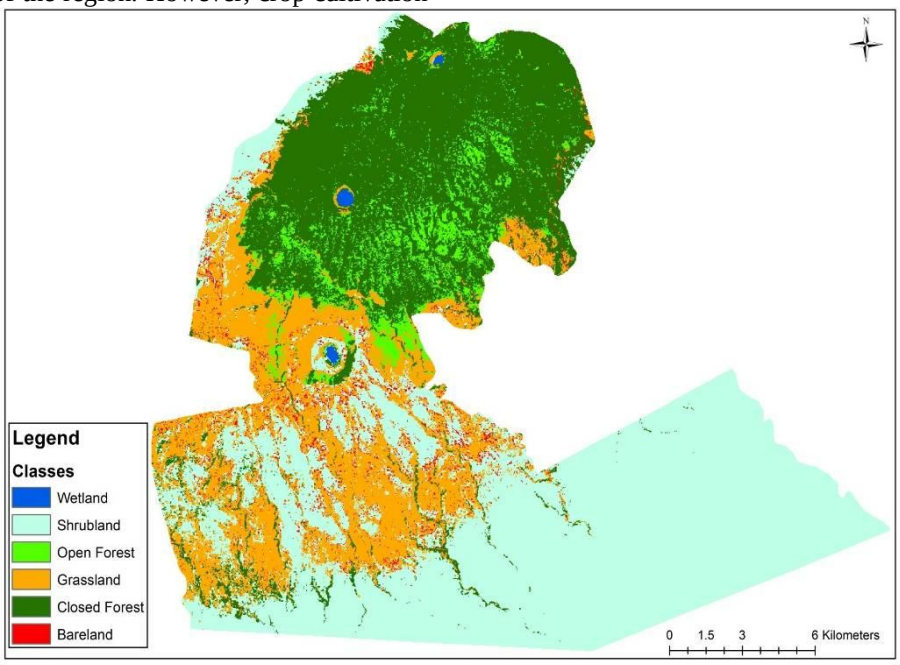

Figure 3: Map showing 1990 Land use/ land cover classes.

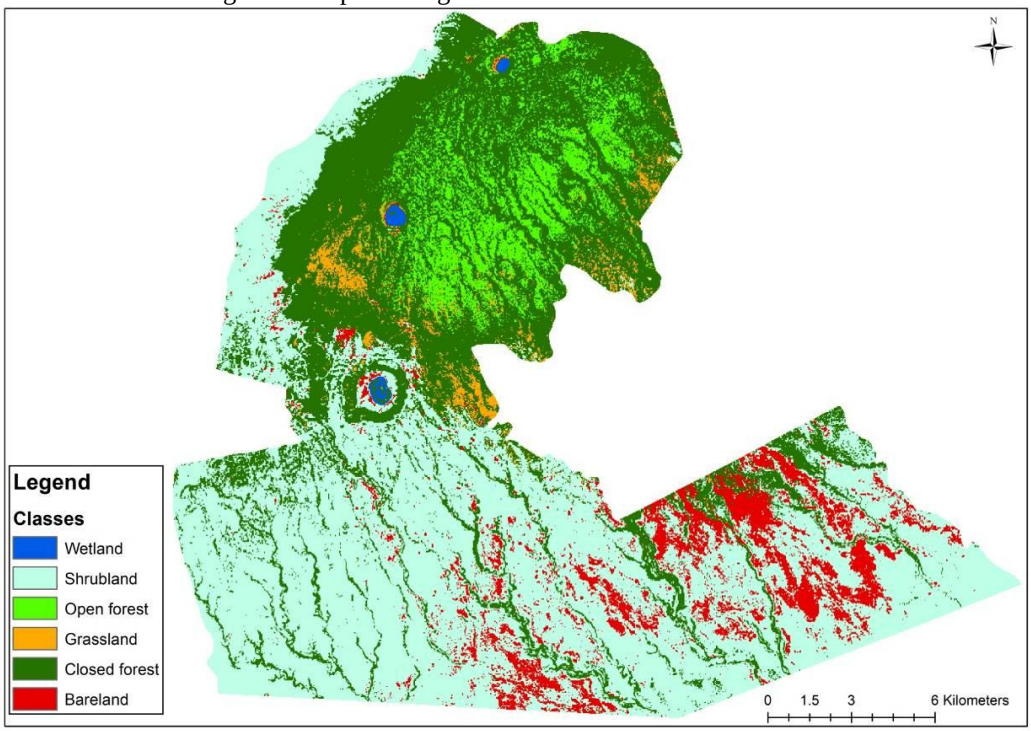

Figure 4: Year 2000 LULC classes for the year 2000

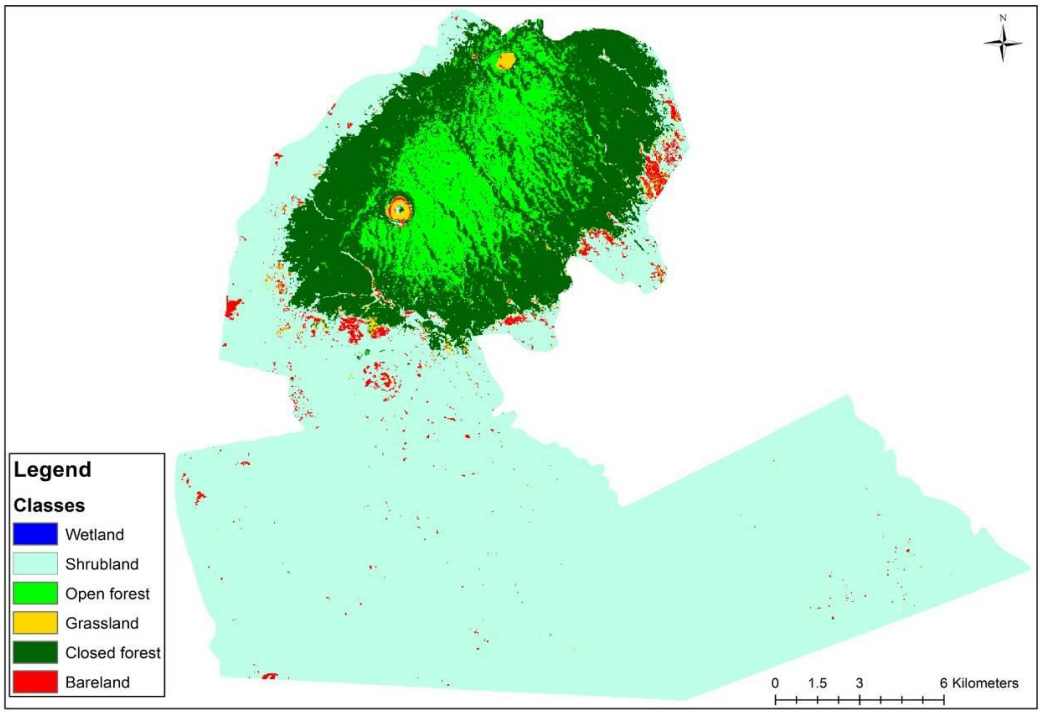

Figure 5: 2010 LULC classes

Closed forest increased from 1990 to 2000 but greatly reduced in 2010. Open forest increased between years 1990 and 2000 but acreage reduced in year 2010. A different trend is exhibited by shrub land which increased gradually whereas grassland decreased across the study periods. Wetlands exhibited a slight increase between years 1990 and 2000 but acreage drastically dropped to a mere 1 ha in 2010. Bare land increased substantially between years 1990 and 2000 but declined in year 2010 (Table 1).

Table 1: A summary of LULC changes in Mt Marsabit forest for the years 1990, 2000 and 2010.

Land Use/ Land Cover	1990 (Ha)	2000 (Ha)	2010 (Ha)
Closed Forest	11,020.3	13,250.1	7123
Open forest	1,885.76	2,581.01	353.61
Shrub Land	18,302.3	19,923.6	28,722.21
Grassland	7,502.45	829.19	227.03
Wetland	73.44	93.61	1
Bare land	821.18	2,927	479.59

3.3 Ecosystem Changes and Wildlife Distribution

This research indicated that ecosystem changes are related to wildlife distribution *(Fig. 6, 7).* In 1990, wildlife was distributed on the southern side of the mountain especially on shrub land but rarely on grassland and open forest. The entire forest was covered by closed canopy with sparse openings of open forest (*fig 6*). In 2000, the open forest increased and elephants moved into it. However, sparse distribution was also found in shrub land (*fig 7*). Wildlife concentration in the year 2010 was around the closed forest edges, shrub land and along riverline forests in the south. In some instances, elephants were spotted on dry water pools/ lakes/ wetland. Although substantial cover of open forest increased within the central section, wildlife did not utilize it (*fig 8).*

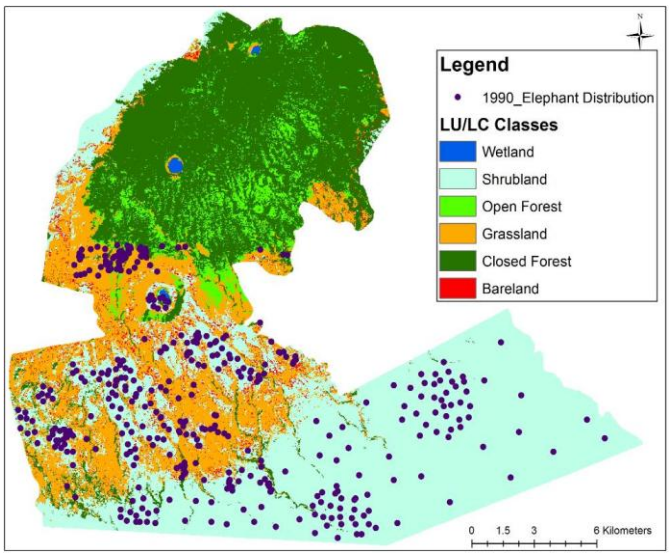

Figure 6: Land cover and Elephant distribution in 1990

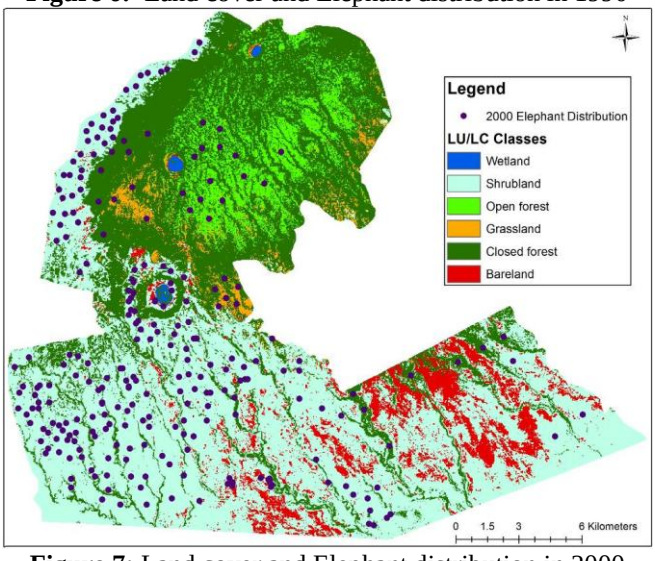

Figure 7: Land cover and Elephant distribution in 2000

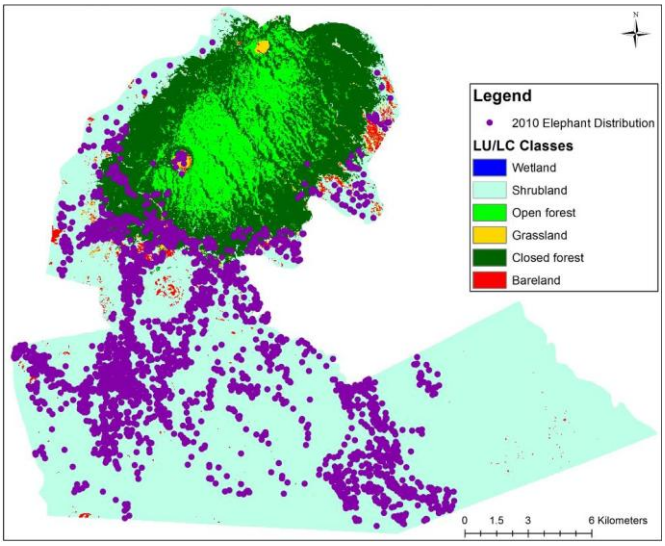

Figure 8: Land cover and Elephant distribution in 2010

3.4 Drivers of Change

Closed Forest

There were two major drivers identified; logging and water abstraction, by community (40%, 25%) and control (38%, 32%). However, management identified water abstraction (35%) and climate change (28%) as the major drivers while placing logging at a low of 22% (Fig. 9).

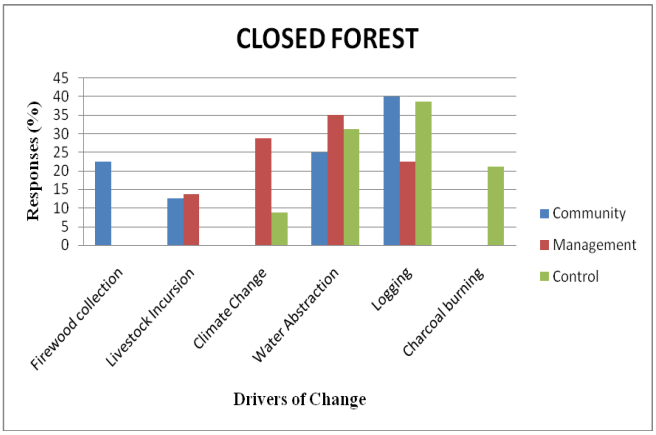

Figure 9: Responses on drivers of change in closed forest

Open Forest

The three categories of respondents rated livestock incursion/ grazing as the main driver of change in open forest (Community 41%, management 40%, control 36%). Communities accessed this LULC for fuel wood collection (32%) and medicinal plants extraction (3%). However, charcoal burning activities also dominated this LULC hence rated as the second driver (Community 24%, management 34%, control 28%), as indicated in figure 10 below.

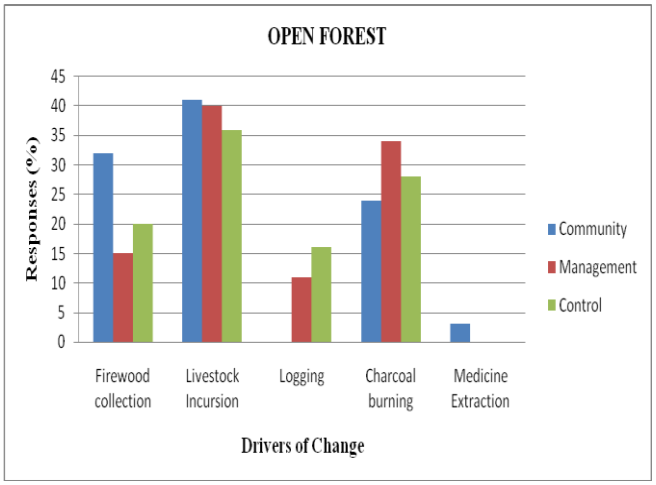

Figure 10: Graph showing responses on drivers of change in open forest

Shrub land

Firewood collection, livestock incursion/ grazing and charcoal burning were identified as the dominant drivers in this LULC, although charcoal burning was rated highest by the three categories of respondents (Community 25%, management 38%, control 32%), (*fig. 11*).

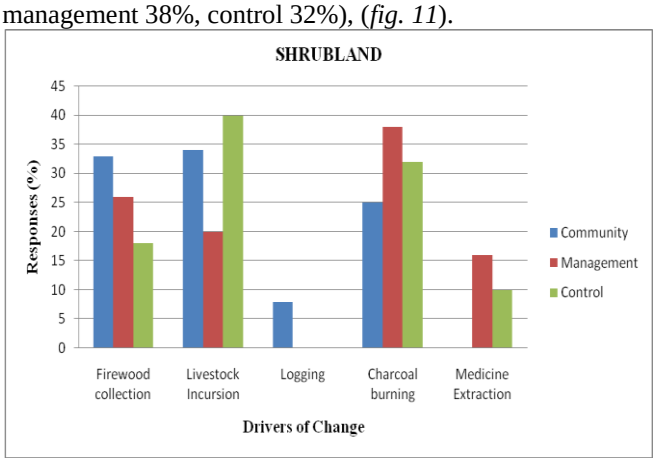

Figure 11: Responses on drivers of change in shrub land

Plate 1: Livestock incursion within the shrub land.

Grassland

Livestock grazing was found to be a major problem in Marsabit Forest especially in the grasslands (Community 76%, management 53%, and control 61%). Hundreds of heads of livestock were spotted grazing on the southern parts

of the mountain. The LULC suffer largely from dry spells while little or no charcoal burning took place (*fig. 12*).

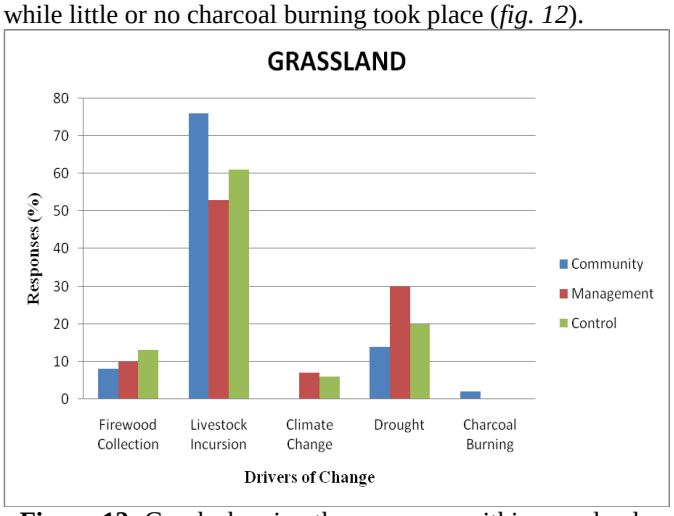

Figure 12: Graph showing the responses within grassland

Wetland

Livestock incursion/ grazing and water abstraction were identified as the major drivers of change (Community 54%, 16%; management 23%, 36%; and control 28%, 35% respectively). Drought and climate change were also found to have substantial impacts to wetlands (*fig. 13*). Effects of these drivers were noted to have adverse effects during the dry season and subside with rains.

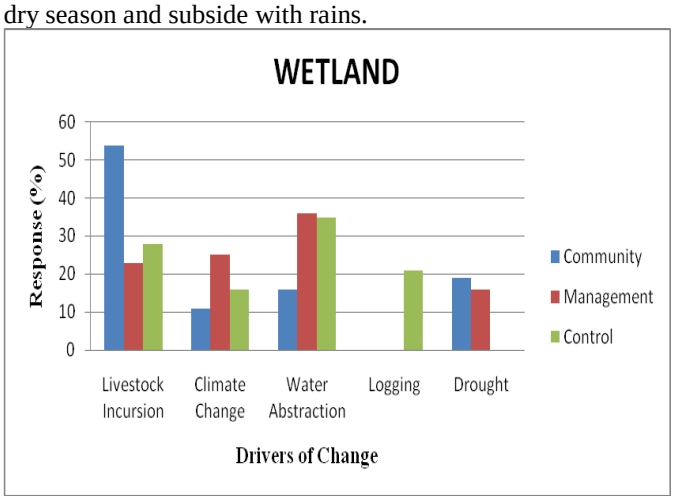

Figure 13: Figure showing responses on drivers of change in wetland LULC class

Bare land

The study identified livestock grazing as the main driver in the bare land LULC (Community 43%, management 62%, and control 75%). Respondents noted that climate change was a driver although rated low (Community 13%, management 14%, and control 15%). Communities sited infrastructure development as new driver with most of bare land exposed to developments (community 8%), (*fig. 14)* e.g. roads and settlement schemes.

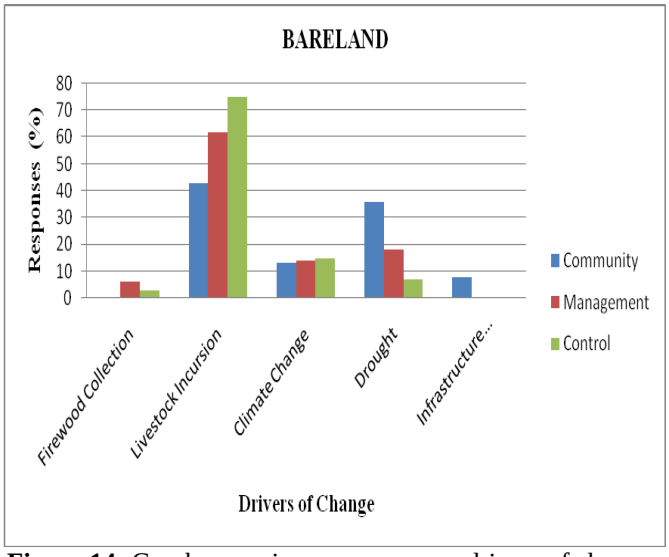

Figure 14: Graph on various responses on drivers of change in bare land

4. Conclusion and Recommendation

4.1 Conclusion

Ecosystem Changes

Land use/ Land cover (LULC) maps showed an increase in closed forest cover from 1990 to 2000 but a drastic decrease in 2010. The increase was as a result of enhanced conservation efforts by KFS, KWS and locals. The decrease may be attributed to the severe drought that hit the country in 2009 which had ripple effects on the natural ecosystems as well as biodiversity. Open forest had a similar trend as closed forests for the study periods. Human activities (illegal logging, firewood collection and livestock incursion) in the closed forest largely contributed to the open cover increase while the decrease was due to 2009 drought effects coupled with effects of the above activities. Shrub land increased tremendously especially in the drier southern area. Livestock incursion and overgrazing contributed largely to the reduction of grassland cover with lowest coverage recorded in 2010. This can be attributed to high numbers of livestock in the forest as a result of 2009 drought since it was the safe haven for pasture. Wetland (Lake Paradise, Elephant pool and Bongore) cover increased between 1990 and 2000 due to conservation efforts similar to closed forest for the same time. The 2009 drought played a critical role in drying up of wetlands. Forest Reserve suffered from intense illegal human activities which can be attributed to the fact that KWS and KFS patrols are concentrated on the National Park. As a result, there was a lot of degradation between 1990 and 2000.

Ecosystem Changes and Wildlife

Wildlife distribution in Mt Marsabit Forest ecosystem was a function of ecosystem changes. Degradation opened up closed forest cover and therefore made it accessible to wildlife. However, elephants had a preference for non woody vegetation hence distributed within shrub land. Generally, change from closed to open forest and shrub land provided habitat for elephants whereas further degradation (grassland, bare land) caused reduced vegetation cover which forms the greatest diet for herbivores.

Ecosystem Change Drivers

Mt. Marsabit forest is a stand-alone ecosystem that is characterised by a cool and wet micro-climate. This uniqueness of the forest exposes it to numerous threats. The study identified major drivers as; firewood collection, human population increase, infrastructural developments, illegal logging, charcoal burning, water abstraction/ dependency, climate change, drought, medicinal plants extraction and livestock incursion. These changes are as a result of direct and indirect human actions in securing essential resources (Misana, S.B. et al, 2012). The surrounding areas suffer from lack of permanent and reliable water sources hence placing Mt. Marsabit forest as the sole source of water for human, livestock and wildlife populations. The situation worsens during the dry season.

4.2 Recommendations

Mt. Marsabit forest is a critical ecosystem whose functions are enormous and immeasurable. Therefore the study recommends the following;

a) Inclusion of other large mammals in studying their distribution within different habitats.
b) Expansion of the study area (Image classification) to include areas surrounding the ecosystem since they form part of the influence zone.
c) The study also finds it important; fencing to deter intruders, joint research and dissemination of research findings, alternative sources of livelihoods and preparation of Integrated Management Plan.

5. Acknowledgement

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