Linking biophysical change to land use land cover dynamics to community socio-economic structure in Mt. Elgon water tower ecosystem.

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ABSTRACT

Mountain ecosystems are vital for provision of ecosystem goods and services which provide direct and indirect benefits to proximate communities and those further apart. They are not only water towers-(sources of rivers which supply water downstream and a habitat to endemic flora and fauna), but providers of climates important for agriculture, livestock production amongst other livelihood activities. Dependence on mountain ecosystems for livelihoods has lead to land use-land cover change to meet socio-economic demand. Management of mountain ecosystems has been challenged by continued access and product extraction, leading to degradation, migration and extinction of plants and animals. Through this study, Mount Elgon forest ecosystem presents a trend analysis of land use land cover, linked to socio-economic structure of communities domiciled up stream. International Forestry Resources and Institutions (IFRI) and Poverty and Environments Network (PEN), tools and methodologies were used to track biophysical and socio-economic condition of Kimothon forest for the year 1997, 2001, and 2012. Historical change detection analysis of land use land cover in Mount Elgon was integrated with the tools for a comparative methodological framework. Results from Mt. Elgon forest ecosystem revealed ecosystem previously dominated by trees and bushes but currently covered by other land uses as farms and settlements. It presented instability in socio-economic status of adjacent dwellers and skewed extraction of resources in response to secure and obtain livelihoods. The research further recommends a multi-stakeholder involvement in forest management, by engaging local institutions while to ensure a forest landscape management approaches.
Key words: Mountain ecosystems, Livelihoods, Land use/cover.

INTRODUCTION

Background

Mountain ecosystems are crucial part of the environment which provides ecosystem goods and services. They play several roles in the ecosystem to ensure a stable environment and most importantly mitigating climate change which is a global problem. These ecosystems therefore are key components of global environment and human socio-economic development. Efforts have been made to rehabilitate the natural resources by engaging the communities in the management and conservation and also devolving the forests with more emphasis being put on the Kenya's major water towers Mt. Elgon forest ecosystem being one of them.

The World Watch Institute (2007) accentuates a rapid loss of forest cover around the world and related threats to biodiversity. Biodiversity is of significant importance to people, wildlife and the ecosystem and plays an important role on the sustainable relation between humans and nature. Changes and loss in biodiversity affect diversity at both local and global level. This change is effected by resource users that vary from small scale farmers who need resources such as fodder and firewood for survival, to companies who collect large quantities and are often supported by governments as they contribute to the national economy.

Land use and cover changes have been significantly noticed in Kenya especially the forest ecosystem from the precolonial period to present postcolonial periods with environmentalists, foresters, economists and socialists taking an active role in ensuring that forests are managed and conserved. Population increase has been the major driver of the changes since communities adjacent and those further have to find means of surviving. Forests have been continuously encroached in forests for settlement and product access leading to massive degradation and destruction of the water towers. The realization of this has led to the introduction of management tools like participatory forest management that will ensure that communities involved are taking part in the active management and conservation of degraded areas at the same time meeting their basic needs by deriving products from these areas.

In the post-colonial era more land of indigenous forest was allocated to farmers and communities for subsistence. The unequal pattern of land ownership and the expansion of agriculture into marginal areas and forests have been some of the major drivers of natural resource degradation and the loss of water catchments and wildlife habitat. (Forest Policy, 2014).

The realization of massive destruction due to land cover and use changes made the government to make some steps that included legalization of forestry by creating a legal framework under the forest act, chapter 385 in the laws of Kenya with the aim of control and regulation of central forests. The establishment of a forest policy which was reinstated by the government of Kenya in 1968 as a sessional paper number 1 196. The main objectives of the forest policy were to reserve forest areas for catchment protection, provide timber and other forest products, protecting forests from fire and illegal grazing, promoting sustainable yield management, developing industrial forestry, providing funds for policy implementation and providing employment through shamba system for reforestation and forest maintenance. The outcomes were forest loss were due to the introduction of shamba system and conflicts between the adjacent communities and the forest department. (Mwangi, 1998).

Since the colonial times the government had the major control of most forest land and resources which was the conservation and control approach. Mt Elgon is one of the major water towers in Kenya that has sustained livelihoods of communities adjacent and further. The conservation and control approach became a limiting factor to the sustainable livelihoods due to lack of benefits from the forests as the government had total control. Introduction of a participatory approach in the management of forests was a breakthrough to communities who now have regulated access to products like firewood, fuel and medicinal herbs.

The study aimed at documenting biophysical status of Mt. Elgon by (a) identifying and comparing the density of plant types, (c) comparing the basal areas of saplings and shrubs and trees in the two forests, and identify change of land use systems within the ecosystem, and contribution of communities towards such change.

Study area

Mount Elgon is a solitary extinct volcano straddling the border between Uganda and Kenya, 100 km north-east of Lake Victoria. It lies at latitude 1° 08’ N and longitude 34°45’E and receives an average annual precipitation of 1280 mm with minimum and maximum temperatures of 9°C and 22°C respectively. It is the oldest of the East African volcanoes, resting on the dissected pen plain of Pre Cambrium bedrock of the Trans Nzoia Plateau (Davies, 1952).

The mountain is vital to the social and economic functioning of the area, and is a water catchment supplying millions of people in Uganda and Kenya (van Heist, 1994). It is also an important area for species conservation due to the richness of endemic plant and animal species (Howard, 1991). The forest area is under the management of the Kenya Wildlife Service (KWS) and the Kenya Forests Service (KFS) for Chorlem, Kimothon and Koptagat forests respectively.

Mount Elgon forest was gazetted as a government forest reserve in 1932 (Ongugo *et al*, 2001). It currently covers an area of about 49,382.9 ha. The forest is divided into three management units namely the natural forest reserve, the commercial exotic plantations and the national park.

Chorlem Forest

Mt. Elgon National Park, managed by KWS was created in 1990, under the Wildlife Act of 1975, chapter 376 (Nield *et al*, 1999). Chorlem forest is under the management of KWS. It is a conservation and protection forest area (National park) for flora and fauna. It covers an area of 169 hectares, of mainly indigenous tree species. Chorlem forest is under strict conservation with only controlled access (no-access-rule), though there is evidence of illegal harvesting for both flora and fauna. Legal access is only granted for tourism, with entrance fee payable to KWS management. The forest is further protected by an electric perimeter fence, to control unmonitored access of individuals into the park and also reduce human-wildlife conflicts (IFRI, 2007).

Kimothon Forest

Kimothon forest is managed by the KFS both as a production and protection forest, covering an area of 10,243 hectares with both exotic and indigenous tree species. The forest is under open and regulated access with monitoring of activities. The forest provides both timber and non timber products in addition to environmental services.

The communities living adjacent to the forest are majorly farmers, who plant crops e.g. maize and beans and vegetables (kales, tomatoes). These communities depend on the forest for timber, poles, herbal medicine, food, fuel wood, grazing amongst environmental and biodiversity conservation purposes. These products are both for subsistence and commercial purposes.

Access to the forest through the CFAs is legal, where various user groups are in agreement with the forest management (Forest policy, 2005). Rules have been formulated jointly by KFS and the CFAs, to ensure that the latter are governed by set rules in accessing the forest and its products. The rules are deemed as clear, fair, easy to understand and legitimate and are flexible in dealing with the unusual problems.

Data collection

Bio-physical analysis

Data was collected using the IFRI tool, methodology and protocol (Wollenberg *et al* 2005) based on Institutional Analysis and Development (IAD). Thirty plots were established in Chorlem and Kimothon forests in 1997, with a revisit to Chorlem in 2001 and 2013 and Kimothon in 2002 and 2012.

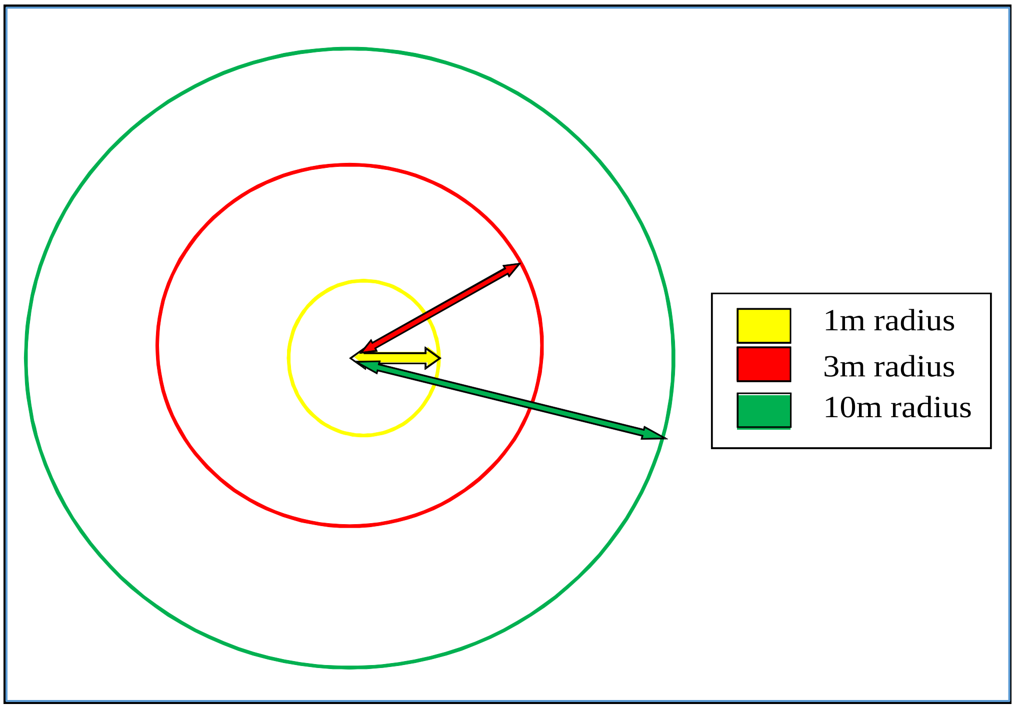

Figure 1 IFRI concentric plot sizes

Each plot consisted of three concentric circular plots of 1m radius (3.14 m^2), 3 m radius (28.26 m^2) and 10 m radius (314 m^2). Within the inner 3.14 m^2 plot, all woody seedlings (counts) and the herbaceous plants (percent ground cover) were recorded. In the 28.26 m^2 subplot, all the shrubs, saplings and woody climbers with diameter at breast height ranging between 2.5cm to 10 cm were measured together with their heights. In the 314-m^2 plot, the diameters and heights of all trees with a diameter at breast height of more than 10 cm were measured. Data analysis was based on plot inventory in both Chorlem and Kimothon sites for the seedlings, saplings and herbs and trees.

Land use classification.

Recent and historical land use classification was conducted. The recent land use classes were assigned using supervised classification, validated using Google link for accuracy. Land cover classification system was used to generate land cover classes.

Historical Land Use Land Cover Classes used unsupervised classification to generate as many classes for the respective years 1984, 1995, 2000 and 2015. The trend changes were identified in the respective classes.

Data analysis

Data collected at the plot level on seedlings, herbs, saplings, shrubs and trees were used to show the differences in species richness during the various visits in Chorlem and Kimothon forests.

To compare the density of the plant types for each of the visits, the area of each plot was calculated using the formula, Area (hectares) =$(\frac{\pi r^2}{10000})$. The plot area covered by seedlings was calculated using $(\frac{\pi * 1^2}{10000})$ = 0.000314 hectares, saplings and shrubs using $(\frac{\pi * 3^2}{10000})$= 0.002826 hectares and trees using $(\frac{\pi * 10^2}{10000})$= 0.0314 hectares, where $\prod$ is 3.14 and r is radius. The density (number per hectare) for each plant type was therefore calculated using $[\text{number of plants}/\text{plotsize}/\text{sample size}(30)]$.

Determination of size distribution was conducted on saplings and shrubs and trees in both Chorlem and Kimothon, based on the basal area per hectare (m^2/ha) for each visit. Having recorded the diameters at breast height, the basal areas were calculated using the formula$\left(\frac{\pi}{4} * 10000\right) * DBH^2$ for each tree or sapling. For each plot, the total basal area was obtained by summing the individual tree's value. The total basal area of the forests was determined by adding the values of the 30 plots. The average basal area per hectare was calculated by dividing the total basal area by the sample size (30), divided by plot size 0.002826 hectares and 0.0314 hectares for saplings and shrubs and trees respectively.

Results

1. **Biophysical analysis**

Density

Chorlem showed a slight increase of mean density in 2013compared to 1997. In Kimothon, there was a decline of mean density in 2002, followed by an increase of mean density in 2012. Kimothon indicated a decline in mean density and inter-quartile range in 2002, compared to 1997, and increased in 2012 Figure 2.

Pooled data however showed a decline in mean and inter-quartile range in 2002 compared to 1997 and a further increase in 2013/2012 Figure 2.

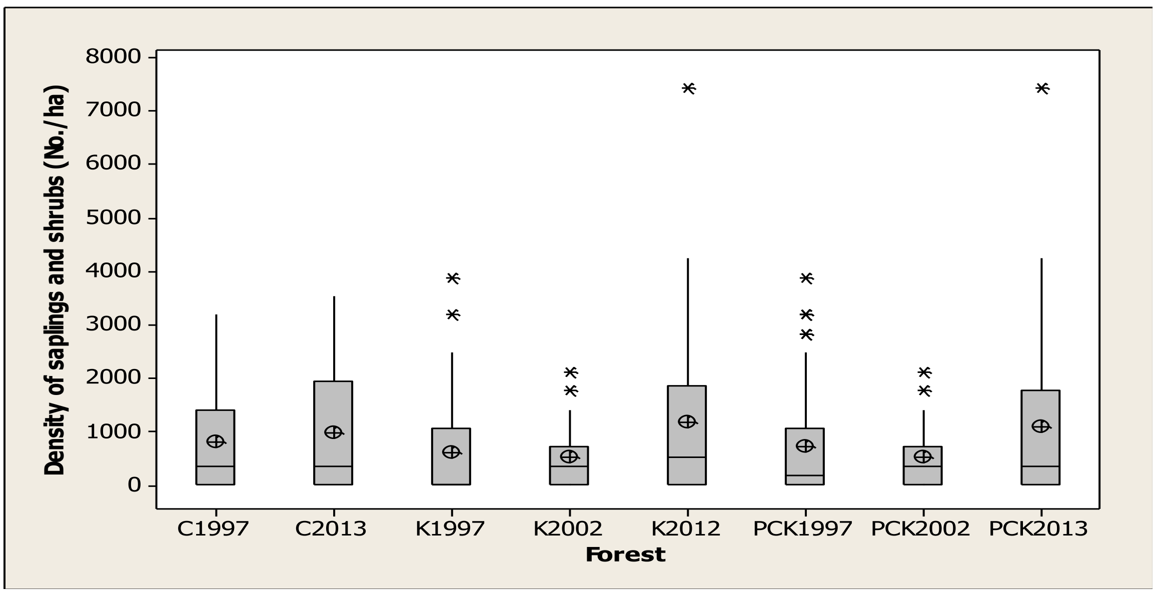

Figure 2 Box plot showing sapling and shrub density in Chorlem and Kimothon and Pooled data

There was a decline in mean tree density in Chorlem in 2001, and 2013 compared to 1997. Kimothon had an increase in mean density in 2002, compared to 1997, with further decline ot tree density in 2012. The pooled data showed a relatively similar tree density in 1997 and 2002, with further decline in 2013Figure 3.

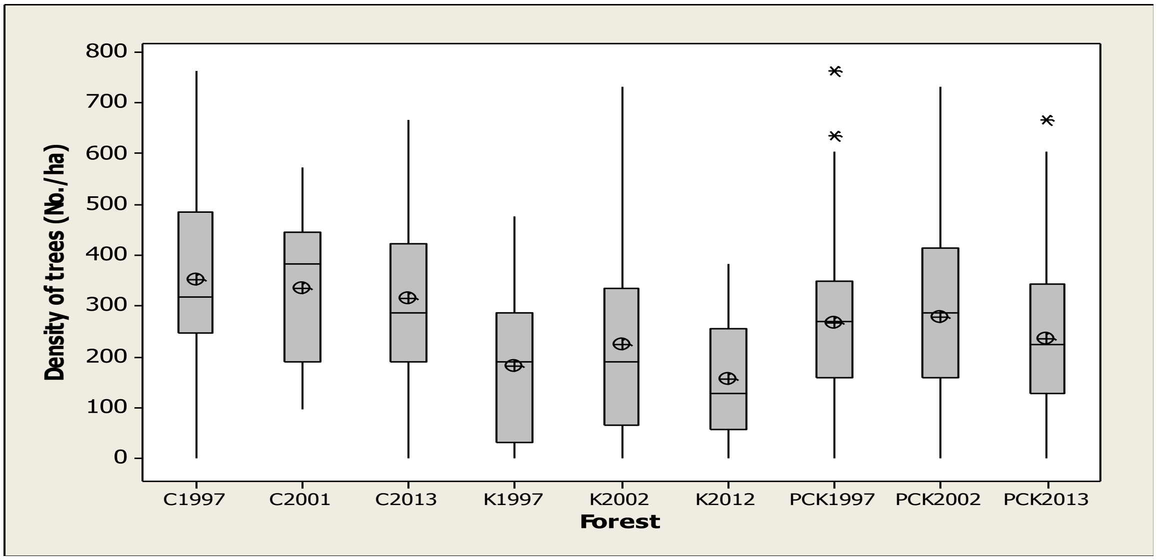

Figure 3 Box plot showing tree density in Chorlem and Kimothon and Pooled data

Basal area

There was a relatively similar sapling and shrub basal area in 1997 and 2001 in Chorlem, with a slight increase in 2013. However, there was a relatively similar sapling and and shrubs basal area in 1997 and 2002 followed by a slight increase in 2012 in Kimothon and Pooled data respectively Figure 4 .

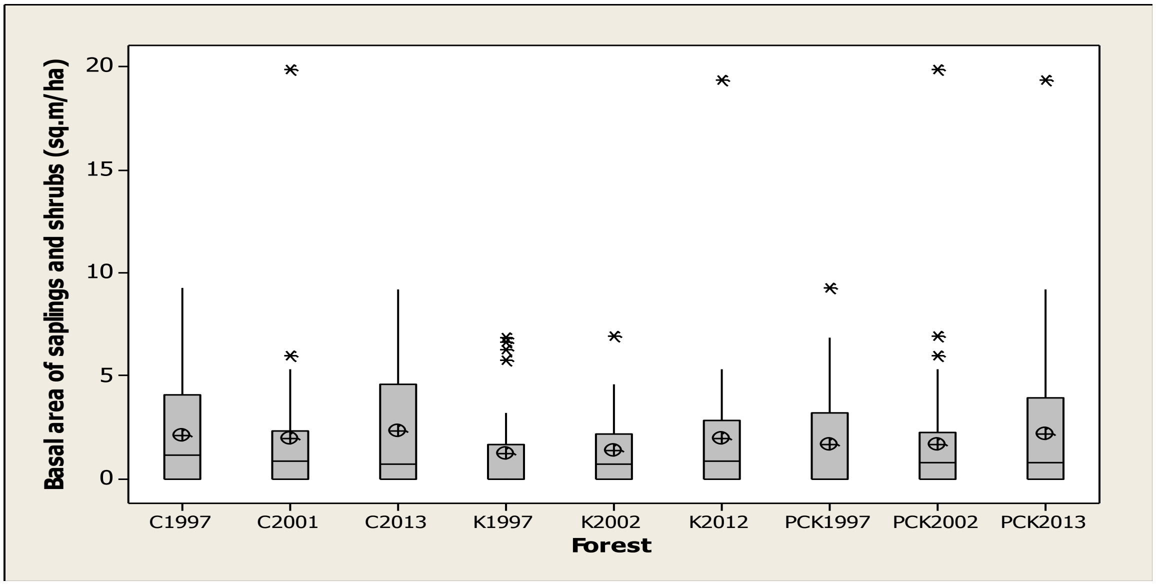

Figure 4 Box plot showing sapling and shrub basal area in Chorlem and Kimothon and Pooled data

There was an increase in tree basal area in 2001 compared to 1997 followed by a decline in 2013 in Chorlem. Kimothon and Pooled data showed a steady decline of tree basal area Figure 5.

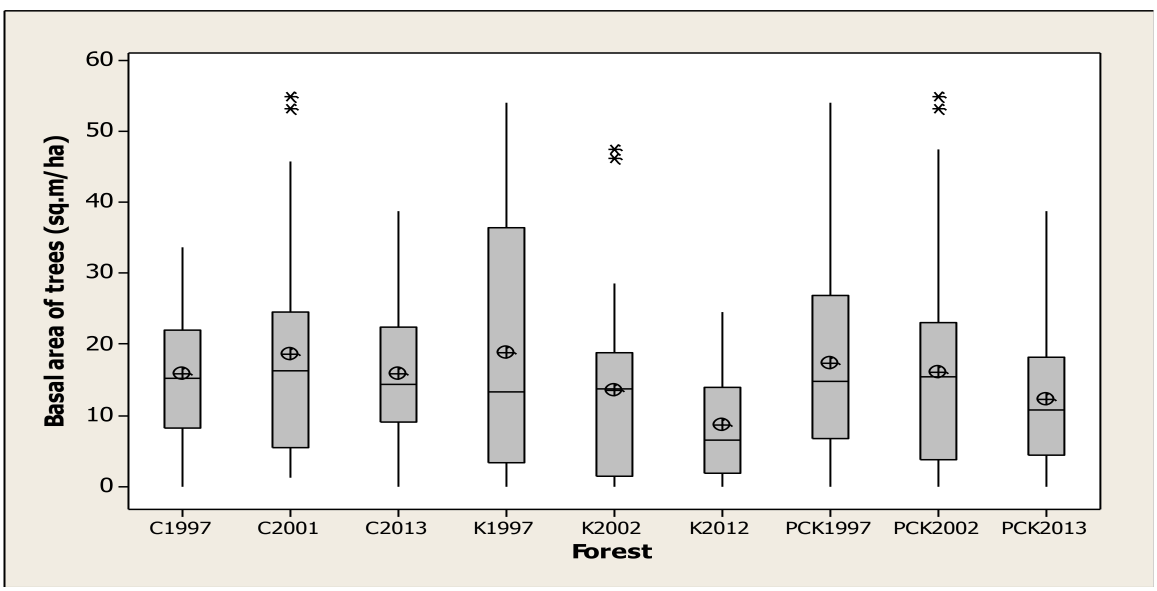

Figure 5 Box plot showing tree Basal area in Chorlem and Kimothon and Pooled data

Saplings, shrubs and trees were characterized by periods of decline and recovery of density and basal area in Chorlem and Kimothon. However, tree density and basal area steadily declined in Chorlem (2001 and 2013 compared to 1997) and Kimothon(1997,2002 and 2012).

The high sapling and shrub density and low tree density Chorlem and Kimothon denotes a low transition of saplings to trees. Intense livestock grazing and charcoal production encourages the development of herbs, which show periodic forest disturbance. As a result continuous and illegal access of forest products such as fittoes, poles and firewood, the canopy is continuously opened, thereby reducing growth of light intolerant species.

The low sapling and shrub basal area and high tree basal area in Chorlem and Kimothon denoted preference of saplings and trees to shrubs. Access of trees is limited by size and the effort for processing. Overall, the low sapling, shrub and tree density affected sapling, shrub and tree basal area.

The forests in 1970s and 80s were encroached, leading to change in bio-physical cover. Initiatives such as restoration planting through establishment of plantations and natural regeneration aided by protection were conducted which later lead to increase of saplings in the forests. This resulted to the establishment and survival of pioneer species within the forests.

However management harvesting and illegal access of climax and pioneer species respectively resulted to decline of saplings, shrubs densities and basal areas.

Dominant species uses in Mt. Elgon

Table 1 Dominant species uses in Mt. Elgon

Species	Main use
Brachylaena huillensis	Construction, wood carving, firewood
Cassipourea malosana	Construction, tool handles, firewood
Croton macrostachyus	Construction, medicinal, firewood, charcoal, tool handles, furniture
Diospyros abyssinica	Construction, tool handles, timber, furniture
Dombeya torrid	Firewood, medicinal, rope making, timber
Euclea divinorum	Firewood, medicinal, timber, construction, fodder and forage,
Hesperocyparis lusitanica	Timber, construction, pulpwood, furniture
Olea Africana	Charcoal, construction medicinal, ceremonial, firewood, timber
Olinia rochetiana	Posts, charcoal, construction
Pinus patula	Firewood, timber, pulpwood
Pinus radiate	Pulpwood, timber

Solanum indicum	Medicinal
Teclea nobilis	Construction, medicinal, furniture, handicraft, firewood

Communities derive direct and processed products form Chorlem and Kimothon forests. However, the species provide overlapping product uses within and outside the settlement for medicine, firewood, construction, charcoal, timber, furniture thereby increasing their demand for access and use.

2. Land use Classification

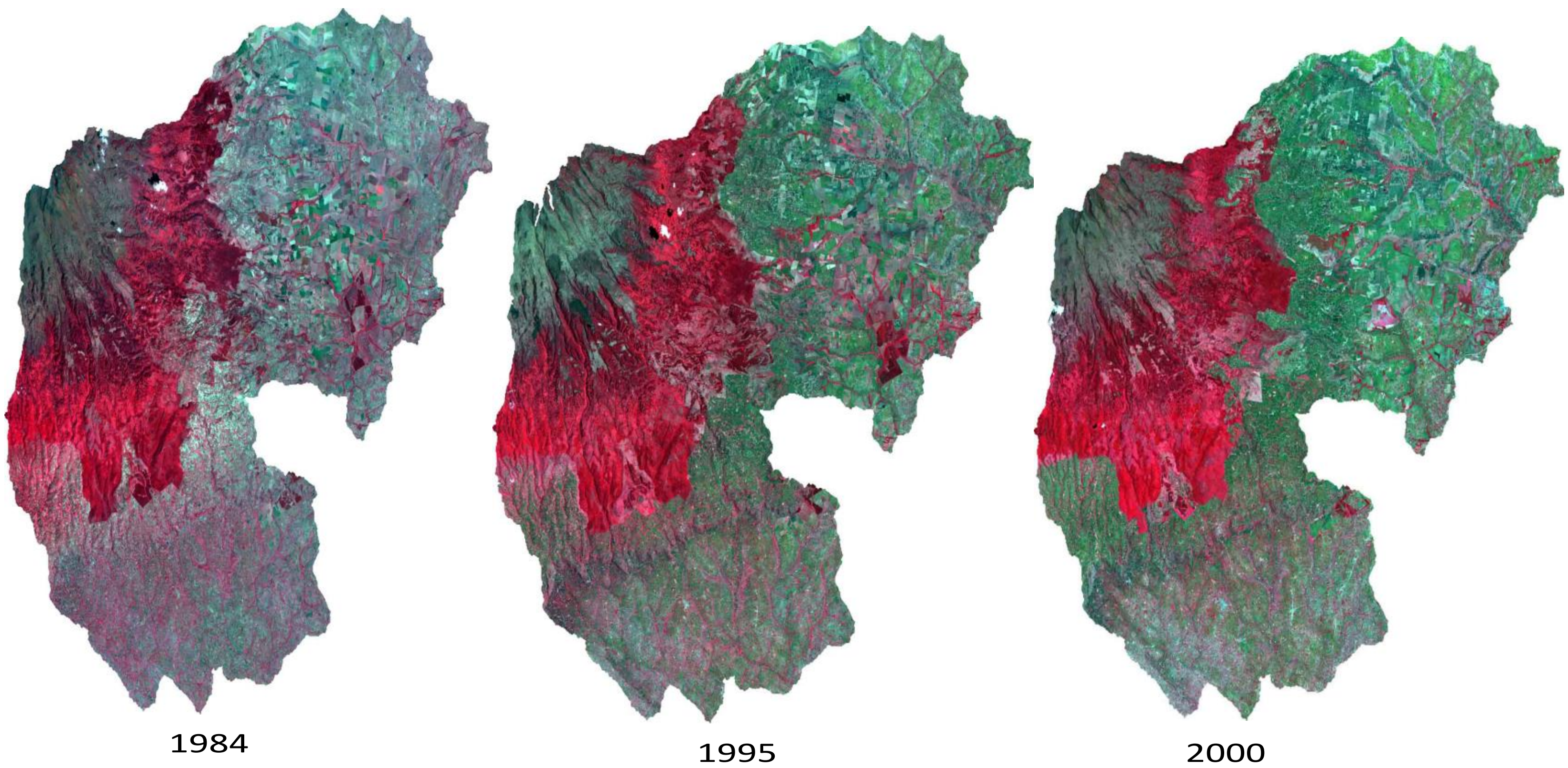

Figure 6 Mt. Elgon 1984, 1995 and 2000 Landsat images

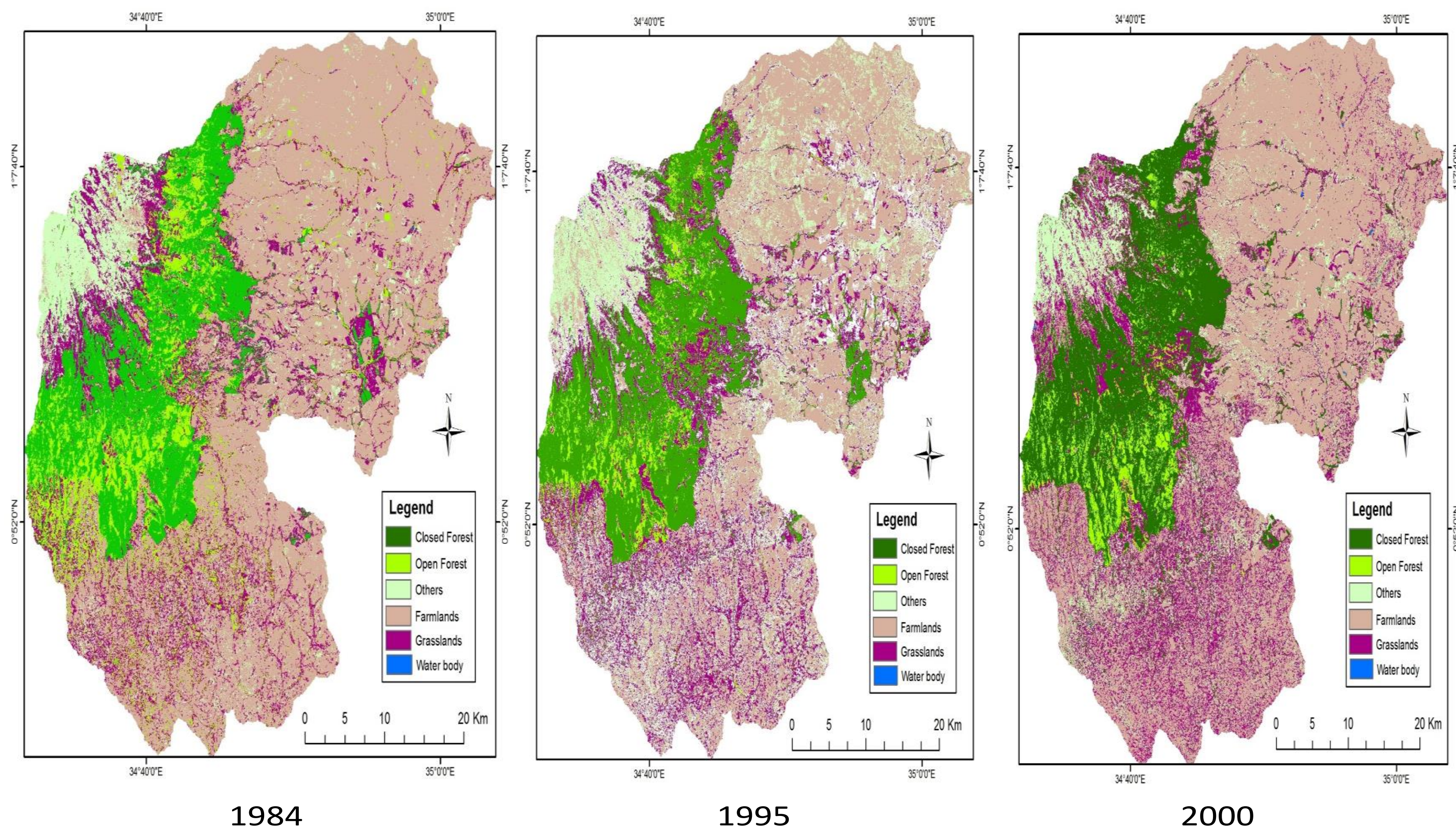

Figure 7 Mt. Elgon 1984, 1995, and 2000 Land use classes

Historical Trend

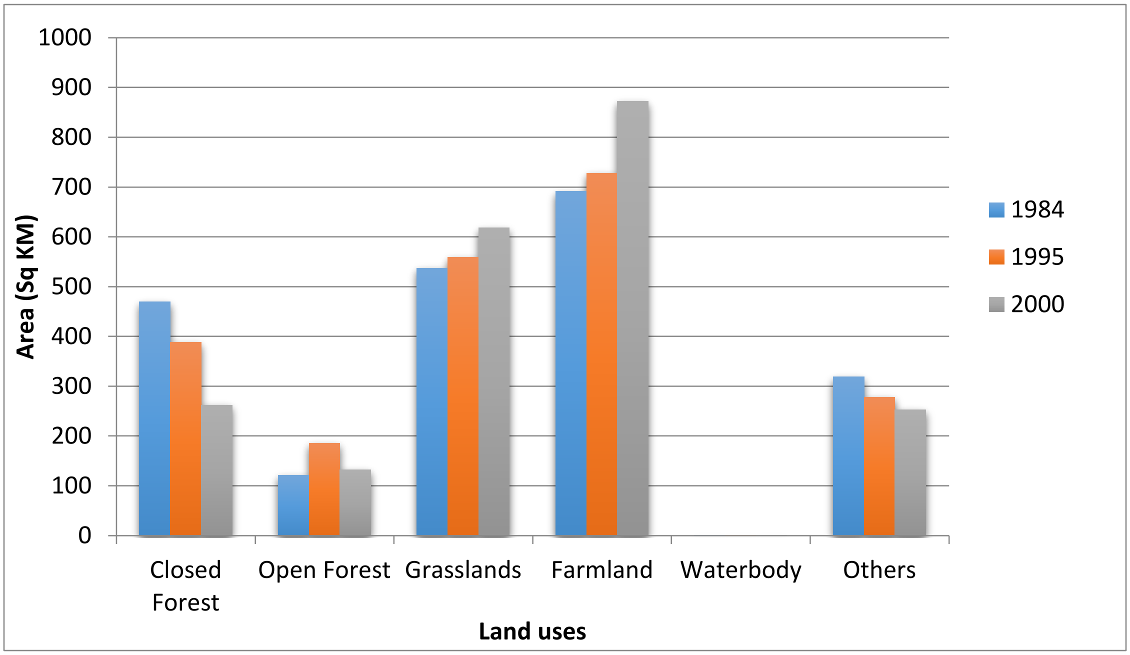

Figure 8 Summarized historical trend (area-Sq km) for Mt. Elgon forest ecosystem

The land use types identified were; Farm land, closed forest, Open forest, Grassland, Water bodies and others (bare surfaces, Riparian Vegetation etc.). Figure 7 shows the thematic map of the land use types of 1984,5 and 2015 for Mt. Elgon Ecosystem, and Table above shows the spatial estimates of each Land use categories. It is observed from the information that Farmland was the dominant class covering an area of approximately 32.3% of total area. Area under grassland was about 25.1%, while closed forest and other land use type's covers 22.0% and 14.89% respectively. Open forest covers approximately 5.67% and lastly water bodies covering the smallest area of less than 1% of the study area.

Form the result, other and closed forest has lost 20.60% and approximately 10% of cover respectively. Farmland has gained about 26% of cover while grassland and open forest gained 15% and 8.71% respectively.

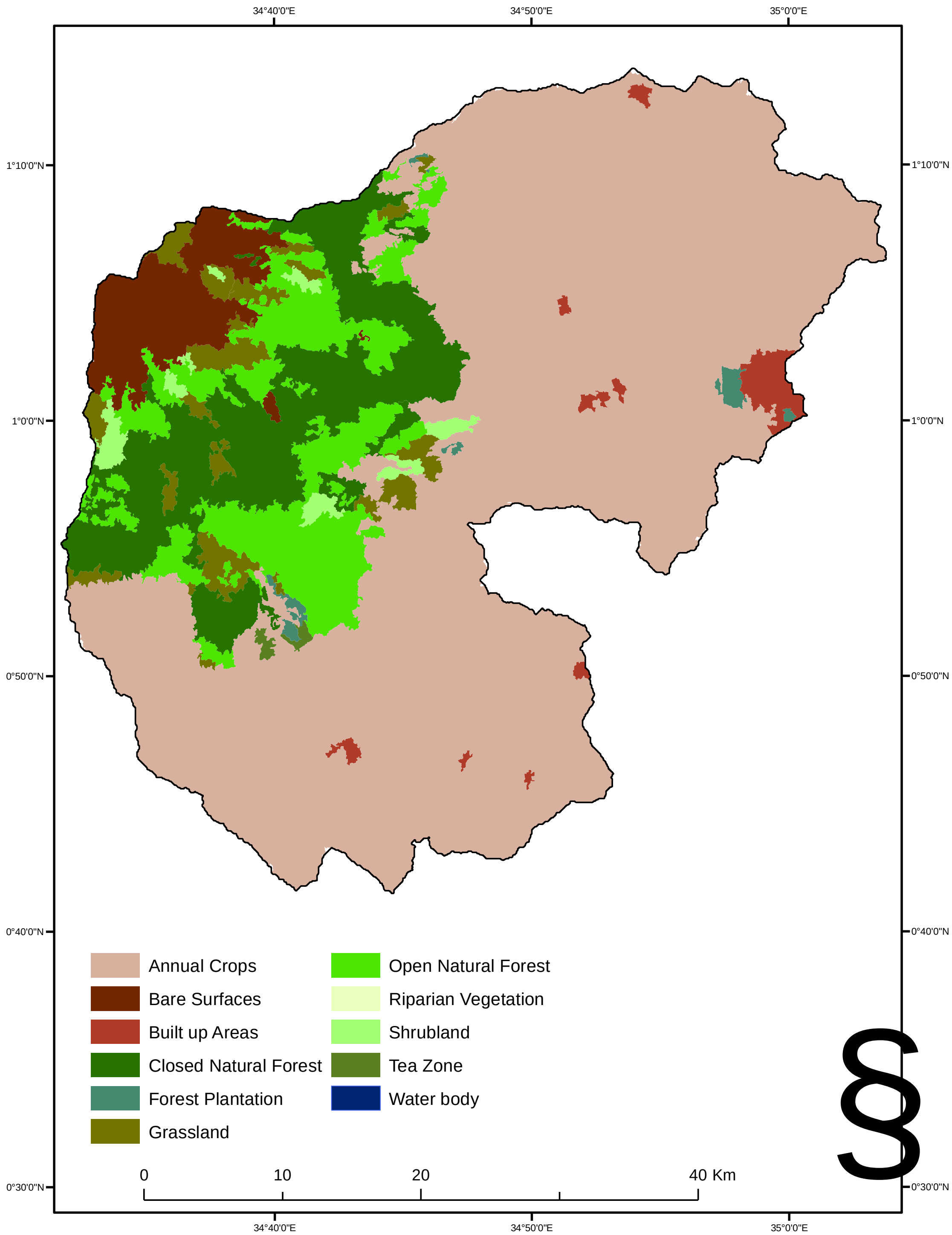

Figure 9 Recent Land use land cover (2015) for Mount Elgon Water Tower Ecosystem

Result discussion

Mount Elgon water tower ecosystem

Closed forest observed to be decreasing over the three years having lost to steady increase in grasslands and farmlands. Open forest declined in 1995 and appears to have recovered/regenerated slightly in 2000 (table 1 and figure 9). The class categorized as others (riparian vegetation, bare areas and rock surfaces) appears to be decreasing, conquered by farmlands and grasslands). The decline in closed forest cover agrees with a study conducted by Nield et al, 1999, pinpointing loss in vegetation diversity and density, attributed primarily to a combination of encroachment by local communities and large illegally allocated logging concessions (Nield et al, 1999).

Biophysical analysis of forest condition in Mount Elgon-ADapTEA project suggested that between the periods 1985, 1995 and 2008, significant areas in Mount Elgon forest ecosystem transitioned from high canopy cover to low/no canopy cover. Figures 6, 7 and 8 of this analysis represent land uses in the year 1994, 1995 and 2000 with change results summarized in table 1 or figure 9. Change detected during AdapTEA study with decline in canopy cover is reflected in this analysis. This transition is further corroborated by IFRI plot-level forest vegetation sampling data from both Chorlim and Kimothon IFRI sites in Mount Elgon, showing trending decline in tree cover since 1997-2013. According to the IFRI article, forest vegetation cover declined by approximately 20.4% given 1997 &2013 tree mean density. Aerial photography and Land cover mapping of Mt. Elgon 1999 and 1960s cited in IFRI site report 2001, further confirms this depreciation by a marked decline in the area covering the indigenous forest. Forest cover declined from 49% to 35% while the shamba systems rose from non existence to 9%. Linked to this analysis, farmlands have remained on the ascent indicating the forest ecosystem encroached for agricultural motives among others.

Farmlands and grasslands have conquered forested areas according to the historical trend analysis. Most clearing are a function of subsistence agriculture, though logging and infrastructure development has also contributed to forest loss (Russel 2012). Mount Elgon forest holds a high percentage of forest resources, crucial to local community' livelihoods (van Heist, 1994). Major products contributing to socio-economy are firewood, poles or timber, vines, water and fodder (Scott, 1994). The value of the resource to proximate communities and those further apart designated as indirect users puts pressure on the resource capacity.

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