Detecting Forest degradation in Kenya: An analysis of hot spots and rehabilitation techniques in Mt. Elgon and Cherangani Hills ecosystems

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ABSTRACT

Forest management in Kenya has been challenged by undefined boundaries, illegal access, forest excision, competing claims for its products amongst other factors as communities depend on the forests for various products. While forests are owned by state, private individuals or communities, gazette public forests have also been claimed by indigenous groups, and in some cases, private entities.

Such claims have resulted in conflicts of management which limit monitoring of forest access by the state through Kenya Forests Service (KFS). As a result, forests' ability to produce quality ecosystem goods and services has been curtailed by the declining forest cover. Mt. Elgon and Cherangany hills forest ecosystems provide ecosystem goods and services, which impact positively on the livelihoods of communities. They are also water towers; a source of numerous rivers and streams, which supply millions of people downstream in Kenya and Uganda. The ecosystems' ability to provide direct and indirect benefits has been affected by declining forest cover and competing claims of ownership. As a result of destruction and degradation, the local climate has changed leading to migration or alteration of flora and fauna altitudinal habitation, product and service provision thus affecting ecosystem dependent livelihoods.

Reducing forest degradation to improve its condition through Participatory Forest Management (PFM), Natural Resource Management and local forest institutional strengthening through training and capacity building has been conducted to enhance sustainable forest management.

Using ground trothing techniques and analysis of satellite imagery, degraded hot spots were identified in the two ecosystems for intervention through rehabilitation. Results showed that degradation occurred from unmonitored access and exploitation of the forest for charcoal production. Others included over-grazing, farming and harvesting of timber, poles and fuel wood. Rehabilitation was carried out by establishing demonstration plots on forest blocks, encouraging tree planting on farms, carrying out training activities and improving forest based enterprises.

Key words: Degradation; livelihoods; and, hot spots.

Introduction

Natural and socioeconomic factors affect the condition of forests and their utilization by humans in time and space determine the land use land cover (LULC) pattern of a region (Zubair 2006; Rahdary 2008; Bhagawat 2011; Shiferaw 2011). The surface of the earth has been modified considerably over the past 50 years by human activities especially through urbanization, deforestation and intensive agricultural practices. The disturbances are exacerbated by increased human population and demand for more agricultural land for food production, which have resulted in destruction of the vegetation cover (Gordon O. et al. 2010), and subsequently rampant environmental degradation and deforestation.

Deforestation refers to the continued destruction of forest cover and conversion of forests to other land uses (Wunder, 2004) and forest degradation is the loss of quality of forests which impair ecosystem functioning by altering the structure, spatial distribution, crown cover, diversity and other attributes.

Forest reserves in Kenya are managed by Kenya Forest Service (KFS) and Kenya Wildlife Service (KWS). Over the past three decades, large forest reserves have been de-gazetted and illegally converted into farmlands to meet population demands for agriculture and settlement. The forests have been degraded by decades of logging leading to reduced carbon stocks and degraded biodiversity values. Forests on community trust lands also continue to be destroyed and degraded for timber, poles, charcoal, fuel wood, grazing, agricultural expansion, wood extraction and all manner of infrastructure seem to be the main direct drivers of deforestation and forest degradation (Hosonuma, et al., 2012) (GoK, 2010). Even the state owned plantations have progressively reduced from 150000 ha in the 1990s to 107000 ha by 2011 (GoK, 2010), however, tree cover on farms has increased slightly over the same period.

Kenya's high population growth, interacting with other underlying drivers and the manifestation of agricultural expansion, are considered to be the major drivers of forest loss. The principal drivers (GoK, 2010) were linked to rural poverty and rapid population growth, unsustainable utilization, institutional failures in the forest sector and past governance which saw the excision of 67,000 ha of forest land by the government most of which critical water catchment areas such as Mau, Mt. Elgon and Mt. Kenya, which were cleared for new settlements and illegal logging (Ochieng, 2009).

Sustainable forest management can therefore be achieved through re-orienting forestry profession, and making its institutions more responsive to changing societal needs. These changes include recognizing forest adjacent communities as key stakeholders, empowering institutions responsible for forest governance (KFS), and advocacy groups, improving quality and relevance of forestry education and training, setting forestry research and extension agenda to address dynamic changes of societal needs. The changes should be accompanied by forest information and benefit sharing amongst stakeholders to guide evolution of sound forestry practices to achieve desired management goals.

While forest degradation continues to occur, its effects are being felt by the dwindling economy that it supports, through reduced forest productivity, loss of biodiversity, reduced carbon stock, loss of ecosystem services, and poor forest health among other effects.

In order to control deforestation and degradation effects, several policy reform measures to enhance forest conservation include;

- Banning of the *shamba* system following increased influx of forest neighboring communities. By 1988, all forest cultivators were evicted from forest areas (Imo, Ochieng, Ogweno, Senelwa, & Ototo, 2007).
- Establishment of *Nyayo* Tea Zones Development Corporation in 1986 to protect and conserve gazetted forests by providing buffer zones.
- Ban on forest logging in all state forests to regulate saw millers operations (Wasike, 2010).
- Policy and institutional reforms such as establishment of Kenya Forest Service and enactment of Forest Act 2005, to involve more stakeholders to ensure an integrated and harmonized conservation and management system.
- Improved public perception on forest degradation resulting in disapproval by the public on attempts by the government to convert gazetted forests to any other use except for purposes of conservation (Gachanja, 2003).

The project aimed at establishing the status of the two ecosystems in terms of land use, land tenure, biodiversity status, sedimentation level, hydrological and water characteristics to inform rehabilitation and conservation actions for climate change adaptation and mitigation.

The specific objectives were to detect forest degradation by identifying hot spot and vulnerable areas and design rehabilitation techniques for conservation and demonstration to rehabilitate the degraded sites in Mt. Elgon and Cherangany hills ecosystems using remote sensing and ground based methods of spatial data acquisition. Replication of these techniques will be done within the two ecosystems and in other forest reserves in Kenya.

The study was conducted in Mt. Elgon and Cherangany forest ecosystems, covering 11 counties. Mt. Elgon forest ecosystem is located on the slopes of the extinct volcano straddling the boundaries of Kenya and Uganda, with a height of 4321M a.s.l. it is between 0849'–18130 N and 348050 –348470 E, and covers approximately 78,025 ha of National Park and Forest Reserve managed by KWS and KFS respectively. The forest has undergone excisions (Suda, 1992) since its gazettement as a forest reserve in 1932. The mean annual temperature is 15.2–18.0 8C (Joetzold & Schimidt, 1983) with a bimodal rainfall peak in May and August and dominated by an alternating topography of hills and bottoms, with soils developed from basic igneous rocks (olivine basalt) and volcanic ashes (Joetzold & Schimidt, 1983) making the soils fertile (Troeh & Thompson, 1993).

Cherangany hills are a collection of thirteen forest blocks in western Kenya. The forested area which covers about 1200 square meters , which has been gazetted as a forest reserve (Kimani, 2011) with an elevation of 3500 m a.s.l. The hills were formed as a result of erosion of surrounding material leaving behind high residual mountain ridges.

The forest consists of high closed canopy natural forest, plantations and open bush and grasslands. The two ecosystems provide ecosystem goods and services that influence community livelihoods and are water catchments which supply water to rivers and lakes in Kenya and Uganda.

Materials and methods

Study area

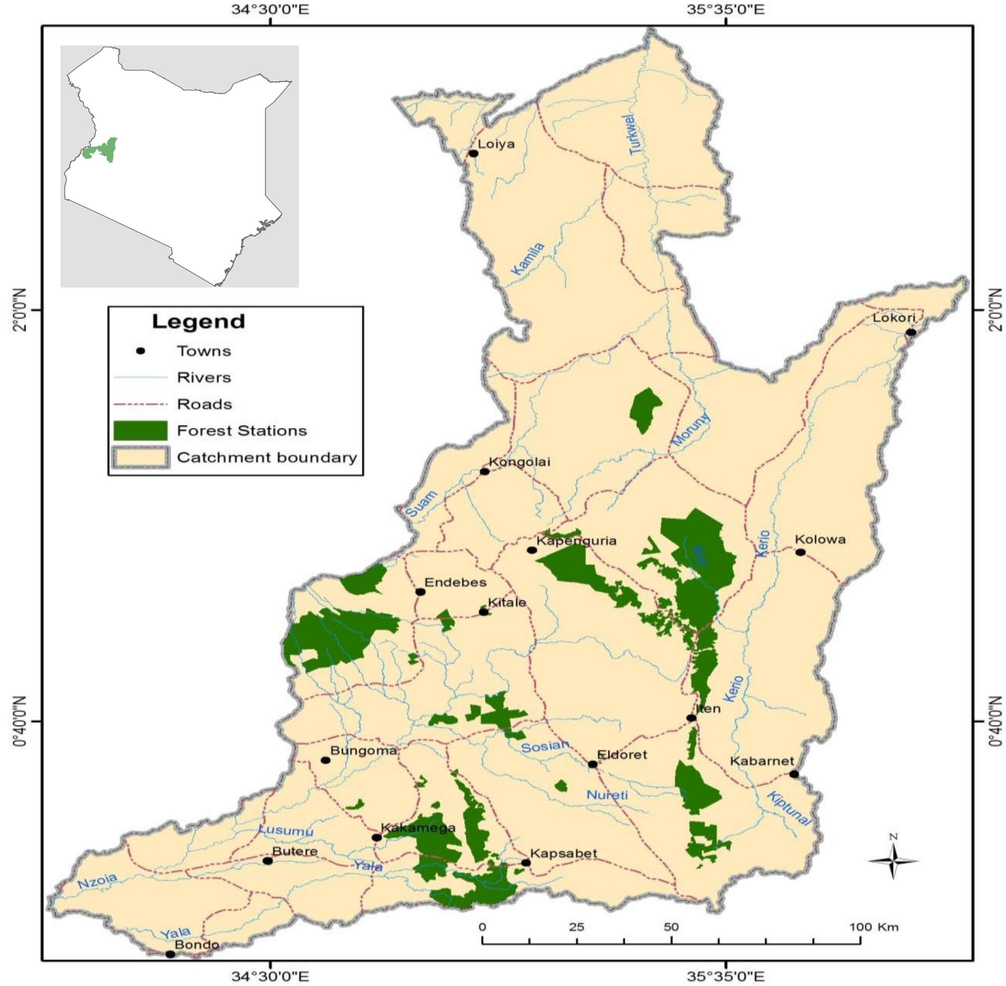


Figure 1 Mt. Elgon and Cherangany catchment map

Methodology

Multi-temporal satellite images of 1985 and 2016 datasets were used for analyzing forest degradation with the two ecosystems as shown in the table below.

Year	Path and Raw/Scene	Date	Ecosystem
1985	170/59	31st December	Mount Elgon/Cherangany
2016		27th January	
1985	169/60	1st March	Cherangany ecosystem
2016		4th February	

1985	169/59	1st March	
2016		4th February	

The data of the same season with minimum possible gaps between them were selected for analysis in order to minimize the impacts of the changing seasons on the mapping. Both unsupervised and supervised classification techniques were applied in the study, and to attain accurate results, omission and commission errors were calculated for accuracy assessment.

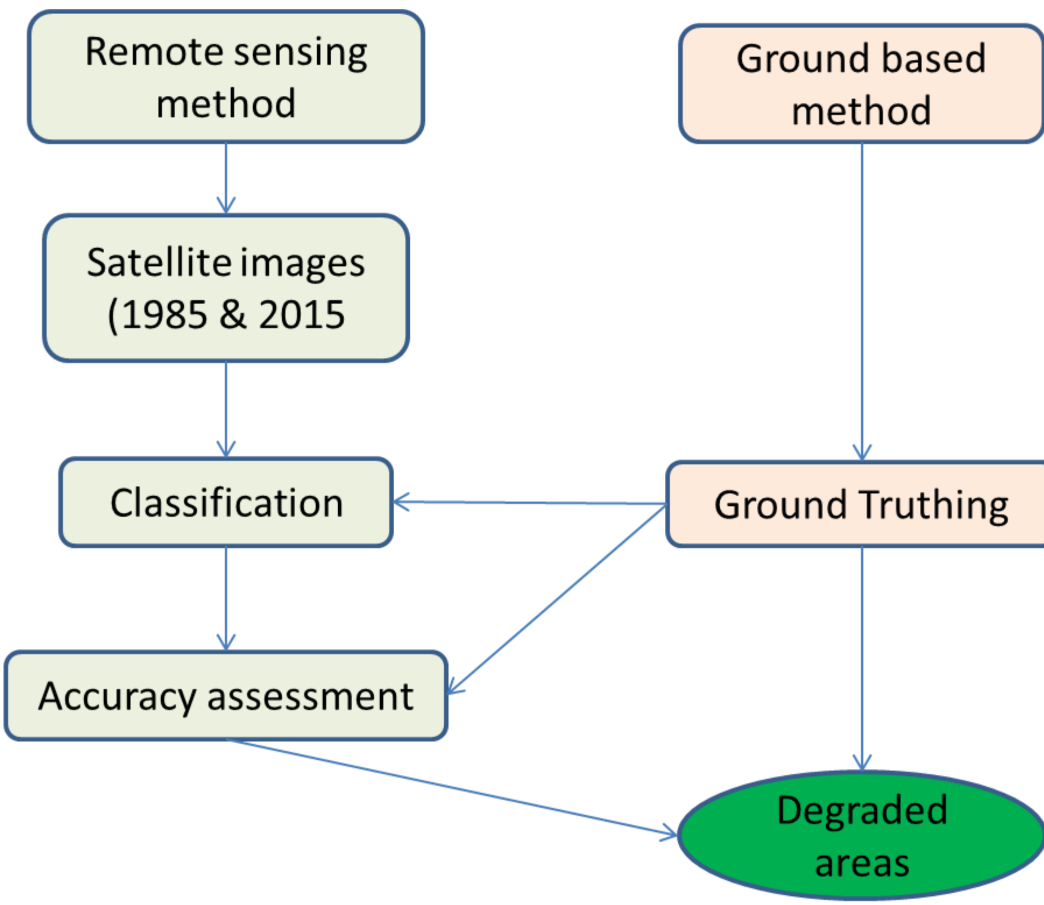


Figure 2: Methodology for Degradation Assessment

Ground truthing

Based on area/pixel count/value of the 8 unsupervised classes generated from each ecosystem (Cherangani and Mount Elgon), a sample size calculation algorithm using the determined formula of estimating n bound specified as % (Allowable Error (AE)) of either of the population mean or total (finite populations) was used to generate sample points, $\boldsymbol{n} = \frac{4N(CV)^2}{(AE)^2N} + 4(CV)^2$

Where,

N=total area, pixel value of all the classes generated,

n= number of sample plots per class,

AE=Allowable Error (%),

CV= Co-efficient of Variation (%)

Total number of samples and class samples were tested at different allowable errors (AE), to give a range to base decisions on representative number of sample points. Allowable errors of 20%, 15% and 10% were tested, generating varying points for Cherangany ecosystem Table 1 and Mt. Elgon ecosystem Table 2.

Recent LULC assessment employed unsupervised classification to generate as many classes as possible, developed training areas from the unclassified classes to perform supervised classification of confined classes.

Table 1 Cherangany site sample points

CLASSES	PIXEL COUNT	20% Allowable Error	15% Allowable Error	10% Allowable Error
1	8258	0	0	1
2	355739	10	19	49
3	369760	10	20	50
4	720915	19	39	98
5	183777	5	10	25
6	69650	2	4	9
7	3763	0	0	1
8	663933	18	36	91
TOTAL	**2375795**	**64**	**128**	**324**

Table 2 Mt. Elgon site sample points

CLASSES	PIXEL COUNT	20% Allowable Error	15% Allowable Error	10% Allowable Error
1	282459	3	7	17
2	1441383	11	33	84

3	986052	11	23	58
4	643364	7	15	38
5	520622	6	12	30
6	373771	4	9	22
7	105795	1	2	6
8	1184300	14	27	69
TOTAL	**5537746**	**57**	**128**	**324**

Rehabilitation

Following the identification of hotspots in Mt. Elgon and Cherangany, potential sites suitable for rehabilitation were identified for establishment of demonstration plots. The criteria for selection were site accessibility and strategic position to ensure ease of access for training and learning and willingness of adjacent communities to provide security to the demonstration plots. Selection of sites was done through a participatory process in which Kenya Forest Service (KFS) officers, members of a Community Forest Association (CFA), Local administration and community members participated.

The sites covered three Counties within Cherangany catchment areas (Elgeyo Marakwet, West Pokot and Trans-Nzoia). The sites were prepared before planting, which included fencing (to prevent encroachment of livestock and other agents of disturbance), chaining, staking and pitting (spacing of 3mx3m). Participatory planting was done according to the set layout.

Results

Land cover types in Mt. Elgon and Cherangany Hills Ecosystems

The ground truthing exercise yielded a total of 415 ground truth points in both Mt. Elgon and Cherangany forest ecosystems Table 3. The ground truthing points were overlaid on the unsupervised map with the location of the 411 ground truthing points collected in the two ecosystems.

Table 3 Ground truthing points in Mt. Elgon and Cherangany Forest Ecosystems

S. No.	Land cover type	No. of Points
1	Built up area	32
2	Grassland	33

3	Farmland	90
4	Forest	144
5	Water body	46
6	Shrub land	32
7	Riparian vegetation	16
8	Wetland	18
	Total	411

From the ground truthing data, the unsupervised classes were allocated the following land cover types Table 4.

Table 4: The vegetation types in Mt. Elgon and Cherangany Ecosystems

Unsupervised class	Vegetation type
1	Wetland
2	Forest
3	Bamboo
4	Grassland
5	Bare ground
6	Shrub land/build up area
7	Farmland
8	Clouds**

Ground Truthing points

The ground truthing points in Mt. Elgon and Cherangany ecosystem were grouped into classes such as built up areas, farmlands, forests, grassland, riparian vegetation, shrub land, water body and wetlands .

Hot spots/Degraded areas identified

The hotspot or degraded areas within the two ecosystems were identified based on ground truthing points **Error! Reference source not found.**, based on knowledge, criteria of identification and observation. The hot spot points would then be used to inform rehabilitation technologies to be demonstrated within the two ecosystems.

Description of degraded areas

The degraded sites identified in Mt. Elgon and Cherangany hills ecosystems were within the forest reserves (closed natural forest, forest plantation, open natural forest and shrub land) and private farms Figure 3. Other degraded sites were river-rines within the ecosystem. The main cause of degradation within the forest was over-grazing of livestock, illegal harvesting for timber and charcoal production and agriculture (where forest land was illegally acquired for farming and settlement).

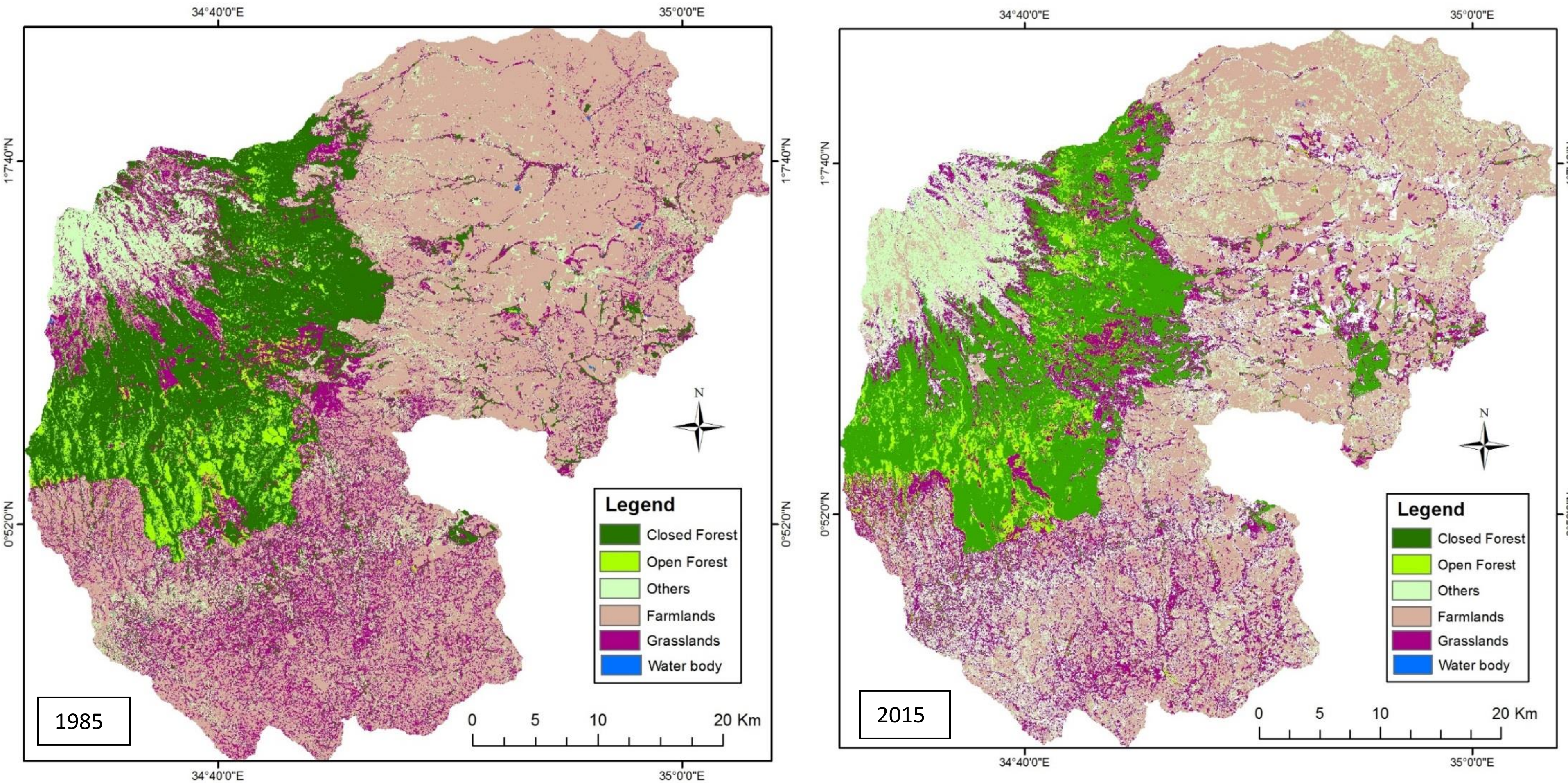
Riverines were characterized by sand harvesting and river bank cultivation, thereby destroying riparian vegetation, making the rivers and other water bodies prone to siltation due to soil erosion.

The forest, shrub land and grass land underwent seasonal burning to encourage the growth of grass for livestock. This encouraged proliferation of grass and shrubs to colonize the disturbed areas.

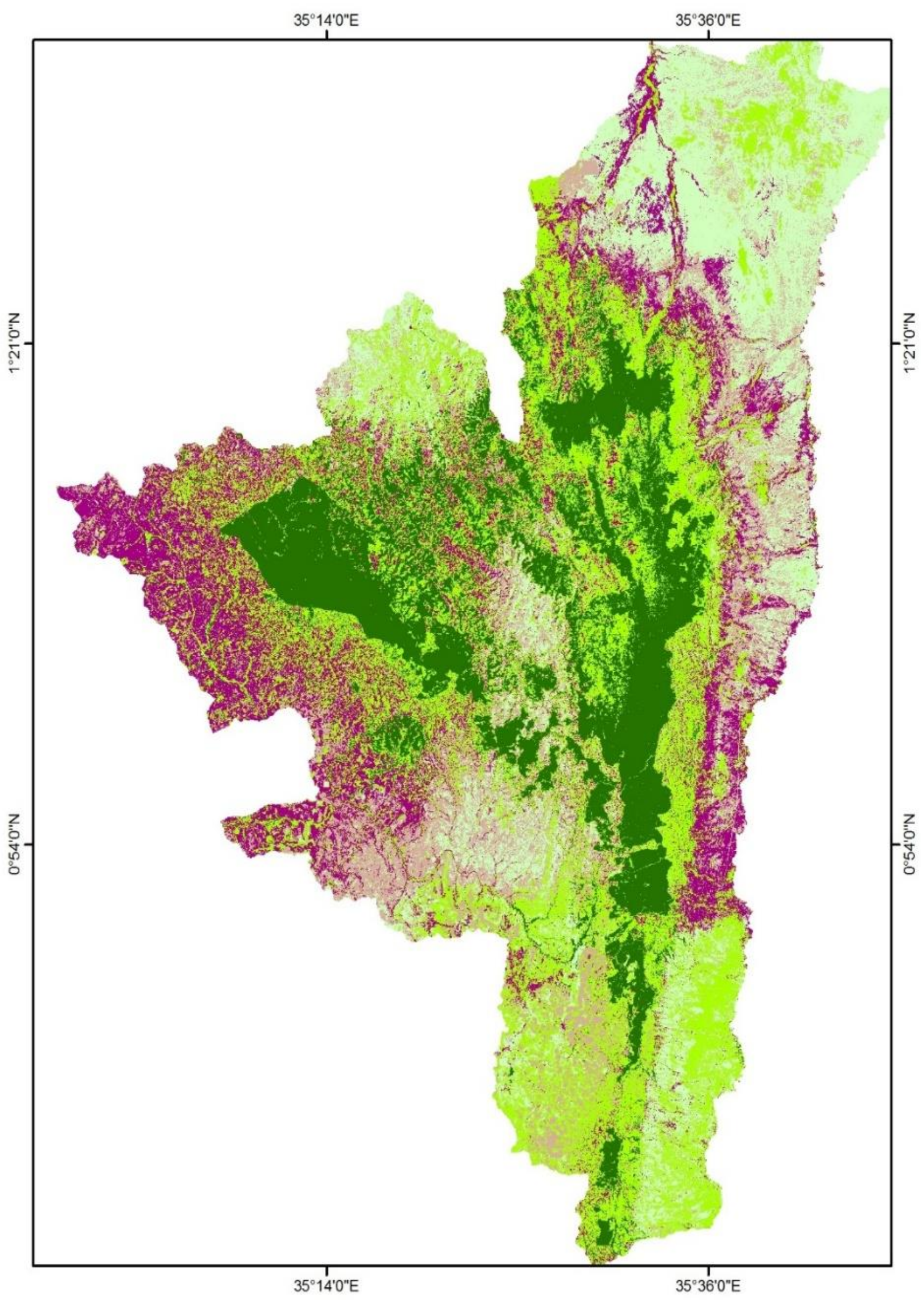
The built-up areas and farms were characterized by continuous loss of tree cover. The trees provided the raw materials for construction of houses and fences, and also gave room for infrastructure development within the ecosystem.

Since the ecosystem is on a hilly terrain and dominated by agricultural activities, poor agricultural and soil management practices resulted to continued soil erosion from farms. As a result, farms were characterized with gullies and exposed stone outcrops as remnants of erosion effects.

Sections of the forest reserves were put under Plantation Establishment and Livelihood Scheme (PELIS), which is a non-residence forest cultivation program, for a period of 3-4 years. This is only carried out in young exotic plantations, where farmers tend to the tree saplings and grow crops such as maize, beans and potatoes.



34°40'0"E
35°0'0"E
1°7'40"N
0°52'0"N
Legend
Closed Forest
Open Forest
Others
Farmlands
Grasslands
Water body
N
0 5 10 20 Km
1985
34°40'0"E
35°0'0"E
1°7'40"N
0°52'0"N
Legend
Closed Forest
Open Forest
Others
Farmlands
Grasslands
Water body
N
0 5 10 20 Km
2015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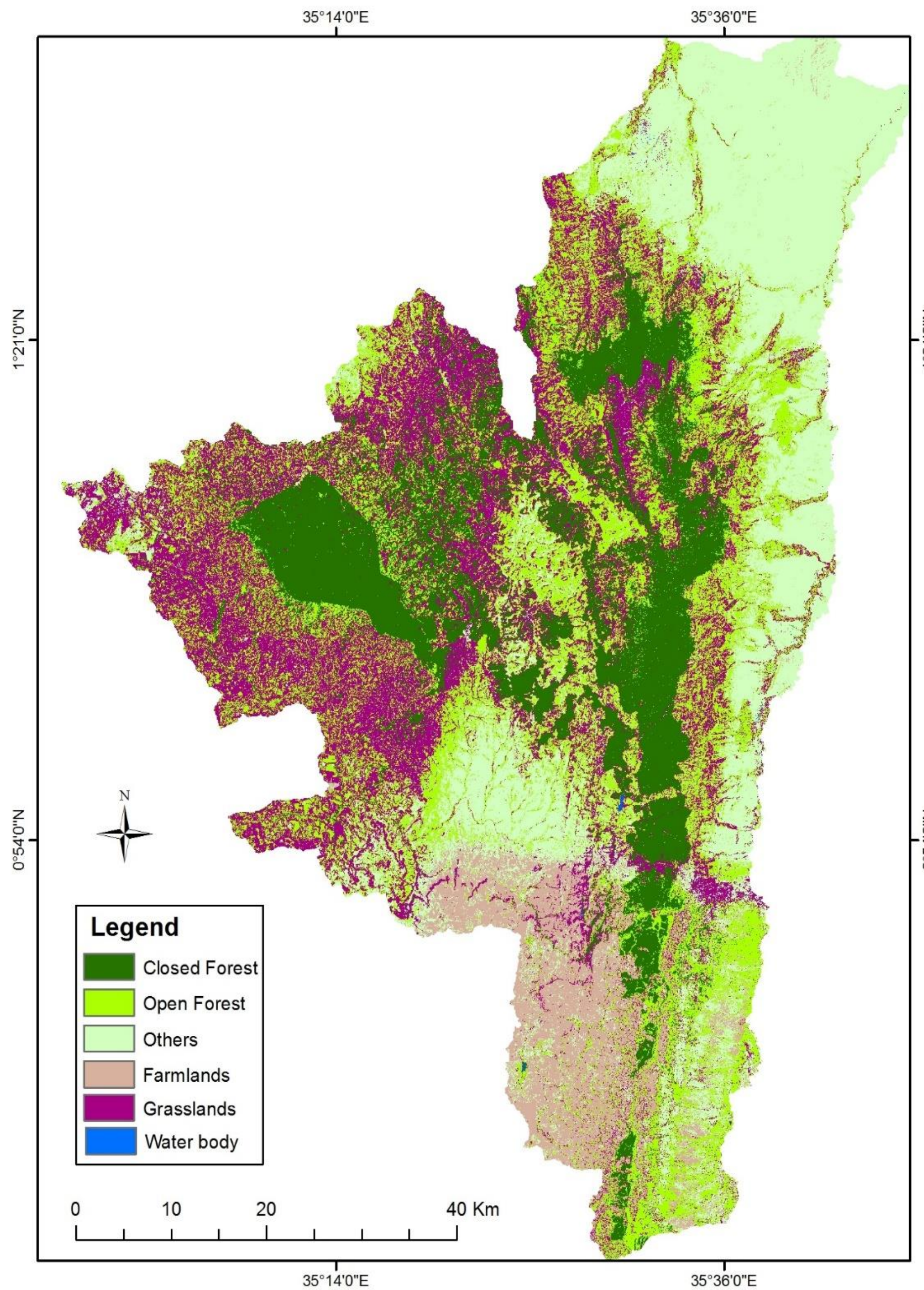
35°36'0"E
1°21'0"N
0°54'0"N


35°14'0"E
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1°21'0"N
0°54'0"N
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Legend
Closed Forest
Open Forest
Others
Farmlands
Grasslands
Water body
0
10
20
40 Km

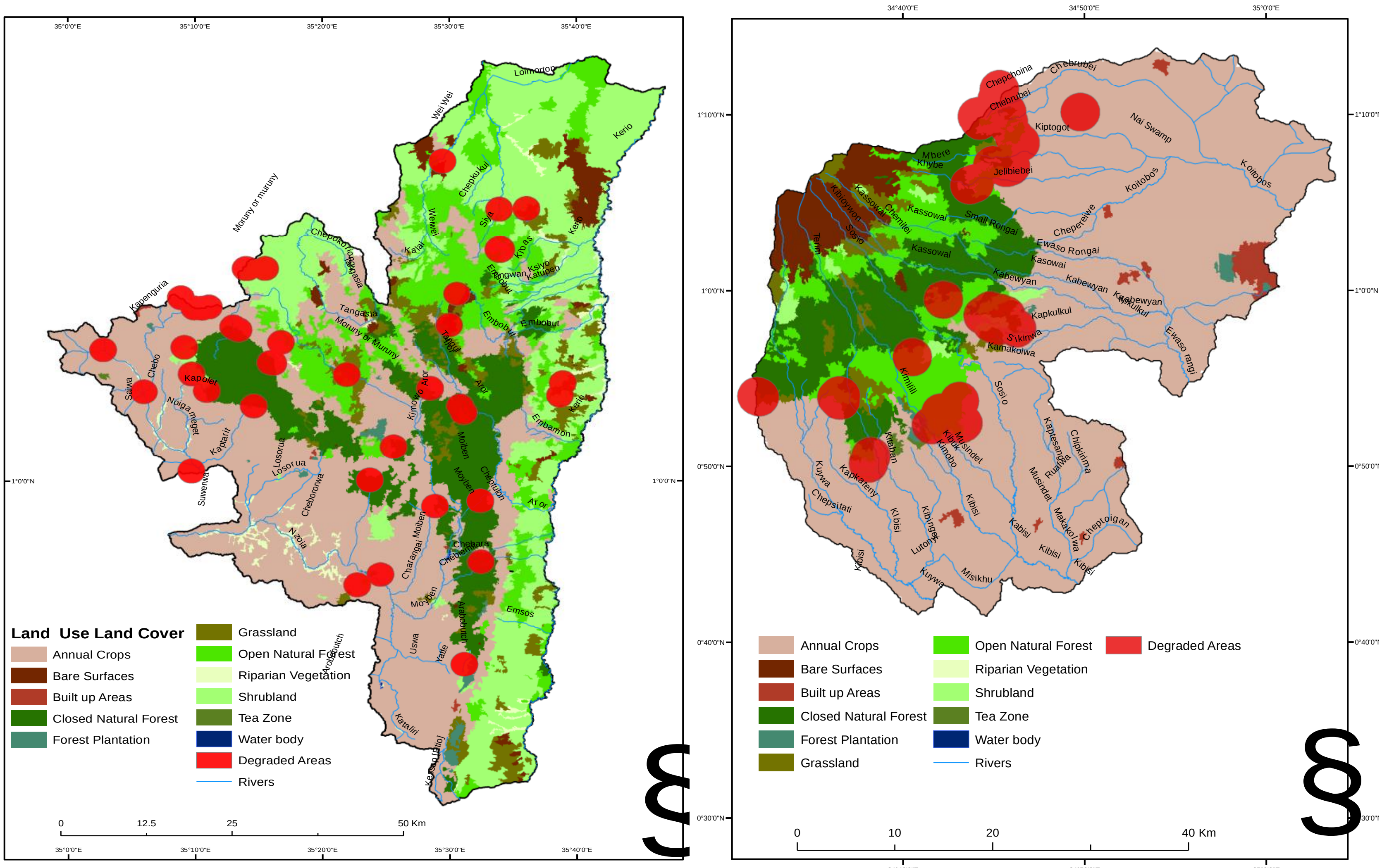

Figure 3 Degraded areas identified

Rehabilitation Technologies in Cherangany

Three types of restoration technologies were demonstrated using 17 potential restoration indigenous tree species Table 5. The demonstration technologies were used depending on the extent of degradation and recovery status of disturbed sites. The restoration technologies demonstrated were:

- Active Restoration (Maximum diversity framework and fast growing group species combination technique)
- Passive restoration (assisted restoration technique)

Table 5 Restoration species used to rehabilitate degraded areas

Fast Growing	Moderate Growing	Slow Growing
Albizia gummifera	*Juniperus procera*	*Cassearia battiscombei*
Polyscias kikuyensis	*Prunus africana*	*Pordocarpus latifolius*
Neoboutonia macrocalyx	*Syzygium guineense*	*Croton megalocarpus*
Dombeya torrida	*Makaranga kilimandscharica*	*Haggenia abbyssinica*
Zanthoxylum gillettii	*Ekebergia capensis*	*Xymalos monospora*
		Cassipourea malosana
		Markhamia lutea

Active restoration approaches

- **Maximum diversity framework technique**

Using a3m x3m spacing, the technology involved planting of fast growing, middle-phase and slow growing mature-phase species Table 6. The rehabilitation was conducted on sites where recovery did not occur or negligible with few or none remnant trees but in close proximity to a natural forest. The fast growing species acted as nurse trees, by outcompeting weeds to create suitable conditions for colonization and recruitment of other tree species as well as attract seed dispersers for enhanced recovery.

Table 6 Maximum diversity framework restoration technology

Albizia gummifera (**FG**)	*Prunus africana (**MG**)*	*Albizia gummifera(SG)*
Prunus africana	*Albizia gummifera*	*Prunus africana*
Albizia gummifera	*Prunus africana*	*Albizia gummifera*
Prunus africana	*Albizia gummifera*	*Prunus africana*
Albizia gummifera	*Croton megalocarpus (**SG**)*	*Albizia gummifera*
Croton megalocarpus	*Albizia gummifera*	*Croton megalocarpus*
Albizia gummifera	*Croton megalocarpus*	*Albizia gummifera*
Croton megalocarpus	*Albizia gummifera*	*Croton megalocarpus*

Key: FG-Fast growing, **MG-**Moderate growing **SG-**Slow growing

- **Fast growing group framework technique**

This involved planting of fast growing tree species in a mix for rehabilitation. *Albizia gummifera* and *Polyscias kikuyuyensis* were used. The technique was demonstrated on sites that were not close to intact natural forests and were heavily degraded with no recovery taking place.

Passive restoration approaches

- **Assisted restoration technique**

Two ha each of Ceder and *Syzigium guineense* dominated species in Sinen, Kapcherop and Lomuge in West Pokot County respectively were fenced to boost natural recovery. This technique was applied on sites where natural recovery occurred but was suppressed by continued disturbance especially by grazing, thus precluding succession, existence of relic tree species which can act as seed source. The sites were fenced to eliminate drivers of disturbance and allowed to naturally recover through colonization and succession.

Rehabilitation Technologies in Mt. Elgon

The rehabilitation techniques in Mt. Elgon were natural forest rehabilitation, aided restoration, restoration planting, strip planting and liberation thinning using indigenous species Table 7.

Table 7 Restoration species used to rehabilitate degraded areas

Croton megalocarpus (**FG**)	*Prunus africana (**MG**)*	*Olea capensis(SG)*
Syzigium cuminii	*Zanthoxylum gilletii*	
Cordia abyssinica		

- **Natural forest rehabilitation**

This was done by promoting natural forest recovery without planting any trees. It thrives in situations where factors that affect natural forest regeneration are controlled by erecting enclosures. Successful cases under this technology include demo plots in Kibiri, South Nandi and Wire forests in western Kenya.

- **Aided forest regeneration using framework tree species**

Indigenous tree species were planted to aid and accelerate natural forest regeneration.

- **Restoration planting**

Restoration species were planted at dense spacing e.g. 2m, 1m or 0.5m spacing. The purpose was to restore vegetation cover to the degraded forest site at a much faster rate. It uses a mix of light-demanding and shade-tolerant woody species

- **Strip planting**

Strips were cleared in a degraded forest site and trees planted along the strips.

- **Liberation thinning**

Degraded sites were cleared of herbs and shrubs that inhibited natural forest regeneration. This created space for light capture and lessened competition for woody species located therein.

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