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EVALUATION OF LAND AND VEGETATION DEGRADATION INDICATORS IN KIANG'OMBE LANDSCAPE, MBEERE NORTH, KENYA

***Kigomo J.N., Kuria M.N., Gatama S. and Waweru E.M.**

Kenya Forestry Research Institute, P.O. Box 201412-00200, Nairobi, Kenya
***Correspondent's email**: *Kigomo2@yahoo.com*

ABSTRACT

Land and vegetation degradation is mainly driven by inappropriate land use which mainly results from use of inadequate technologies and rapid increase of human population. Climate variability and change have also exacerbated the land and vegetation degradation problem. This study was undertaken to provide a valuable tool for assessing land and vegetation degradation risk and analyzing the effectiveness of various woodland rehabilitation practices. This was undertaken through integration of local and scientific techniques in Kiang'ombe landscape, Mbeere North in Kenya. The methods used included; Focus Group Discussions (FGD), key informant interviews with local community and vegetation data collection. Sample plots were laid to characterize and enumerate vegetation along degradation gradient. Major land degradation drivers prioritized by local people were overgrazing (70%), soil erosion (65%), unsustainable charcoal production (55%) wildfires (30%), and uncontrolled sand harvesting (20%). Major land and vegetation degradation indicators identified by local community were; reduced vegetation cover (75%), loss of soil fertility (70%) and low water discharge form springs (53%). Results on vegetation data revealed a significant difference in stocking density and tree diversity along degradation gradient (p<0.05). Protea gaugedi was identified as wildfire tolerant tree species due to its high occurrence in fire prone areas. In addition, Croton macrostachyus, Acacia hockii and Faurea saligna were prioritized tree species for rehabilitation of degraded areas. The study recommends integration of scientific and local knowledge during monitoring of woodland degradation and assessing the impact of rehabilitation interventions.

Key words: Local knowledge, woodland, land degradation gradient, rehabilitation, Kiang'ombe landscape.

INTRODUCTION

Kenya's economic blue print, Vision 2030 (GOK, 2007) recognizes several challenges facing environmental management in Kenya. Among these are severe destruction and degradation of critical wildlife habitats; environmental degradation caused by *inter alia* industrial, car and wood fuel emissions; climate change and desertification; and low capacity to harness natural resources. One of the Vision 2030 flagship projects is to achieve and maintain a tree cover of at least ten percent (10%) of the land area and utilize the environment and natural resources for the benefit of the people of Kenya. The national forest cover is estimated at 7 % of the land area according to the inventory undertaken in 2010 (KFS, 2013). In addition, dryland forests constitute about 49% of the Kenya's forests. Improvement and maintaining tree cover in the arid and semi-arid lands (ASALs) of Kenya will be crucial in achieving the target of at least 10% tree cover of the country's land area. This is because ASALs cover over 89% of Kenya's land and its home to 36 % of human population (GOK, 2015)

A major threat to the ecosystems of the ASALs is the inappropriate land use which is caused by many interrelated factors such as inadequate technologies, poor agricultural and rangeland practices, rapid increase in livestock and human population which results to over-exploitation of the vegetation resources leading to land degradation. Apart from extensive grazing land, the ASALs provide charcoal, timber, gums and resins, honey, fodder and are rich in biodiversity. Increasing climatic variability and lack of knowledge among farmers and pastoralists to cope with unreliable weather patterns have exacerbated the problem. Based on climate change scenarios, the ASALs of Kenya will experience significant changes in precipitation and temperatures, with some places becoming wetter and others drier (Herrero, 2010). These changes will have dramatic impacts on the phenology, distribution and composition of vegetation species that form pastures for livestock and other domestic uses. These will have a considerable impact on local community since vegetation resources play essential role in the livelihoods of over 10 million people living in the ASALs (MENR, 2016).

Although ASALs in Kenya are in general hot and dry, there are within these areas localized habitats associated with hills that are endowed with more than the average rainfall largely due to high elevations that attract relief rainfall (Gachathi, 1996). Due to their favourable microclimates, these hills create a resource endowed ecosystem around them that attract larger populations of people, livestock and in some cases wildlife. These areas are exposed to environmental dangers including ecosystem degradation as a result of removal of forest resources (e.g. timber, poles, and herbs) and overgrazing. In addition, encroachment and frequent fires and obvious increased competition for resources become inevitable. All these factors lead to ecological imbalances and deterioration of the health of these important but fragile ecosystems. Conservation of natural forest in the hilltops is vital since they are species-rich ecosystems which are known to hold diverse and unique biodiversity owing to cooler temperatures and higher precipitation relative to the surrounding dry savannahs (IUCN, 1996). Kiang'ombe in Mbeere North is one such hilltop forest in the ASALs of Kenya. The forest provides fuel wood, charcoal, timber and non-wood forest products, besides the environmental services and biodiversity conservation (Ngugi *et al.*, 2011). However, this hilltop forest is undergoing degradation due to anthropogenic causes and requires urgent conservation measures and rehabilitation efforts.

For a comprehensive roadmap to counter land and vegetation degradation, it's important to evaluate indicators both at the local and national level. Due to complexity of land degradation, it cannot be assessed simply by any single measure. Therefore, various indicators of land degradation have to be used according to FAO, (2003) and Kosmas *et al.*, (2014) as a tool to understand; how vulnerable an area is to land degradation, how rapidly the land degradation is progressing and how effective are the actions taken to mitigate land degradation. In order to assess the level of land vulnerability to degradation due to various processes and causes, it is necessary to accurately define its present state and, if possible, its past states. This will play a major role in planning for future land related developments. For example, satellite images in different epochs can be analyzed to delineate degradation gradients (Omuto *et al.*, 2014; Kigomo *et al.*, 2015). Local knowledge and scientific methods have been used to derive various land and vegetation indicators in various eco regions (Kosmas *et al.*, 2014)

This study was undertaken to provide a valuable tool for assessing land degradation risk and analyzing the effectiveness of the various woodland rehabilitation practices through empowering local communities to identify indicators of woodland degradation in Kiang'ombe landscape. The specific objectives were;

i. To develop accurate and relevant indicators that can be easily used as baseline by land managers to monitor and appropriately respond to land and vegetation degradation in agro-pastoral production systems.
ii. To integrate local and scientific knowledge base to develop land and vegetation degradation indicators aimed to support conservation and rehabilitation efforts of degraded woodlands.

MATERIALS AND METHODS

Study Area

The study was conducted in Kiang'ombe landscape which is located in Mbeere North Sub-county, Embu county at Latitude 0°33´37.61"S and 0°33´36.59"S; Longitude 37°40´48.08"E and 37°44´0.21"E (Figure 1). The climate within Mbeere north sub-county consist of low unreliable rainfall, falling in two distinct seasons, one shorter and less reliable (March to May) and the other longer and more reliable (October to January). Mean annual temperatures ranges from 20 °C to 32 °C (GOK 2009). The bulk of Mbeere North Sub-county is semi-arid (Figure 1). The projected population within the sub-county in 2015 based on the census carried out in 2009 was 96,837 (GOK, 2013)

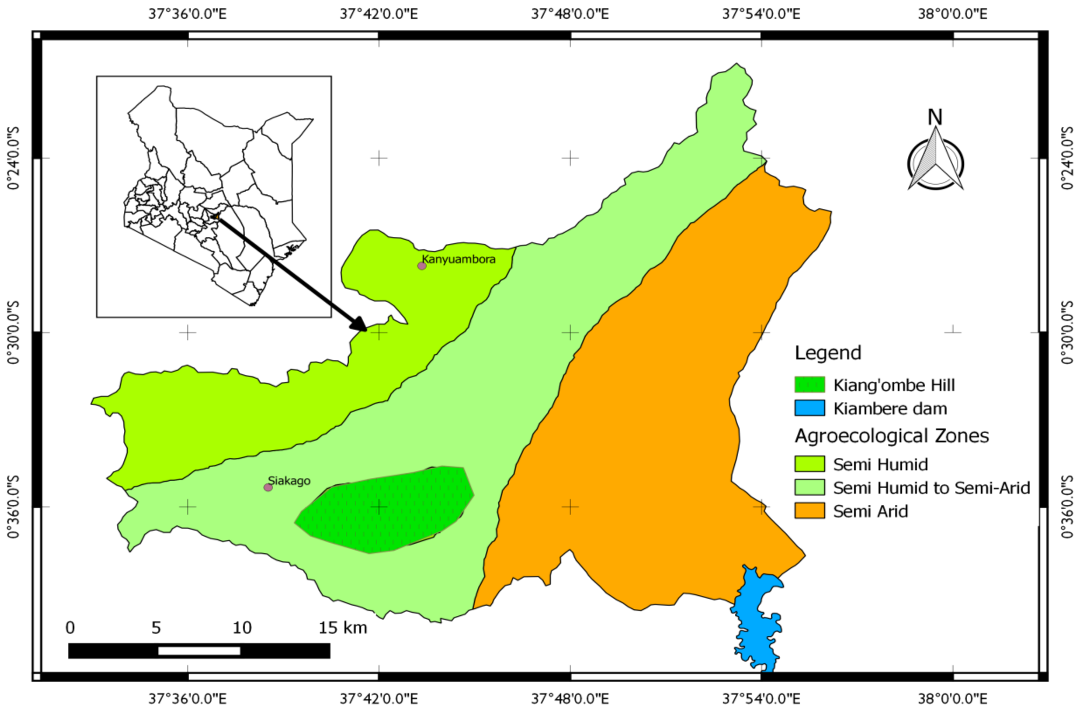

Figure 1: Location of Kiang'ombe landscape in Mbeere North, Embu County

Kiang'ombe landscape extends over an area of 3600 ha including a hill top forest which occupies 2000 ha of a predominantly indigenous forest. A larger proportion of the hill is under secondary forest. Exotic plantations namely; *Eucalyptus camaldulensis*, *Pinus patula* and *Cupressus lusitanica* located at the foot and top of the hill, cover less than 5% of the forest. The hill rises from about 1000 m to1800 m above sea level. On the lower slopes, it's mainly covered with bush land and wooded grassland which stretches from about 1300 m to 1500 m. Closed canopy forest stretches from about 1500 m to 1800 m. The forest is a trust land under the management of County Government of Embu, with technical backstopping from Kenya Forest Services (GOK, 2009). Kiang'ombe hill forest forms a major water catchment area from which five streams arise, some of which are tributaries of Tana River that provides water to some of the important hydropower plants. The streams also provide water to the local communities for domestic purpose (Ngugi et al. 2011). The land use around the hill forest is mainly mixed farming through crop production including fruit tree production and livestock husbandry (GOK, 2009).

Methodology

i. Assessment of Land and Vegetation Degradation Indicators by M~~m~~eans of Local T~~t~~echniques

Participatory data collection was undertaken in the three locations within Kiang'ombe landscape namely; Siakago, Riandu and Gangara. Two environmental groups from each location were purposively selected for this study. Ten respondents from each group were randomly selected for intensive key informant interviews and focus group discussions between October and November, 2014 in the three locations. This was aimed to identify the main land and vegetation degradation problems and the affected ecosystems. These degradation problems are viewed to have interlinking environmental and socio-economic factors that have a great impact towards the attainment of sustainable development. Respondents were asked to identify signs they would expect to see in land and vegetation that had lost its long-term productivity (due to over-use rather than drought). Respondents were then asked to identify which signs might provide an early warning that detrimental change was likely. Respondents were also asked to identify the characteristics of useful indicators, which could be used as selection criteria and as tools for assessing land and vegetation degradation and for policy making. Many criteria were elicited, but ‘accuracy’ and ‘ease of use’ summarize most of them well (Reed and Dougill, 2002). Interviews continued until theoretical saturation was reached, when few new indicators were emerging. Indicators were then combined from interviews and focus group discussions for the study area and were evaluated against community-derived criteria in focus groups using Multi-Criteria Evaluation techniques (Miranda, 2001).

ii. Analysis of Vegetation-Based Indicators by scientific techniques

Vegetation cover changes were evaluated using scientific techniques to compliment information acquired from the local community. This was carried out through vegetation data collection. Vegetation indicators were assessed using 36 sample plots of 20 m x 20 m laid randomly along degradation gradients. These plots were used to collect data on trees (woody plant species with DBH above 5 cm and height above 2 m) including tree height, diameter at breast height (DBH) and crown dimensions. Within these plots, stumps were also enumerated. This was followed by calculation of ecological variables and indices according to Magurran, 1988; Kigomo *et al.*, 2015. The measured variables included; tree abundance, frequency, density and tree diversity.

Data Analysis

The ecological variables were calculated as follows;

Relative abundance = (Number of individuals of the species recorded / Total number of trees in all the plots) × 100

Relative Frequency = (Number of sample plots in which the tree species occurred/ Total number of plots) × 100

Density = Total number of stems tallied for a given tree species/ Total area of the measured plots (stems per hectare)

Basal Area (BA): The cross sectional area of each tree stem measured at 1.3 m above the ground. This value is normally obtained using the following equations:

$BA = \pi * (dbh/2)^2$

$\pi = 3.14$

dbh = Diameter at beast height

Within the plot, BA (Basal Area) is calculated by sum of the basal area of each tree species from all plots divided by the total area of all of the measured plots ($m^2\ ha^{-1}$)

Shannon diversity Index (*H’*): This was obtained using the following equation;

$H' = -\sum pi \ln pi$ where, *i* is the proportion of the species relative to the total number of species (*p*i) multiplied by the natural logarithm of this proportion (ln *p*i) and the final product multiplied by -1. The index assumes that each representative sample species has an equal chance of being included in each sampling point (Magurran 1988).

Data collected through local and scientific techniques were subjected to descriptive analysis using Microsoft Excel and Genstat version 13. statistical software. A one-way analysis of variance (ANOVA) with degradation gradient as predictor and tree variables as dependent variables was performed to test differences of measured variables in Kiang’ombe landscape.

RESULTS

Land and Vegetation Degradation Processes and Indicators

Figure 2 shows major land and vegetation degradation processes prioritized by local people. It was evident that overgrazing (70%) and soil erosion (67%) were highly rated by the local community while charcoal production followed closely with 55% and sand harvesting was the least degrading factor at 20%.

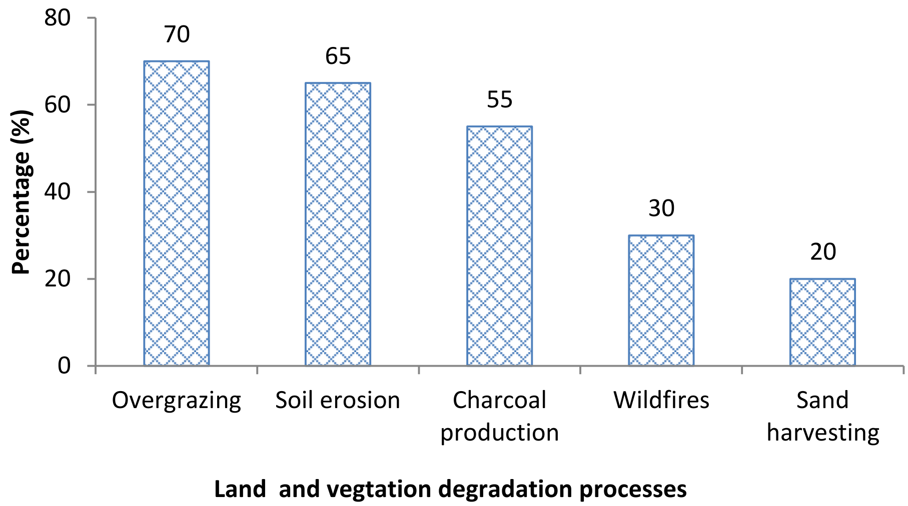

Figure 2: Percentage of land and vegetation degradation processes in Kiang'ombe landscape

Figure 3, 4 and 5 summarizes the indicators that were short-listed by local communities in the three locations around Kiang'ombe landscape. Each indicator was deemed both accurate and easy to be used by local people.

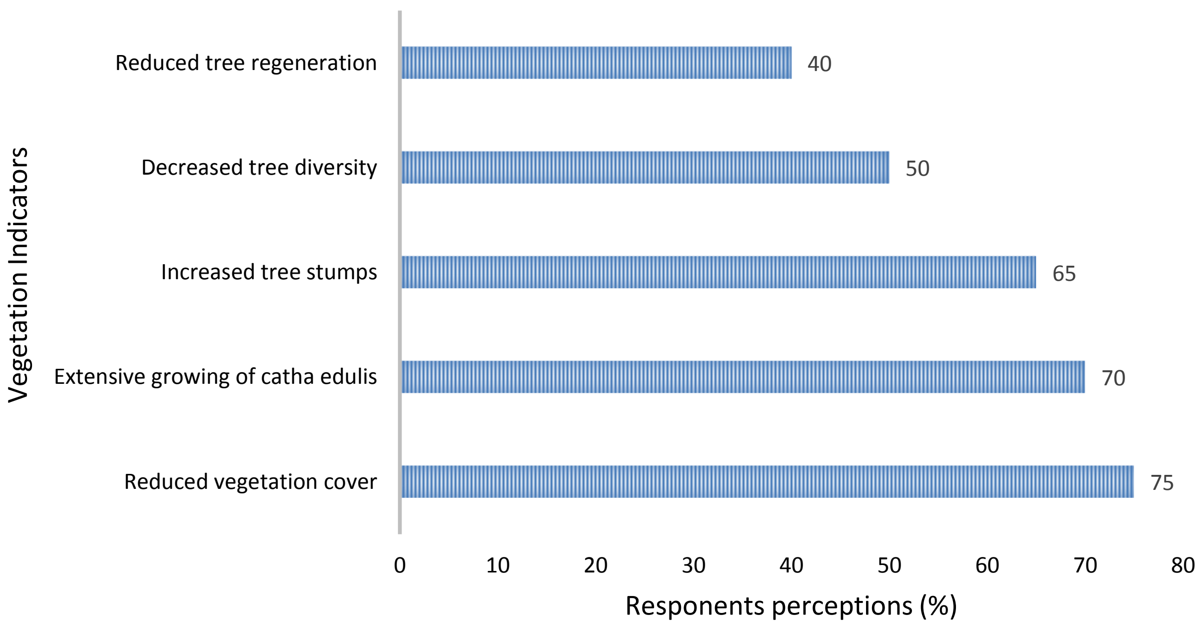

Figure 3: Prioritized vegetation degradation indicators around Kiang’ombe Landscape

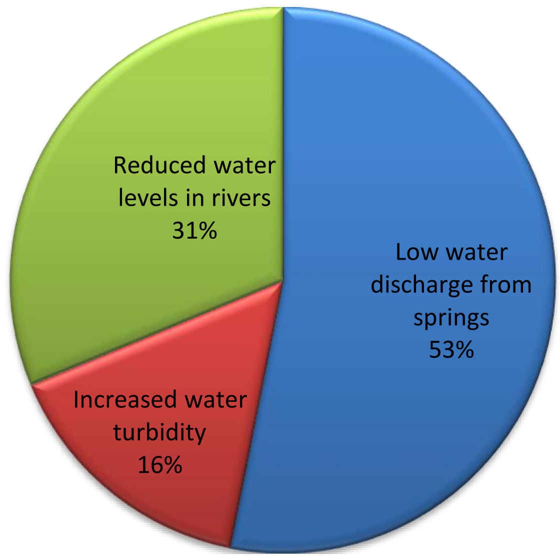

Figure 4: Local perceptions of highly prioritized land and vegetation degradation indicators related to water in King'ombe Landscape

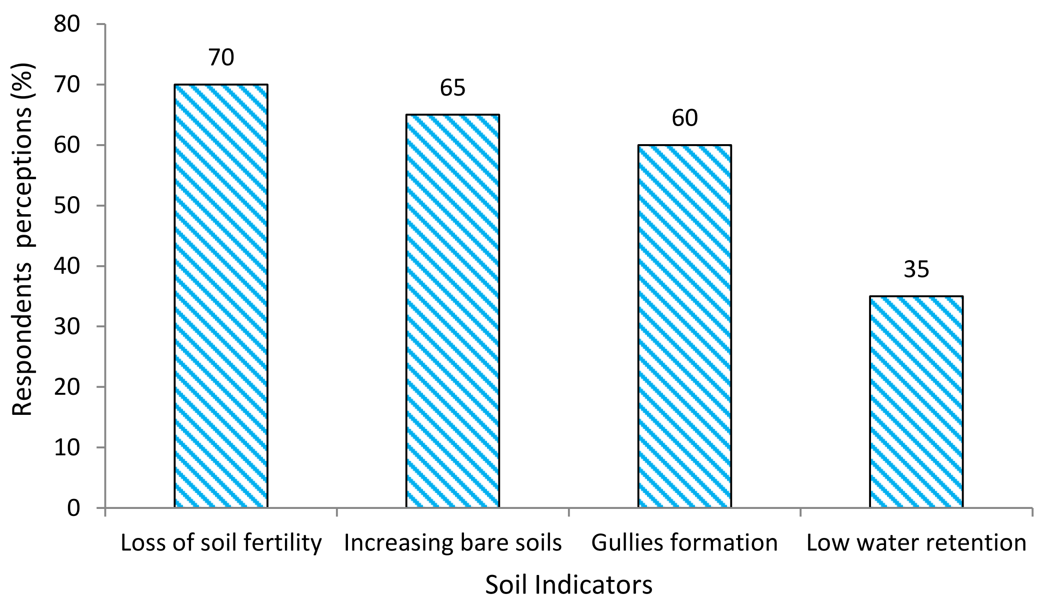

Figure 5: Local perceptions of land and vegetation degradation indicators related to soils in Kiang'ombe landscape

Most of the respondents indicated reduced vegetation cover (75%) and extensive growing of *Catha edulis* (70%) as the major vegetation related indicators for degradation in Kiang'ombe landscape (Figure 3). However, 40% indicated low tree regeneration as a key vegetation indicator. Figure 4 shows that the respondents only prioritized three land and vegetation Indicators related to water. Loss of soil fertility (70%) and increasing bare soils (65%) were the major soil related indicators for land and vegetation degradation.

Major Vegetation Characteristics along Degradation Gradient of Kiang'ombe Landscape

The study indicated that the tree density and diversity were significantly different ($p<0.5$) along degradation gradient (Table 1).

Table 1: Description of tree characteristics along degradation gradient of Kiang'ombe landscape

Degradation category	Sample plots	Density (stems ha^{-1})	Basal Area (m^2 ha^{-1})	Shannon diversity index (*H'*)
Low	13	622	9.8	2.5
High	11	155	1.7	2.0
Moderate	12	316	7.1	2.1
Mean		364	6.2	2.2
P-value		<0.5	NS	<0.5

Table 2 shows abundance and relative frequency of the dominant tree species. The study shows highly valued trees such as *Combretum molle* and *Faurea saligna* were not represented in highly degraded areas suggesting they have been heavily logged as evidenced from high number of stumps recorded of 30 % and 25 % respectively (Figure 6). On the other hand, *Combretum molle* had high relative frequency and occurrence both in low and moderate degradation category. *Protea gaguedi* was the dominant tree species in high degraded areas. In the plots where the relative frequency and occurrence of *Protea gaguedi* was high, there were wildfire scars, an indicator of fire tolerant species or one which has a potential of resilience after wild fire events.

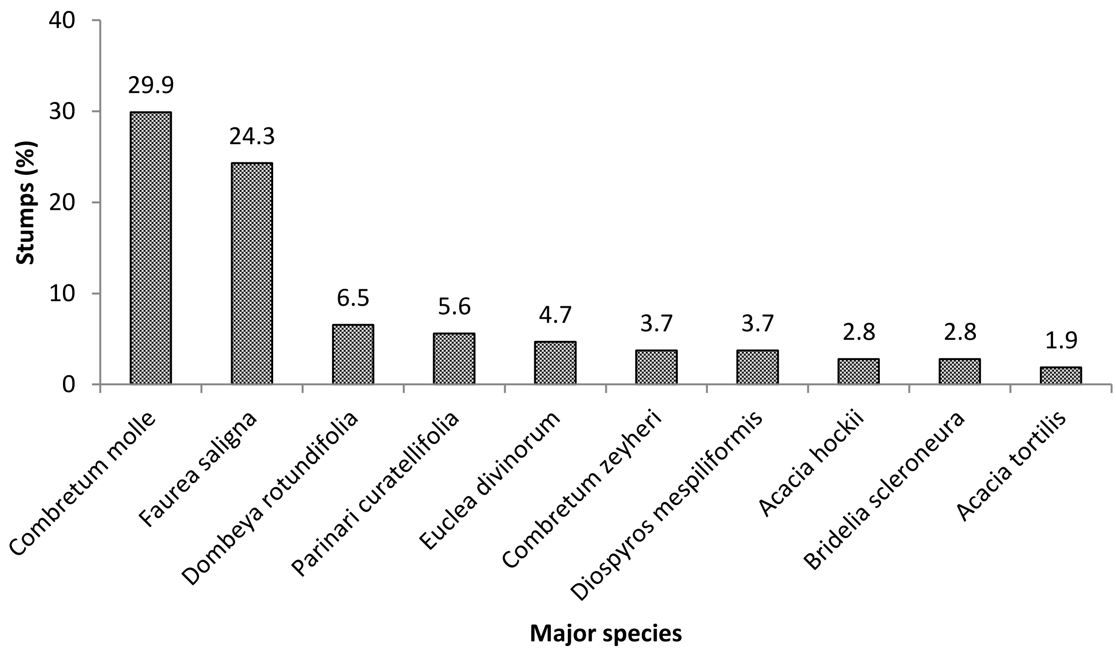

Figure 6: Percentage of tree stumps observed in sample plots

Table 2: Relative frequency and occurrence of 10 most abundant trees species with DBH above 5cm along degradation gradient of Kiang'ombe landscape

Degradation category/Tree species	Family	Relative Frequency (%)	Relative Occurrence (%)
Low degradation			
Combretum molle	Combretaceae	5.97	16.73
Faurea saligna	Proteaceae	4.48	12.45
Uvariodendron anisatum	Annonaceae	1.49	6.51
Parinari curatellifolia	Chrysobalanataceae	3.73	5.58
Bersama abyssinica	Melianthaceae	1.49	5.39
Xymalos monospora	Monimiaceae	0.75	4.46
Rhus natalensis	Anacardiaceae	3.73	3.53
Deinbollia kilimandscharica	Sapindaceae	0.75	3.16
Euclea divinorum	Ebenaceae	2.24	2.42
Protea gaguedi	Proteaceae	0.75	2.04
High degradation			
Protea gaguedi	Proteaceae	2.17	30.59
Rhus natalensis	Anacardiaceae	4.35	7.06
Croton macrostachyus	Euphorbiaceae	2.17	6.47
Acacia hockii	Mimosaceae	2.17	5.88
Combretum molle	Combretaceae	6.52	4.71
Faurea saligna	Proteaceae	2.17	3.53
Oncoba spinosa	Flacourtiaceae	2.17	3.53
Diosypos mespiliformis	Ebenaceae	2.17	2.94
Euclea divinorum	Ebenaceae	2.17	2.94
Mangifera indica	Anacardiaceae	4.35	2.94
Moderate degradation			
Combretum molle	Combretaceae	4.35	10.47
Deinbollia kilimandscharica	Sapindaceae	2.9	9.3
Vepris simplicifolia	Rutaceae	2.9	9.3
Protea gaguedi	Proteaceae	1.45	8.91
Xymalos monospora	Monimiaceae	1.45	6.2
Combretum zeyheri	Combretaceae	2.9	4.65
Dichrostachys cinerea	Mimosaceae	2.9	3.49
Dombeya rotundifolia	Sterculiaceae	2.9	3.49
Rhus natalensis	Anacardiaceae	4.35	2.71
Chrysophyllum viridiflorum	Sapotaceae	1.45	2.33

DISCUSSION

The study shows many of the degradation processes highlighted by the local community in Kiang'ombe landscape focused on changes in vegetation. This can be explained by the key role the vegetation plays in rural livelihood strategies. Studies of Ngugi *et al.*, (2011) indicated that Kiang'ombe hill forest contributes about 55.42% to the household income, and this confirmed the high dependency of vegetation resources. The studies of Sonneveld *et al.*, (2010) in the dry parts of Ethiopia indicated strong relationship between overgrazing patterns and land degradation. In Kenya, over 70% of the Kenya's livestock and 90% of the wild game are found in the ASALs (GOK 2015). Due to fragile ecosystems in this area, the high numbers of livestock have resulted to negative impacts of the natural resource base. While developing a framework for assessing land degradation in the drylands of Somali, Omuto *et al.*, 2014, identified soil erosion by water and overgrazing as the major drivers of land degradation which were mainly contributed to poor governance and land tenure systems. The current study has also indicated overgrazing and soil erosion as major drivers of land and vegetation degradation (Figure 2). In the drylands of Kenya, lack of alternative livelihoods have led to extensive charcoal burning in the ASALs to meet high demand of biomass energy which is approximately 68 % of national domestic energy needs (Mutimba and Barasa, 2005). Although participatory land and vegetation indicator development are locally-based, they can also be used in similar ecological zones in analysis of land degradation.

Vegetation indicators namely reduced vegetation cover, decreased tree diversity and stumps can be mainly attributed to overgrazing and charcoal burning which are key drivers of vegetation degradation in Kiang'ombe landscape (Figure 2). Most of the farmers in the surrounding area are subsistence farmers with few alternative livelihoods hence charcoal burning and livestock keeping are some of the sources of income (GOK 2009). This has led to high exploitation of vegetation resources as reported by Maluki, (2007). Poor crop yield due to low soil fertility have been reported in Mbeere north (Maina, 2013). Furthermore, studies of Kinuthia et al., (2009) indicated drying of some springs within the landscape which have resulted to water scarcity within the surrounding villages. This compares well with the perceptions of the local community in Figure 4.

During focused group discussion, the local community attributed the enhanced land and vegetation degradation to increased commercial growing of *Catha edulis* (muguka). A study by Maina, (2013) indicated that most farmers have abandoned growing of their preferred cash crops such as cotton (*Gossypium spp*), tree growing and [illegible] trees production e.g. mangos (*Mangifera indi*[illegible] preference to 'muguka' because the latter takes about 2 years to mature and have high return on investment. The expansive cultivation of 'muguka' could have contributed to some farmers uprooting major on-farm trees which used to provide firewood and timber leading to low vegetation cover (Figure 3). Furthermore, studies of Ngugi *et al.* (2006). showed that firewood is the major source of domestic cooking energy among the Kiang'ombe forest adjacent communities. The studies of Mutimba and Barasa, (2005) indicated 87% of charcoal is sourced from private and communal land mainly from the ASALs of Kenya. A decline in the availability of fuel wood and timber particularly from indigenous species was considered as indicative of land degradation by local people. The decline of plant cover was highlighted by Kosmas *et al.*, (2014) as land degradation indicator. This demonstrates how vegetation changes often have the greatest impact at species level and how ecological changes including land degradation are socially, culturally and economically interpreted, depending on the role of the affected resource in the overall remit of daily living (Dove, 2004).

The synergy between local and scientific vegetation degradation indicators is well illustrated in this study since local communities reported a reduction in tree density and diversity to be indicative of land and vegetation degradation. This was statistically supported by field measurements since low mean tree density was recorded as 364 stems ha^{-1} with mean species diversity of 2.2 (Table 2). Furthermore, low degraded areas had higher tree resource distribution compared to moderate and highly degraded areas (Table 2). Kiang'ombe vegetation landscape is rather degraded based on the low basal area and tree density in all the degradation categories (Table 2) compared to other similar forests in Kenya e.g. the arc forests of Taita Hills (Omoro *et al.*, 2010) which had relatively higher basal areas. This can be attributed to increasing anthropogenic activities such as poaching of big trees for charcoal burning and firewood. In most of the forest, lower basal area is mainly characterized by high number of young trees and sometimes few or lacking individuals in the larger size class (DBH>30cm) as observed in this study (Table 2).

Mitigation of key land and vegetation degradation drivers using scientific evidence such as low tree basal areas, density and diversity in addition to local community perceptions on degradation indicators is important in enhancing rehabilitation and conservation of Kiang'ombe landscape. As shown in Table 3, tree species which were common in all degradation gradients and also highly prioritized in highly degraded areas such as *Croton macrostachyus*, *Acacia hockii*, *Combretum molle* and *Faurea saligna* can be prioritized for rehabilitation interventions of degraded areas of King'ombe landscape.

CONCLUSION

We have explored how local people consider some changes to be 'degradation' and have revealed how communities holistically assess the ecological, economic and social systems in which they operate in accordance with their management objective study indicated a significant overlap between scientific and local knowledge in most instances and this iterative process can lead to both accurate and relevant periodical monitoring of woodland degradation. It would therefore be recommended that conservation strategies and rehabilitation interventions be developed that will involve the local people in the management of the Kiang'ombe landscape and similar ecosystems in the ASALs of Kenya for sustainable provision of ecosystem services and livelihoods.

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