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Vegetation composition and dynamics along degradation gradient of Kiang'ombe hill forest in the drylands of Kenya

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Kiang'ombe hilltop forest is overexploited for fuel wood, charcoal, timber and non-wood forest products, thus threatening its biodiversity conservation role. The extent of forest degradation is not yet quantified and this impedes rehabilitation interventions. This study was conducted to evaluate the status of Kiang'ombe forest resources to initiate rehabilitation interventions and to support sustainable forest management. Remote sensing and geographic information systems (GIS) were used to determine trends of spatial and temporal vegetation changes over 25 years. Image analysis revealed high, moderate and low categories of forest degradation over the assessment period. Thirty two nested sample plots were used for vegetation inventory in the three degradation gradient clusters. Additional data was obtained from local informants through focused discussions and field observations. A total of 155 plant species belonging to 58 families were identified. Shannon Weiner diversity index of seedling and sapling were higher in low and moderate than in high degraded areas. Based on species importance values, the candidate trees for rehabilitation of degraded areas were *Croton macrostachyus*, *Acacia hockii*, *Combretum molle* and *Faurea saligna* whereas *Enteropogon macrostachys*, *Cymbopogon* sp., *Eragrostis superba* and *Hyparrhenia rufa* were the most suitable grass species for reseeding expansive glades. The recommended rehabilitation techniques are enrichment tree planting in water catchments areas, enhancing natural regeneration through protection and grazing management, gully healing at the hill slopes and establishment of woodlots plantations and boundary planting in the surrounding farmlands.

Key words: Hilltop forest, geographic information systems (GIS), vegetation inventory, rehabilitation techniques.

INTRODUCTION

In Arid and Semi-Arid Lands (ASALs), hilltop forests play a significant biodiversity conservation role as their microclimate is ameliorated by altitude, hence their vegetation differs from that of their surroundings (IUCN,

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1996, Aerts et al., 2011). Since the hilltop forests are also the most suitable areas in ASALs for human activities such as farming, grazing and harvesting non-timber forest products, their conservation role is either compromised or at crossroad (Kirubi et al., 2000). In the past, hilltop forests were conserved through informal traditional management practices. However, Indigenous Knowledge Systems (IKS) are gradually disintegrating either because of their conflict with legislative policies or the collapse of indigenous institutions (Stave et al., 2001). Formal management is often inadequate as evident from poor forest condition of state managed forests ecosystems whereas forest adjacent local communities cannot adhere to prescribed government regulations because of their overexploitation of forest resources for their basic needs (Kirubi et al., 2000; Stave et al., 2001; Aerts et al., 2011). Mismanagement of hilltop forest has led to their spatial decline, fragmentation and biodiversity loss (Aerts et al., 2011). Participatory forest management can limit encroachment into forests in areas where local human populations are heavily dependent on agriculture and extraction of non-timber forest products from indigenous forests (Blomley et al., 2008; Porter-Bolland et al., 2012). Therefore, participatory forest management and rehabilitation of degraded areas through proven technologies can mitigate further degradation of hilltop forests but this would require baseline data on forest's ecological condition and resources to guide appropriate interventions.

Kiang'ombe hilltop top forest in the Eastern part of Kenya is one of the most overexploited hilltop forests which were identified for rehabilitation through a Global Environment Facility (GEF) funded Sustainable Land Management Project (SLM) in Kenya. Land cover change studies undertaken between 1987 and 2000 classified the vegetation of the hill as dense woodland (Maluki, 2007). In addition, an ethno-botanical study was undertaken to ascertain the forest condition and forest use by local communities (Ngugi et al., 2011). From the study, it was evident that despite the forest contributing about 55% to the household income, it has undergone a serious degradation, yet community members continue to derive their fuel wood, charcoal, timber and non-wood forest products from the forest. Degradation trend analysis was therefore identified as an important gap, whose findings could provide a sustainable plan for participatory rehabilitation interventions. This study was aimed to establish baseline species composition, density and diversity along degradation gradient to support rehabilitation and sustainable forest conservation of Kiang'ombe landscapes.

MATERIALS AND METHODS

Study area

Kiang'ombe Hill forest is located in Mbeere North District, Embu County (Figure 1) and its surrounded by semi-humid to semi-arid Agro-Ecological Zone (AEZ) of Kenya (GOK, 2009). It occupies about 2000 ha of a predominantly indigenous forest, with less than 5% exotic plantations mainly found at the foot and top of the hill (Ngugi et al., 2011). There are also pockets of exotic plantations which include *Eucalyptus camaldulensis*, *Pinus patula* and *Cupressus lusitanica*. The hill rises from about 1000 m to 1800 m above sea level. A larger proportion of the hill is under secondary forest with little ruminant primary forest. On the lower slopes, it's mainly covered with bush land and wooded grassland which stretches from about 1300 to 1500 m, closed canopy forest stretches from about 1500 to 1800 m. The forest is a trust land under the management of county government of Embu, with technical backstopping from Kenya Forest Services (KFS). The climate is characterized by low unreliable rainfall, falling in two distinct seasons, one shorter and less reliable (March to May) and longer and more reliable (October to January). Mean annual temperatures ranges from 20 to 32°C and low humidity (GOK, 2009; Kamau, 2004). Kiang'ombe hill forest forms a major water catchment area from which five streams rise, some of which are tributaries of Tana River that holds the country's most important hydropower plants that produce 50% of Kenya's total electricity output. Some seasonal streams that provide water to the local community for domestic purpose also originate from the forest.

Delineation of degradation gradients

Remote sensing and Geographic Information Systems (GIS) were used to determine trends of temporal vegetation changes around Kiang'ombe hill landscape. Satellite images from Landsat 7 Enhance Thematic Mapper plus (ETM+) and Landsat 5 Thematic Mapper (TM) were used in this study (Table 1). The Landsat data were acquired from the U.S. Geological Survey's (USGS) Global Visualization Viewer (GLOVIS). Although images of exact date are desirable to avoid seasonal effects in change detection analysis over several years (Im and Jensen, 2005), quality images were unavailable to meet this criterion. However, selected images were adequate since they covered the same season with minimal significant phenological shift. The selected images were of high quality with less than 10% cloud cover. Furthermore, they were all pre-processed with the Standard Terrain Correction by USGS. This process gives systematic, radiometric and geometric corrected images by using ground control points and Digital Elevation Models (DEM). The data has a medium spatial resolution of 30 m which makes it suitable for studying changes in forest cover (Zhang et al., 2005).

From the raw geo-referenced Landsat images captured over the dry seasons, Normalized Difference Vegetation Index (NDVI) maps were generated using EARDAS Imagine 2011. The NDVI is the ratio of reflected spectrum over the incoming total radiation. It measures the density of the green vegetation and is often used to monitor photosynthetic activity at regional and global scale in order to detect vegetation fluctuations (Seaquist et al., 2002).
NDVI is defined as:

$$NDVI = (NIR - RED) / (NIR + RED)$$

Where NIR (band 4) and RED (band 3) stand for the spectral reflectance measurements acquired in the near-infra red and red regions respectively with NDVI values ranging from -1.0 to +1.0.

Land cover change analysis was implemented through compositing the NDVI maps, where for every change period, NDVI maps were chosen for the RGB guns, with the NDVI of the most current anniversary presented by Green gun while both Red and Blue guns representing the NDVI maps of the oldest anniversary. This technique was applied to aid in the detection and visualization of areas where potential change of NDVI values may have occurred.

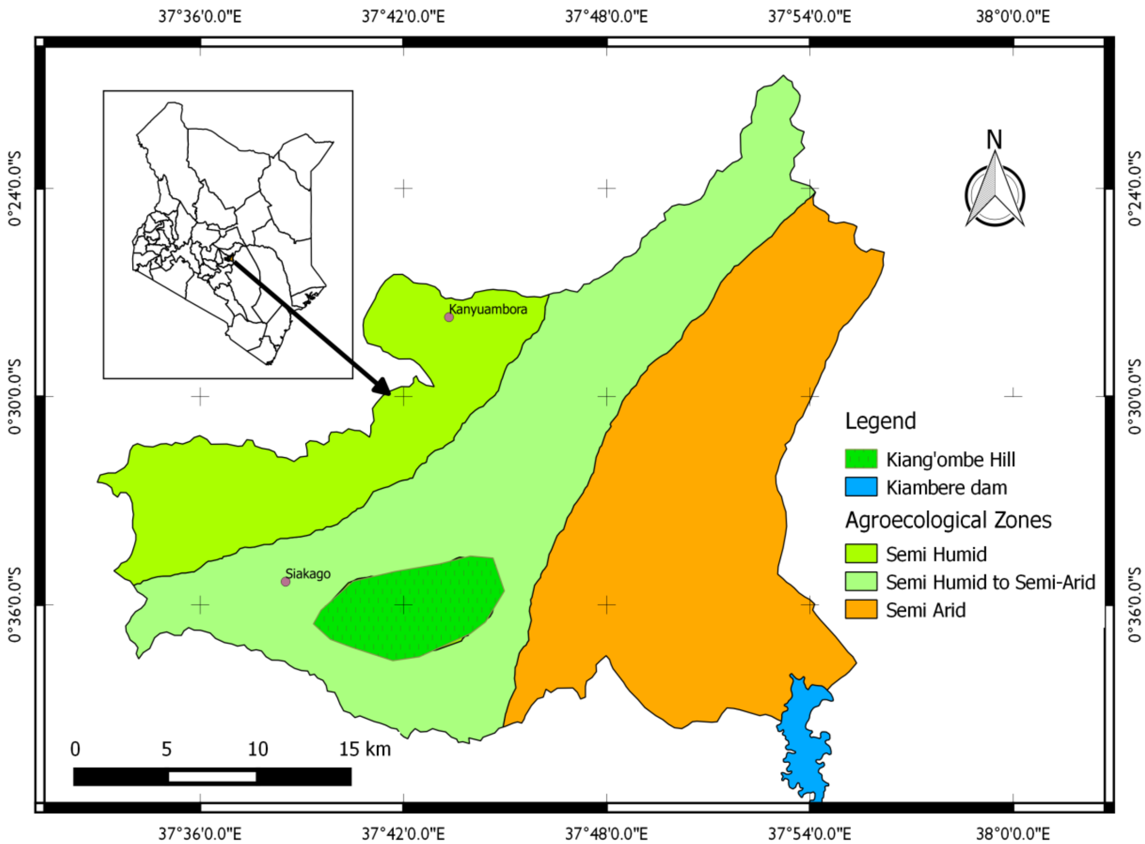

Figure 1. Location of Kiang'ombe hill forest in Mbeere north, Embu County.

Table 1. Details of images used in assessment of land degradation.

Image registration date	Image ID
5th January, 1986	LT51680601986
21st February, 2000	LE71680602000
10th January, 2011	LT51680602011

Areas of positive change were represented by green colour while areas of negative change were represented by cyan colour. White or black colour represented no-change areas. Differencing technique was then applied, where values of NDVI map of a target anniversary was used to subtract values of NDVI map of a past anniversary. The resulting differencing map was then clipped to the extent of the project study area and classified into range of classes (Table 2). The outputs for this analysis revealed changes that were classified as positive or negative and unchanged land use or land cover condition. The practical interpretations of the positive change is an increase of leaves or crown greenness (phenological change), increase in ground vegetation cover and forest improvement through regeneration signifying low forest degradation, while the contrary applies for the negative change detection designating high forest degradation. Neutral status is associated with moderate conditions in the examples already given or unchanged condition in land use or land cover and in physical features such as ground soils and water bodies.

Ground truthing and assessment of baseline vegetation resources

Ground truthing was subsequently carried out to ascertain varied conditions of change guided by hand-held Global Positioning System (GPS). A stratified random design was used where by sample plots were randomly generated using QGIS version 2.4 in each of the three degradation (Liu et al., 2003). The UTM coordinates were then uploaded into a GPS receiver to guide ground navigation sample plots. These same sample plots were used for vegetation assessment. Additional data was obtained from local informants through focused discussions and field observations.

After navigating the sample plots, the primary reference coordinates loaded into a GPS were used as plot centres. One of the team members remained stationery at the plot centre to guide plot establishment by the field crew. This was particularly crucial to enhance accuracy due to thickets and dense canopies. Using reference north and bearing of 45°, 135°, 225° and 315° to locate plot corners, each plot was laid using tape measure with the respective dimensions as shown in Figure 2. In sloppy areas, a suunto clinometer was used to determine the degree of the slope then a correction table was used to adjust the plot dimensions (FAO, 2009).

The nested plot design (Mengistu et al., 2005) was used to collect data on trees, shrubs, saplings, seedlings and herbaceous species. The design consisted of the inner sub-plot of 2 × 2 m (0.0004 ha) nested at the centre, used for identification and estimation of percentage ground cover of all herbaceous species (including grass) and seedlings (a woody plant less than 0.5 m tall

Table 2. Assessment of land covers changes based on normalized difference vegetation index.

Decrease in NDVI values	NDVI remain unchanged	Increase in NDVI values
Mild negative change	No change	Mild positive change
Moderate negative change		Moderate positive change
Severe negative change		Extreme positive change

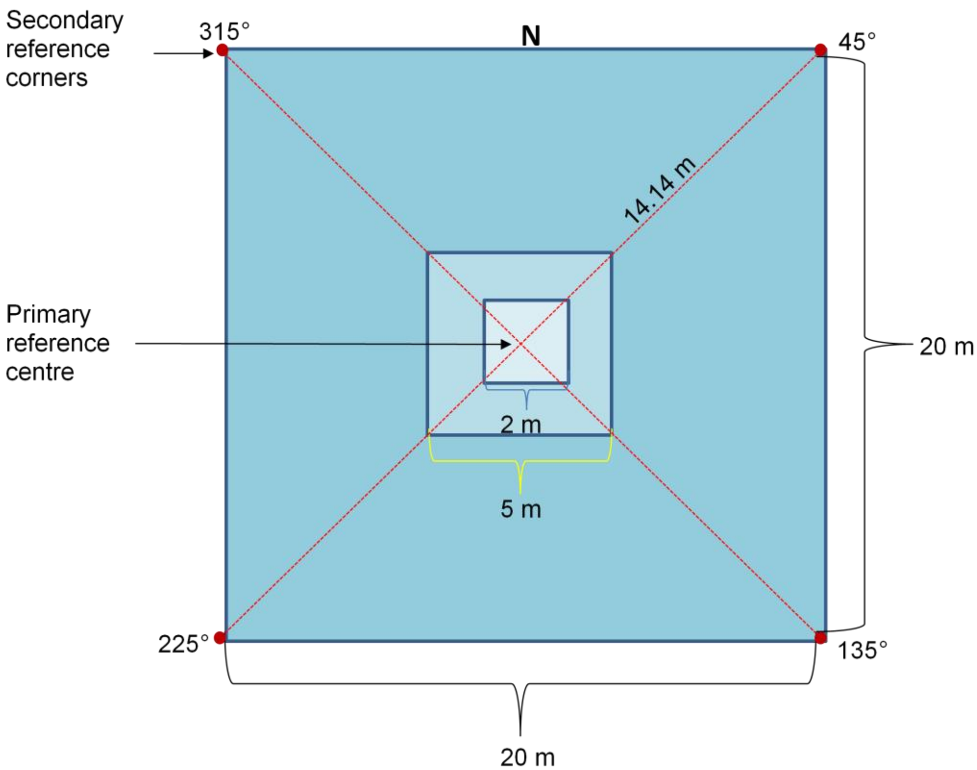

Figure 2. Square plot layout used in ground truthing and assessment of vegetation.

and has a potential of becoming a tree). The sub-plot of 5 × 5 m (0.0025 ha) was used for identification and height measurements of saplings of woody plants (a tree more than 0.5 m height but less than 2.0 m tall). The main plot of 20 × 20 m (0.04 ha) was used for assessment of general plot details such as slope angle/direction, disturbance level, landscape position and measurements of tree height, diameter at breast height (DBH) and crown dimensions. For forked trees, each stem was treated as an individual tree provided the stem branching occurred below 1.3 m above the ground. For multi-stemmed trees, diameters were measured for the average stem and all stems counted. After measurements, four photographs were taken in North-East-South-West orientation which would allow best vantage-points for taking clear shots for further study of vegetation characteristics in the plots assessed. Plant species were identified and classified according to Beentje (1994) and Agnew (2013). The nomenclature of the identified species was cross-checked through international plant names index website (www.ipni.org).

Data analysis

Analysis of NDVI changes for the respective time intervals was based on seven (7) levels of such changes; severe negative change, moderate negative change, mild negative change, no change, mild positive change, moderate positive change, and extreme positive change. Thereafter, converted to high, moderate and low degradation clusters for ease of interpretation and planning rehabilitation interventions

Population structure has been used widely to study regeneration pattern in natural forest ecosystems (Mekuria et al., 1999, 2005; Rocky and Mligo, 2012). Hence, diameter at breast height (DBH) size distribution was used to assess regeneration status of forests along delineated degradation gradient. Species diversity, density, basal area, frequency and other derived ecological variables and indices were calculated using standard formulas (Magurran, 1988). Some of the derived variables were as follows:

1. 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 dominance) is calculated by sum of the

basal area of each tree of a species from all plots divided by the total area of all of the measured plots ($m^2 ha^{-1}$).
2. Relative dominance: Basal area of a given species divided by the sum of the basal areas of all of the species * 100.
3. Frequency: The number of plots in which a given species is found divided by the total number of plots sampled.
4. Relative frequency: Frequency of a given species divided by the sum of the frequencies of all the species * 100.
5. Density: The total number of individuals tallied for a given species divided by the total area of the measured plots (plants per hectare)
6. Relative density: Density of a given species divided by the sum of the densities of all of the species* 100.
7. Importance value index (IVI): Relative frequency + Relative density + Relative basal area for each species
8. Average percentage cover: Total percentage cover of species in the plots divided by total number of plots sampled
9. 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 (*pi*) multiplied by the natural logarithm of this proportion (ln *pi*) 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. This method was selected because it provides an account for both abundance and evenness (Magurran, 1988). It also does not disproportionately favour some species over the others as it counts all species according to their frequencies (Lou, 2006)

Descriptive synthesis and analysis of data was carried out using Microsoft Excel and Genestat version 16 respectively. A one-way analysis of variance (ANOVA) with degradation gradient as predictor and woody vegetation variables as dependent variables was performed to test differences of measured variables in the study area. For variables with significant differences, Fisher's Protected Least Significant Difference (LSD) was used to determine differences between the three degradation categories.

RESULTS AND DISCUSSION

Changes of vegetation cover derived from NDVI

The overall level of woody vegetation change that was experienced from 1986 to 2011 is shown in Figure 3. Four areas suffered heavy degradation and have not yet recovered as observed from the stable areas of the hills situated at the hill-top, these four sites include Riandu, Kariru, Kirie, and Nguthi locations (Figure 3). Indeed, a lot of dynamics occurred in the periphery of the hill-slopes, some spots experiencing moderate to severe decimation of woody vegetation while others showed some recovery. The peripheries of the hill-slopes constitute a big track of private lands while the hill-slopes occupy mostly the communal land. Studies of Maluki (2007) indicated that most of dense woodland in the greater Mbeere district is found in protected areas, and conversion of thick forest to bushland and grassland is an indication of selective cutting of trees as well as overgrazing. This scenario has also been evidenced from this study since highly degraded areas were mainly found at the periphery of the hill, where intensive grazing and overexploitation of woody resources has been relatively high. Our discussion with the local community indicated that lack of clear forest boundary and weak forest patrol by the county government has accelerated invasion to the forest. This is more pronounced during the dry season when large herds of livestock from the neighbouring locations are taken to the hill forest to search for pastures. The slash and burn is still being practiced by the forest adjacent communities and this has been a major cause of wildfires which has been causing a lot of forest disturbances at the periphery of the forest.

Species composition and diversity in Kiang'ombe hill forest

A total of 155 plant species belonging to 58 families were identified in the 32 plots assessed. The plant composition consisted of 46% trees, 28% shrubs, 13% herbs, 7% grass and 6% climbers. Gramineae and Mimosaceae families had the highest number of species with nine and eight species respectively. Four families had 7 species each, while 9 families had two species each (Table 3). The tree species richness of 56 species ha^{-1} is relatively lower than that recorded by Kacholi (2014) in Kilengwe forest in Tanzania where 93 species ha^{-1} were recorded. However, the recorded tree species for this study is within the range of 24 to 122 species ha^{-1} obtained in Budongo forest in Uganda (Mwavu, 2007).

The Shannon diversity index and density of seedlings and trees were higher in low degraded areas compared to moderately and highly degraded areas (Table 4). The saplings density and Shannon diversity index were higher in both low and high degraded areas. The low sapling density in moderately disturbed areas could be attributed to the effect of recruitment on regeneration at various succession stages due to forest disturbances such as grazing of young seedlings. The tree density recorded in low degraded areas is relatively similar to that recorded in similar cloud indigenous forests of Taita hills (Omoro et al., 2010). According to the local community, the low density of trees in highly degraded areas can be attributed to illegal poaching of high valued trees for construction and charcoal production. The Shannon diversity index of seedling, sapling and tree species in high, moderate and low degraded areas were significantly different (p< 0.05). The density of seedlings and saplings were not significantly different but tree species density was significantly different along degradation gradient (p< 0.05).

Tree diameter size class distribution in Kiang'ombe Hill Forest

In all the three degradation categories, the diameter class

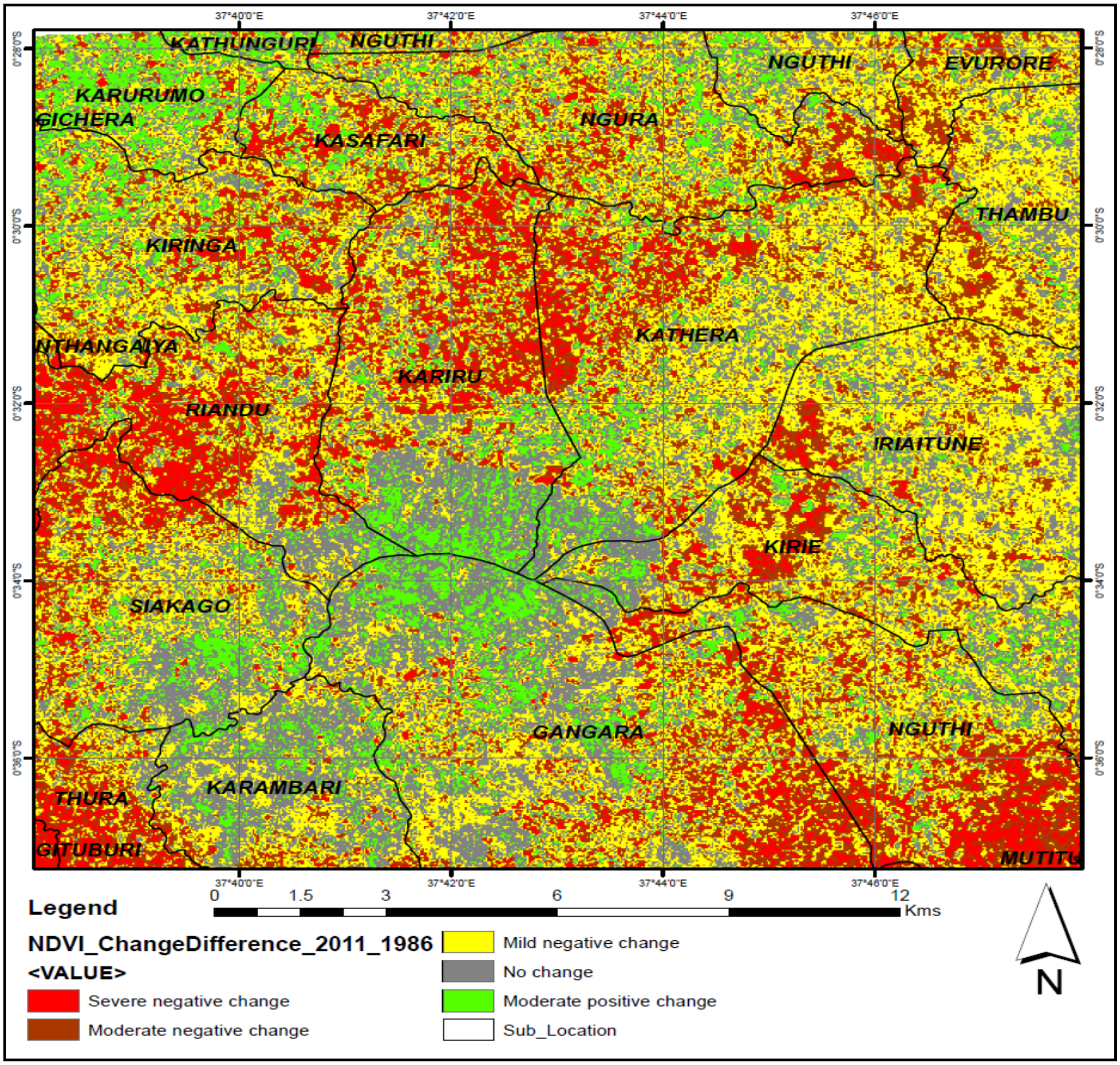

Figure 3. Land degradation map based on vegetation changes in Kiang'ombe Hill and surrounding areas.

distribution exhibited inverted J-shaped pattern with most of the trees in the smaller size classes and fewer in the larger size classes (Figure 4a to c). The small size classes of trees with a DBH of below 12.5 cm was represented with 90%, 85 and 77% for low, high and moderate degradation categories respectively. In the highly degraded areas some size classes were missing. The maximum DBH recorded in low degraded was 159.0 cm for *Eucalyptus camalduensis*, followed by *Newtonia buchananii* (87.1 cm) and then *Albizia gummifera* (78.0 cm). In moderate areas *Croton megalocarpus* dominated the maximum DBH ranging from 35.0 to 50.3 cm. *Lannea triphylla* and *Terminalia brownii* with a DBH of 30.5 and 28.5 cm respectively were the highest DBH recorded in the high degraded areas.

The size class distributions in all the degradation categories suggest that the forest is at a crucial stage of regeneration and recovering from disturbances. The lack of individuals in the larger size classes could be due to over-exploitation of bigger trees by the locals for charcoal, timber and construction purposes or possibly wild fires. The study shows highly valued trees such as Combretum molle*, Faurea saligna and Croton macrostachyus* were not represented in the large size classes since they have been heavily logged and its coppices which were mainly measured with low

Table 3. Families with more than one plant species.

Species per family	Family (Number of species in bracket where applicable)
5 and above	Gramineae (9), Mimosaceae (8), Anacardiaceae (7), Rubiaceae(7), Euphorbiaceae(7), Papilionaceae (7) Caesalpiniaceae (6), Compositae (6), Rutaceae (6),Malvaceae (5), Celastraceae (5)
4	Combretaceae , Sapotaceae , Verbenaceae, Moraceae, Labiatae
3	Apocynaceae,Burseraceae, Proteaceae, Sapindaceae,Sterculiaceae,Ebenaceae
2	Araliaceae, Flacourtiaceae, Myrsinaceae, Vitaceae, Boraginaceae, Commelinaceae, Flacourtiaceae, Rhizophoracea, Tiliaceae

Table 4. Woody plant species diversity and density along degradation gradient.

Degradation category	Seedling		Sapling		Tree	
	H´	Density ha^{-1}	*H´*	Density ha^{-1}	*H´*	Density ha^{-1}
Low	2.6^{a}	9808	2.8^{a}	954	3.4^{a}	1035^{a}
High	2.1^{b}	4688	2.1^{b}	750	2.7^{b}	531^{b}
Moderate	2.2^{b}	5313	2.0^{b}	700	3.3^{a}	806^{ab}
p-value	<0.05	NS	<0.05	NS	<0.05	<0.05

H´: Shannon diversity index. The p-value show significance levels of a one way ANOVA test for differences between degradation category. Values followed by the different letter superscripts are significantly different at $p < 0.05$ level.

diameters.

Tree species important value index (IVI) along degradation gradient

The IVI has been used in various studies to show ecological importance of species in a given ecosystem (Magurran, 1988; Aerts et al., 2011; Kacholi, 2014). In the low degraded areas, although *Combretum molle* and *Fuarea saligna* are widely distributed with relative frequency of 6 and 4% respectively, their IVI were low since their relative dominance is rather low. Most of the assessed individual trees of this species were coppices for the harvested primary and secondary forest. The high IVI of *Uvariodendron anisatum* (12.5), *Protea gaugedi* (62.5) and *Xymalos monospora* (27.4) in low, high and moderate degradation gradient respectively can be attributed to their high relative dominance and density compared to other species (Table 5). In the plots where the relative frequency and density of *P. gaugedi* was high, there were wildfire scars, an indicator of fire tolerant species or has a potential of resilience after wild fire events. The resistance of *P. guagedi* against forest disturbances is demonstrated by reasonably high IVI compared to other species. Other species with high IVI in degraded areas included; *Croton macrostachyus* (14.7), *Acacia hockii* (13.7) and *Faurea saligna* (11.6). There is no species which highly dominate the low degraded areas, which could be attributed to climax stage of the forest with less disturbance and probably diebacks of old trees with low recruitment.

Herbaceous species ground cover and distribution along degradation gradient

Our findings for the herbs and grass showed that Gramineae family dominated the low degraded areas compared to highly and moderately degraded areas. *Hyparrhenia rufa* and *Hypoestes verticillaris* were highly ranked in all degradation categories. This could be attributed to low palatability, high regeneration upon browsing by livestock or high resilience after drought effects. *Tridax procumbens* was widely distributed in highly degraded areas. Although *Pteridium aquilinum* was the most distributed herbaceous species in highly and moderately degraded areas with a mean cover of 8.2 and 20.0% respectively, it was found in relatively few plots of 4 and 8% respectively (Table 6). *Pteridium aquilinum* was mostly found in the transition zone of woodlands and closed forest of Kiang'ombe hill. This zone is prone to wildfires since during vegetation survey, there was evidence of wildfire scars. The invasion of disturbed areas by *Pteridium aquilinum* (Bracken fern) and the subsequent arrested succession is a typical example of inhibition of other species as demonstrated by Rodrigues Da Silva and Matos (2006) in Brazil. Other widely distributed species in highly degraded areas and moderately degraded area were *Hyparrhenia rufa, Enteropogon macrostachys* and *Hypoestes verticillaris* each with relative frequency of 7.7%. Although data

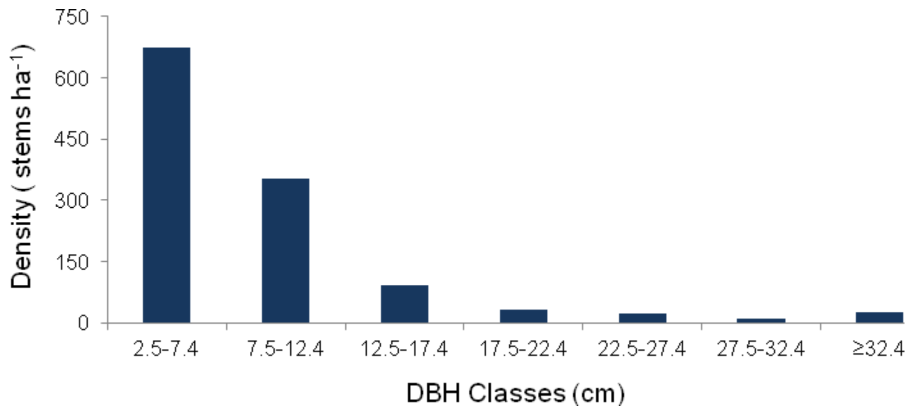

Figure 4a. Size class distribution of tree species recorded in low degraded areas.

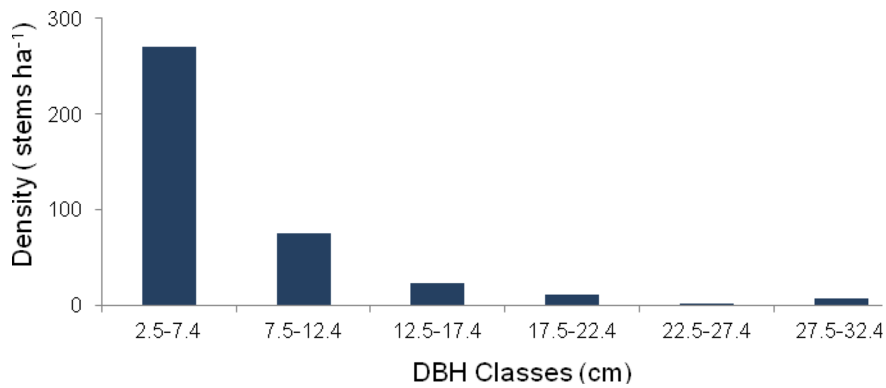

Figure 4b. Size class distribution of tree species in high degraded areas.

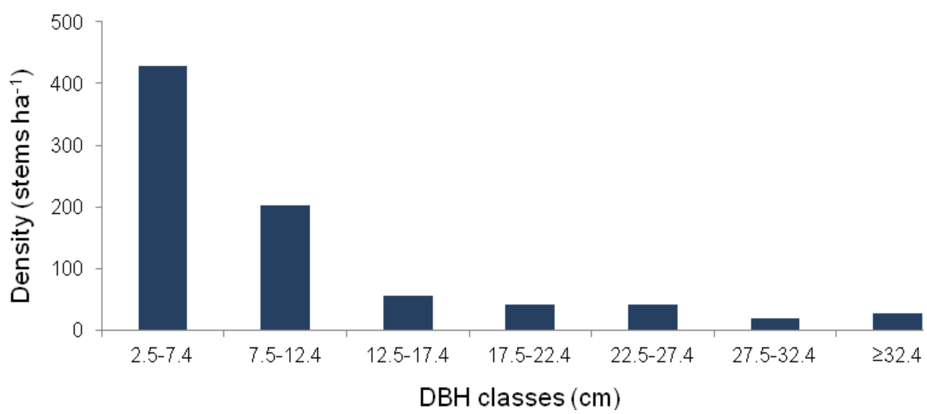

Figure 4c. Size class distribution of tree species in moderately degraded areas.

collection was unertaken during dry season, analysis of variance showed significant difference in relative frequency ($p < 0.05$) but the mean cover showed no significant difference. Reliable estimate of herbal layer can only be realized after data collection during wet and dry season.

CONCLUSION AND RECOMMENDATIONS

This study shows that, Kiang'ombe landscape is rich in biodiversity but is threatened with destruction and encroachment of its vital water catchment areas as evidenced from vegetation dynamics in three degradation

Table 5. Prioritized 10 tree species based on IVI along degradation gradient (RF: Relative Frequency, Rdom: Relative dominance, Rden: Relative density).

Tree species/degradation category	Family	Derived ecological variables			
Low degradation		**RF**	**Rdom**	**Rden**	**IVI**
Uvariodendron anisatum	Annonaceae	1.49	3.52	7.48	12.49
Bersama abyssinica	Melianthaceae	1.49	4.26	5.86	11.61
Xymalos monospora	Monimiaceae	0.75	1.15	9.70	11.60
Combretum molle	Combretaceae	5.97	0.86	4.55	11.38
Newtonia buchananii	Mimosaceae	0.75	9.21	0.40	10.36
Faurea saligna	Proteaceae	4.48	1.25	4.51	10.24
Grevillea robusta	Proteaceae	0.75	7.31	1.21	9.27
Deinbollia kilimandscharica	Sapindaceae	0.75	1.08	6.87	8.70
Albizia gummifera	Mimosaceae	2.99	3.79	0.71	7.49
Parinari curatellifolia	Crysobalantaceae	3.73	0.28	2.42	6.43
High degradation					
Protea gaugedi	Proteaceae	2.17	26.36	36.09	62.59
Croton macrostachyus	Euphorbiaceae	2.17	6.94	7.63	14.72
Acacia hockii	Mimosaceae	2.17	6.65	6.94	13.73
Faurea saligna	Proteaceae	2.17	7.24	4.16	11.55
Terminalia brownii	Combretaceae	2.17	8.37	0.69	9.21
Lannea triphylla	Anacardiaceae	6.52	4.35	1.16	5.93
Rhus natalensis	Anacardiaceae	4.35	1.43	4.16	5.88
Erythrina abyssinica	Papilionaceae	2.17	4.99	0.69	5.82
Adansonia digitata	Bombaceae	2.17	4.54	0.69	5.38
Oncoba spinosa	Flacourtiaceae	2.17	0.93	4.16	5.24
Moderate degradation					
Xymalos monospora	Monimiaceae	1.45	18.53	8.73	27.38
Protea gaugedi	Proteaceae	1.45	4.84	12.55	17.51
Deinbollia kilimandscharica	Sapindaceae	2.90	6.74	6.82	13.81
Croton megalocarpus	Euphorbiaceae	2.90	10.21	0.82	11.28
Nuxia congesta	Loganiaceae	1.45	6.73	2.18	9.04
Vepris simplicifolia	Rutaceae	2.90	1.16	6.55	7.96
Combretum molle	Combretaceae	4.35	2.28	4.91	7.57
Piliostigma thonningii	Caesalpiniaceae	1.45	3.92	2.18	6.23
Syzygium cordatum	Myrtaceae	2.90	3.80	1.09	5.14
Combretum zeyheri	Combretaceae	2.90	1.32	3.27	4.84

An analysis of variance of all the tree species showed that relative frequency and dominance were significantly different while relative density showed no significant difference among degradation categories (p < 0.05).

categories. The high proportion low diameter classes were mainly composed of vigorously regenerating coppices which can be managed through protection from livestock damage and other adaptive management practices. Most of the degraded areas were found in the foots of Kiang'ombe hill where poaching of high valued tree species was recorded. In this regard, strengthening the capacity of the forest adjacent community in woodland resource management and rehabilitation as well as land use planning is recommended to ensure sustainable land management.

The highly ranked tree species in degraded areas namely; *Protea gaugedi, Croton macrostachyus, Acacia hockii* and *Faurea saligna* can be prioritized for any rehabilitation activities such as enrichment planting in addition to widely distributed species along degradation gradient namely; *Combretum molle, Parinari curatellifolia* and *Albizia gummifera.* Although *Lannea triphylla* and *Rhus natalensis* have fairly higher relative frequency this study recommends for their conservation and not enrichment planting due to their low preference by the local community. *Enteropogon macrostachys*, *Cymbopogon* sp., *Eragrostis superba* and *Hyparhenia rufa* and *Setaria verticillata* are the most suitable grass

Table 6. Prioritized 5 herbaceous species based on Relative Frequency (RF).

Herbaceous species/degradation category	Family	Mean cover (%)	RF
Low			
Hyparrhenia rufa	Gramineae	12.7	11.3
Hypoestes verticillaris	Acanthaceae	4.6	11.3
Setaria verticillata	Gramineae	4.7	6.8
Cymbopogon sp.	Gramineae	5.0	4.5
Indigofera sp.	Papilionaceae	3.5	4.5
High			
Tridax procumbens	Compositae	3.2	15.4
Hyparrhenia rufa	Gramineae	7.7	7.7
Enteropogon macrostachys	Poaceae	5.0	7.7
Hypoestes verticillaris	Acanthaceae	1.5	7.7
Pteridium aquilinum	Cytheaceae	8.2	3.9
Moderate			
Hypoestes verticillaris	Acanthaceae	3.3	16.1
Pteridium aquilinum	Cytheaceae	20.0	8.1
Hyparrhenia rufa	Gramineae	6.3	8.1
Indigofera sp.	Papilionaceae	3.3	8.1
Enteropogon macrostachys	Poaceae	6.3	4.0

An analysis of variance of all the herbaceous species showed that relative frequency was significantly different while mean species cover showed no significant difference among degradation categories ($p < 0.05$).

species for reseeding expansive glades.

Conflict of interest

The author declares no conflict of interest

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