Vol. 16(2), pp. 46-71, April-June 2024
DOI: 10.5897/IJBC2023.1598
Article Number:80086F771942
ISSN 2141-243X

http://www.academicjournals.org/IJBC

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International Journal of Biodiversity and Conservation

Full Length Research Paper

Plant species composition, abundance, diversity, and threats affecting their survival in Kiang'ombe and Kianjiru hills of Embu County, Kenya

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Received 12 August, 2023; Accepted 25 September, 2023

Forest cover loss is one of the major challenges facing Kenya; and there is insufficient data to guide sustainable biodiversity conservation stratagems. We determined the floristic and growth characteristics, plant species diversity, evenness, relative density, frequency, dominance, important value index, and indicators of biodiversity disturbance. From the 52 plots sampled in Kiang'ombe and Kianjiru hills, we recorded 472 plant species belonging to 90 families. Plants of the Poaceae family were the most abundant and the most diverse, contributing to 90% of all plant species in the study sites. In terms of growth forms, trees were the commonest, followed by herbs and shrubs, while climbers were the least common in both hills. Besides, Kiang'ombe hill had a higher population of herbs than Kianjiru hill. Besides, the Kiang'ombe hill had a higher species diversity (230 plant species; H'= 5.12) than Kianjiru hill (162 plant species; H'= 4.7). Notably, *Vepris glandulosa* and *Euphorbia friesorum* were endangered and vulnerable, respectively. Human activities, especially grazing, threatening plant existence and diversity were observed in the two studied hills. Therefore, the two hills are richly endowed with diverse plant species and are refugia for endemic and vulnerable species which should be conserved.

Key words: Belt transect, Shannon-Wiener diversity index, plant growth form, diversity threats, species diversity, species evenness, relative density, species dominance.

INTRODUCTION

Forest ecosystems support the surrounding communities' livelihood by providing a wide range of products, including food, firewood, timber, medicine, and other services such as soil conservation and water catchment (Ngugi et al., 2011). However, many forests are prone to human encroachment due to the rapid growth of the human population, leading to deforestation and the destruction of natural habitats (Gonçalves-Souza et al., 2020; Scanes, 2018). Habitat loss threatens plant species' survival, especially those that are endemic, vulnerable, and

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endangered, and thus calls for mitigation measures to avert extinction (Gonçalves-Souza et al., 2020).

About 20% of the world's plant population are threatened with extinction, whereby most of these plant species lie within the tropics, and bryophytes being the most threatened (Corlett, 2016). Additionally, Afromontane forests are the most threatened vegetation types in Africa (Razgour et al., 2020).

Recent reports indicate that plant biodiversity losses are already being experienced in Kenya, China, Nepal, Tanzania, and Uganda, among other regions (Government of Kenya, 2013; Roberson, 2008; Pacifici et al., 2015). The local population's lack of awareness about threatened and endangered species contributes to the indiscriminate harvesting of plants, thereby accelerating their extinction (Kayombo et al., 2013).

Kenya's estimated forest cover is currently at 7.4% of the total land area (Ministry of Forestry and Wildlife, 2013; Kenya Forest Service, 2017), below the recommended global minimum of 10%. Additionally, the closed-canopy forest cover is 2% of the total land area against Africa's and the World's average of 9.3 and 21.4%, respectively (Ogweno et al., 2009). About 258 plant species are categorised as threatened (critically endangered, endangered, or vulnerable) in Kenya (Gereau et al., 2016; Nyawira, 2019; Van Dieren, 1995). The accelerating rate of biodiversity loss calls for a botanical inventory of species in their natural habitats to guide conservation strategies (Wass, 1995). The lack of adequate information on existing plants regarding their usage and distribution is among the major hindrances to establishing effective and sustainable strategies towards conserving plant biodiversity (Government of the Republic of Kenya, 2015; Nyawira, 2019).

The Republic of Kenya's constitution stipulates the general conservation, protection, and controlled utilisation of trees in the gazetted and non-gazetted forest reserves (Republic of Kenya, 2014). Due to the lack of proper policy implementation, poor management, and lack of control, the forests under trust land in Kenya are generally exposed to overexploitation (Government of the Republic of Kenya, 2015; Republic of Kenya, 2019; Scanes, 2018). However, the Kenyan government has recently renewed efforts towards safeguarding forests, including declaring a moratorium on timber harvesting in all public and community forests effective 24th February 2018 (Ministry of Environment and Forestry, 2018). Moreover, the National Museums of Kenya has recently constructed a planetarium to attract tourists to the Kianjiru hill as a conservation strategy (National Museums of Kenya, 2019). Despite these efforts, data on plant biodiversity and threat status of many forest areas, especially Kiang'ombe and Kianjiru hills of Embu County, is scanty, which derail conservation efforts.

Kiango'mbe forest is very significant to the lives of surrounding communities since it serves as a source of livelihood and harbours sacred sites where traditional rituals are performed (Ngugi et al., 2011). The forest is surrounded by an ever-increasing population that is continuously encroaching on it. In the past years, much emphasis has been put on tree planting in the area, leading to establishing a forest reserve at its summit (Brokensha and Riley, 1977). Over the years, the hill has been decreasing in tree cover. The hilltop is under tremendous pressure due to overexploitation of its trees for fuelwood, timber, and non-wood forest products (John et al., 2015).

Kianjiru hill is categorised as woodland (Maluki, 2007) and is surrounded by an ever-increasing population, continuously encroaching on it. The hill is a Trust land under the Embu County Government's management, working closely with the Kenya Forest Services (KFS). Human activities, such as charcoal production, overexploitation of medicinal plants, timber harvesting, grazing, and seasonal forest fires, are among the major drivers of deforestation and forest degradation in Embu County (Maitima et al., 2009; Maluki, 2007; Kenya Forest Service, 2019). As a result, urgent conservational measures are required to ensure the sustainable utilisation of forest products and avert their extinction. This study aimed to establish plant species composition, diversity, abundance, and biodiversity disturbances threatening the plants' survival in the natural habitats of Kiang'ombe and Kianjiru hills, Embu County, as a framework for conservation efforts.

MATERIALS AND METHODS

Study site

The current study was conducted at the Kiang'ombe and Kianjiru hills of Embu County in Kenya. They were selected based on their significance to the surrounding community and their biodiversity threat status. Kiang'ombe hill is situated in Mbeere North Constituency at longitude 37° 42' 52" East and latitude 0° 34' South (Figure 1). It is the tallest in Embu County, rising from about 1000 to 1800 m above sea level and covering 2104 ha of landmass (The Government of Kenya, 2013). It is an indigenous hill with less than 5% exotic plantations at the foot and top (Ngugi et al., 2011). A significant proportion of the land is under secondary vegetation, especially on the lower slopes, covered by bushland and wooded grassland. At the same time, the closed canopy zone stretches from 1548 to 1800 m above sea level. Besides, Kianjiru hill lies at longitude 37° 28' 30" East and latitude 0° 21' South within Mbeere South Constituency and is the second tallest in Embu County (Figure 1). It assumes a ridge-like form covering 1004 ha and rising to about 1549 m above sea level (The Government of Kenya, 2013).

Fieldwork

This study was conducted between August 2020 and May 2022, after a prior general reconnaissance, which enabled the researchers to identify vegetation types of the hills' ecosystems based on visual evaluation and topographical pattern and size before the actual study. The method described by Sahu and Dhal

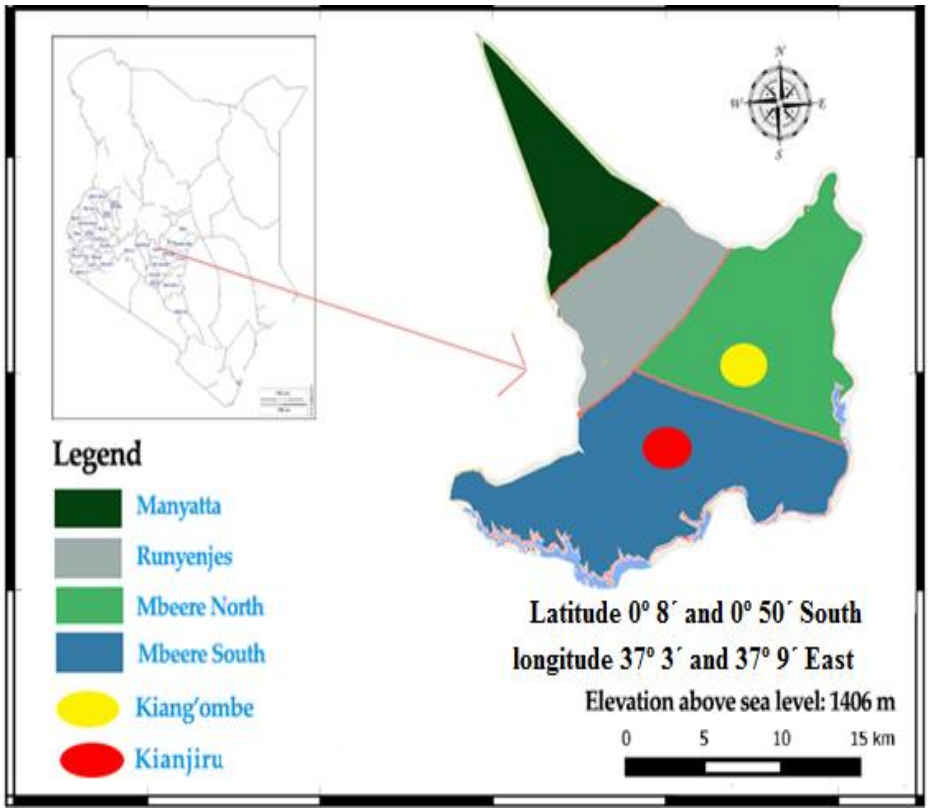

Figure 1. A map of Kenya and Embu County showing the study sites (Kiang'ombe and Kianjiru hills).
Source: The Government of Kenya (2013).

(2012) was adopted in this study. A stratified sampling technique was adopted to ensure that different vegetation formations were considered while proportionately distributing the transects in the two studied hills. One-kilometre belt transects were laid on both hills in radiating orientations from the tops of the hills in all directions. Systematic sampling was then used to sample four plots, each measuring 20×20 m on each transect at intervals of 200 m. In each sampled plot, nested plots measuring 5×5 m and 1×1 m were randomly established and used to estimate the number of shrubs and herbs, respectively. Diameter at breast height (dbh) (≥5 cm) of all trees measuring > 5 m long, above the ground, was measured within the 20×20 m plots. Plant specimens that could not be identified in the field were confirmed at the East Africa Herbarium of the National Museums of Kenya. Plant nomenclature was based on Beentje (1994) and Maundu and Tengnäs (2005) criteria.

Determination of composition, population structure, and the species-area curve

The population structure was analysed by categorising the tree diameters into classes and noting their distribution. The percentage cover for each plant layer (herb, shrub, and tree canopies) was used to estimate trees' canopy cover in the study sites. The average height of trees in each sampled plot was estimated and recorded. Also, we used the PRIMER (Plymouth Routines in Multivariant Ecological Research) version 5 software to plot a species-area curve based on the cumulative species numbers in the sampled areas.

Determination of plant diversity, species evenness, relative density, relative frequency, relative dominance, and important value index

Plant species diversity and evenness were calculated on PRIMER (Plymouth Routines in Multivariant Ecological Research) version 5 analytical software. The Shannon-Wiener diversity Index (H') was determined as shown in Equation 1 (Rocky and Mligo, 2012).

$$H' = -\sum[pi \times \ln(pi)] \quad (1)$$

where *pi* is the proportion of individuals found in the i^{th} species.

The species evenness (J') was calculated using the formulae shown in Equation 2 (Pielou, 1975).

$$J' = \frac{H'}{\text{Log } S} \quad (2)$$

where *H'* is the Shannon-Wiener diversity index and S is the total number of species in a sample.

The relative density (Rd) of plant species was calculated using the formula presented in Equation 3:

$$Rd = \frac{\text{Number of plants in a species}}{\text{Total number of all plant species}} \times 100\% \quad (3)$$

Besides, the relative frequency (RF) and relative dominance RD) were computed according to Equations 4 and 5 as shown:

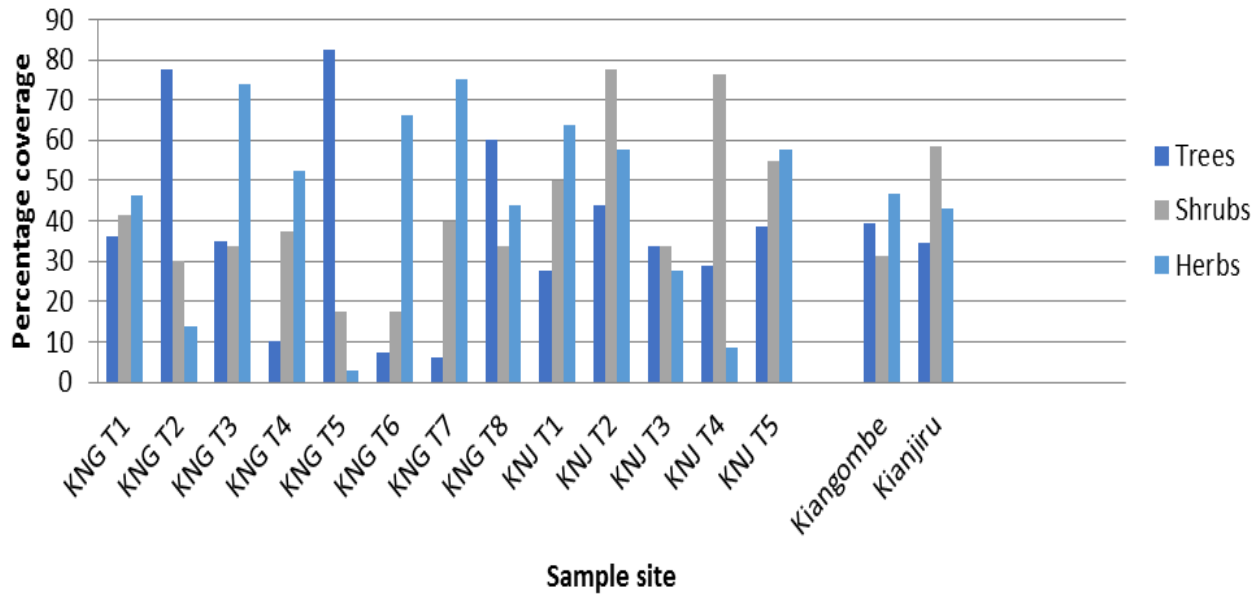

Figure 2. Plant growth form and the percentage coverage in the sampled transects at Kiang'ombe and Kianjiru hills.

$$RF = \frac{\text{Frequency of a plant species}}{\text{Total frequency of all plant species}} \times 100\% \quad (4)$$

$$RD = \frac{\text{Tree basal area of a species}}{\text{Tree basal area of all species}} \times 100\% \quad (5)$$

Additionally, important value indices of the plants were computed using Equation 6.

$$\text{Important Value Index} = \sum[Rd, RF, RD] \quad (6)$$

Species similarity between the survey sites and zones

Species similarity was evaluated using the PRIMER (Plymouth Routines in Multivariant Ecological Research) analytical software version 5. We used ordination with non-metric multidimensional scaling (MDS) and linkage clusters to determine the dispersion of sampling zones and plots based on their species similarity.

Botanical uniqueness (endemic and threatened plants)

The IUCN Red List of plants (IUCN, n.d.-a, n.d.-b) and the List of East African Plant databases (East African Plants, n.d; Eastern Africa Plant, n.d; IUCN, n.d.; BRAHMS, n.d.; Kenya Natural History-Plants, n.d.) were used to identify the endemic and threatened plant species in the studied sites.

Assessment of biodiversity disturbance in Kiang'ombe and Kianjiru hills

At each sampled site, indicators of biodiversity disturbance, such as grazing, charcoal burning, human or animal tracks, firewood, and wood harvesting, were quantified by assigning numbers up to a maximum of 3, based on levels of strengths as follows: 0 = absent; 1 = Low; 2 = Moderate; and 3 = High.

RESULTS

Overall floristic composition

From the 52 sampled plots in both Kiang'ombe and Kianjiru hills, 472 species belonging to 90 families were recorded, whereby 392 plants were encountered within the sampled plots (Appendix 1). In Kiang'ombe hill, five transects (KNG T1, KNG T3, KNG T4, KNG T6, and KNG T7) had a higher population of herbs than trees and shrubs; however, the tree population in three transects (KNG T2, KNG T5, and KNG T8), was higher than that of herbs and shrubs (Figure 2). Generally, King'ombe hill comprised a higher population of herbs, followed by shrubs and trees (Figure 2). The herbs' population was higher than that of trees and shrubs in transects KNJ T1 and KNJ T5 in Kianjiru hill (Figure 2). Additionally, a higher shrub population in transects KNJ T2 and KNJ T4 compared with the populations of trees and herbs in Kianjiru hill. The tree and shrub population in transect KNJ T3 in Kianjiru hill were similar (Figure 2).

Furthermore, we compared the plant life-form spectra between the two studied sites. The findings showed that Kiang'ombe hill had a higher population of trees and herbs than Kianjiru hill (Figure 3). On the other hand, the Kianjiru hill had a higher proportion of shrubs and climbers than Kiang'ombe hill (Figure 3). Generally, Kiang'ombe hill posited a higher plant population than Kianjiru.

The Poaceae family's plants were the most abundant and the most diverse contributing to 15 % of the total plant species growing in the two study sites (Figure 4). Other prominent contributing families were Papilionaceae

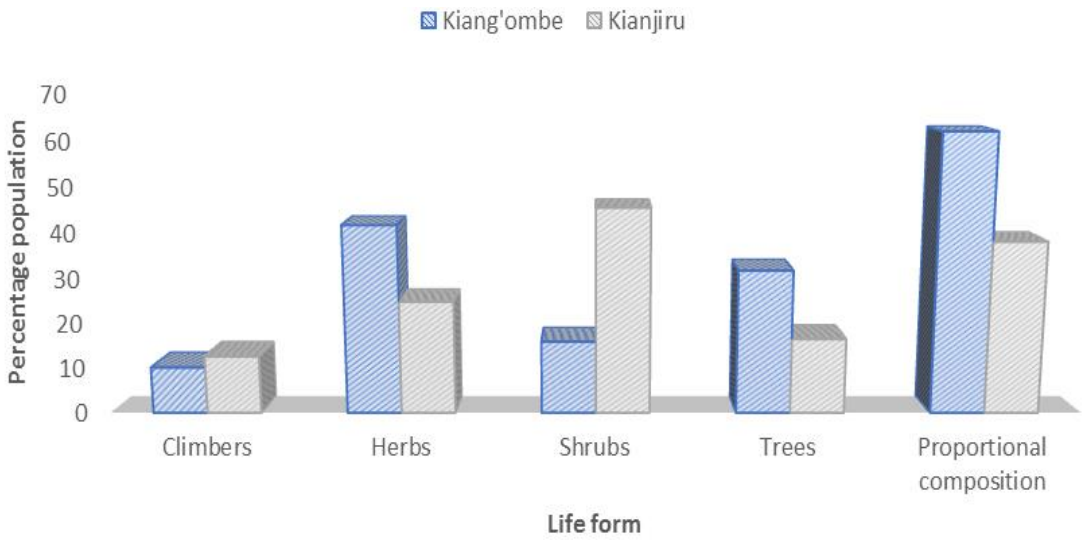

Figure 3. Plants' growth form and abundance at Kiang'ombe and Kianjiru hills.

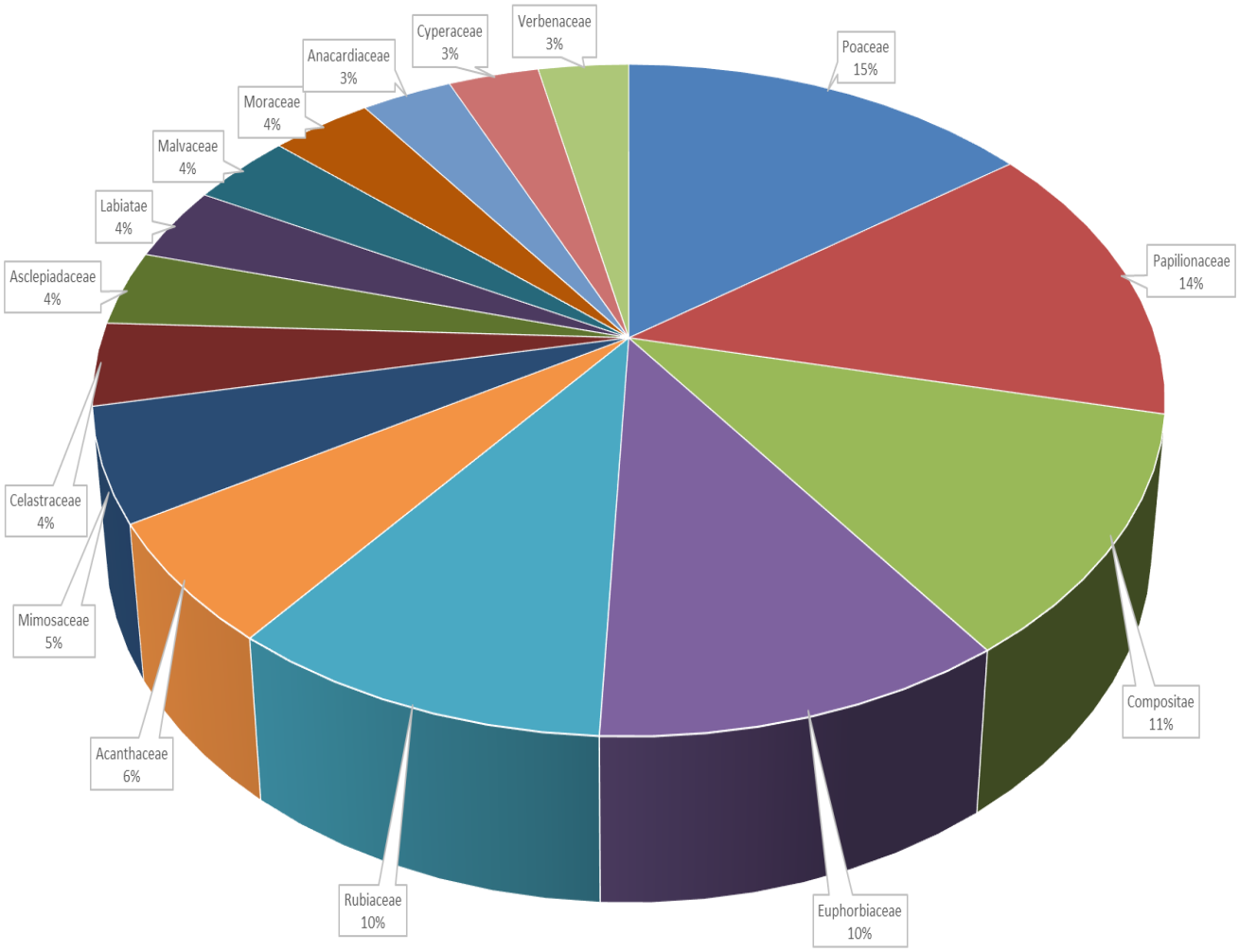

Figure 4. The relative percentage contribution of species diversity by the topmost 15 plant families in the studied sites.

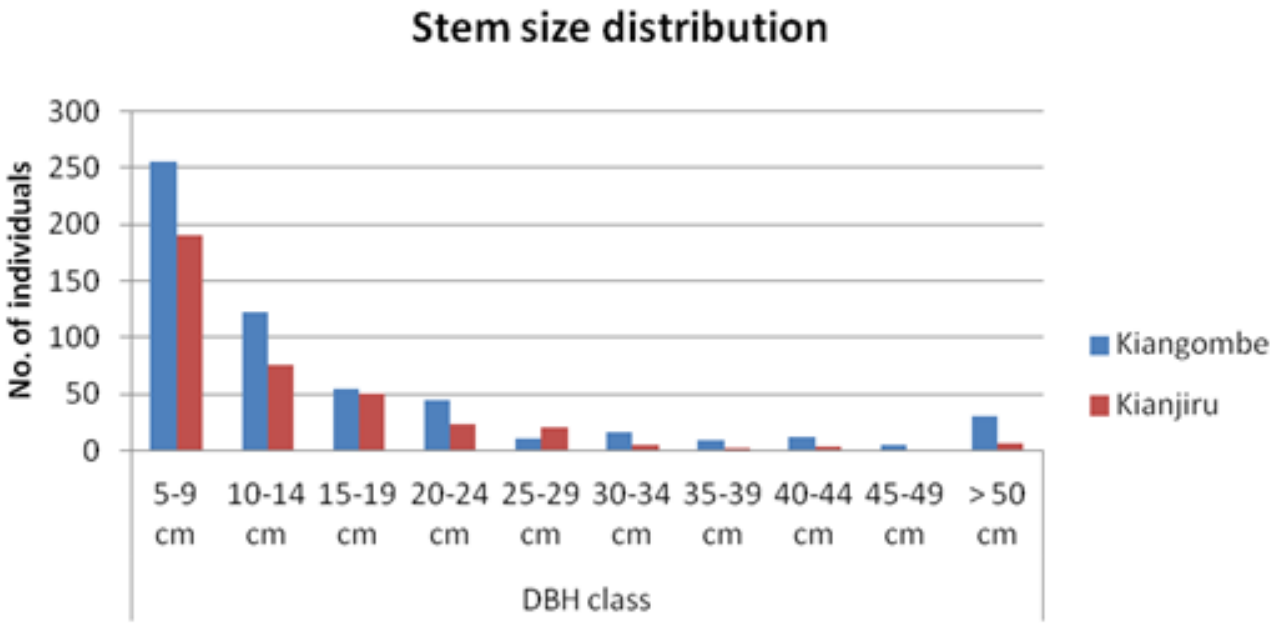

Figure 5. Stem size distribution in sampled sites.

(15%), Asteraceae (11%), Euphorbiaceae (10%), Rubiaceae (10%), Acanthaceae (6%), and Mimosaceae (5%) (Figure 4). Celastraceae, Asclepiadaceae, Lamiaceae, Malvaceae, and Moraceae contributed to 4% of plant species, while Anacardiaceae, Cyperaceae, and Verbenaceae, each contributed to 3% of all plant species (Figure 4). Each of the other families contributed to ≤2% of plant species (not shown).

Floristic structure

Tree population structure

Diameters of 940 trees exceeding the height of 5 m were measured in Kiang'ombe and Kianjiru hills and classified into the diameter of breast height (DBH) class categories, which were plotted in a dendrogram to make an age-based succession assessment (Figure 5). We observed that 560 trees belonged to 94 species found in the Kiang'ombe hill, while 380 trees encountered in the Kianjiru hill belonged to 72 species. Additionally, more trees occupied the lower DBH classes and gradually declined in the successive stages (Figure 5). A dendrogram plot depicted an inverse J shape, an indication of an actively regenerating population.

Overall tree heights

The tallest trees (average height of 38 m) were encountered in transects two and five of Kiang'ombe hill (KNG T2 and T5), in the forest patches on the hilltop near the peak (Figure 6). These trees mostly belonged to the Sapotaceae family, and they included *Manilkara discolor*, *Pouteria adolfi-friedericii, Casaeria battiscombe, Newtonia buchananii, Cola greenwayi,* and *Trichilia emetica.* The average tree heights of Kiang'ombe plots were greater than those of Kianjiru (Figure 6).

Overall species area curve

The species-area curve (Figure 7) showed that the 52 sampled plots sufficiently represented the study area's species variation. As a result, the number of new species increased as the sample area increased; however, the curve did not reach an asymptote.

Abundance, tree basal area, density and important value indices of plants encountered in Kiang'ombe and Kianjiru hills

Combretum molle was the most abundant tree species in Kiang'ombe (22.10%) and Kianjiru (11.08%) hills and mostly dominated the riverine (KNG T1 and T8) and grassed woodland habitats (KNG T3, T6, and KNJ T5) (Table 1). *Commiphora africana* was the second most abundant (8.70%) in Kianjiru hill habitats and rare in the Kiang'ombe hill forest (0.17%) (Table 1). The third most abundant (7.92%) was *Mysthroxylon aethiopicum*, which only occupied the Kianjiru habitats. *Xymalos monospora* was the fourth most abundant tree species (7.84%); however, it was only encountered in Kiang'ombe's moist forest habitat (KNG T2 and T5) (Table 1). Apart from

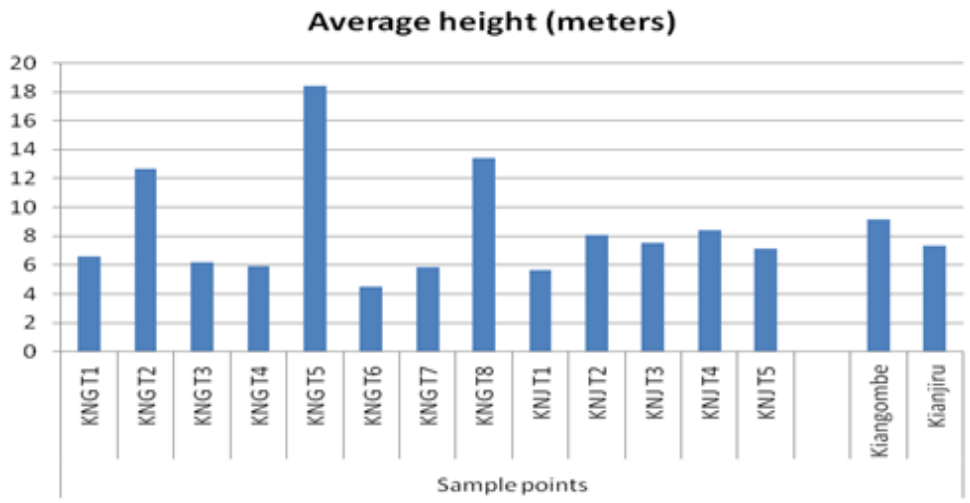

Figure 6. Distribution of tree heights in the sampled sites.

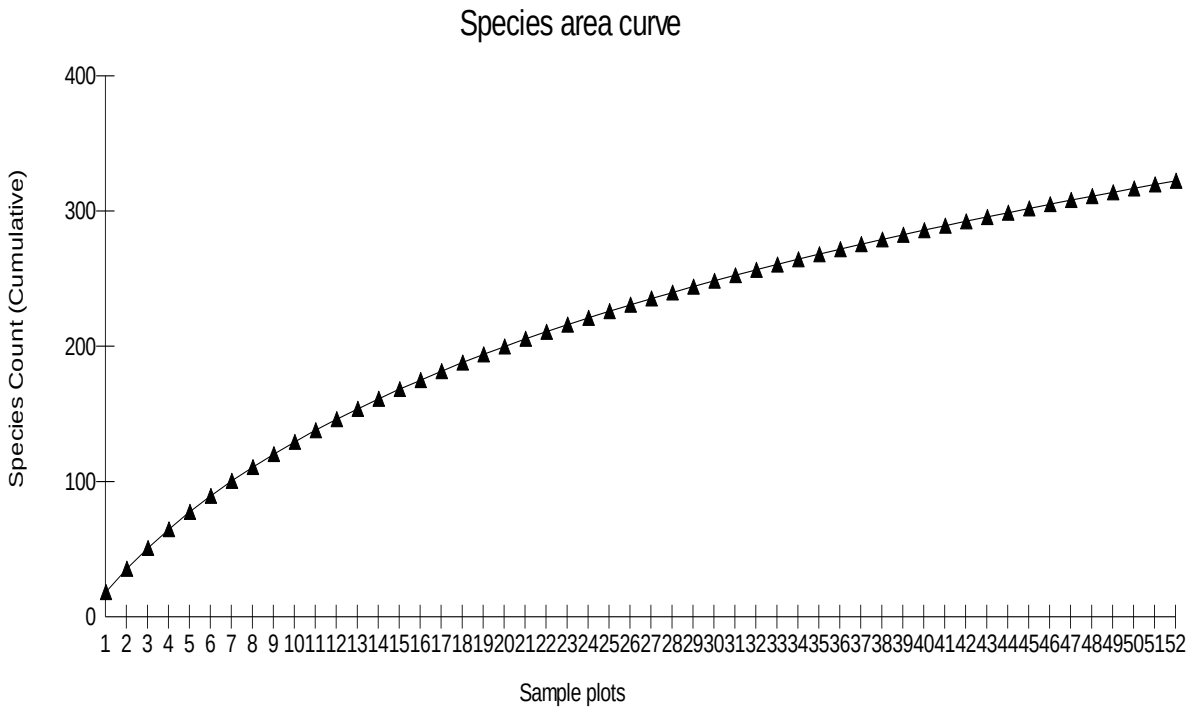

Figure 7. Species-area curve.

being the fifth most abundant tree species (7.13%), *Faurea saligna* inhabited three out of the four habitats sampled in Kiang'ombe hill (Grassed woodland, fern transition zone, and the riverine); but was absent in Kianjiru hill (Table 1).

Overall, Kiango'mbe had a higher relative dominance of 78% against 22% of Kianjiru. The entire Kiangombe hill had a higher tree basal area of 7049.9 M^2/Acre than Kianjiru hill (1969.86 M^2/Acre). Notably, transect two of Kianjiru hill (KNJ T2) and transect five of Kiangombe hill (KNG T5), which lay on the forest patch around the hill peak, had the highest relative dominance of 42.4 and 37%, respectively, and tree basal areas of 591.15 and 516.2 M^2/Acre, respectively. Transect four of the Kiango'mbe hill (KNG T4), which lay in the fern transition zone, had the least relative dominance of 0.54%.

Table 1. Percentage abundance, tree basal area, density, and important value indices of plants encountered in Kiang'ombe and Kianjiru hills.

Species	Family	% Abundance		TBA (M^2/Acre)		Density/ha		IVI	
		KNG	KNJ	KNG	KNJ	KNG	KNJ	KNG	KNJ
Lannea schimperi (A. Rich.) Engl.	Anacardiaceae	1.06	1.05	-	0.007	4.68	5	10.68	9.00
Ozoroa insignis Delile		0.53	0.79	0.67	0.32	2.34	3.75	6.02	7.07
Lannea rivae (Chiov.) Sacleux		-	0.52	0.07	0.44	-	2.5	0.07	4.94
Rhus natalensis Krauss		0.35	0.26	0.01	-	1.56	1.25	3.57	2.25
Sclerocarya birrea (A. Rich.) Hochst.		-	0.26	0.01	0.009	-	1.25	0.01	2.25
Sorindeia madagascariensis DC.		0.89	-	0.05	-	3.90	-	8.96	-
Rhus vulgaris Meikle		0.35	-	-	0.003	1.56	-	3.56	0.003
Rhus longipes Engl.		0.17	-	0.10	-	0.78	-	1.88	-
Uvaria scheffleri Diels	Annonaceae	-	0.26	-	0.01	0.78	-	1.80	-
Carissa edulis (Forssk.) Vahl	Apocynaceae	-	0.26	-	0.005	-	1.25	1.79	-
Tabernaemontana stapfiana Britten		0.17	-	0.01	-	0.78	-	-	2.25
Cussonia holstii Engl.	Araliaceae	0.71	-	0.01	-	1.56	-	3.57	-
Ehretia cymosa Thonn.	Boraginaceae	1.06	-	0.01	-	0.78	-	10.70	-
Cordia africana Lam.		0.17	-	0.13	-	4.68	-	1.91	-
Commiphora africana (A. Rich.) Engl.	Burseraceae	0.17	8.70	0.003	0.88	0.78	41.25	1.78	75.13
Commiphora samharensis Schweinf.		-	5.54	0.01	0.18	-	30	0.01	54.18
Commiphora eminii Engl.		0.17	2.375	-	1.46	0.78	11.25	1.781	21.71
Mystroxylon aethiopicum (Thunb.) Loes.	Celastraceae	-	7.91	-	0.062	-	37.5	-	67.53
Maytenus putterlickioides (Oliv.) Exell & Mendon¦a		-	0.79	-	0.008	-	3.75	-	6.75
Elaeodendron buchananii (Loes.) Loes.		-	0.52	-	0.010	-	2.5	-	4.51
Maytenus undata (Thunb.) Blakelock		0.71	0.26	-	0.06	3.125	1.25	7.125	2.31
Maytenus heterophylla (Eckl. & Zeyh.) N. Robson		-	0.26	0.007	-	-	1.25	0.007	2.25
Combretum molle G. Don	Combretaceae	22.10	11.08	-	0.43	96.875	52.5	220.87	94.93
Combretum zeyheri Sond.		-	6.86	-	0.11	-	32.5	-	58.61
Terminalia brownii Fresen.		0.71	2.11	8.89	1.35	-	11.25	8.89	21.60
Combretum collinum Fresen.		-	0.52	-	6.05	-	2.5	-	10.55
Diospyros consolatae Chiov.	Ebenaceae	0.17	4.22	0.06	-	0.781	2.5	1.841	36

Table 1. Contd.

Euclea divinorum Hiern		1.246	2.63	0.0062	0.01	5.46	12.5	12.47	22.51
Diospyros abyssinica (Hiern) F. White		0.17	0.52	0.02	0.46	0.78	20	1.80	4.96
Erythroxylum emarginatum Thonn.	Erythroxylaceae	-	0.52	0.022	0.36	-	2.5	0.02	4.86
Euphorbia friesiorum (Hassl.) S. Carter		-	7.38	-	0.0030	-	36.25	-	65.25
Croton megalocarpus Hutch.		-	2.63	0.66	-	-	12.5	0.66	22.5
Macaranga kilimandscharica Pax		3.03	-	0.51	-	13.28	-	30.79	-
Bridelia micrantha (Hochst.) Baill.	Euphorbiaceae	0.71	-	0	0.59	3.125	-	7.12	0.59
Bridelia taitensis Vatke & Pax		-	0.52	-	0.12	-	-	-	-
Drypetes gerrardii Hutch.		0.53	-	0.002	-	2.34	-	5.34	-
Croton macrostachyus Delile		0.53	-	0.11	-	2.34	-	5.45	-
Euphorbia candelabrum Kotschy		0.17	-	-	0.46	0.78	-	1.78	0.46
Flacourtia indica (Burm.f.) Merrill		1.24	0.52	0.25	-	5.46	2.5	12.72	4.5
Casearia battiscombei R.E.Fr.		3.56	-	1.67	-	15.625	-	37.30	-
Ludia mauritiana J.F. Gmel.	Flacourtiaceae	2.13	-	0.002	0.024	9.375	-	21.37	0.024
Scolopia zeyheri (Nees) Harv.		0.17	-	0.0050	-	0.781	-	1.78	-
Rawsonia lucida Harv. & Sond.		0.17	-	0.11	-	0.78	-	1.89	-
Garcinia buchananii Baker	Guttiferae	1.24	-	0.45	-	5.46	-	12.92	-
Lonchocarpus eriocalyx Harms		-	1.05	0.41	0.005	-	5	0.41	9.00
Acacia hockii De Wild.		1.78	0.79	-	0.02	7.81	3.75	17.81	6.77
Senna singueana (Delile) Lock		0.71	0.52	-	0.003	3.125	2.5	7.125	4.50
Ormocarpum kirkii S. Moore		-	0.52	0.28	0.010	-	2.5	0.28	4.51
Dichrostachys cinerea (L.) Wight & Arn.		-	0.26	-	0.001	-	1.25	-	2.25
Acacia polyacantha Willd.		-	0.26	0.62	-	-	1.25	0.62	2.25
Acacia ataxacantha DC.	Leguminosae	-	0.26	-	0.252497	-	1.25	-	2.50
Acacia brevispica Harms		-	0.26	0.06	-	-	1.25	0.06	2.25
Newtonia buchananii (Baker) G.C.C. Gilbert & B		3.20	-	0.02	-	14.06	-	32.09	-
Baphia sp		1.78	-	-	0.08	7.81	-	17.81	0.08
Erythrina abyssinica DC.		0.89	-	0.07	-	3.90	-	8.98	-
Millettia dura Dunn		0.35	-	9.05	-	1.56	-	12.627	-
Albizia schimperiana Oliv.		0.17	-	0.02	-	3.125	-	7.14	-
Strychnos henningsii Gilg	Loganiaceae	0.17	0.26	0.05	0.027	0.78	1.25	1.83	2.27

Table 1. Contd.

Nuxia congesta Fresen.		0.53	-	0.85	-	2.34	-	6.19	-
Strychnos spinosa Lam.		0.17	-	0.003	0.0025	0.78	-	1.80	-
Thespesia garkeana	Malvaceae	-	0.263	0.01	-	-	1.25		
Bersama abyssinica Fresen.	Melianthaceae	0.89	-	1.04	-	3.90	-	9.95	-
Albizia gummifera (J.F. Gmel.) C.A.Sm.	Mimosaceae	0.89	-	0.02	-	4.68	-	10.71	-
Xymalos monospora (Harv.) Warb.	Monimiaceae	7.84	-	1.24	-	34.37	-	10.71	-
Ficus lutea Vahl		0.17	0.26	1.82	-	0.78	1.25	3.60	2.25
Ficus stuhlmannii Warb.		-	0.26	0.38	0.25	-	1.25	0.38	2.50
Ficus glumosa Delile		-	0.26	-	0.04	-	1.25	-	2.29
Ficus sur Forssk.	Moraceae	0.35	-	-	0.0028	1.56	-	3.56	0.002
Ficus vallis-choudae Delile		0.35	-	0.81	-	1.56	-	4.37963	-
Ficus sycomorus L.		0.17	-	0.01	-	0.78	-	1.791	-
Ficus thonningii Blume		0.17	-	0.03	-	0.78	-	1.81	-
Eucalyptus sp		-	2.63	0.00054	-	-	12.5	0.01	22.5
Syzygium guineense (Willd.) DC.	Myrtaceae	2.85	-	-	0.07	12.5	-	28.5	0.07
Eugenia sp		0.71	-	4.18	-	3.125	-	11.3	-
Syzygium cordatum Hochst.		0.53	-	0.01	-	3.125	-	7.14	-
Ochna insculpta Sleumer	Ochnaceae	-	1.31	0.29	-	-	6.25	0.29	11.25
Ochna holstii Engl.		0.17	-	0.03	-	0.78	-	1.81	-
Ximenia americana L.	Olacaceae	-	0.26	-	0.03	-	1.25	-	2.28
Strombosia scheffleri Engl.		1.069	-	0.09	-	4.68	-	10.77	-
Faurea saligna Harv.	Proteaceae	7.13	-	0.10	-	31.25	-	71.35	-
Protea sp		3.03	-	3.06	-	13.28	-	33.34	-
Scutia myrtina (Burm.f.) Kurz	Rhamnaceae	-	0.26	0.054	-	0.78	-	0.05	2.25
Ziziphus abyssinica A. Rich.		0.17	-	-	0.001	-	1	1.78	0.001
Cassipourea malosana (Baker) Alston	Rhizophoraceae	-	1.055	0.046	-	-	1.059	0.04	9
Hymenodictyon floribundum (Hochst. & Steud.) B.L. Ro	Rubiaceae	-	1.31	-	0.18	-	6.25	-	11.43
Rothmannia fischeri (K. Schum.) Bullock		-	0.79	-	0.29	-	3.75	-	7.049

Table 1. Contd.

Catunaregam nilotica (Stapf) Tirveng.		-	0.79	-	0.016	-	3.75	-	6.76
Rytigynia sp			0.52	2.92	0	0.78	3.75	4.70	6.75
Vangueria madagascariensis J.F. Gmel.		-	0.52	0.002	-	-	2.5	0.002	4.5
Tapiphyllum schumannianum Robyns		-	0.52	0.0015	-	-	2.5	0.001	4.5
Psydrax schimperiana (A. Rich.) Bridson		-	0.26	0.017	-	-	1.25	0.03	2.25
Pyrostia tree		-	0.26	-	0.04	-	1.25	0	2.29
Psydrax parviflora (Afzel.) Bridson		0.71	-	-	0.04	3.125	-	7.125	0.04
Vangueria volkensii K. Schum.		0.71	-	0	0.16	3.125	-	7.125	0.16
Tricalysia pallens Hiern		0.53	-	0.03	-	2.34	-	5.37	-
Oxyanthus speciosus DC.		0.17	-	-	0.025	0.78	-	1.78	-
Canthium oligocarpum Hiern		0.17	-	0.003	0.10	0.78	-	1.78	0.10
Rothmannia manganjae (Hiern) Keay		0.17	-	0.017	-	0.78	-	1.79	-
Tarenna graveolens (S. Moore) Bremek.		0.17	-	-	0.04	0.78	-	1.78	0.04
Fagaropsis hildebrandtii (Engl.) Milne-Redh.	Rutaceae	-	0.52	0.03	-	-	1.25	0.037	4.5
Vepris simplicifolia (Engl.) Verd.		-	0.26	0.0023	-	-	2.5	0.002	2.25
Vepris glandulosa (Hoyle & Leakey) Kokwaro		0.35	-	-	0.06	1.56	-	3.56	0.06
Fagaropsis angolensis (Engl.) Dale		0.17	-	-	0.05	0.78	-	1.78	0.05
Pappea capensis Eckl. & Zeyh.	Sapindaceae	-	2.63	-	0.008	-	12.5	-	22.50
Zanha africana (Radlk.) Exell		-	0.79	-	0.04	-	3.75	-	6.79
Allophylus rubifolius (Hochst.) Engl.		-	0.52	0.91	-	-	2.5	0.91	4.5
Haplocoelum foliosum (Hiern) Bullock		-	0.26	-	0.004	-	1.25	-	2.25
Dodonaea viscosa (L.) Jacq.		-	0.26	7.8	0.0022	0.78	1.25	1.78	2.25
*Deinbollia kilimands*charica Taub.		0.53	-	-	0.77	2.34	-	5.34	0.77
Manilkara discolor (Sond.) J.H. Hemsl.	Sapotaceae	0.17	0.26	-	0.34	0.78	1.25	1.78	2.59
Unknown		1.78	-	0.0021	-	7.8125	-	17.81	-
Manilkara butugi Chiov.		0.71	-	1.76	-	3.125	-	8.89	-
Aningeria adolfi-friedericii (Engl.) Robyns & Gilbert		0.53	-	1.06	-	2.34	-	6.40	-
Afrosersalisia sp		0.17	-	0.0027	0.04	0.78	-	1.78	0.044
Mimusops kummel A.DC.		0.17	-	0.004	-	0.78	-	1.78	-
Dombeya kirkii Mast.	Sterculiaceae	-	2.90	2.50	-	-	13.75	2.50	24.75
Cola greenwayi Brenan		4.45	-	-	0.59	19.53	-	44.53	0.59
Dombeya rotundifolia Planch.		0.71	-	0.05	-	3.125	-	7.17	-
Peddiea fischeri Engl.	Thymelaeaceae	0.89	-	0.44	-	3.90	-	9.35	-

Table 1. Contd.

Grewia plagiophylla K. Schum.	Tiliaceae	-	0.26	-	0.10	-	1.25	0	2.35
Grewia sp		0.179	-	0.022	-	0.78	-	1.80	-
Heteromorpha trifoliata (H.L. Wendl.) Eckl. & Zeyh	Umbelliferae	-	0.52	-	0.09	-	2.5	-	4.59
Steganotaenia araliacea Hochst.		-	0.52	-	0.01	-	3.75	-	6.76
Clerodendrum myricoides (Hochst.) Vatke	Verbenaceae	-	0.79	-	0.0050	-	3.75	-	6.75
Vitex payos (Lour.) Merr.		0.35	0.26	0.37	-	1.56	1.25	3.93	2.25
Vitex keniensis Turrill		0.17	-	0.01	0.31	0.78	-	1.79	0.31

TBA: Tree Basal Area; IVI: Important Value Index

Besides, transect five of the Kianjiru hill (KNJ T5), in the grassed woodland, had the highest relative dominance of 28.0%. Also, transect three of this hill (KNJ T3), which was categorised as woodland habitat, had the least tree dominance of 15.11%. It was further established that *Acacia* species plants, such as *Acacia ataxacantha, Acacia brevispica, Acacia hockii,* and *Acacia polyacantha*, largely dominated the two hills.

C. molle was the most significant species in both hill ecosystems, positing the highest relative density of 18% and accounting for approximately 80 plants per hectare. It was also the highest contributor to tree density in Kiang'ombe hill (22%) and Kianjiru hill (11%) and the most frequently encountered plant (frequency=18%) appearing approximately 166 times within the 52 sampled plots. Others with high densities included *X. monospora, C. africana, F. saligna, M. aethiopicum, C.greenwayi*, and *Euphorbia friesiorum. Oxyanthus speciosus* had the least density of 0.1%.

Shrub abundance and density in Kianjiru and Kiang'ombe hills

The results showed that, *Triumfetta tomentosa* was the most abundant (16.46%) and common shrub in the King'ombe hill fern transition zone (KNG T4 and T7); however, it posited an abundance of 7.07% Kianjiru hill (Table 2). *Rhus natalensis* was the second most abundant shrub (10.77%) in Kianjiru habitats (grassed woodlands, dry forest, and woodland) and recorded lower abundance (3.69%) in Kiang'ombe hill (Table 2). The third most abundant (8.52%) shrub was *Aspilia mossambicensis,* which was common in Kianjiru hill dry forest habitats (KNJ T2 and T4) (Table 2). In Kiang'ombe, this plant posited an abundance of 6.77%. *Gnidia subcordata* was the fourth most abundant shrub and posited an abundance of 7.88% in Kianjiru and a lower abundance in Kiang'ombe hill (4.61%) (Table 2). We further observed that *Rhus natalensis* was the densest species in Kiang'ombe (8125 ha^{-1}) and Kianjiru hills (12440 ha^{-1}) shown in Table 2.

Abundance and density of herb species in Kiang'ombe and Kianjiru hills

It was observed that *Hyparrhenia filipendula* was the most abundant herb, commonly encountered in the grassed woodlands (KNG T6) of Kiang'ombe hill (10.04%) and grassed woodland (KNJ T5), and woodland habitats (KNJ T1 and T3) of Kianjiru hill (13.10%) (Table 3). The second most abundant herb species (10.84%) was *Panicum trichocladum,* commonly encountered in all the sampled habitats of Kiang'ombe hill except the moist forest areas (Table 3). However, it was absent in the Kianjiru hill forest habitats. *Pteridium aquilinum* was the third most abundant herb species (9.95%) and was common in the Kiag'ombe fern transition zone habitat (KNG T4 and T7) and absent in the Kianjiru hill forest (Table 3). The fourth and fifth most abundant herb species were *Jasminum fluminense* (6.43%) and *Oplismenus hirtellus* (6.19%), respectively, and were commonly encountered in Kianjiru hill and absent in Kiang'ombe hill (Table 3).

About 127 herb species, mainly grasses, were spread across the sampled areas of Kiang'ombe and Kianjiru hill forests, whose abundance and densities are presented in Table 3. *H. filipendula* (grass) was the most abundant (13.10%) in Kianjiru hill forest with a density of 13750 ha^{-1}, and the second most abundant (10.04%) in King'ombe hill forest (density of 17500 ha^{-1}, after *Panicum trichocladum* which posited a density of 18906.25 ha^{-1} and an abundance of 10.84% (Table 3). Other herbs with high densities included *Heteropogon contortus, P. aquilinum, Ageratum conyzoides,*

Table 2. Abundance and density of shrub species in Kiang'ombe and Kianjiru hills.

Plant species	Family	% Abundance		Density/ha	
		KNG	KNJ	KNG	KNJ
Dyschoriste spp.	Acanthaceae	-	0.80	-	120
Dyschoriste hildebrandtii Lindau ex Engl.		-	0.64	62.5	-
Barleria submollis Lindau		-	0.48	12.5	60
Rhus natalensis Krauss	Anacardiaceae	3.69	10.77	1337.5	-
Rhus longipes Engl.		1.53	-	12.5	180
Lannea spp.		-	0.16	112.5	-
Rhus vulgaris Meikle		1.23	1.12	87.5	20
Uvaria scheffleri Diels	Annonaceae	1.38	4.66	550	400
Monanthotaxis parvifolia (Oliv.) Verdc.		2.615	0.96	537.5	60
Monanthotaxis parvifolia (Oliv.) Verdc.		-	0.64	-	80
Uvariodendron anisatum Verdc.		-	0.48	-	60
Artabotrys monteiroae Oliv.		0.15	-	-	20
Landolphia buchananii (Hallier f.) Stapf	Apocynaceae	2.15	2.09	75	160
Carissa edulis (Forssk.) Vahl		0.15	-	-	200
Asparagus africanus Lam.	Asparagaceae	-	0.48	-	60
Cordia sinensis Lam.	Boraginaceae	-	0.16	25	-
Maytenus heterophylla (Eckl. & Zeyh.) N. Robson	Celastraceae	-	-	262.5	-
Mystroxylon aethiopicum (Thunb.) Loes.		0.15	0.48	-	80
Maytenus undata (Thunb.) Blakelock		-	0.32	37.5	-
Maytenus senegalensis (Lam.) Exell		0.15	-	12.5	-
Combretum molle G. Don	Combretaceae	3.38	-	287.5	-
Terminalia brownii Fresen.		-	0.16	-	20
Aspilia mossambicensis (Oliv.) Wild	Asteraceae	6.76	8.52	-	1340
Vernonia lasiopus O. Hoffm.		1.07	-	-	160
Vernonia auriculifera Hiern		1.07	-	-	140
Agelaea pentagyna (Lam.) Baill.	Connaraceae	3.53	-	12.5	440
Ipomoea kituensis Vatke	Convolvulaceae	-	0.16	-	20
Euclea divinorum Hiern	Ebenaceae	4.15	5.14	212.5	440
Diospyros consolatae Chiov.		-	-	125	-
Erythroxylum emarginatum Thonn.	Erythroxylaceae	-	1.44	137.5	-
Bridelia taitensis Vatke & Pax	Euphorbiaceae	-	-	100	-
Euphorbia friesiorum (Hassl.) S. Carter		-	0.96	87.5	-
Phyllanthus fischeri Pax		-	0.80	-	100
Acalypha volkensi Pax		0.76	-	25	60
Bridelia micrantha (Hochst.) Baill.		0.76	-	62.5	-
Croton dichogamus Pax		-	0.64	-	80
Euphorbia matabelensis Pax		-	0.32	-	40
Flacourtia indica (Burm.f.) Merrill	Flacourtiaceae	1.23	-	-	260

Table 2. Contd.

Scolopia zeyheri (Nees) Harv.		0.46	-	-	60
Trimeria grandifolia		0.46	-	37.5	-
Garcinia livingstonei T. Anderson	Guttiferae	-	0.16	-	20
Apodytes dimidiata Arn.	Icacinaceae	0.15	-	12.5	-
Ocimum gratissimum Forssk.		2.15	0.16	137.5	380
Plectranthus barbatus Sims	Labiatae	1.53	-	125	-
Leucas grandis Vatke		-	0.48	-	100
Indigofera swaziensis Bolus		1.692	2.41	-	640
Pseudarthria hookeri Wight & Arn.		4	3.69	312.5	20
Bauhinia tomentosa L.		-	3.69	325	-
Acacia brevispica Harms		0.15	-	-	460
Dichrostachys cinerea (L.) Wight & Arn.		1.53	1.44	125	-
Senna singueana (Delile) Lock	Leguminosae	0.76	-	62.5	-
Indigofera garckeana Vatke		0.46	-	37.5	-
Indigofera spp.		0.46	-	37.5	-
Tephrosia spp.		0.30	-	-	40
Crotalaria spp.		-	0.16	-	20
Newtonia buchananii (Baker) G.C.C. Gilbert & B		0.15	-	12.5	-
Psoralea foliosa Oliv.		0.15	-	12.5	-
Strychnos madacascariensis	Loganiaceae	-	0.32	-	40
Lawsonia inermis L.	Lythraceae	0.46	-	37.5	-
Hibiscus calyphyllus Cav.	Malvaceae	1.38	1.28	-	180
Abutilon mauritianum (Jacq.) Sweet		-	0.64	-	80
Bersama abyssinica Fresen.	Melianthaceae	0.15	-	12.5	-
Cissampelos pareira L.	Menispermaceae	0.15	-	12.5	-
Xymalos monospora (Harv.) Warb.	Monimiaceae	0.76	-	62.5	-
Syzygium cordatum Hochst.	Myrtaceae	0.15	-	12.5	-
Ochna insculpta Sleumer	Ochnaceae	0.92	-	-	320
Jasminum spp.	Oleaceae	0.46	-	37.5	-
Pittosporum viridiflorum Sims	Pittosporaceae	0.15	-	12.5	-
Protea spp.	Proteaceae	1.07	-	87.5	-
Faurea saligna Harv.		0.15	-	12.5	-
Scutia myrtina (Burm.f.) Kurz	Rhamnaceae	-	0.80	-	120
Cassipourea malosana (Baker) Alston	Rhizophoraceae	-	0.48	-	60
Tapiphyllum schumannianum Robyns		-	1.28	212.5	-
Pentas parvifolia Hiern		-	0.48	175	-
Tricalysia pallens Hiern		1.69	1.60	100	60
Psychotria spp.	Rubiaceae	1.07	0.96	87.5	-
Pavetta teitana K. Schum.		0.30	-	-	100
Catunaregam nilotica (Stapf) Tirveng.		-	-	-	60
Tapiphyllum schliebenii Verdc.		-	0.32	-	40
Pentas spp.		0.30	-	25	-
Psychotria kirkii Hiern		0.30	-	25	-

Table 2. Contd.

Tarenna graveolens (S. Moore) Bremek.		-	0.16	-	20
Clausena anisata (Willd.) Benth.	Rutaceae	6.61	3.53	-	980
Toddalia asiatica (L.) Lam.		0.15	-	12.5	-
Osyris lanceolata Hochst. & Steud.	Santalaceae	0.15	-	12.5	-
Dodonaea viscosa (L.) Jacq.	Sapindaceae	-	3.05	337.5	120
Pappea capensis Eckl. & Zeyh.		-	0.48	-	80
Allophylus rubifolius (Hochst.) Engl.		0.46	0.32	37.5	-
Zanha africana (Radlk.) Exell		-	0.16	-	20
Manilkara butugi Chiov.	Sapotaceae	0.30	0.16	25	-
Solanum campylacantha	Solanaceae	-	0.32	-	40
Dombeya tembensis	Sterculiaceae	-	-	-	20
Gnidia subcordata Meisn.	Thymelaeaceae	4.61	7.87	112.5	1060
Gnidia latifolia (Oliv.) Gilg		-	0.48	375	580
Triumfetta tomentosa Bojer	Tiliaceae	16.46	7.07	8125	12440
Grewia tembensis Fresen.		-	3.21	300	880
Triumfetta rhomboidea Jacq.		3.84	-	175	300
Grewia similis K. Schum.		2.61	2.57	-	380
Grewia spp.		-	-	-	40
Heteromorpha trifoliata (H.L. Wendl.) Eckl. & Zeyh	Umbelliferae	0.76	-	62.5	-
Vitex strickeri Vatke & Hildebrandt	Verbenaceae	-	3.53	-	460
Lantana camara L.		3.23	3.05	275	-
Clerodendrum myricoides (Hochst.) Vatke		0.76	0.64	62.5	-

Hypoestes forskahlii, Indigofera atricephala, Setaria plicatilis and *Pellaea viridis* (Table 3).

Seedling densities

Regenerating seedlings of 31 plant species were encountered (15 in Kiangombe hill and 16 in Kianjiru hill) belonging to 18 families within the sampled areas (Table 4). The most actively regenerating species were *Ochna insculpta,* with an approximate density of over 6000 seedlings per hectare (Table 4). Other most dense seedlings were those of *Clausena anisata, Euclea divinorum, Bauhinia tomentosa, Monanthotaxis parvifolia, Millettia vatke, Uvaria scheffleri, C. molle, Pappea capensis,* and *Ludia mauritiana.* In Kiang'ombe, the densest seedlings were of *Monanthotaxis parvifolia,* while in Kianjiru hill, more dense seedlings belonged to the *Ochna insculpta* plant (Table 4).

Diversity of plants in Kiang'ombe and Kianjiru

Comparing the two hills' ecosystems, Kiang'ombe posted the highest diversity (H'= 5.12) against Kianjiru's (H'= 4.7) on the Shannon-Wiener diversity index (Table 5). More diverse vegetation types were observed in Kiang'ombe, contributing to higher species numbers (230) than in Kianjiru (162) (Table 5). In Kiang'ombe, the highest diversity was observed in grassed woodlands (KNG T3 and T6) and riverine habitats (KNG T1 and T8). In Kianjiru hill, the highest diversity was observed in the woodland habitats (KNJ T1 and T3) (Table 5).

Generally, KNJ T1 was the most diverse (H'= 4.26) and recorded the highest number of species (78) in Kanjiru hill. In Kiang'ombe hill, the moist forest (KNG T2 and T5) and fern transition zones (KNG T4 and T7) habitats recorded the least diversity. Besides, in Kianjiru hill, the least diversity was observed in the dry forest habitats (KNG T2 and T4). Overall, transect 5 of Kiang'ombe hill

Table 3. Abundance and density of herb species in Kiang'ombe and Kianjiru hills.

Species	Family	% Abundance		Density/ha	
		KNG	KNJ	KNG	KNJ
Hypoestes forskahlii (Vahl) R.Br.	Acanthaceae	2.06	5.95	3593.75	6250
Phaulopsis imbricata (Forssk.) Sweet		1.61	-	2812.5	-
Ruellia patula Jacq.		0.89	1.66	1562.5	1750
Dyschoriste hildebrandtii Lindau ex Engl.		-	2.85	-	3000
Barleria eranthemoides R.Br.		-	2.61	-	2750
Blepharis maderaspatensis Heine ex Roth		0.98	-	1718.75	-
Barleria spp.		-	1.90	-	2000
Justicia nyassana Lindau		0.62	-	1093.75	-
Ruellia prostrata (Nees) T. Anderson		0.35	-	625	-
Aspilia mossambicensis (Oliv.) Wild		-	0.71	-	750
Dyschoriste spp.		-	0.71	-	750
Thunbergia spp.		-	0.71	-	750
Justicia spp.		-	0.47	-	500
Asystasia spp.		0.08	-	156.25	-
Hypoestes aristata (Vahl) Roem. & Schult.		-	0.23	-	250
Actiniopteris dimorpha Pic.Serm.	Actiniopteridaceae	-	1.66	-	1750
Pellaea viridis (Forssk.) Prantl	Adiantaceae	2.59	0.71	4531.25	750
Pellaea longipilosa Bonap.		-	0.47	-	500
Doryopteris kirkii (Hook.) Alston		0.08	-	156.25	-
Landolphia buchananii (Hallier f.) Stapf	Apocynaceae	0.80	-	1406.25	-
Carissa bispinosa (L.) Desf.		0.08	-	156.25	-
Secamone attenuifolia Goyder	Asclepiadaceae	-	1.42	-	1500
Gomphocarpus carp		0.08	-	156.25	-
Periploca linearifolia Quart. -Dill. & A. Rich.		0.08	-	156.25	-
Secamone punctulata Decne.		0.08	-	156.25	-
Asparagus setaceus (Kunth) Jessop	Asparagaceae	0.53	-	937.5	-
Cynoglossum spp.	Boraginaceae	0.53	-	937.5	-
Cynoglossum coeruleum A.DC.		0.17	-	312.5	-
Maytenus undata (Thunb.) Blakelock	Celastraceae	0.08	-	156.25	-

Table 3. Contd.

Commelina forskalaei Vahl	Commelinaceae	-	0.23	-	250
Commelina spp.		0.08	-	156.25	-
Ageratum conyzoides L.	Asteraceae	6.09	-	10625	-
Achyrothalamus marginatus O. Hoffm.		-	4.76	-	5000
Aspilia mossambicensis (Oliv.) Wild		-	1.90	-	2000
Conyza bonariensis (L.) Cronquist		0.71	-	1250	-
Vernonia smithiana Less.		0.44	-	781.25	-
Tridax procumbens L.		0.35	-	625	-
Helichrysum spp.		0.26	-	468.75	-
Tagetes minuta L.		0.26	-	468.75	-
Vernonia schimperi DC.		0.26	-	468.75	-
Vernonia spp.		0.26	-	468.75	-
Gutenbergia cordifolia Benth. ex Oliv.		0.17	-	312.5	-
Helichrysum abietinum O. Hoffm.		0.08	-	156.25	-
Helichrysum forskahlii (J.F. Gmel.) Hilliard & B.		0.08	-	156.25	-
Helichrysum odoratissimum (L.) Less.		0.08	-	156.25	-
Vernonia aemulans Vatke		0.08	-	156.25	-
Ipomoea obscura (L.) Ker Gawl.	Convolvulaceae	0.26	-	468.75	-
Ipomoea spp.		0.08	-	156.25	-
Cyperus spp.	Cyperaceae	2.15	2.38	3750	2500
Bulbostylis spp.		1.79	-	3125	-
Cyperus pseudo-vestitus (C.B. Clarke) Kük.		-	0.71	-	750
Pteridium aquilinum (L.) Kuhn	Dennstaedtiaceae	9.94	-	17343.75	-
Pteridium spp.		4.65	-	8125	-
Clutia abyssinica Jaub. & Spach	Euphorbiaceae	0.35	-	625	-
Acalypha volkensii Pax		-	0.23	-	250
Phyllanthus fraternus Webster		0.08	-	156.25	-
Phyllanthus odontadenius Müll.Arg.		0.08	-	156.25	-
Tragiella natalensis (Sond.) Pax & K. Hoffm.		-	0.23	-	250
Panicum trichocladum K. Schum.	Poaceae	10.84	-	18906.25	-
Hyparrhenia filipendula (Hochst.) Stapf		10.03	13.09	17500	13750

Table 3. Contd.

Heteropogon contortus (L.) Roem. & Schult.		6.09	1.66	10625	1750
Setaria plicatilis (Hochst.) Engl.		1.88	2.85	3281.25	3000
Panicum spp.		2.24	1.66	3906.25	1750
Paspalum scrobiculatum L.		2.77	-	4843.75	-
Oplismenus hirtellus (L.) P. Beauv.		-	6.19	-	6500
Melinis minutiflora P. Beauv.		1.88	-	3281.25	-
Loudetia spp.		1.25	0.95	2187.5	1000
Panicum maximum Jacq.		0.53	2.85	937.5	3000
Aristida adscensionsis L.		1.43	-	2500	-
Sporobolus spp.		1.43	-	2500	-
Heteropogon spp.		-	2.85	-	3000
Eragrostis macilenta (A. Rich.) Steud.		0.80	-	1406.25	-
Sporobolus pyramidalis P. Beauv.		0.80	-	1406.25	-
Aristida adoensis Hochst.		0.71	-	1250	-
Sporobolus spp. (Vahl) Kunth		0.71	-	1250	-
Cymbopogon spp.		0.62	-	1093.75	-
Enteropogon macrostachyus K. Schum. ex Engl.		-	1.66	-	1750
Pennisetum purpureum Schumach.		0.62	-	1093.75	-
Sporobolus spicatus (Vahl) Kunth		0.62	-	1093.75	-
Hyparrhenia		0.53	-	937.5	-
Setaria sphacelata (Schumach.) Moss		-	1.42	-	1500
Brachiaria spp.		-	0.95	-	1000
Cymbopogon caesius (Hook. & Arn.) Stapf		0.35	-	625	-
Themeda triandra Forssk.		0.35	-	625	-
Cynodon spp.		-	0.71	-	750
Digitaria diagonalis (Nees) Stapf		-	0.71	-	750
Aristida spp.		-	0.47	-	500
Leucas grandis Vatke		-	0.71	-	750
Ocimum americanum L.		-	0.71	-	750
Aeollanthus repens Oliv.	Labiatae	0.17	-	312.5	-
Endostemon spp.		-	0.47	0	500
Leucas spp.		0.17	-	312.5	-
Indigofera atricephala Gillett		3.58	-	6250	-
Chamaecrista mimosoides (L.) Greene	Leguminosae	1.70	-	2968.75	-
Neonotonia wightii (Wight & Arn.) Lackey		0.44	2.85	781.25	3000

Table 3. Contd.

Stylosanthes fruticosa (Retz.) Alston		-	2.61	-	2750
Leucaena spp.		0.44	-	781.25	-
Eriosema psoraleoides (Lam.) G. Don		0.26	-	468.75	-
Chamaecrista mimo		0.17	-	312.5	-
Dolichos sericeus E. Mey.		0.17	-	312.5	-
Indigofera spp.		0.08	0.23	156.25	250
Zornia setosa Baker f.		0.08	0.23	156.25	250
Crotalaria spp.		0.08	-	156.25	-
Sida ovata Forssk.	Malvaceae	0.53	-	937.5	-
Hibiscus calyphyllus Cav.		-	0.71	-	750
Hibiscus fuscus Garcke		0.26	-	468.75	-
Dissotis spp.	Melastomataceae	0.08	-	156.25	-
Cissampelos pareira L.		-	0.71	-	750
Dorstenia spp.	Moraceae	0.08	-	156.25	-
Jasminum fluminense	Oleaceae	0.44	6.42	781.25	6750
Jasminum floribundum Fres.		-	1.42	-	1500
Jasminum spp.		0.089	-	156.25	-
Adenia gummifera (Harv.) Harms	Passifloraceae	0.26	-	468.75	-
Adenia spp.		-	0.23	-	250
Pentas parvifolia Hiern	Rubiaceae	-	5	-	5250
Richardia brasiliensis Gomes		0.71	-	1250	-
Smilax anceps Willd.	Smilacaceae	0.62	-	1093.75	-
Solanum lycopersi	Solanaceae	0.17	-	312.5	-
Waltheria indica L.	Sterculiaceae	0.53	3.33	937.5	3500
Hermannia exappendiculata (Mast.) K. Schum.		-	0.95	-	1000
Hermannia spp.		-	0.95	-	1000
Melhania spp.		-	0.23	-	250
Rhoicissus tridentata (L.f.) Wild & R.B. Drumm.	Vitaceae	0.53	-	937.5	-
Cissus rotundifolia (Forssk.) Vahl		-	0.71	-	750
Rhoicissus revoilii Planch.		-	0.71	-	750
Cyphostemma spp.		0.08	-	156.25	-

Table 4. Seedling density of plants in Kiang'ombe and Kianjiru hills.

Plant	Family	Seedling density/ha	
		KNG	KNJ
Rhus natalensis Krauss.	Anacardiaceae	-	250
Rhus longipes Engl.		156.25	0
Monanthotaxis parvifolia (Oliv.) Verdc.	Annonaceae	1093.75	0
Uvaria scheffleri Diels.		0	1250
Landolphia buchananii (Hallier f.) Stapf.	Apocynaceae	156.25	0
Maytenus heterophylla (Eckl. & Zeyh.) N. Robson.	Celastraceae	156.25	0
Combretum molle G. Don.	Combretaceae	781.25	0
Combretum zeyheri Sond.		0	250
Euclea divinorum Hiern.	Ebenaceae	156.25	2000
Erythroxylum emarginatum Thonn.	Erythroxylaceae	0	250
Euphorbia friesiorum (Hassl.) S. Carter.	Euphorbiaceae	0	250
Tragiella natalensis (Sond.) Pax & K. Hoffm.		0	250
Bridelia taitensis Vatke & Pax.		156.25	0
Croton macrostachyus Delile.		156.25	0
Drypetes gerrardii Hutch.		156.25	0
Ludia mauritiana J.F. Gmel.	Flacourtiaceae	312.5	250
Bauhinia tomentosa L.	Leguminosae	0	1750
Millettia vatke.		937.5	0
Newtonia buchananii (Baker) G.C.C. Gilbert & B.		312.5	0
Acacia mellifera (Vahl) Benth.		0	250
Senna singueana (Delile) Lock.		156.25	0
Strychnos madacascariensis	Loganiaceae	0	500
Ochna insculpta Sleumer.	Ochnaceae	312.5	6500
Jasminum floribundum Fres.	Oleaceae	312.5	0
Pittosporum viridiflorum Sims.	Pittosporaceae	0	250
Cassipourea malosana (Baker) Alston.	Rhizophoraceae	0	500
Rothmannia fischeri (K. Schum.) Bullock.	Rubiaceae	0	250
Clausena anisata (Willd.) Benth.	Rutaceae	625	1750
Vepris simplicifolia (Engl.) Verd.		0	500
Pappea capensis Eckl. & Zeyh.	Sapindaceae	0	750
Dodonaea viscosa (L.) Jacq.		0	500
Haplocoelum inopleum Radlk.		156.25	0

(KNG T5) recorded the least diversity of (H'=3.2) as well as the lowest number of species (29) (Table 5).

Species similarity

Non-metric multidimensional scaling (MDS) of plots was used to observe species similarity levels in the two hills' sampled sites. In this study, the similarity between plots seemed to be defined by the vegetation classification of the sampled areas (Figure 8). Plots of Kianjiru hill formed a distinct cluster (encircled with red) compared to those of Kiang'ombe hill that were more variable and widely dispersed (Figure 8). Besides, the moist forest and fern vegetations of Kiang'ombe were the most unique. In Kiang'ombe hill, the grassed woodland habitat slightly overlapped with the riverine vegetation.

Botanical uniqueness

It was noted that *Vepris glandulosa*, observed in

Table 5. Diversity, Evenness, Tree Basal Area and Densities/Ha of plants in Kiang'ombe and Kianjiru hills.

Parameter	KNG	KNJ	KNG T1	KNG T2	KNG T3	KNG T4	KNG T5	KNG T6	KNG T7	KNG T8	KNJ T1	KNJ T2	KNJ T3	KNJ T4	KNJ T5
Species No. per site (S)	230	162	54	42	61	40	29	54	43	54	78	49	66	53	56
Diversity H' (Log e)	5.12	4.73	3.86	3.61	3.99	3.59	3.26	3.90	3.63	3.90	4.26	3.78	4.08	3.85	3.89
Evenness (J')	0.94	0.93	0.97	0.97	0.97	0.97	0.97	0.98	0.96	0.98	0.98	0.97	0.97	0.97	0.97
Tree Basal Area (M^2)	721.6	181.1	5.8	167.5	12.9	2.9	139.5	2.7	2.8	61.9	39.3	14.8	19.4	19.1	28.6
Tree Density/ha	437	473	663	875	300	131	663	231	269	363	438	581	363	331	544

KNG: Kiang'ombe hill; KNJ: Kianjiru hill; T1-T8: transects.

Kiang'ombe moist forest habitat (KNG T5), and *E. friesorum*, encountered in Kianjiru woodland (KNJ T1 and T3) and dry forest habitat (T4), are endemic to Kenya (Table 6). Additionally, *V. glandulosa* was found to be listed as endangered, while *E. friesorum* was found to be vulnerable, according to the IUCN (Table 6). *Dyschoriste keniensis,* which was encountered outside the two studied hills' sampled sites, has been described only recently, and its information is scanty; however, we speculate it is a rare and endemic plant species. *M. parvifolia* was recorded in Kiango'mbe riverine habitats (KNG T1 and T4) and Kianjiru dry forest (KNJ T2 and T4), and woodland (KNJ T5) habitats (Table 6).

Biodiversity threats facing the existence of plants in Kiangombe and Kianjiru hills

Grazing domestic animals within the forests was observed as one of the most common causes of biodiversity disturbance in nearly all sites (Figure 9). Other human activities, including wood harvesting, charcoal kilns, hunter snares, and numerous paths crisscrossed most of the sampled plots, were observed (Figure 9). In Kiag'ombe hills, many pipes used to tap water from the hills to the surrounding homes were evident. In most mid-altitude zones of the hills, incidences of erosion caused by floodwater were noted. A previous forest fire was noticed at the forest edge on transect two of Kiang'ombe hill. Besides, past human settlements or encroachments were observed in both Kiango'mbe and Kianjiru hills. Debarking several plant species, probably for medicinal use, was also observed in the two study sites. *Vepris simplisifolia* was extensively harvested and used for making handles for hoes and Jembes and as walking sticks. Moreover, *G. subcordata* was extensively harvested, and its bark used as ropes for house constructions.

DISCUSSION

The ever-increasing human population, which requires more land space for dwelling, and climate change, pose a threat to biodiversity in natural forests (Gereau et al., 2016; Service, 2019). Furthermore, human activities and the overexploitation of forest products is the primary cause of biodiversity loss, especially in the studied regions (Government of Kenya, 2013; Maluki, 2007; Nyawira, 2019; Scanes, 2018). The lack of awareness and insufficient documentation on the existing plants and their value hinders the establishment of conservation measures. As a result, there is a potential threat of extinction of various plants and the loss of biodiversity if mitigation measures are not implemented, thereby adversely affecting the natural ecosystem (Corlett, 2016; Gonçalves-Souza et al., 2020). Therefore, we sought to establish the species composition, diversity, abundance, and possible biodiversity disturbances threatening the plants' survival in the natural habitats of Kiang'ombe and Kianjiru hills, Embu County, as a framework for conservation efforts aimed at averting loss and extinction of valuable plants.

Previous research shows that the Poaceae family is the fifth most diverse among the flowering plants, after Asteraceae, Orchidaceae, Fabaceae, and Rubiaceae, and the most diverse among the monocotyledons (Finot et al., 2018). The present findings revealed that plants of the Poaceae family were the most diverse and predominant in the two studied sites (Kiang'ombe and Kianjiru hills), demonstrating high abundance. In this study, more tree species were encountered than herbs, shrubs, seedlings, and climbers, thus strengthening the characterisation of the general ecosystems of the study sites as woodlands. This concurs with previous findings of a survey that classified Kiang'ombe as a wood land hill forest (Maluki, 2007). As expected, more herbs were recorded in transects characterised as open

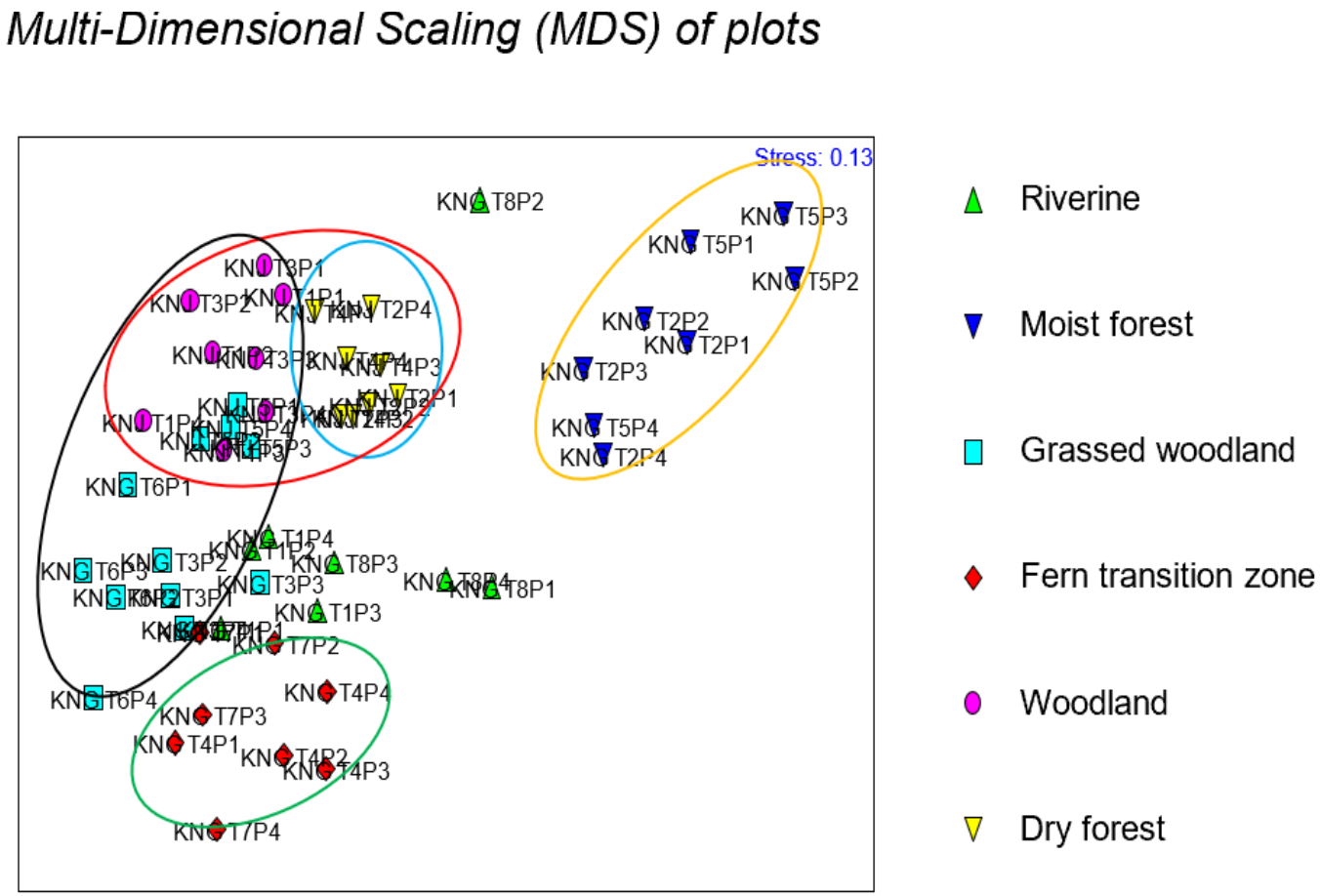

Figure 8. Similarity level the vegetation of Kiang'ombe and Kianjiru hills based on Multidimensional Scaling (MDS) of plots.

Table 6. Botanically unique species in the studied sites and their threat status.

Species	Family	Endemic/Conservation	IUCN status	Source/Reference
Vepris glandulosa	Rutaceae	Kenyan endemic	Endangered	EA; IUCN 1997, UFT (VOL 1 NO 3) 1988; FTEA, 1982; KTSL
Euphorbia friesorum	Euphorbiaceae	Kenyan endemic	Vulnerable	EA; IUCN 1997; FTEA, 1988; KTSL; UKWF2
Dyschoriste keniensis	Acanthaceae	Kenyan endemic? newly described	Vulnerable	EA; IUCN 1997; FTEA, 1988; KTSL; UKWF2
Monanthotaxis parvifolia ssp. *kenyensis*	Annonaceae	Kenyan endemic.		

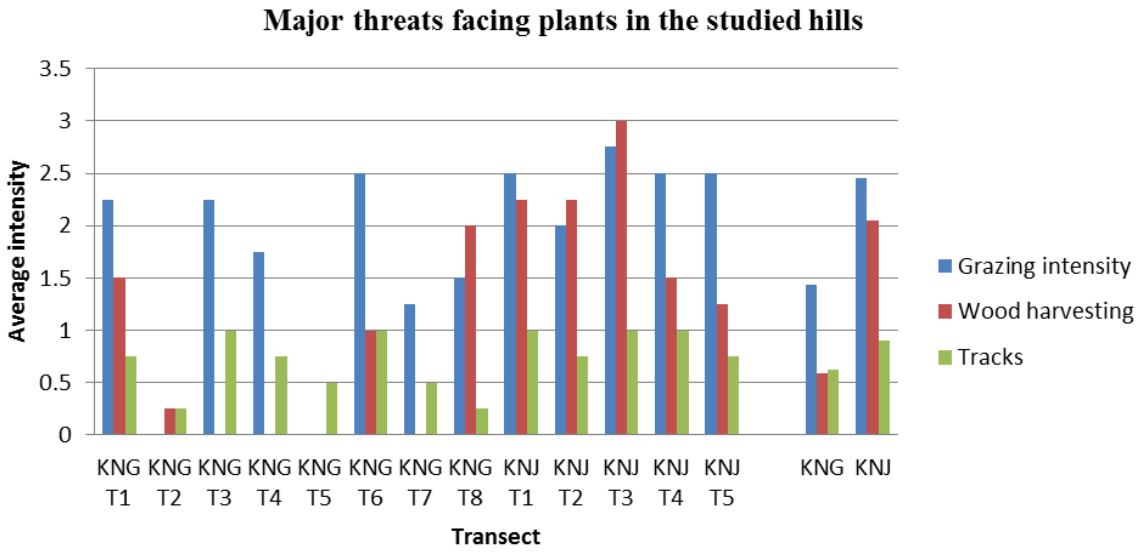

Figure 9. Major biodiversity threats facing plants of Kiang'ombe and Kianjiru Hills.

canopy compared to those with a closed canopy. Open Canopy allows for more sprouting of herbaceous vegetation.

Kiang'ombe had a higher diversity index (H'=5.12) than Kianjiru (H'=4.73). The high species diversity of Kiang'ombe was attributed to its high species richness since species diversity increases with increased species richness (Okpiliya, 2012). The highest diversity in both hills was recorded in woodlands and the riverine habitats. This finding was attributed to the open nature of woodlands and riverine habitats that allowed herbaceous vegetation to sprout, thus boosting biodiversity. The least diversity was recorded in the moist forest habitats of Kiang'ombe. This was attributed to its canopy cover that consequently hinders the undergrowth vegetation.

Identification of tree regeneration patterns is mainly based on structural analysis (size and age) in a population (Rocky and Mligo, 2012). More stems were recorded in Kianjiru as compared to Kiang'ombe. However, the dendrogram depicted an inverse J' shape in both hills, typical of all types of forests, particularly in the logged-over forest, where small trees emerge due to canopy opening in the forest area (Kunwar and Sharma, 1970). It is also a good indication of an actively regenerating population. The important value index has been used in various studies to show the ecological importance of species in a given ecosystem (Didita et al., 2010; Kacholik, 2014). In this study, *C. molle* had the highest IVI and was considered significant in forming the forest structure of both the Kiang'ombe and Kianjiru hills.

In the MDS scaling of plots, close distance between points on the distribution chart depicts high similarity. In this study, plots of Kianjiru formed a distinct cluster compared to those of Kiang'ombe, which exhibited a more dispersed cluster. Woodlands of both hills showed a distant similarity whose dissimilarity link could perhaps be the less grassed nature of Kianjiru. In both the riverine and grass woodland habitats, *C. molle* was the most abundant plant species. These habitats are highly disturbed, especially by frequent forest fires common to both hills due to cultural beliefs that they attract more rainfall (The Government of Kenya, 2013). However, there was a slight dissimilarity between the riverine and the woodland habitats, probably due to the presence of species unique to woodlands habitats such as *C. africana, Combretum zeyheri, T. tomentosa, Grewia tembensis, P. aquilinum* and *H. filipendula*. Moist forest and fern transition zones of Kiang'ombe were the most unique when compared with other vegetation types. In the moist forest zone, *X. monospora* was the most dominant trees species. This species is described as an interior species which thrives best in native African submontane moist forest (Lehouck et al., 2009).

The presence of fern usually denotes past environmental disturbances because they are very responsive to changes in abiotic factors (Leão and Schmitt, 2015). Consequently, the presence of a fern transition zone in the Kiang'ombe hill forest could confirm past disturbances that promoted the growth of these invasive species. *T. tomentosa* was the most dominant species in the fern transition zone. A previous study by Mathooko et al. (2012) indicates that *T. tomentosa* is an invasive shrub that thrives best in moist disturbed habitats. Also, *T. tomentosa* and *P. aquilinum* have been reported to dominate the disturbed habitats of Mount Kenya forest and are indicators of prior biodiversity disturbance (Kenya Wildlife Service, 2010).

V. glandulosa is one of the endangered species encountered in the Kiang'ombe hill forest. This is a shade-loving lower canopy tree species, which is also

found in Muguga, Nyeri, Limuru, and all localities in Central Kenya (Mwaura and Schmidt, 2012). *Dyschoriste keniensis* was recently described, and hence very little information about it is available in the literature; however, it has been found to dominate degraded habitats (Chumchim et al., 2015). Another species encountered in this study was *Osyris lanceolata,* which is endemic to Kenya and is endangered by overexploitation and thus currently the subject for domestication and conservation. The presence of some endangered and vulnerable species in the two hills calls for strategic measures geared towards conservation.

Climate change, environmental degradation, overexploitation, invasion by alien species, plants, and lack of proper documentation threatens the existence of valuable plants' diversity in their natural habitats, thereby increasing chances of extinction if not mitigated (Díaz-Reviriego et al., 2016). The impacts of climate change are unprecedented, pervasive, and unpredictable (Corlett, 2016). Research has indicated that habitat loss due to human activities such as pastoralism and overexploitation are the major threats to diversity (Corlett and Primack, 2011; Corlett, 2016). Habitat loss by converting forests to pastures and overexploitation through timber and medicinal plant harvesting are among the main contributors to the extinction of plant species (Gonçalves-Souza et al., 2020; Scanes, 2018). Indeed, grazing of domestic animals was one of the major forms of biodiversity disturbance noted in the two studied hills, which threaten the survival of grass species, especially those that are highly palatable but less resistant to high grazing intensities. However, it was observed that plants of the *Eragrostis* genus were the most dominant among the Poaceae family, probably due to their high resistance to intense grazing by animals (Mganga et al., 2015).

There is a need to educate the local communities on the importance of the forest and the need to conserve them. This is critical since the plants in this hill are prone to threats of biodiversity loss, including intensive grazing, charcoal burning, forest fires, and tree harvesting. Deep gullies arising from soil erosion were observed in Kiang'ombe, a scenario linked to the removal of vegetation cover over the years. Previous studies have reported intensive grazing and overexploitation of woody resources in Kiang'ombe (John et al., 2015).

The study revealed that the two hills are rich in plant species and refugia for several endemic, vulnerable species that should be conserved. The checklist will provide important information for developing management plans to utilise the forest resources sustainably and conserve the rear or threatened species. The conservation of the natural habitats of plants requires concerted and coordinated strategies aimed at averting biodiversity loss (Hawkins, 2008). Some valuable approaches include developing systems for plant species inventorying and status monitoring, well-coordinated conservation practices based on *in-situ*, *ex-situ,* and *circa-situ* cultivation, and community sensitization (Chen et al., 2016).

CONCLUSIONS AND RECOMMENDATIONS

Based on the study findings, the two studied hills are endowed with various plant species in varying degrees. The plants are faced with biodiversity threats, mainly resulting from human activities. Conservational measures to avert biodiversity loss, including habitat restoration, community sensitisation and training, enactment and implementation of conservation policies. Besides, the concerned authorities should promote the protection of indigenous forests and threatened species to ensure sustainable utilisation of the forest products and heritage.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

The authors thank the botanists at the East Africa Herbarium of the National Museums for identifying and validating the botanical names of the studied plants. Further, they thank the local community in the study sites and the county government of Embu, Kenya for their goodwill and logistical support during our study.

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