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Understory Tree Composition, Diversity and Natural Regeneration Status of Uluguru Forests in Morogoro - Tanzania

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Abstract

Most of the studies on tropical forests vegetation have tended to focus on trees with a diameter at breast height (DBH) greater or equal to 10cm, and limited attention has been paid to understory. This study was conducted in Uluguru forests in Morogoro region, Tanzania, with an objective of describing the understory tree composition, diversity and natural regeneration of some threatened species in the seven surveyed forests. Sampling was done in the forests whereby classification of understory was done into three layers: seedling (individuals with height < 1m), small sapling (DBH ≤ 3 cm), and large sapling ($3 <$ DBH < 10 cm) layers. Large saplings were sampled in 20m $\times$ 20m plots, while subplots of 5m $\times$5m and 2m $\times$2m were placed at the centre of each plot for sampling small saplings and seedlings, respectively. A total of 2119 seedlings, 1798 small saplings, and 2585 large saplings belonging 91, 102, and 104 species, respectively, were recorded. Fabaceae was the most speciosefamily in all the studied compartments, and had higher familial importance value (FIV). The seedling layer had higher tree density than the large and small sapling layers, but the large and small sapling layers were more diverse than the seedling layer ($p < 0.05$).The species richness in each forest was significantly higher in the understory than overstory layer ($p < 0.034$); and the pairing was strongly positively correlated ($r = 096$, $p = 0.0003$). The Sørensen coefficients of similarities between understory and overstory ranged between 0.53–0.77, and were higher within each forest than among them. All forests revealed to have good regeneration, though it is important to understand that some species unveiled poor or hampered regeneration pattern.In summary, the understory was observed to be speciose than overstory layer; it was dominated by family Fabaceae, and the natural regeneration of the forests were good, however, some species need due attention.

Key words: *conservation, exploitation*, *IVI, regeneration, similarity, understory*

1. Introduction

Tropical forests are recognized to harbour unique biota, for both flora and fauna (Gentry, 1988; Philips et al., 1994). In sub-Saharan Africa, one of the regions of global importance as a centre of biodiversity is the Eastern Arc forests (Uluguru forests included), harbouring 1.3% and 3.7% of the global plant and vertebrate species, respectively (Myers et al., 2000). Many studies (Oliveira et al., 1999; Mrema, 2006; Addo-Fordjouret al., 2009; Silva et al., 2011; Kacholi et al., 2015) on tropical forests have concentrated on the overstory layer (trees with diameter at breast height (DBH) $\geq$ 10cm), whereas the understory remains the least understood despite of the fact that the understory is responsible for a high percentage of total plant diversity and inherent sustainability of tropical forests (Tchouto et al., 2006). The

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understory is an essential component of any forest ecosystem sustaining a large fraction of total community floristic diversity (Lu et al., 2011), and provides habitat and food resources for different organisms (Gentry & Emmons, 1987; Hirao et al., 2009). The understory layer can influence community dynamics and succession patterns (Royo & Carson, 2006), contribute to nutrient cycling (Nilsson & Wardle, 2005), helps the conservation of forests, and is a vital constituent of forests aesthetic value (Bauhus et al., 2001). The understory composition, diversity and regeneration differs considerably between forest types due to various factors such as: overstory structure and composition (Sangar et al., 2008); environmental factors such as distribution of rainfall, temperature, topography, edaphic factors (*e.g.,* soil nutrients and moisture), light availability, seed viability, seed dormancy, seed predation and herbivory (Khurana & Singh, 2001; McLaren & McDonald, 2003; Enoki & Abe, 2004), succession history (Frankie et al., 2006), forest management strategies (Hart & Chen 2008; Ares et al., 2009) and forest fragmentation (Benitez-Malvido, 1998).

Uluguru forests are facing a number of problems, including destruction by fire, deforestation, fragmentation, and encroachment by local people for farmlands and establishment of settlements as a result of increasing anthropogenic population pressure by the community living nearby (Kacholi, 2013). The increasing population has resulted into unsustainable utilization of the forests; and poor cultivation methods such as shifting cultivation. Such activities accelerate soil erosion and land degradation, leading to low crop productivity of the agricultural land, which consequently promote illegal annexing of forestlands for habitation and cultivation (Burgess et al., 2002; Temu & Andrew, 2008). Although, understory is very sensitive to forest degradation and fragmentation (Muthuramkumar et al., 2006), the status of understory vegetation in face of fragmentation in Uluguru is lacking. Assessing the understory layer is an important measure of tree quantity, composition and regeneration in forests, which impacts future canopy structure and composition. Moreover, the presence of regenerating trees in the understory layer is an imperative for continuing forest succession when natural disturbances like winds, storms, and fire create gaps or eliminate the majority of the canopy trees.

This study aimed to: (1) determine and compare composition, diversity and density of seedling, small sapling and large sapling layers among the forests; (2) examine how the understory species richness differ from the overstory in the forests; and (3) assess natural regeneration status of observed threatened species and endemic or near-endemic species (according to IUCN) encountered in the forests using size class distributions (SDCs). The data for the overstory layer were taken from Kacholi et al., (2015) for comparison purposes. The results of this study are expected to increase the understanding of the Uluguru forests by presenting full outlook of their understory, and are thus fundamental for sustainable management of the forests.

2. Materials and Methods

2.1 Description of the Study Area

The Uluguru Mountains are situated about 200km West of Dar es Salaam city, and lies south of Morogoro town. The Mountainsare among the component blocks of the Eastern Arc mountains forests that stretch from the Taita Hills in southern Kenya to Udzungwa Mountain in south-central Tanzania. The Uluguru Mountains cover an area of

1, 500km^2 with an altitude ranging from 150–2630m above mean sea level. The climate is oceanic due to nearness to the Indian Ocean; with bimodal rainfall regime.The long rainy season lasts from March to May, while shorter ones last from October to December. Agriculture is the main socioeconomic activity for the people living in the villages adjacent to the forests. Only seven lowland forests (i.e. < 800m above mean sea level) were studied (Table 1). Common anthropogenic distrubances like removal of barks for medicinal purposes, tresspassing, illegal cutting of trees for timber, firewood/ charcoaling and poles for building purposes were observed in the forests.The criteria for selecting the forests were lowland forests with low anthropogenic pressure.

Table 1: List of Studied Forests, Location, Size and Altitude in Uluguru, Morogoro

Forest Name	Latitude/Longitude	Size (ha)	Altitude (m)
Kilengwe	07°29´S/37°32´E	995	182-228
Kimboza	07°00´S/37°48´E	405	300-400
Kisego	06°59´S/37°47´E	119	280-420
Milawilila	06°58´S/37°45´E	13	320-400
Nemele	07°11´S/37°46´E	8	280-500
Ngambaula	06°58´S/37°45´E	3	480-594
Gunauye	06°58´S/37°50´E	3	300-420

2.2 Data Collection

The classification of understory was done into three main layers as follows: seedling (individuals with height < 1m), small sapling (DBH ≤ 3cm), and large sapling (3 < DBH < 10cm) layers. The large saplings were sampled in 20m × 20 m plots while subplots of 5m × 5m and 2m × 2m were placed at the centre of each plot for sampling small saplings and seedlings, respectively. A total of 114 plots forlayerwere randomly established in all the forests. Kimboza, Kilengwe, Kisego, Milawilila and Nemele forest had 18 plots; while Gunauye and Ngambaula had 12 plots for each layer. In every plot and subplot, large saplings and small saplings were counted, identified and DBH was measured at 1.3m above the ground. The seedlings were also identified and counted. The identification was done to species level with an aid of forest experts from the Forest and Beekeeping Department of the Morogoro region using relevant flora identification monographs. The overstory species composition data were obtained from Kacholi et al., (2015) for comparison with the understory data from this study.

2.3 Data Analysis

The floristic diversity was determined using the species richness, Shannon-Wiener index, and Pielou's index of species evenness (Magurran, 2004). The dominance of species or family in small and large sapling layer was described by species importance values (IVI) and familial importance values (FIV) according to Curtis and McIntosh (1950) and Mori et al., (1983), respectively (see formulas (1) and (2)).The IVIs and FIVs for seedling were computed following the modified formula by Rasingam and Parthasarathy (2009) (see formulas (3) and (4)). A one-way ANOVA, followed by a Tukey's HSD post-*hoc* test were used to check for significant differences in density and diversityamong the forests. Inventory data for endemic/near-endemic and threatened species were classified into 9 size class distributions (SCDs) as follows. 1: seedlings, 2: small and large seedling, 3:10–

19.9, 4: 20–29.9, 5: 30–39.9, 6: 40–49.9, 7:50–59.9, 8:60–69.9, 9: > 70cm. This kind of classification is habitually applied to balance samples across SCDs, because the number of stems usually tend to decline with increasing diameter size (Condit et al., 1998; Lykke 1998). The species composition similarity between understory and overstory within forests was done using the Community Analysis Package IV (CAP IV) software.

$$IVI = Rf + RDe + RDo \quad \ldots\ldots (1)$$

$$FIV = RDe + RDi + RDo \quad \ldots\ldots (2)$$

$$IVI = Rf + RDe \quad \ldots\ldots (3)$$

$$FIV = RDe + RDi \quad \ldots\ldots (4)$$

Where;

$$\text{Relative Frequency (Rf)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \text{ x } 100$$

$$\text{Relative Diversity (RDi)} = \frac{\text{Number of species in a family}}{\text{Total number of species in all families}} \text{ x } 100$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Basal area of a species/family}}{\text{Total basal area of all species/family}} \text{ x } 100$$

$$\text{Relative Density (RDe)} = \frac{\text{Number of individuals of a species/family}}{\text{Total number of individuals of all species/family}} \text{ x } 100$$

3. Results

3.1 Species Richness and Diversity

A total of 2119 seedlings, 1798 small saplings and 2585 large saplings belonging to 91, 102 and 104 species in 28, 32 and 30 families, respectively, were recorded in the seven forests. Fabaceae was the most speciose family in all three layers accounting for 30.0%, 29.4% and 30.7% of the total species in seedling, small sapling and large sapling layers, respectively. This was followed by moraceae with 6.7%, 5.9% and 7.5% in the seedling, small sapling and large sapling layers, respectively (Table 3). The forests varied considerably in terms of observed species richness (Table 2), ranging from 13 species (at Nemele and Ngambaula) to 51 species (at Kilengwe) in the seedling layer, 15 species (Ngambaula) to 60 species (Kilengwe) in the small sapling layer, and 23 species (Ngambaula) to 72 (Kilengwe) in the large sapling layer. Generally, the large sapling layerwas the most speciose layerthansmall sapling and seedling layer in all the forests. The Kilengwe forest was the richestforest in all the three layers, followed by Kimboza and Kisego; while Ngambaula forest had the least number of observed species in all the layers.The observed number of tree families ranged from 10 to 21 (seedlings), 11 to 26 (small saplings); and 13 to 28 (large saplings) in the surveyed forests (Table 2). In all the studied tree compartments, the largest number of families was recorded in the Kilengwe forest, while Nemele and Ngambaula had the least number of families in the seedling and small sapling layer, respectively. Gunauye and Ngambaula were the forests with the least number of families in the large sapling layer.

Table 2: Species Richness, Families, Density and Diversity Indices of the Understory Layers in Each Forest

Location	No. of Species	No. of Family	Mean (± SE) (Individuals ha^{-1})	Shannon-Wiener (± Jack SE)	Evenness (± Jack SE)
Seedling Layer					
Kilengwe	51	21	56944 ± 6222^{ac}	3.57 ± 0.08	0.91 ± 0.02
Kimboza	43	20	76806 ± 10079^{a}	2.96 ± 0.14	0.78 ± 0.04
Kisego	33	20	45556 ± 3989^{bc}	3.07 ± 0.12	0.88 ± 0.03
Milawilila	19	13	39583 ± 4178^{bc}	2.36 ± 0.12	0.80 ± 0.04
Nemele	13	9	25833 ± 2492^{b}	2.46 ± 0.10	0.96 ± 0.04
Ngambaula	13	10	28542 ± 5334^{b}	2.41 ± 0.10	0.94 ± 0.04
Gunauye	24	10	45833 ± 5718^{bc}	3.02 ± 0.07	0.95 ± 0.02
Small sapling Layer					
Kilengwe	60	26	8756 ± 670^{a}	3.94 ± 0.05	0.96 ± 0.01
Kimboza	53	21	7556 ± 630^{ac}	3.46 ± 0.19	0.87 ± 0.05
Kisego	38	24	6156 ± 520^{bc}	3.30 ± 0.11	0.91 ± 0.03
Milawilila	24	17	5844 ± 415^{bc}	2.96 ± 0.06	0.93 ± 0.02
Nemele	18	12	4911 ± 415^{b}	2.70 ± 0.08	0.93 ± 0.03
Ngambaula	15	11	4733 ± 603^{b}	2.44 ± 0.10	0.89 ± 0.04
Gunauye	21	12	5367 ± 471^{bc}	2.92 ± 0.07	0.96 ± 0.02
Large sapling layer					
Kilengwe	72	28	550 ± 46^{ab}	4.03 ± 0.06	0.94 ± 0.01
Kimboza	55	21	646 ± 48^{b}	3.43 ± 0.09	0.85 ± 0.02
Kisego	40	19	867 ± 80^{c}	3.06 ± 0.10	0.83 ± 0.03
Milawilila	25	15	542 ± 26^{ab}	2.89 ± 0.06	0.90 ± 0.02
Nemele	24	15	394 ± 20^{a}	2.90 ± 0.06	0.91 ± 0.02
Ngambaula	23	13	383 ± 33^{a}	3.00 ± 0.06	0.96 ± 0.02
Gunauye	26	13	475 ± 62^{ab}	3.01 ± 0.07	0.92 ± 0.02

Note: Values with different letters indicate significant differences between the forests (Tukey's HSD test, $p < 0.05$).

The Shannon-Wiener species diversity indices ranged from 2.36 (Milawilila) to 3.57 (Kilengwe) in the seedling layer, whereby Kilengwe and Kisego displayed higher values of 3.07 and 3.57, respectively (Table 2). In the small sapling layer, the Shannon-Wiener index varied from 2.44 (Ngambaula) to 3.94 (Kilengwe); and in the large sapling layer, it varied from 2.89 (Milawilila) to 4.03 (Kilengwe). In all studied compartments, Kilengwe revealed to have high Shannon-Wiener diversity indices; while Milawilila forest had the least values in seedlings and large saplings layer. Ngambaula forest had the least diversity index value in the small sapling layer. The evenness values layer ranged from 0.78 (Kimboza) to 0.96 (Nemele) in the seedlings, 0.87 (Kimboza) to 0.96 (Gunauye) in the small saplings; and from 0.83 (Kisego) to 0.96 (Ngambaula).Generally, all layers in each forest revealed higher Pielou's species evenness values.

3.2 Understory Tree Density and Composition of the Forests

The density of the seedlings ($F_{(6, 107)} = 8.74$, $p < 0.0001$), small saplings ($F_{(6, 107)} = 7.18$, $p < 0.0001$) and large saplings ($F_{(6, 107)} = 11.52$, $p < 0.0001$) varied significantly between the forests (Table 2). Kimboza forest had significantly higher seedling density

thanthe rest of the forests (Tukey's HSD test, $p < 0.05$); followed by Kilengwe, Gunauye and Kisego forest, while the other forests did not differ substantially. In the small sapling layer, Kimboza and Kilengwe forests had highest density, while Nemele and Ngambaula forest had lowest density values (Table 2). In the large sapling layers, Kisego forest had significantly higher density compared to all other forests. Kimboza had significantly higher large sapling density than Nemele and Ngambaula forests ($p < 0.05$), while the remaining pairs of forests did not differ appreciably in their large sapling densities. Kimboza and Kilengwe did not differ significantly in their densities in all the three understory layers.

The top ten families accounted for 71.4% (67.0%, 75.2%), 68.3% (60.8%, 73.8%), and 73.4% (63.5%, 78.4%) of the FIV (as well as total diversity and density) in the seedling, small sapling and large sapling layers, respectively (Table 3). Fabaceae was the most species rich family in all the three layers; accounting for 29.7%, 29.4% and 30.8% of the total species in seedling, small sapling and large sapling layers, respectively. Anacardiaceae was the second dominant family with 6.2% FIV in the seedling layer, while Moraceae (5.4%) and Euphorbiaceae (6.4%) were the second in small and large sapling layers, respectively. Also, the family Fabaceae had high relative dominance in the small sapling (26.4%) and large sapling (36.1%) layers, followed by far with Rubiaceae (5.9%) and Euphorbiaceae (7.6%), respectively.

The top ten species in seedlings, small sapling and large sapling layers accountedfor 41.3% (46.6%, 35.9%), 39.2% (41.5%, 34.0%) and 42.8% (45.3%, 35.6) of the total IVI (as well as total density and frequency), respectively (Table 4). In terms of relative dominance, the top ten species in small and large sapling accounted for 42.5% and 47.7%, respectively. *Sorindeiamadagascariensis, Scorodophloeusfischeri, Diospyrossquarrosa* and *Ehretia amoena* were common in all the three compartments. *S. madagascariensis*, *S. fischeri* and *D. squarrosa*were the three most abundant species in the seedling layer with 8.5%, 6.3% and 5.5% of the total density, respectively. The most frequent species in the seedling layer were *S. madagascariensis*with 5.9% relative frequency, followed by *Oxyanthusgoetzei* (4.7%), *D. squarrosa* (4.6%)as well as *S. fischeri* and *E. amoena* with 3.9% each. Of the total recorded seedling species, 47% were rare species with only 2-10 individuals, while 6% were very rare each having only 1 individual. For small saplings, *E. amoena*, *O. goetzei* and *S. madagascariensis* were the most abundant and frequent species accounting for 5.8%, 5.5% and 5.3% of the total density; and 4.7%, 5.0% and 4.4% of the total occurrence in all the forests, respectively. 52% of small sapling species were rare with 2–10 individuals, and 4% of species were very rare with only 1 individual. *S. madagascariensis, E. amoena, S. fischeri* and *Margaritariadiscoidea*were the most abundant species in the large sapling layer with 7.5%, 5.6%, 5.5% and 5.3% of the total density of all the forests, respectively. *E. amoena, S. madagascariensis,* and *Margaritaria discoidea* were the most frequency in the large sapling layer with 4.8%, 4.4% and 3.9% relative frequency, respectively. 44% of recorded species in the large sapling layer were rare with 2-10 individuals while 6% of all species were very rare with only 1 individual. In terms of relative dominance, *Albizia versicolor* and *E. amoena* dominated the large and small sapling by 11.4% and 5.8%, respectively.

Table 3: Top Ten Families with the Highest FIVin the Three UnderstoryLayers of the Studied Forests

Family	No. of species	RDi	RDe	RDo	FIV
Seedling Layer					
Fabaceae	27	29.7	26.2	-	56.2
Anacardiaceae	3	3.3	9.6	-	12.9
Moraceae	6	6.6	5.9	-	12.6
Combretaceae	5	5.5	4.6	-	10.1
Apocynaceae	4	4.4	5.4	-	9.8
Annonaceae	4	4.4	5.3	-	9.8
Sterculiaceae	4	4.4	4.4	-	8.8
Ebenaceae	2	2.2	6.1	-	8.4
Meliaceae	2	2.2	5.2	-	7.4
Euphorbiaceae	4	4.4	2.5	-	6.9
∑ 1 - 10	61	67.0	75.2	-	142.9
∑ 11 - 28	30	33.0	24.8	-	57.1
Total	**91**	**100.0**	**100.0**	-	**200.0**
Small Sapling Layer					
Fabaceae	30	29.4	27.3	26.4	83.1
Moraceae	6	5.9	5.3	5.0	16.2
Apocynaceae	5	4.9	6.1	5.2	16.2
Rubiaceae	4	3.9	6.2	5.9	16.0
Anacardiaceae	3	2.9	6.1	6.3	15.3
Sterculiaceae	5	4.9	4.7	4.0	13.6
Boraginaceae	1	1.0	5.9	5.7	12.6
Ebenaceae	2	2.0	4.7	4.4	11.1
Sapindaceae	2	2.0	4.4	4.2	10.6
Annonaceae	4	3.9	3.2	3.2	10.3
∑ 1 - 10	62	60.8	73.8	70.4	205
∑ 11 - 32	40	39.2	26.2	29.6	95
Total	**102**	**100.0**	**100.0**	**100.0**	**300.0**
Large Sapling Layer					
Fabaceae	32	30.8	30.9	36.1	97.8
Euphorbiaceae	5	4.8	6.7	7.6	19.1
Moraceae	6	5.8	7.2	6.0	19.0
Anacardiaceae	3	2.9	8.1	6.9	17.9
Ebenaceae	2	1.9	5.6	5.2	12.7
Bignoniaceae	3	2.9	4.9	3.9	11.7
Boraginaceae	1	1.0	5.6	4.8	11.4
Apocynaceae	4	3.8	3.9	3.1	10.8
Combretaceae	5	4.8	2.8	2.4	10.0
Annonaceae	5	4.8	2.8	2.2	9.8
∑ 1 - 10	66	63.5	78.4	78.3	220.2
∑ 11 - 30	38	36.5	21.6	21.7	79.8
Total	**104**	**100.0**	**100.0**	**100.0**	**300.0**

Note: (RDi = Relative Diversity, RDe = Relative Density, RDo = Relative Dominance and FIV = Family Importance Value)

Table 4: Top Ten Species with Highest IVI in the Seedling, Small Sapling and Large Sapling Layers

Species	RDe	Rf	RDo	IVI
Seedling Layer				
Sorindeiamadagascariensis DC.	8.5	5.9	-	14.4
Scorodophloeusfischeri (Taub) J.Leon	6.3	3.9	-	10.2
*Diospyrossquarrosa*Klotzsch.	5.5	4.6	-	10.1
*Oxyanthusgoetzei*K.Schum.	4.4	4.7	-	9.1
*Ehretiaamoena*Klotzsch.	4.3	3.9	-	8.2
Khaya anthotheca (Welw.) C. DC.	4.7	1.7	-	6.4
Xylopiaparviflora (A. Rich.) Benth.	3.8	2.4	-	6.2
Dichrostachscinerea Wight et Arn.	3.7	2.5	-	6.2
Markhamiazanzibarica (Bojer ex DC.)	2.5	3.5	-	6.0
*Dombeyanatalensis*Sond.	2.8	2.9	-	5.7
∑ 1 - 10	46.6	35.9	-	82.5
∑ 11 - 91	53.4	64.1	-	117.5
Total	**100.0**	**100.0**	-	**200.0**
Small Sapling Layer				
*Ehretiaamoena*Klotzsch.	5.8	4.7	5.8	16.2
*Oxyanthusgoetzei*K.Schum.	5.5	5.0	5.6	16.1
Sorindeiamadagascariensis DC.	5.3	4.4	5.7	15.4
Albizia glaberrima (Schum & Thonn.)Benth.	4.7	3.4	4.8	12.9
Scorodophloeusfischeri (Taub) J.Leon	4.6	3.4	4.2	12.3
*Voacangaafricana*Stapf.	3.6	3.4	3.9	10.9
*Diospyrossquarrosa*Klotzsch.	3.6	3.2	3.5	10.4
*Dichrostachscinerea*Wight et Arn.	3.3	1.8	3.4	8.5
Strychnosspinosa Lam.	2.7	1.9	3.2	7.8
*Deinbolliaborbonica*Scheff.	2.4	2.7	2.3	7.3
∑ 1 - 10	41.5	34.0	42.5	117.9
∑ 11 - 102	58.7	66.0	57.5	182.4
Total	**100.0**	**100.0**	**100.0**	**300.0**
Large Sapling Layer				
*Sorindeiamadagascariensis*DC.	7.5	4.4	6.2	18.1
*Albizia versicolor*Welw. exOliv.	2.6	2.5	11.4	16.5
*Ehretiaamoena*Klotzsch.	5.6	4.8	4.9	15.3
Scorodophloeusfischeri (Taub) J.Leon	5.5	3.7	4.6	13.8
Margaritariadiscoidea (Baill)G.L.Webster	5.3	3.9	4.4	13.6
*Diospyrossquarrosa*Klotzsch.	4.3	3.4	3.8	11.5
Markhamiazanzibarica (Bojer ex DC.)	4.3	3.5	3.3	11.1
Albizia glaberrima (Schum & Thonn.)Benth.	3.9	3.5	3.6	11.0
Antiaristoxicaria (Pers.) Lesch.	3.3	2.9	3.0	9.3
*Millettiausaramensis*Taub.	3.1	2.8	2.5	8.4
∑ 1 - 10	45.3	35.6	47.7	128.6
∑ 11 - 104	54.7	64.4	52.3	171.4
Total	**100.0**	**100.0**	**100.0**	**300.0**

Note: (RDe = Relative Density, Rf = Relative Frequency, RDo = Relative Dominance and IVI = Species Importance Value)

The species frequency distributions (Fig. 1) show that Kilengwe, Kimboza and Kisego forests had higher species richness in the first frequency class (i.e., < 20%) in all the forest compartments while the other four forests possessed more species in the second (20–40%) and third (40–60%) frequency classes.

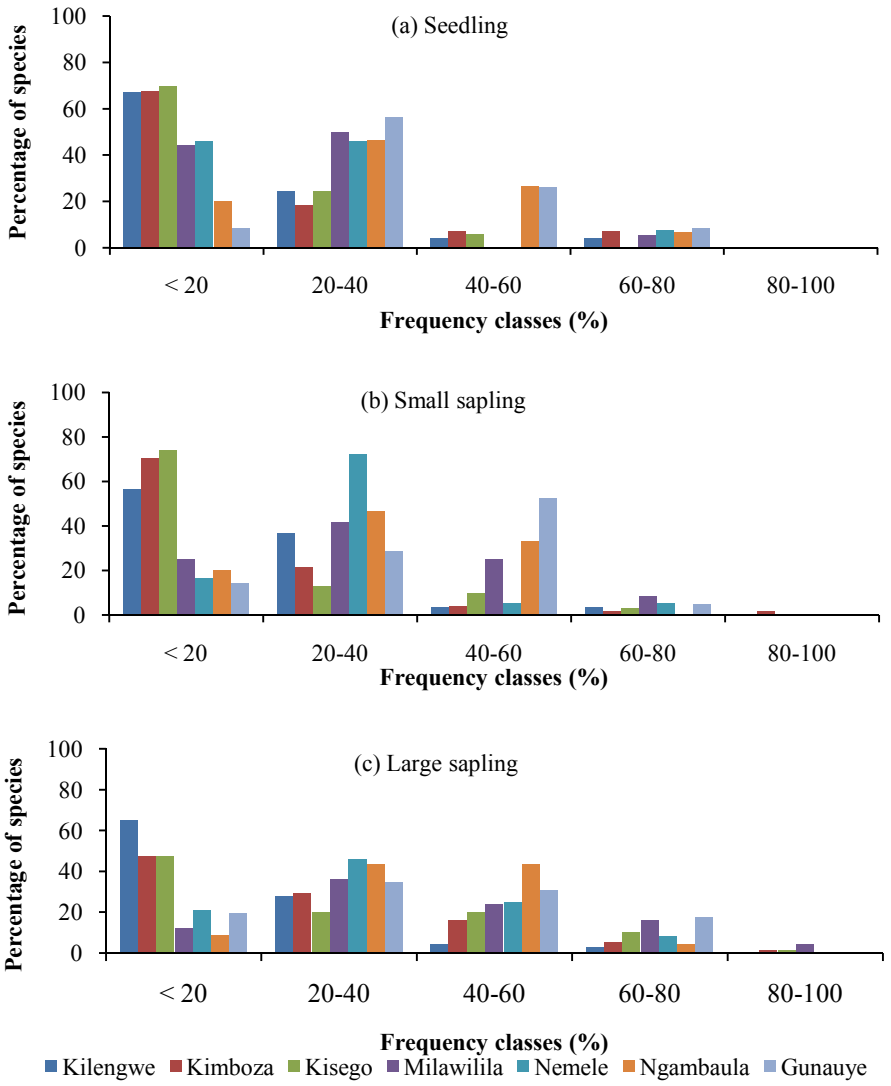


Figure 1: ***Species frequency distributions in the three forest layers in all the studied forests***

The comparison between overstory and understory revealed thatspecies richness in each of the forest was relatively higher in the understory layer than overstory (Fig. 2). Only the number of species at Kisego forest revealed to have significant difference between the two layers ($p < 0.05$). When all the forests are pooled together, the overall mean species richness of the understory layer (59 ± 9 species ha^{-1}) was significantly higher than the overstory (47 ± 10 species ha^{-1}) (Paired t test: $t = 4.05$, $d.f = 6$, $p = 0.0034$); and the pairing was strongly positively correlated ($r = 0.96$, $p = 0.0003$). Comparison of floristic similarity coefficients between overstory and understory layers within forests ranged from 0.53 (Kisego) to0.77 (Kilengwe), wherebythe cluster reveals that similarity between the overstory and understory is higher within each forest than among the forests (Fig. 3).

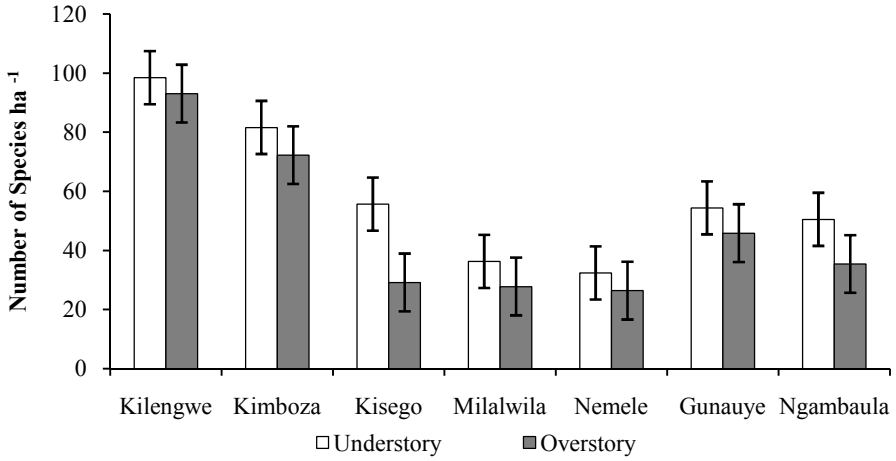


Figure 2: ***Comparison of species richness between overstory and understory layers within each studied forest in Uluguru.***

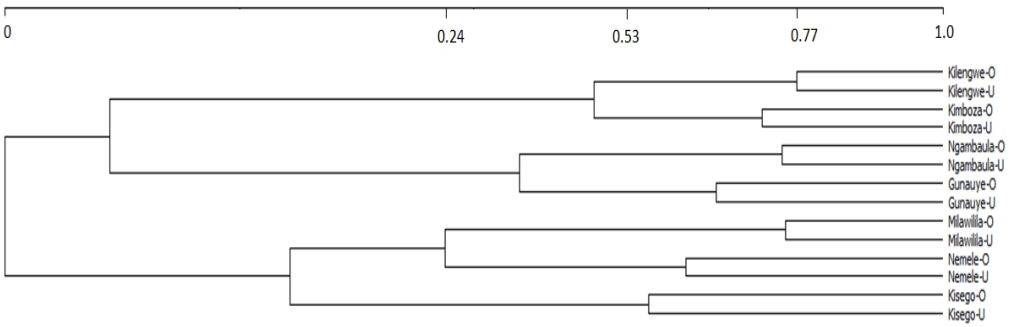
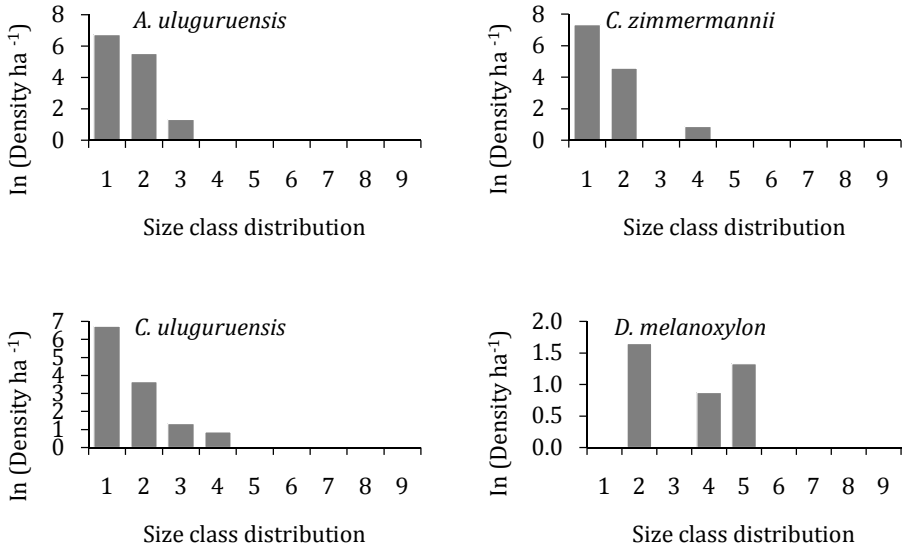


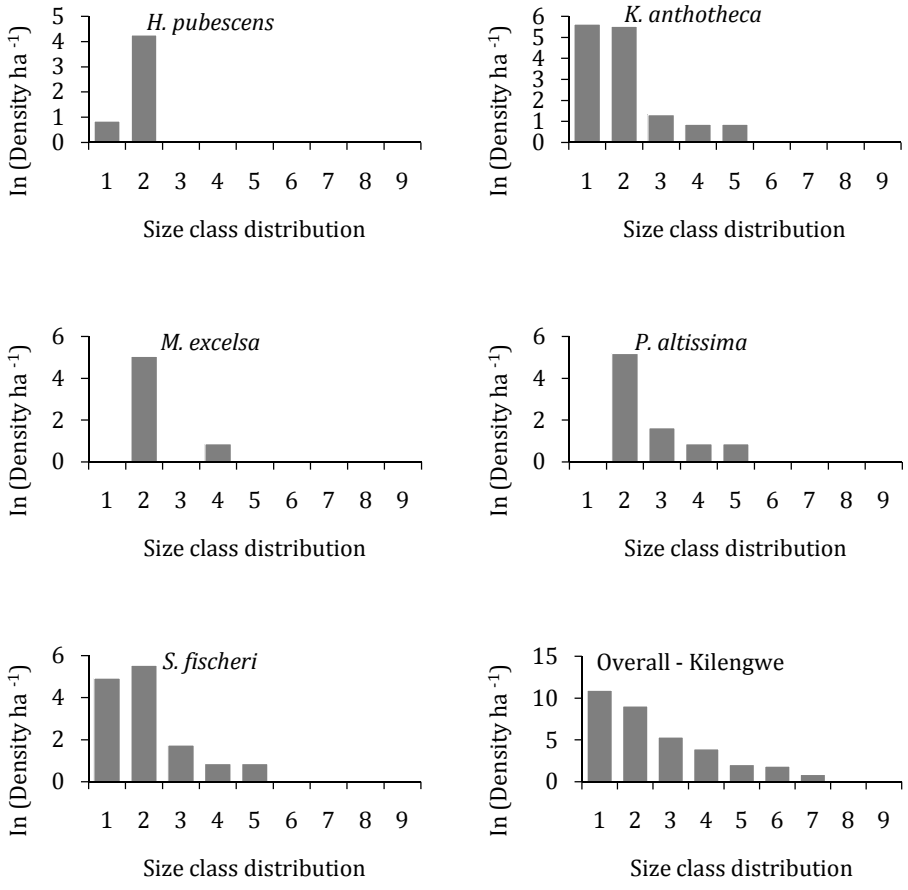
Figure 3:*Dendrogram showing floristic similarity between overstory and understory within and among the Uluguru studied forests (letter O indicates Overstory layer and U indicates understory layer).*

3.4 Natural Regeneration

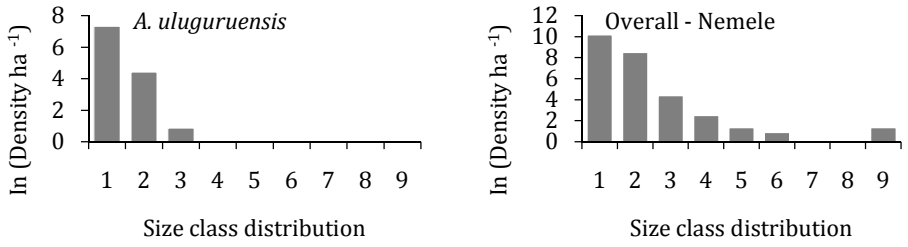
The size class distributions of species (Fig. 4) unveiled both good and poor regeneration. For those species that possessed higher density in the lower size classes and displayed an inverse J–curve suggest that they have good regeneration. On the contrary, species that had no or low density in the first size class indicate poor regeneration status. For instance, *S. fischeri*showed good regeneration in all the forests where it was observed, although, at Kilengwe forest, it was somehow hampered. *Khaya anthotheca* showed good regeneration at Kimboza, Kilengwe and Ngambaula forests. *Allanblackiauluguruensis* revealed good regeneration at Kilengwe and Nemele, but was hampered at Milawilila forest. Other species that showed good regeneration patterns are *Holarrhenapubescens (*Kimboza), *Cussoniazimmermannii* and *Cynometrauluguruensis (*Kilengwe), and *Milicia excelsa (*Kisego). Many species that showed good regeneration were hampered in medium to higher size classes. Species that showed poor regeneration include *Dalbergiamelanoxylon*, *C. uluguruensis, Pterocarpusangolensis*, *Pandanus rabaiensis*, and *Millettiasacleuxii* at Kimboza, *Pouteriaaltissima, M. excelsa, H. pubesciens,* and *D. Melanoxylon (*Kilengwe), *M. excelsa* (Ngambaula), *A. Stuhlmannii*and *A. uluguruensis (*Milawilila), and *C. Zimmermannii (*Gunauye). With an exception of Milawilila and Kimboza that had individuals in all size classes, the SCD's of other forests exhibited a fairly reverse "J"-curve distribution with hampered recruitment in some higher size classes.

Kilengwe Forest

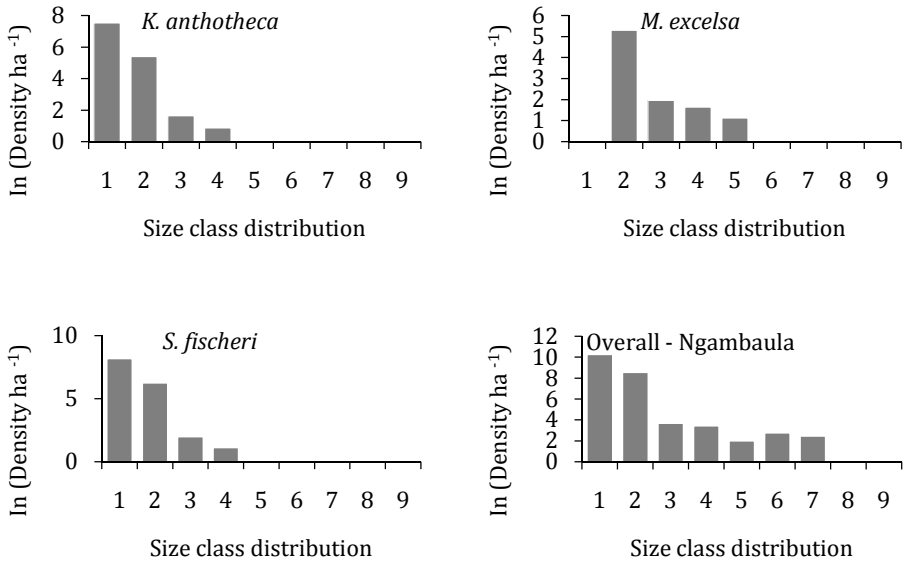




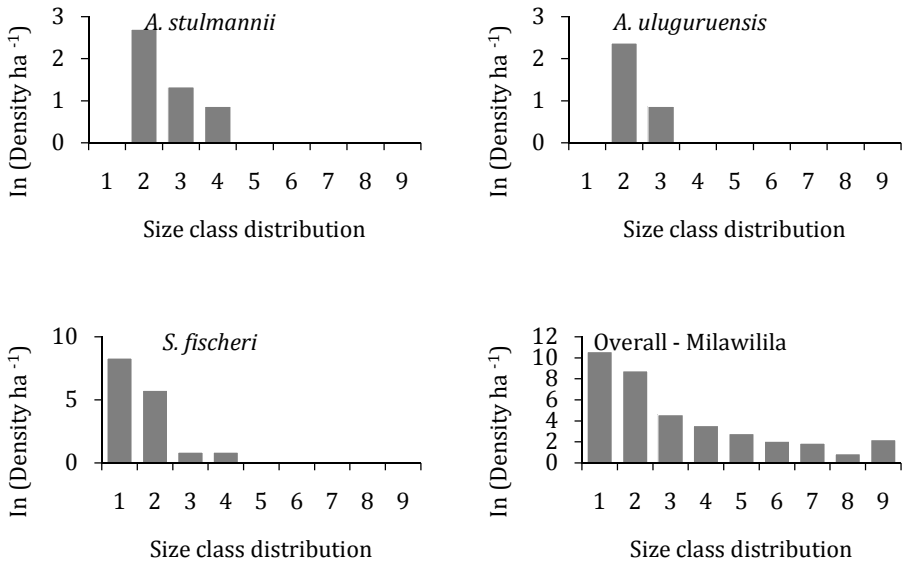
Nemele Forest



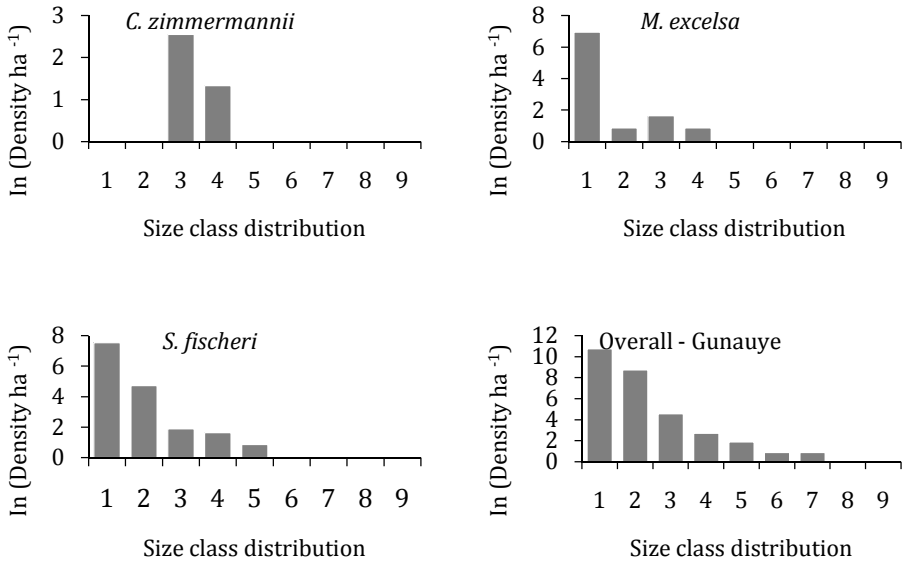
Ngambaula Forest



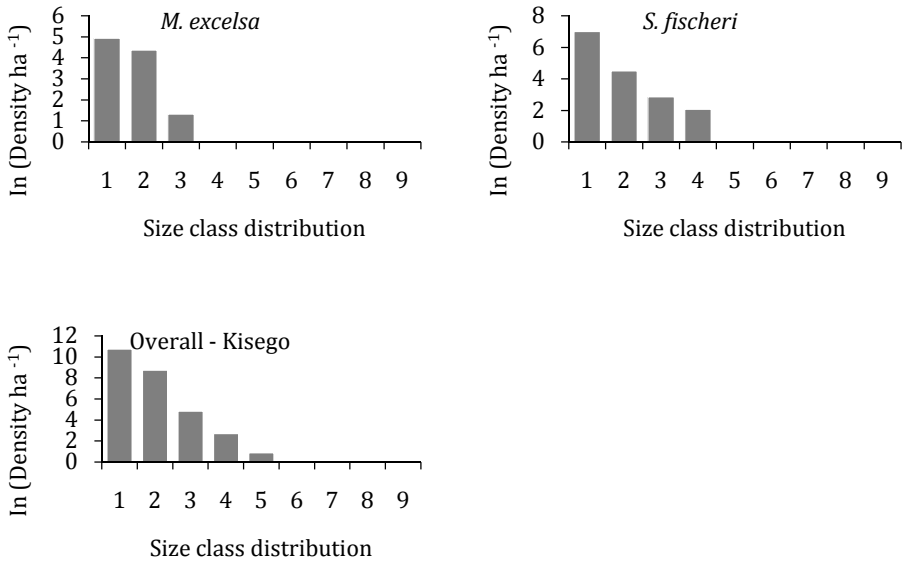
Milawilila Forest



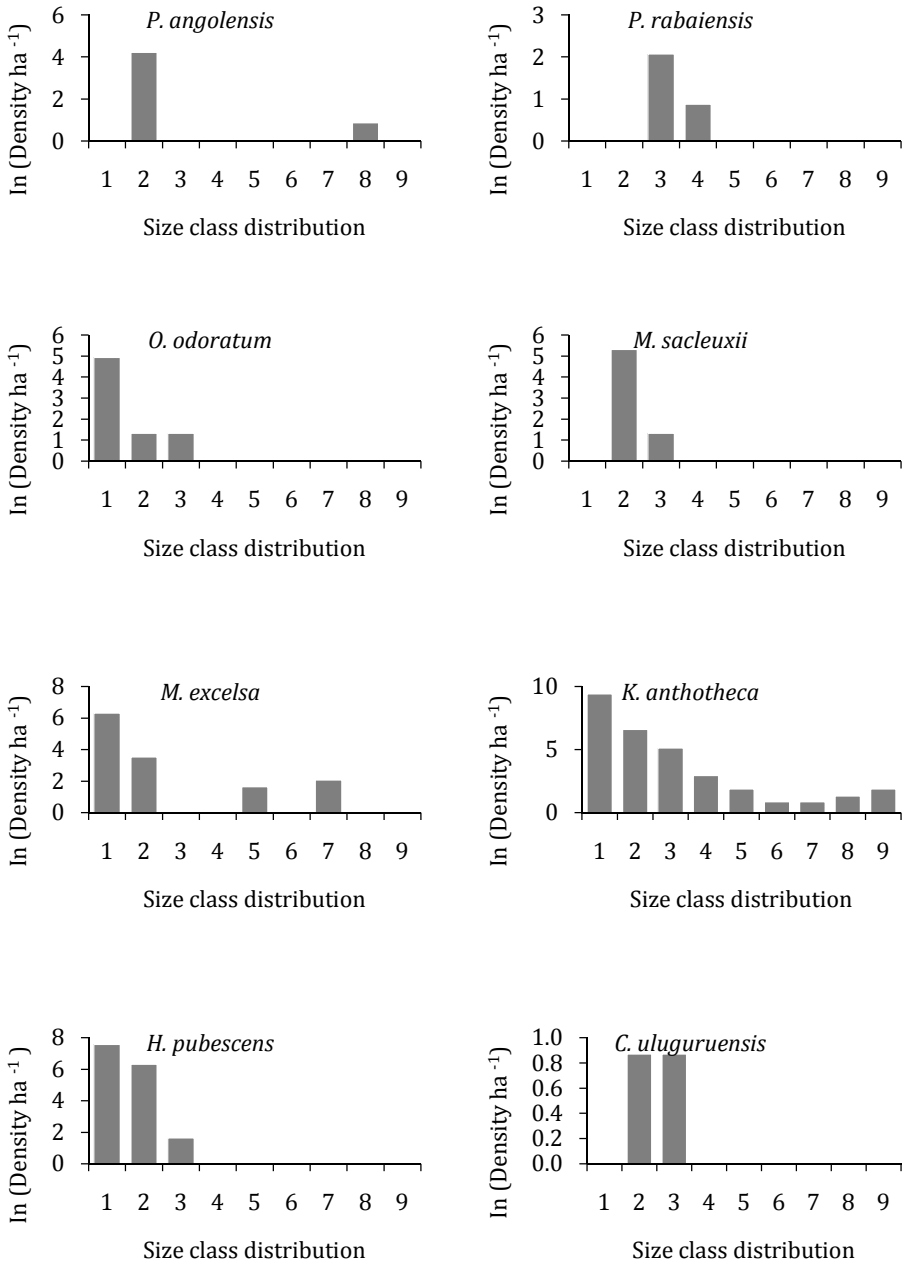
Gunauye Forest



Kisego Forest



Kimboza Forest



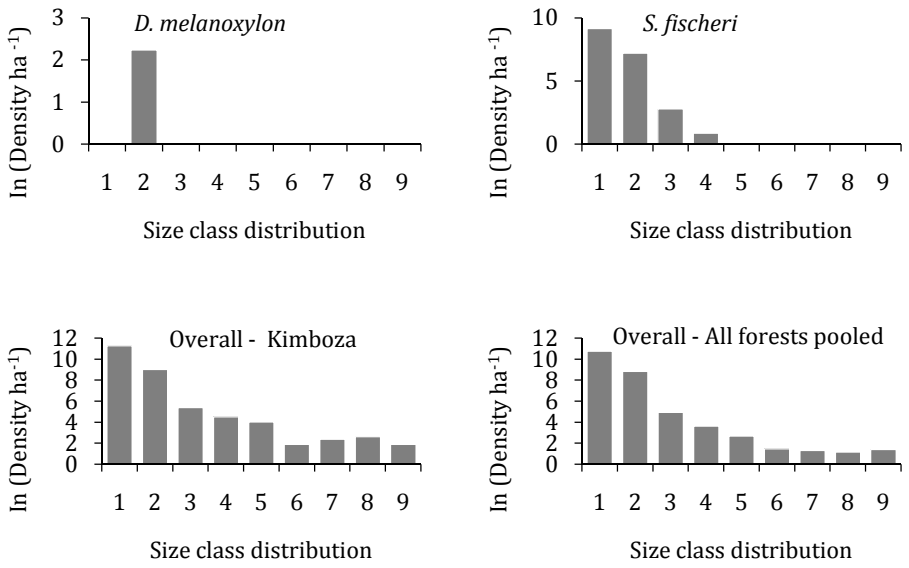


Figure 4: ***Size class distribution (SCDs) of threatened, endemic/near endemic tree species and overall SCDs of each studied forest***

4. Discussion

4.1 Species Richness and Diversity

Studying understory layer is an important step in understanding its quantity, composition and regeneration in any forest ecosystemasa measure of future canopy structure and composition. It also helps in prioritizing management strategies of a forest and conservation of species (Zegeye et al., 2006).The observed species richness and diversity indices of the large sapling layer were high than in the seedling and small sapling layer within each forest (Table 2). This could be principally attributed to the larger sampling plots used for large sapling. This is due to the fact that the larger the sampling plot used, the more species are likely to be encountered as compared to small plots (Magurran, 2004). A tropical forest community is said to be rich when it possesses a Shannon-Wiener diversity index of ≥ 3.5 (Kent & Coker, 1992). In our case, all the three compartments displayed a range of diversity values from 2.44 to 4.03, which imply that some forest layers had relatively poor diversity, and others were rich (Table 2). For instance, Kilengwe forest revealed to have high diversity values (ranging from 3.57 to 4.03) in all the layers, while the remaining forest had relatively poor diversityindices of less than 3.5. Though not studied, edaphic heterogeneity plays an important role in the maintenance of high floristic diversity as tree species are influenced by soil characteristics (Tuomisto & Ruokolainen, 2005; Ruokolainen et al., 2007), which are also influenced by forest size (Kacholi, 2013). Thus, the higher diversity values observed at Kilengwe could be attributed to its large size compared to other studied forests.

In all the forests, the evenness indices (Table 2) in large and small sapling layers were relatively high, indicating that no one species dominated a forest. However, in the seedling layer, Kimboza and Milawilila forests had the evenness index values lower than the other forests, which indicate dominance of some species. For instance, in this layer Kimbozaforestwas dominated by *K. anthotheca* with 89 individuals; while Milawilila was dominated by *Xylopiaparviflora* with 75 individuals. In contrast, no species in the seedling layer had more than 50 individuals recorded in the rest of the forests.

4.2 Frequency Distribution

The frequency distribution reflects on the dispersal patterns, and provides an approximation indication of rarity of species and heterogeneity of stands (Simon, 2002).The high floristic diversity in Kilengwe, Kimboza and Kisego forest signifies occurrence of low-abundance species across the forests. This can be seen from the frequency distribution (Fig. 1), where considerable numbers of species in these three forests are concentrated in the first lower frequency class in all layers; while the other forests had more species in the second and third frequency classes. Occurrence of more species in higher frequency classes is a good indication that a forest is characterized by common species than rare ones. Milawilila, Nemele, Ngambaula and Gunauye revealed to have more common species than rare ones. Moreover, the occurrence is attributed to habitat differences, habitat preferences among species, and low values in the higher frequency classes is an indication higher degree of environmental heterogeneity in the forests (Zegeye et al., 2006).

4.3 Comparison of Understory and Overstory

The findings from all the seven forests revealed the understory layer to be more diverse than the overstory layer (Fig. 2), which suggests that studies depending only on overstory may not reflect the overall diversity of a forest. The observed high diversity of understory may be associated with the wetter conditions provided by the overstory canopy that allows trees to be more shade tolerant, so a larger number of tree functional types could potentially survive (Huang et al., 2003). Several studies, including those by Tchouto et al., (2006) and Lu et al., (2011), have reported that the understory is more diverse than the overstory. Thus, the present study endorses that the understory deserves more attention during biodiversity inventories in the future. Moreover, the higher species compositional similarity between understory and overstory within the studied forests is an indication that the understory is influenced by overstory (Eilu & Obua, 2005). However, natural and anthropogenic disturbances can affect the species composition and diversity of the understory in different forests (Hart & Chen, 2008; Rasingam & Parthasarathy, 2009), which may have great implications for succession, dynamics as well as ecosystem function and services (Royo & Carson, 2006). In the studied forests, some anthropogenic activities like removal of the barks, tree cutting, tress passing, fire setting, uprooting young trees for medicinal purposes and encroachment were observed. Elsewhere, human activities have been reported to cause loss of overstory diversity (Zhu et al., 2004), changes of soil seed bank (Lin & Cao, 2009), habitat modification (Didham & Lawton 1999; Yan et al., 2007) and reduction of carbon storage (Li et al., 2008): all of which affect understory composition in one way or another.

4.4 Understory Density and Composition

The density of trees varied considerably in the forest layers (Table 2). The decline in density from seedling to large sapling layer is well explained by the self-thinning effect (size hierarchy - stem density relationship). Actually, the decline imply that the younger trees die at a competitive disadvantage from crowding and suppression as stand approach a limiting number of trees of a given size that can coexist within a given area.Moreover, the bigger trees use a disproportionately large amount of resources, which lead to the observed size hierarchy in natural tree populations. A substantial variation in density among species couldalso be due to habitat differences (soil moisture and nutrients), habitat preferences among the species, adaptation ability of species, degree of anthropogenic exploitation and presence of favourable environmental conditions for species regeneration (e.g., light penetration) (Richards, 1952; Tuomisto & Ruokolainen, 2005). Other factors like seed dispersal, seed viability, seed dormancy, seed predation and herbivory could also account for the differences (McLaren & McDonald, 2003; Enoki & Abe, 2004).

Fabaceae was the most dominant family with highest FIV in all the three layers mainly due to high species richness and greater abundances of the constituent species (Table 3). Similarly, the family Fabaceae were observed to dominate the overstory layer (Kacholi et al., 2015). When compared with other studies done in other lowland forests in Tanzania (Burgess & Muir, 1994; Burgess & Clarke, 2000; Mrema et al., 2006), the family Fabaceae has been reported to dominate too. Burgess and Clarke (2000) reported Fabaceae being the dominant family in the coastal forests of Tanzania by 25% to 50% of the species. In the present study, Fabaceae dominated by 29.7%, 29.4% and 30.8% of the total species in seedling, small sapling and large sapling layer respectively. Other authors elsewhere have also reported the Fabaceae family being the most dominant in their studies (Addo-Fordjour et al., 2009; Silva et al., 2011).Gentry (1988) reported family Fabaceae being the one with highest percentages of species in the lowland forests of Africa.Moraceae, Annonaceae, Apocynaceae, Ebenaceae and Anacardiaceae were also among the dominant ones not only in the overstory layer (Kacholi, 2013), but also occurredin all the three understory layers, suggesting that these families contribute strongly to the composition of these lowland forests. Among the top 10 families registered in this study were similarly reported among the most dominant families in different studies elsewhere (Mrema, 2006; Mwavu, 2007).

The species' importance value (IVI) is an important measure that tells the ecological significance of species in a given ecosystem (Lamprecht, 1989). The IVI can be used for prioritizing conservation of species (Simon, 2002) because species with high IVI value need less conservation priority compared to those with low IVI value that need high conservation efforts.From the findings (Table 4), *S. madagascariensis* had high IVI in the seedling and large sapling layers. Its dominance in seedling layer is mainly attributed by both higher density and frequency, while in large sapling layer was chiefly influenced by density. The small sapling layer is dominated by *E. amoena*, which was influenced by density of individuals. *S. madagascariensis, S. fischeri* and *D. squarrosa* occurred in all the three layers and had relatively higher frequency compared to other species, especially in seedling and large sapling compartments. The possession of high frequency by these

three species is an indication of wider range of their ecological adaptations as compared to other species. For instance, *S. fischeri*is reported to be the most common species and dominant in the coastal forests of Tanzania (Temu, 1990; Mrema, 2006). Some of the species that had less IVI value in the studied compartments are shown in Table 5. Some of these were also observed to have poor regeneration patterns, hence conservation efforts are needed.

Table 5: List of Species with LowestIVI in the Studied Forests

Species	Kilengwe	Kimboza	Kisego	Milawilila	Nemele	Ngambaula	Gunauye
Pterocarpusangolensis		+					
Dalbergiamelanoxylon	+	+					
Cynometrauluguruensis		+					
Pandanus rabaiensis		+					
Millettiasacleuxii		+					
Pouteriaaltissima	+						
Holarrhenapubescens	+						
Pterocarpusrotundifolius		+					
Zanthoxylumderemens		+					
Pseudolachnostlismaprounefolia	+						
Allanblackiastuhlmannii				+			
Allanblackiauluguruensis				+			
Milicia excelsa +	+					+	
Dalbergiaboehmii	+						
Antiaristoxicaria	+				+		
Bombaxrodognaphalon					+	+	+
Cussoniazimmermannii							+
Combretummolle		+	+				
Combretumadegonium		+	+				
Polysciasfulva			+				
Stereospurmumkunthianum		+					
Grewiagoetzeana		+					
Burkeaafricana			+				
Lonchocarpusbussei		+					
Steganotaeniaaraliaceae	+					+	+
Grewiasimilis						+	+
Sterculiaafricana		+					
Oncobaspinosa	+						+

Note: + indicate presence of species in the forest.

4.5 Natural Regeneration

The size class distributions (SDCs) of trees are used as indicators of species composition change and rejuvenation, and they help in assessing the state of populations for a variety of management purposes (Addo-Fordjour et al., 2009). The classic reverse "J"-curve represent the population that recruits fairly frequently over time, and it implies also a stable population structure (West et al., 2000; Mwavu & Witkowski, 2009). The absence of juveniles on the first size class suggests that a tree species is suffering a population decline, hence poor regeneration (Condit et al., 1998). In this study, the observed SDCs of the species displayed both good and poor regeneration patterns. The possible reasons for

some species to have poor regeneration could be anthropogenic disturbances, especially selective and illegal logging of the species, which also cause damage to sapling and seedlings when trees fall. The signs of selective removal for some species like *P. angolensis*, *Milicia excelsa, K. anthotheca,* and *D. melanoxylon*were observed in the studied forests.Moreover, the density of seedlings are influenced by the density of large trees, i.e., overstory layer (Eilu & Obua, 2005). This means thatif a tree species does not have big trees in the higher size classes, there will be no seedling of the same species.This could also be the cause for some species (like *P. angolensis, P. rabaiensis, D. melanoxylon, C. Zimmermannii* and *Milicia excelsa)* in the studied forest to have no individuals in the first size class. Other processes that affect seedling production are predation and dormancy (Janzen & Vazyuez-Yanes, 1991) while seedling recruitment processes (i.e., growth, survival and establishment) is influenced by light intensity, edaphic conditions (e.g., nutrients and moisture), as well as meteorological parameters like temperature and rainfall (Clack et al., 1999, Sasaki et al., 2008). Though these processes were not investigated in this study, they are however considered to play an important role.

The under-representation or absence of individuals in some size classes, especially the middle/higher size classes for some species, for instance, *M. excelsa, P. angolensis* and *D. melanoxylon*at Kimboza; and *C. zimmermannii, D. melanoxylon*and *M. excelsa* at Kilengwe indicate poor and/or broken/discontinuous regeneration pattern (Poorter et al., 1996). This is usually associated with regeneration failure in combination with illegal or selective exploitation for timber, poles and charcoaling. Species like *K. anthotheca*, *M. excelsa*, *D. melanoxylon* and *P. angolensis* are illegally harvested for timber by the locals at sizes below the legal minimum harvestable diameter (MHD) in most of the coastal forests of Tanzania (Ahrends, 2005; Modest et al., 2009), which also seem to affect their SCDs. The intense exploitation of small stems (i.e., poles) for building purposes has similarly been blamed for poor recruitment of some species in Kakamega forests in Kenya (Fashing et al., 2004). The lack of individuals in seedling and/or saplings size classes for some species like*D. melanoxylon, M.excelsa* and *P. altissima*atKilengwe, *M.excels (*Ngambaula), *A. stulmannii and A. uluguruensis* (Ngambaula), *C. zimmermannii* (Gunauye) and *P.rabaiensis, P. angolensis, M. sacleuxii, C. uluguruensis,* and *D. melanoxylon* (Kimboza) is clear enough to raise some doubts and questions concerning their long-term populations' survival. Usually, few seedlings and sapling individuals imply that population is unlikely to be maintained at the present level. This is due to the fact that for a species to maintain a relative constant population, more individuals are required in the smaller size classes than in larger ones (Lykke, 1998; West et al., 2002). This means that the species with no seedlings and saplings could be eliminated completely from the forests if harvesting of the mature trees in overstory layer will continue. The existence of species with poor/hampered regeneration pattern suggests the need for development of the forest conservation plans to reverse these trends and facilitate a healthy regeneration pattern.

5. Conclusion

Though most studies in tropical forest communities heavily focus on overstory layer (trees with DBH $\geq$ 10cm), this study has demonstrated that understory have high species richness than overstory, which suggests that the understory should be given

more attention.On the other hand, the overstory and understory layers revealed to have higher floristic similarity within a forest than between forests. Moreover, the findings enlighten that though the forests displayed a good regeneration pattern, there are some species that had poor/hampered regeneration and lowest IVI, thus need due attention. Considering that most of these forests are facing anthropogenic pressure, special priority should be given to conserve not only the overstory but also the understory due to its richness.

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