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Floristic Composition, Diversity and Structure of the Kimboza Forest in Morogoro Region, Tanzania

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Abstract

Kimboza forest reserve in Morogoro region, is an important biodiversity hotspot among the Eastern Arc forests of Tanzania. High population pressure and encroachment threatens its conservation values. This is based on a study which aimed at investigating the composition, diversity, and structure of the tree community in the forest. All trees with DBH ≥ 10cm were inventoried from 0.72ha in a total of 18 plots of 20m × 20m placed randomly from the forest edge to the interior. Most important families and species were determined using familial importance value (FIV) and species importance value (IVI) indices, respectively. Diversity was analyzed using species richness, Shannon-Wiener, Fisher-α, and Simpson's indices. A total of 52 species belonging to 22 families were identified. The family Fabaceae had the highest FIV (66.70) and species richness (15 species) while *Khaya anthotheca* had the highest IVI value (48.11). The Shannon-Wiener (3.40), Simpson (20.60), and the Fisher-α (18.80) indices were very high signifying high floristic diversity within the forest. 69% of the species were rare, occurring in less than 20% of the surveyed plots. The mean density and basal area of trees were 390 stems ha^{-1} and 24 m^2 ha^{-1}, respectively. The species accumulation curve revealed an escalating trend suggesting that more sample plots could result to a number of species in the forest. In summary, the study suggests for proper management, protection, and wise utilization of the forest resources so that it sustains its original biodiversity and ecological processes for future generations.

Keywords*: anthropogenic, biodiversity, importance values, species richness, density*

1. Introduction

Tropical forests are the most species-rich ecosystems that provide natural resources to help sustain nearby communities in many developing countries (Gentry, 1988). In tropical forests, tree diversity is fundamental to total biodiversity as it provides resources like food, traditional medicine, energy, timber, shade, and habitats for other organisms (Wilfred et al., 2006; Kacholi, 2013). Globally, the rapid increase in human population has increased threats of degradation and fragmentation of the forest ecosystems (FAO, 2010). Between 1967 and 2012 the population increase in Tanzania has more than tripled from 12.3 million to 44.9 million people, with 80% of them living in rural areas and depending on subsistence farming (URT, 2013). The annual population growth rate of Morogoro region is 2.4% (URT, 2013), while the annual population growth in Uluguru forest areas was reported to be 6.5% (Bhatia & Ringia, 1996). The rapid increase of population near forest areas is putting more pressure to forest

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resources due to increased demand (Madoffe et al., 2006). Tanzania has lost about 403,000ha of forest cover between 2000 and 2010 due to agricultural clearings, overgrazing, charcoaling, fuel wood harvest, fire, and timber harvest (FAO, 2010). The loss of forest cover does not only jeopardize biodiversity, but it seriously affects the ecological structure, processes, and put at risk the livelihoods of millions of people who depend on them for various uses.

Kimboza forest is a priority conservation area (IUCN category IV-habitat/species management area) as it is the home of abundant important endemic flora (e.g., *Cynometra uluguruensis, Garcinia bifasciculeta, Scorodophloeus fischeri and Ophrypetalum odoratum*) and fauna species (e.g., the blue dwarf gecko (*Lygodactylus williamsi*), which is an endemic lizard species found only on *Pandanus* tree species). Moreover, the forest has a high number of threatened species like *Khaya anthotheca, Milicia excelsa, Pterocarpus angolensis* and *Cynometra uluguruensis* (MNRT, 2004; Temu & Andrew, 2008). The forest is also known to serve scientific, educational, recreational and aesthetic interests. Some of the special sites in Kimboza forest include, Choka Wahawi (the place used to burn witches doctors and wizards during the Arab colonial era), Dogo la Njiwa (the place where doves seasonally visit for sand/soil bathing inside the cave of inclined limestone), Kimboza spring and butterfly breeding site (MNRT, 2004).

Like many other forests in Tanzania, Kimboza forest is facing a great threat of losing its biodiversity due to increased anthropogenic disturbances, which result from a rapid human population increase in the villages surrounding it. The human population puts more pressure on the ecosystems as more farmlands are needed for agriculture to increase productivity, timbers and poles for building purposes, and increasing cutting of trees for firewood and charcoaling as an energy source. Moreover, low productivity of agricultural activities promotes illegal annexing of forest lands for cultivation and habitation (Burgess et al., 2002). Such threats should not be underrated as they disturb forest and result in floristic composition and structure change (Madoffe et al., 2006; Addo-Fordjour et al., 2009). Thus, attention is needed for studies of the floristic composition and structure as they provide essential data in assessing the sustainability of the forest and the role they play in the conservation of species and management of the forest ecosystem. The objectives of this study were to: (1) determine the current status of tree species composition, species richness, and diversity; (2) assess the structure (i.e., stand density, basal area and size class distribution) of the forest; and (3) compare the findings with other forest inventories done in Morogoro region and other tropical forests at large.

2. The Study

Kimboza forest reserve is located in the eastern part of the Uluguru foothills in Morogoro region. It is about 60km from the Morogoro Municipal, between 06° 59' and 07° 02' South and 37° 47' and 37° 49' East. The forest is at an average elevation of 300 – 400m above sea level, with the size of 405ha. The forest is surrounded by four villages: Uponda to the West, Mwarazi to the East, Kibangile to the South, and Changa to the North. The forest harbours about 226 vertebrates, which include 52 amphibians and 174 mammals, and it has several flora species (MNRT, 2004). The climate of the Morogoro region is oceanic due to proximity to the Indian Ocean, with bimodal rainfall regime. The long rains last from March to May, peaking in April, and the short rains last from

October to December. The mean annual rainfall and temperature in Morogoro region is about 740mm and 25.1°C respectively. Agriculture is the main socio-economic activity in the villages surrounding the forest. Other land use practices include livestock keeping, bee-keeping, fishing, carpentry, and small scale gold mining.

All the tree species (with diameter at breast height (DBH) ≥ 10cm) were randomly sampled from 18 plots of 20m × 20m, placed from the forest edge to the forest interior. In each plot, the tree species were counted identified, and stem diameters were measured (at 1.3m above the ground) and recorded. Trees with multiple stems at 1.3m height were treated as a single individual, whereby the diameters of all stem were taken and averaged. If a tree had buttress or an abnormality at 1.3m height, the diameter was measured just above the buttress where the stem assumes near cylindrical shape. The identification was done with the help of experts from the forest department in Morogoro region.

3. *Floristic composition and structure of the forest*

The tree composition of the forest was described by family/species dominance, while the forest structure was described by stems density (stems ha^{-1}), basal area (m^2 ha^{-1}), and size class distributions (SCDs). The dominance of species was determined by the species importance value index (IVI), according to Curtis and McIntosh (1950) (*see* formula 1); while dominance of families was determined using the familial importance value index (FIV) calculated according to Mori *et al.*, (1983) (*see* formula 2). Basal area was calculated according to formula 3 below. A total of 7 size class distributions arranged in 10cm intervals was formed based on the recorded trees diameters.

$$IVI = Rf + RDe + RDo \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$IV = RDe + RDi + RDo \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Where; Rf = Relative Frequency, RDe= Relative Density,
RDo= Relative Dominance, RDi= Relative Diversity

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

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

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

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

$$\text{Basal area} = 0.00007854 \times \text{DBH}^2 \ldots\ldots\ldots\ldots\ldots\ldots 3$$

Where: DBH = Diameter at breast height in centimetre (cm)

Species richness and diversity

The number of observed species in the forest and three non-parametric richness estimators (Michaelis-Menten (MMMeans), first order Jackknife, and Chao 2) were used as measure of species richness (Magurran, 2004). These richness estimators were computed using the *EstimateS* software (version 8.2) (Collwell, 2009). Species accumulation curves were constructed for comparing the increase of the number of species with increasing sample size (Magurran, 2004). A range of commonly used alpha diversity measures (Shannon-Wiener's, Simpson's and Fisher's α- diversity) were computed using species richness and diversity IV (SDR IV) software (Seaby & Henderson, 2006).

4. *Results*

Floristic patterns at family and species level within the forest

A total of 390 stems ha^{-1} belonging to 52 species, 39 genera and 22 families were recorded in the forest reserve. The most species-rich family was Fabaceae (15 species), followed by Moraceae (5 species) and Sterculiaceae (4 species), while the remaining families had less than four species (Table 1). Fabaceae had the highest FIV, which accounted for 22.2% of the total FIV, followed by Meliaceae (15.5%) and Moraceae (13.8%). The family Meliaceae had greater relative dominance accounting for 31.5% of the total in the forest, followed by Moraceae and Fabaceae with 20.6% and 18.3%, respectively. The three most abundant families were Fabaceae, Meliaceae and Moraceae; which also possessed the highest basal area values than other families (Table 1). Bombacaceae, Bignoniaceae and Rutaceae had the lowest FIV values.

Table 1: No. of species, stem density, basal area, relative diversity, relative density, relative dominance and FIV

Family	No. of Species	Stems ha^{-1}	Basal area (m^2 ha^{-1})	Relative Diversity	Relative Density	Relative Dominance	FIV
Fabaceae	15	76.4	4.45	28.85	19.57	18.28	66.70
Meliaceae	1	51.4	7.68	1.92	13.17	31.54	46.63
Moraceae	5	43.1	5.03	9.62	11.03	20.63	41.28
Anacardiaceae	2	40.3	0.97	3.85	10.32	4.00	18.16
Boraginaceae	1	33.3	1.25	1.92	8.54	5.14	15.60
Sterculiaceae	4	16.7	0.80	7.69	4.27	3.28	15.24
Tiliaceae	2	23.6	0.88	3.85	6.05	3.63	13.53
Verbenaceae	2	18.1	0.55	3.85	4.63	2.25	10.72
Combretaceae	3	12.5	0.22	5.77	3.20	0.89	9.86
Annonaceae	2	12.5	0.30	3.85	3.20	1.23	8.28
Ebenaceae	2	9.7	0.24	3.85	2.49	1.00	7.34
Burseraceae	2	5.6	0.46	3.85	1.42	1.91	7.18
Loganiaceae	1	9.7	0.65	1.92	2.49	2.67	7.08
Euphorbiaceae	2	5.6	0.30	3.85	1.42	1.24	6.51
Pandanaceae	1	8.3	0.21	1.92	2.14	0.87	4.93
Rubiaceae	1	8.3	0.09	1.92	2.14	0.36	4.42
Cluciaceae	1	4.2	0.17	1.92	1.07	0.68	3.67
Apocynaceae	1	4.2	0.04	1.92	1.07	0.17	3.16
Salicaceae	1	2.8	0.02	1.92	0.71	0.10	2.73
Bombacaceae	1	1.4	0.02	1.92	0.36	0.06	2.34
Bignoniaceae	1	1.4	0.01	1.92	0.36	0.05	2.33
Rutaceae	1	1.4	0.01	1.92	0.36	0.04	2.32
Total	**52**	**390.3**	**24.36**	**100.00**	**100.00**	**100.00**	**300.00**

The three species with the highest IVI were *K. anthotheca* followed by *Antiaris toxicaria* and *Ehretia amoena* (Table 2), which all together contributed for 30.34% of the total IVI; while *Dombeya natalensis, Stereospermum kunthianum* and *Zanthoxylum deremens* were the species with lowest IVI (Table 2). *K. anthotheca, Sorindeia madagascariensis* and *E. amoena* were the top three abundant species; while *K. anthotheca, A. toxicaria* and *M. excelsa* had highest dominance values. The three species with the highest frequency value were *E. amoena*, *A. toxicaria* and *S. fischeri*. On the other hand, 25% and 37% of the total species occurred once and twice, respectively. The frequency distribution (Fig. 1) showed 67.3% of the total species were in the first frequency class (< 20%), while the higher frequency classes (i.e. 60–80 and 80–100) had no species.

Table 2: Relative frequency, relative density and relative dominance and IVI

Species	Relative Frequency (%)	Relative Density (%)	Relative Dominance (%)	IVI
Khaya anthotheca	3.40	13.17	31.54	48.11
Antiaris toxicaria	5.44	6.76	10.91	23.11
Ehretia amoena	6.12	8.54	5.14	19.80
Sorindeia madagascariensis	2.72	9.61	3.74	16.07
Milicia excelsa	3.40	2.85	8.84	15.09
Grewia similis	3.40	4.98	3.17	11.55
Scorodophloeus fischeri	4.76	4.27	1.07	10.11
Acacia polyacantha	3.40	2.49	2.77	8.67
Brachystegia boehmii	2.04	1.42	4.85	8.31
Strychnos spinosa	2.72	2.49	2.67	7.88
Albizia glaberrima	2.04	2.14	3.20	7.37
Vitex doniana	3.40	2.49	1.12	7.02
Dombeya rotundefalia	3.40	2.49	0.70	6.59
Premna chrisoclada	2.72	2.14	1.12	5.98
Oxyanthus goetzei	3.40	2.14	0.36	5.90
Pandanus rabaiensis	2.72	2.14	0.87	5.72
Annona senegalensis	2.04	2.49	1.09	5.62
Combretum molle	2.72	2.14	0.70	5.56
Millettia usaramensis	3.40	1.78	0.30	5.48
Sterculia quinqueloba	1.36	1.07	2.46	4.89
Dalbergia boehmii	1.36	1.42	1.03	3.82
Diospyros squirrosa	1.36	1.42	0.82	3.61
Brachystegia spiciformis	2.04	1.07	0.48	3.58
Senna siamea	1.36	1.07	0.75	3.18
Bridelia micrantha	1.36	0.71	1.05	3.12
Garcinia kimbozensis	1.36	1.07	0.68	3.11
Commiphora africana	0.68	0.71	1.69	3.08
Pterocarpus angolensis	0.68	0.36	2.03	3.07
Albizia guminifera	1.36	1.07	0.64	3.07
Grewia goetzeana	1.36	1.07	0.46	2.89
Diospyros mespiliformis	1.36	1.07	0.18	2.61
Holarrhena pubesiens	1.36	1.07	0.17	2.60
Ficus sycomorus	1.36	0.71	0.51	2.58
Mangifera indica	1.36	0.71	0.26	2.33
Commiphora eminii	1.36	0.71	0.22	2.29
Millettia sacleuxii	1.36	0.71	0.22	2.29

Drypetes gerradii	1.36	0.71	0.20	2.27
Ophrypetalum odoratum	1.36	0.71	0.14	2.21
Acacia nigrescens	1.36	0.71	0.14	2.21
Combretum stuhlmanii	1.36	0.71	0.13	2.21
Oncoba spinosa	1.36	0.71	0.10	2.17
Julbernadia globiflora	0.68	0.36	0.39	1.42
Pterocarpus rotundifolius	0.68	0.36	0.35	1.39
Ficus lutea	0.68	0.36	0.32	1.36
Sterculia appendiculata	0.68	0.36	0.07	1.11
Bombax rhodognaphalum	0.68	0.36	0.06	1.10
Cynometra ulugurensis	0.68	0.36	0.06	1.10
Ficus exasperata	0.68	0.36	0.05	1.09
Teminalia sambesiaca	0.68	0.36	0.05	1.09
Dombeya natalensis	0.68	0.36	0.05	1.08
Stereospermum kunthianum	0.68	0.36	0.05	1.08
Zanthoxylum deremens	0.68	0.36	0.04	1.08
Total	**100**	**100**	**100**	**300**

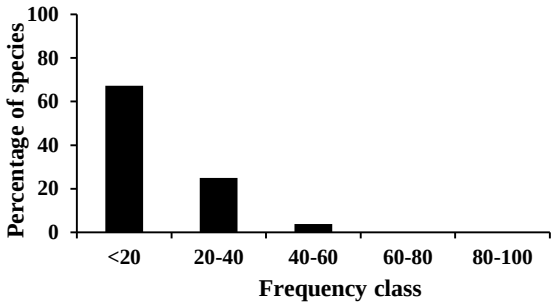


Figure 1: ***Frequency distribution of the species in the forest*.**

Species accumulation curve, species richness and diversity

The species accumulation curve shows an increasing trend as the number of sample area added (Fig. 2). The non-parametric species richness estimators revealed a higher species richness (ranging from 59 to 70 species) than the observed (Table 3). Likewise, the used diversity indices (Shannon-Wiener, Simpson and Fishers alpha) revealed the forest to have a high diversity of tree species (Table 3).

Table 3: Structural parameters, diversity measures and species richness estimators of the forest

Parameter	Mean ± S.E
Tree density (Stems ha^{-1})	390 ± 52
Basal area (m^2 ha^{-1})	24 ± 5
Shannon-Wiener index (H')	3.40 ± 0.14
Simpson diversity (D)	20.6 ± 6.1
Fisher's alpha diversity	18.8 ± 1.8
Jackknife 1	64 ± 3
Chao 2	59 ± 4
MMMeans	70

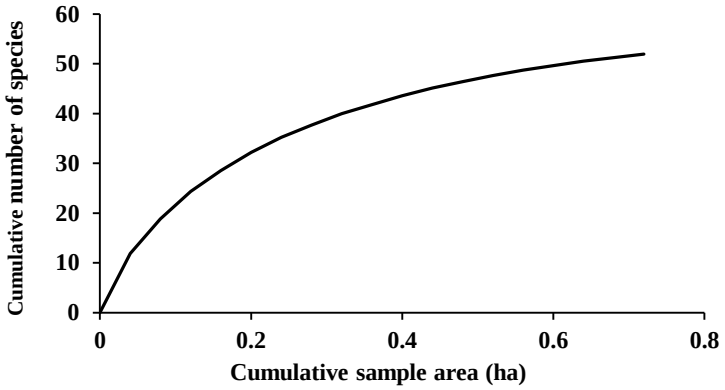


Figure 2: Species accumulation curve of tree species in the studied forest

Structural composition of the forest

The size class distribution of trees exhibited an inverse J-curve (Fig. 4) whereby 54.8% and 22.8% of the recorded trees were represented in the first and second DBH classes, respectively. When all trees with DBH values above 30 cm are pooled together, this DBH class represents only 22.4% of all the recorded individuals. The majority of the large trees with DBH greater than 70 cm were dominated by *K. anthotheca*; the maximum recorded DBH for this species was 126 cm. The stems density (100 – 850 stems ha^{-1}) and basal area (3 – 61 m^2 ha^{-1}) varied extensively among the surveyed plots. The average stem density

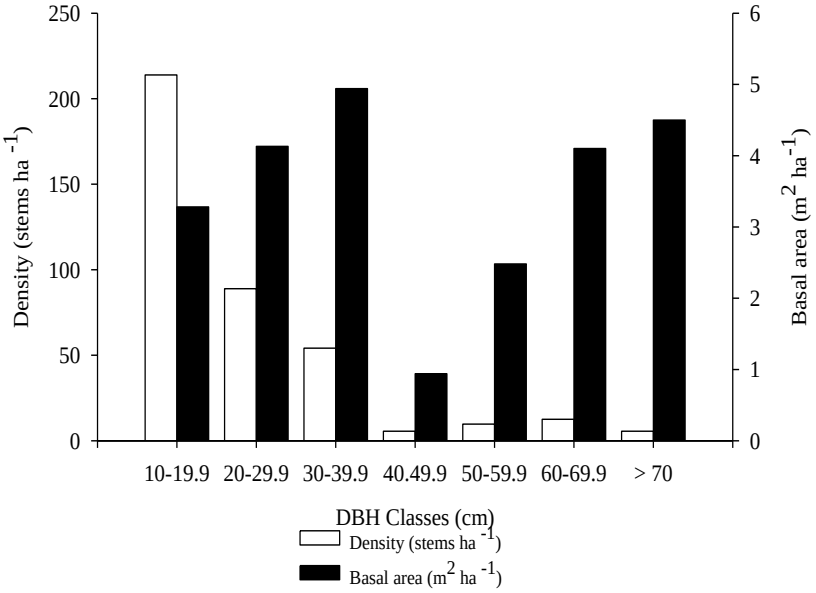


Figure 3: ***Size class distributions of the trees in the Kimboza forest***

and basal area of the forest was 390 stems ha^{-1} and 24 m^2 ha^{-1} respectively (Table 3). The species with the higher basal area was *K. anthotheca* (7.7 m^2 ha^{-1}) followed by *A. toxicaria* (2.7 m^2 ha^{-1}).

5. Discussion

Floristic composition, species richness and diversity

This study describes a lowland forest of high conservation value among the eastern arc forests present in the Uluguru Mountains in Morogoro region. It provides data set that can be compared to a large number of inventories of tropical forests. The most important family (Fabaceae) was attributed mainly by high species richness and abundance of the constituent species. The family Fabaceae dominated by 29% in this study. This finding concurs with Burgess and Muir (1994) and Burgess and Clarke (2000) who reported coastal forests of Tanzania to be dominated by Fabaceae by 25%–50%. Likewise, Mrema (2006) and Rwamugira (2008) recorded family Fabaceae as the most important family in Dindili and Ruvu forest, respectively. Moreover, the finding is in conformity with Gentry (1988) findings, who revealed Fabaceae being the most diverse family in lowland forests of Africa. The inclusions of family Meliaceae and Boraginaceae in the top ten most important families were due to their high relative dominance and density as compared to other families with more than one species. Among the most important families recorded in the present study (Table 1) were similarly recorded being the top-most important families in other lowland forests elsewhere (e.g., Wittman et al., 2006; Mwavu, 2007; Addo-Fordjour et al., 2009).

The use of IVI is a common practice in quantitative descriptive studies as it reveals the ecological significance of species in a given ecosystem. Species with high IVI value are considered ecologically more important than those with low IVI value. The IVI value is also used for prioritizing species conservation (Zegeye et al., 2006). Species with high IVI value need less priority for conservation effort as compared to those with low IVI value. The high IVI displayed by *K. anthotheca* was essentially contributed by its higher relative dominance and relative density compared to other species. This study suggests that all species with IVI less than 5.00 (Table 2) should be prioritized for conservation. The presence of many species with lower IVI values is an indication that the majority species are rare in the forest. This is confirmed by the frequency distribution (Fig. 1) where 69% of the identified species occurred in less than 20% of the surveyed plots, 13 species occurred once, while 19 and 4 species occurred in two and three plots respectively. The rarity of species may be ascribed by the occurrence of abundant infrequent species with low frequency in a forest (Oyun et al., 2009). The high percentage of rare species observed in this study confirms the commonly acclaimed notion that most of the species in the ecological community are rarer, rather than common (Magurran & Henderson, 2003). The possible reason for rarity in tropical forests is that rare species suffer strong density-dependency than common species (Hubbell et al., 2001). The existence of a resource gradient can also cause species to occupy different positions within it, resulting in variation in abundance, and distribution (Comita et al., 2007). Moreover, poor dispersability of the species, disturbances and

competition may also account for the presence of many rare species in tropical forests (Schwarz et al., 2003).

The escalating trend shown by the species accumulation curve as the numbers of the plots were added suggests that increasing numbers of sample plot/area could increase the number of species in the forest. This result is supported by the species richness estimators (Jackknife 1, Chao 2 and MMMeans) in Table 3, which provide a higher number of species than the observed species in the forest. The findings simply tell us that the sample size used was not enough to capture all the species in the forests, signifying that more plots will be required for future inventories in this forest. The high species richness in the forest could be attributed to high environmental heterogeneity within the forest. The larger the forest size, the more the diverse/heterogeneous habitats, which actually contribute to the maintenance of species richness (Tuomisto et al., 2003; Kacholi, 2013). Conversely, increasing anthropogenic activities and fragmentation will result not only to the loss of a valuable portion of the forest ecosystem, but also a significant decline in species richness, especially the rare species (Kacholi, 2013).

The 52 species (i.e., 72 species ha^{-1}) observed in 0.72ha were higher compared to 28 species ha^{-1} observed by Malimbwi et al., (2005) in the same forest. The present findings also concur with Mwavu (2007) who recorded a range of 24–122 species ha^{-1} for trees with DBH ≥ 10cm in Budongo forest, Uganda. In contrast, the recorded species richness in the present study is very low compared to Amazon forests, where Gentry (1988) revealed the highest alpha diversity of 275 to 283 species ha^{-1}. However, the comparisons involving different studies are complicated due to fact that different plot sizes are used, and the subjectivity to arrive at a range of values is unclear.

Forest structure

The forest structure parameters in this work are related to stem density, basal area and size class distribution. The mean basal area of $24m^2ha^{-1}$ and mean density of 390 stems ha^{-1} are high by 54% and 65%, respectively, than those ($15.8m^2$ ha^{-1} and 236 stems ha^{-1}) recorded by Malimbwi et al., (2005) in the same forest. This observation signifies that the forest has not been greatly affected by anthropogenic disturbances since then, and it is rejuvenating well. Meliaceae had the highest basal area in the present study, followed by family Moraceae. These families contain important timber species such as *K. anthotheca, A. toxicaria, M. excelsa and Ficus* spp. Bombacaceae, Rutaceae and Bignoniaceae did not contribute much to the total basal area. The family Rutaceae was also noted by Mwavu and Witkowski (2009) not to be a very important family in terms of dominance/basal area. The observed negative exponential in the size class distribution (Fig. 4), suggests high recruitment and stable healthy stand structure. The size class pattern is usual for primary lowland forests, which are not affected, or are weakly affected, by anthropogenic activities (Whitemore, 1989). The presence of relative small number of big trees with a diameter greater than 40cm can be explained by two main reasons. First, probably there might be a limited number of species that grow up more than this diameter; and second, the number of big trees could have already been reduced through illegal and selective

logging by the locals for various uses. Moreover, some illegal timber logging were observed in the forest, which indicate that the forest is somehow still under anthropogenic pressure. Tree species like *P. angolensis, Dalbergia melanoxylon* and *M. excelsa* were observed to be exploited for timber, and the majority are logged below the minimum harvestable diameter. The same species have been observed in other coastal forests of Tanzania to be illegally exploited for timber (Ahrends, 2005; Modest et al., 2009), whereby the exploitation is known to be done by well-coordinated syndicates involving traders, irresponsible local government leaders, some forest officers and unfaithful villagers (*The Guardian*, 2012).

6. Conclusion

The study has shown that the species richness and diversity at Kimboza forest is high. The forest was dominated by *Fabaceae* family in terms of FIV, relative diversity and density; while the family Meliaceae dominated in terms of relative dominance. The tree species with low ecological importance values signify rarity of most of the species, which tell us that more conservation efforts are needed towards these species. The size class distribution revealed the forest to have good regeneration pattern. Thus, proper management, protection, and wise utilization of the forest should be prioritized by the responsible authority so that it sustains its original biodiversity and ecological processes for future generations.

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