COMPOSITION AND SIZE CLASS STRUCTURE OF TREE SPECIES IN IHANG'ANA FOREST RESERVE, MUFINDI DISTRICT, TANZANIA

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ABSTRACT

Ihang'ana Forest Reserve is part of the Udzungwa Mountains ecosystem that falls under the Eastern Arc Mountains (EAM). Previous plant biodiversity studies in this ecosystem concentrated on large-sized Forest Reserves of greater than 20,000 ha (FR) such as the Uzungwa Scarp ignoring small-sized forests of less than 300 hectares. This study was therefore undertaken to assess tree species composition, structure and diversity in Ihang'ana FR (2982 ha), one of the forest reserves in the Udzungwa Mountains Ecosystem. A total of 7 transects with 12 plots of sizes 20 m x 50 m each were established for vegetation sampling. Seventy tree species representing 32 families and a total of 6478 individuals were identified from Ihang'ana FR. Alpha diversity ranged between 1.334 and 2.865 (mean 2.246 ± 0.309) with most plots recording species diversity of greater than 2.014. The most frequent occurring species were Aphloia theiformis (96.4%), Diospyros whyteana (91.6%), Nuxia floribunda (91.6%) Olea europaea (86.9%) and Macaranga capensis var. capensis (77.4%). Majority of these species similarly scored the highest Importance Value Index (IVI) as follows: Aphloia theiformis (112.6), Nuxia floribunda (111.36), Olea europaea (101.75), Bridelia micrantha (101.25), Diospyros whyteana (98.06), Macaranga capensis var. capensis (87.62), Morella salicifolia (71.3). M. capensis var. capensis, an indicator species for disturbance, was poorly represented in the lower DBH size classes, possibly an indication of forest recovery from past disturbance. Despite reports that licensed timber extraction used to take place in the forest in the early 1980s, the situation on the ground as observed during this study shows that the forest has recovered from such disturbance. It is therefore recommended that the central government continue supporting the local communities around the forest reserve for example in maintaining fire lanes as part of conservation and management of Ihang'ana Forest Reserve.

KEYWORDS: *Eastern Arc Mountains, Ihang'ana Forest Reserve, IVI, tree species composition, tree species diversity, Udzungwa Mountains*

INTRODUCTION

Ihang'ana Forest Reserve is part of the Udzungwa Mountains ecosystem located in Southern Highlands of Tanzania. The Udzungwa Mountains ecosystem falls under the Eastern Arc Mountains (EAM) that extend from Southern Kenya to the Southern Tanzania, and comprise of Taita Hills (in Kenya), North and South Pare, West and East Usambara, Nguu, Nguru, Ukaguru, Rubeho, Uluguru, Malundwe, Udzungwa and Mahenge (in Tanzania) (Burgess et al. 2000). Ihang'ana FR is regarded as a plateau forest (Mallango et al. 1997) as opposed to escarpment forests referring to those forests that occur along the Udzungwa mountains escarpment. From the global conservation point of view, the EAM together with the coastal forests of Tanzania and Kenya have been recognised as an Eastern Afromontane biodiversity hotspot, being part of the world's 25 biodiversity hotspots (Mittermeier et al.

2004). The primary vegetation remaining within the biodiversity hotspots covers less than 2% of the planet's land area, and yet accounts for 44% of all vascular plant species (Linder et al. 2005).

The Udzungwa Mountains ecosystem consists of 14 gazetted forest reserves, Ihang'ana FR being one of them. Most previous studies, for example by FRONTIER (1999) and Ndangalasi (2004) on flora and fauna within Udzungwa mountains ecosystem focused on forests found along the Udzungwa escarpment (viz Udzungwa Mountains National Park, West Kilombero Scarp FR, Uzungwa Scarp FR). However, small forest reserves found on the plateau including Ihang'ana FR did not receive any attention. The Udzungwa plateau forests are much drier than those found along the escarpment due to rain shadow effect (Lovett and Congdon 1990). Such habitat conditions are likely to favour a different vegetation community composition when compared to forests along the escarpment.

It should be noted that Ihang'ana FR is the source of Kihansi River downstream which is the second largest Hydro Electric Power (HEP) plant in Tanzania (after Kidatu). At its full capacity, this HEP plant produces 180 MW of electricity that enters into the national power grid. The forest landscape is heterogeneous such that the vegetation is distributed on hill slopes, valley bottoms, wetlands and springs. On the other hand, Ihang'ana FR is surrounded by five villages, namely: Kibengu, Igeleke, Mitanzi, Usokame and Mwatasi with a total population of 26,160 people (Bureau of Statistics 2002). With regard to its relatively small size, one cannot deny that it is under pressure from the surrounding communities. It is feared that some of the plant species under exploitation by the local communities might disappear from this forest even before they are documented by scientists. This study aimed at determining tree species composition, size-class structure and diversity in Ihang'ana FR.

MATERIALS AND METHODS

Location and description of the study area

Ihang'ana FR is located in Mufindi District, about 70 kilometres east of Mafinga town, and about 30 kilometres North-West of the escarpment at Uhafiwa and Ukami villages. It is found between latitude 08°16'45" and 08°18'38"S and longitude 35°42'20" and 35°44'50"E (Lovett and Pocs 1993) (Figure 1). Ihang'ana FR is one among the central government's forests gazetted through Government Notice Number 105 of 1931 (with a Job Number J.B. 21) (Mallango et al. 1997). The total conserved forest area is 1206.8 ha and is surrounded by croplands, settlements and grasslands. This forest is the main catchment and the source of Kihansi River that flows to the east. The forest is moist with closed canopy trees but with patches on the edges having different vegetation community types. The forest floor is wet and covered with various species of fungi, bryophytes and pteridophytes.

Sampling procedure

Prior to undertaking a detailed sampling of the vegetation, a reconnaissance survey was carried out covering as much of the different parts of the forest as possible. During the survey, it was evident that the forest was heterogeneous and therefore an attempt was made to classify it into different vegetation community types based on its physiognomy. Thus, (i) heavily disturbed and less disturbed forest areas were identified for inclusion in the sample, and (ii) sample locations and number of transects to be established in each vegetation community type were determined (Kent and Coker 1992). This was then followed by the actual vegetation sampling where a total of 7 transects each 1200 metres long were established in the entire forest.

These transects were placed in such a way that each of them covered as many microhabitats as possible. The distance between one transect and the other varied considerably because the placing of the transects was guided by the preconceived vegetation communities. Along each transect line, 12 sample plots of the size 20 m x 50 m (0.1 hectare) were systematically established at 50 m interval alternating along the long axis of the transect.

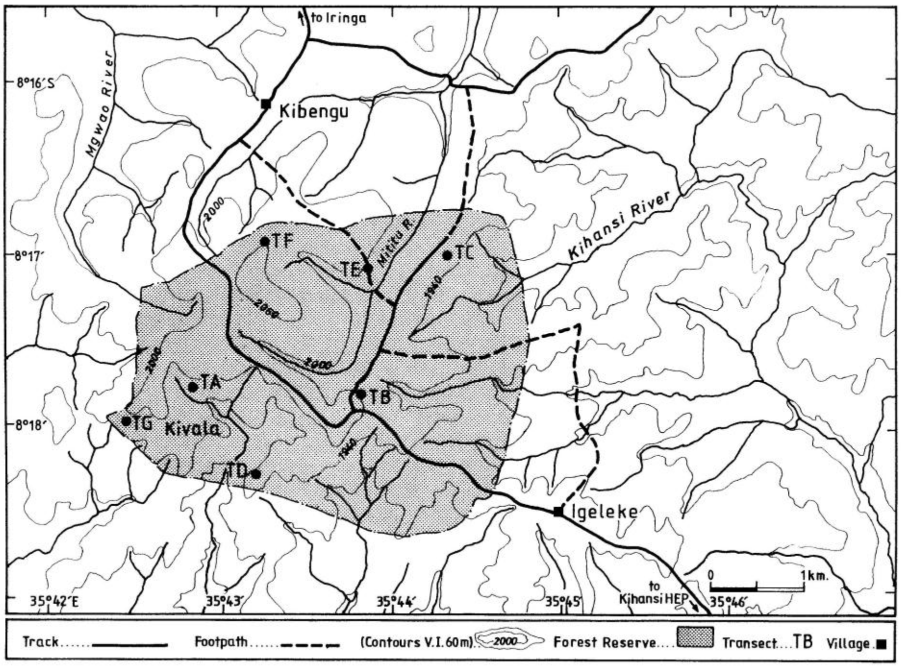


Figure 1: Map of Ihang'ana Forest Reserve to show the seven sampling sites (location of transects in the forests) and sorrounding villages at Mufindi District, Tanzania.

Information recorded for each tree with a diameter at breast height (DBH) equal or greater than 10 centimetres encountered included: species name, number of individuals, DBH and an estimation of height. However, for those trees that could not be identified in the field, were collected, pressed and taken to the Herbarium of Department of Botany, at the University of Dar es Salaam for identification using relevant floras and/or matching with herbarium specimens.

Data analysis

The plant species list generated from different sample plots were used to construct species cumulative curves. Species diversity was calculated using Shannon and Wiener Diversity Index (Shannon and Wiener 1948) and Simpson's diversity Index. Importance Value Index (IVI), an index used to determine the overall importance of each species in a community was calculated using the following formula (Curtis and McIntosh 1951):

Importance Value Index (IVI) = relative density + relative dominance + relative frequency.

Ordination of species data was carried out using Detrended Correspondence Analysis (DECORANA) (PISCES Conservation Ltd, 2007).

RESULTS

Tree species cumulative curve

The assessment of species composition among sampling sites using cumulative curves is represented in Figure 2. It is evident from this figure that for most sites a sample plot of the size 0.5 ha was sufficient to capture most of the tree species. Site B recorded the highest number of tree species followed by sites A, F and E. To a large extent, sites C, D and G recorded the lowest (cumulative) number of trees species. Furthermore, it was observed that, if the aim was just to record tree species richness, a plot of the size 0.8 ha was big enough to capture species richness in the forest under study; the only exception here would be site A where species cumulative number continued to increase with increasing plot size.

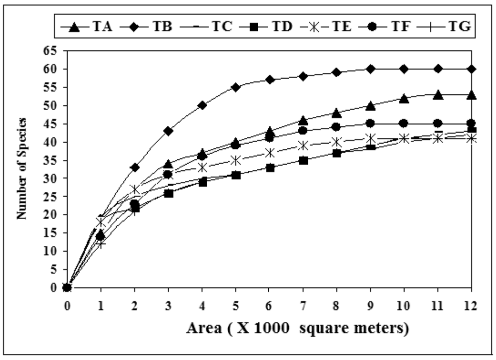


Figure 2: Species cumulative curves (based on tree species only) for the seven transects established in the entire Ihang'ana Forest Reserve, Mufindi District, Tanzania.

Tree species composition and diversity

A total of 70 tree species represented by 6478 individuals grouped into 32 families were recorded from a total of 84 plots. Five families namely Flacourtiaceae, Olaceae, Rubiaceae, Celastraceae and Euphorbiaceae were the most diverse since they were represented by many species (9, 5, 4, 4, and 4, respectively) whereas other families such as Rutaceae, Rosaceae, Myrtaceae, Myrsinaceae, Araliaceae and Anacardiaceae had very few species as they were represented by one to two species only (Appendix 1). The most frequently occurring trees in this forest were *Aphloia theiformis* (96.4%), *Diospyros whyteana* (91.6%), *Nuxia floribunda* (91.6%), *Olea europaea* ssp. cuspidata (86.9%), *Macaranga capensis var. capensis* (77.4%), *Bridelia micrantha* (75%), *Rhus pyroides var. pyroides* (75%), *Bersama abyssinica* (65.4%) and *Myrsine melanophloeos* (60.7%).

The alpha diversity for trees based on Shannon-Weiner Diversity Index ranged from 1.33 to 2.87 with a mean of 2.25 ± 0.31 (Figure 3). Of the 84 plots sampled, 82.1% recorded tree species diversity greater than 2.01. Simpson's Diversity Index ranged between 6.2 and 10. Sites D and G were less diverse than other sites (Figure 3).

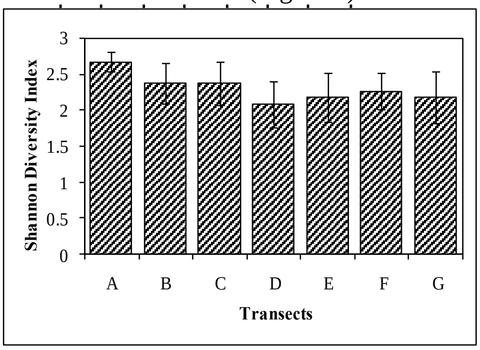


Figure 3: Species diversity using Simpsons' Diversity Index (A) and Shannons' Diversity Index (B) for the different sites around Ihang'ana Forest Reserve, Tanzania.

Importance Value Index (IVI) for tree species

The IVI values for the first 10 tree species in decreasing order of IVI score are summarised in Table 1 below. Only trees with IVI equal or greater than 64.4 are presented. It was found that *Aphloia theiformis* had IVI of 112.6, *Nuxia floribunda* 111.36, *Olea europaea* ssp. *cuspidata* 101.75, *Bridelia micrantha* 101.25, *Diospyros whyteana* 98.06, *Macaranga capensis* var. *capensis* 87.62 and *Morella salicifolia* 71.3. It was further observed that, some important timber tree species in this forest such as *Ocotea usambarensis* with IVI value of 17.7, *Podocarpus latifolius* 6.1, *Faurea saligna* 3.7 and *Chrysophyllum gorungosanum* 2.51 recorded the lowest IVI values. It is interesting to note that some of the tree species that had the highest density such as *Garcinia buchananii* and *Catha edulis* had low IVI value partly because their total basal area was rather small as a consequence of smaller DBH size class among individuals of respective species.

Table 1: Importance Value Index (IVI) for ten top most trees recorded from Ihang'ana Forest Reserve ranked in descending order

S/No.	*Species name*	Total number of trees	IVI
1	*Nuxia floribunda*	680	113.3
2	*Aphloia theiformis*	899	112.6
3	*Olea europaea ssp. cuspidata*	475	101.7
4	*Bridelia micrantha*	342	101.2
5	*Diospyros whyteana*	510	98.1
6	*Macaranga capensis var. capensis*	441	87.6
7	*Rhus pyroides var. pyroides*	281	81.3
8	*Morella salicifolia*	188	71.3
9	*Bersama abyssinica*	149	69.8
10	*Myrsine melanophloeos*	124	64.4

Ordination of tree species data

To test for homogeneity or heterogeneity of the vegetation of Ihang'ana FR, ordination of the 84 (0.1 ha) plots was carried out. Results revealed no clear discernible pattern, even though roughly there was clustering of plots around the centre of the DCA ordination diagram (Figure 4i). A clear picture of clustering was obtained when plot data were lumped into transects and then subjected to DCA ordination. It was evident from the resulting ordination diagram that two groups emerged; transects A, B, C, E and F formed one group, whereas transects D and G formed another group (Figure 4ii).

DBH size class distribution of trees and basal area

The DBH class size distribution showed that majority of individual tree species were in the DBH class sizes of between 9.5 and 40.9 cm whereas trees with DBH sizes above 60 cm were very rare (Figure 5a). Only few species, namely: *Nuxia floribunda*, *Parinari excelsa*, *Pittosporum viridiflorum*, *Bersama abyssinica*, *Cassipourea gummiflua*, *Albizia gummifera*, *Macaranga capensis var. capensis*, *Cussonia spicata*, *Olea europaean*, *Rawsonia lucida* had their individuals in the DBH size classes greater than 60 cm (Figure 5b). However, among the above tree species, only *Nuxia floribunda* and *Parinari excelsa* showed DBH size classes above 120 cm. Comparison of total basal area showed that transect E recorded the highest basal area (5315.9 cm^3) followed by transect A (4792.1 cm^3). On the other hand, transects F and C recorded the lowest basal areas of 1773.12 cm^3 and 1433.27 cm^3, respectively. It should be noted that, the total sampled area for each transect was the same, viz 1.2 hectare.

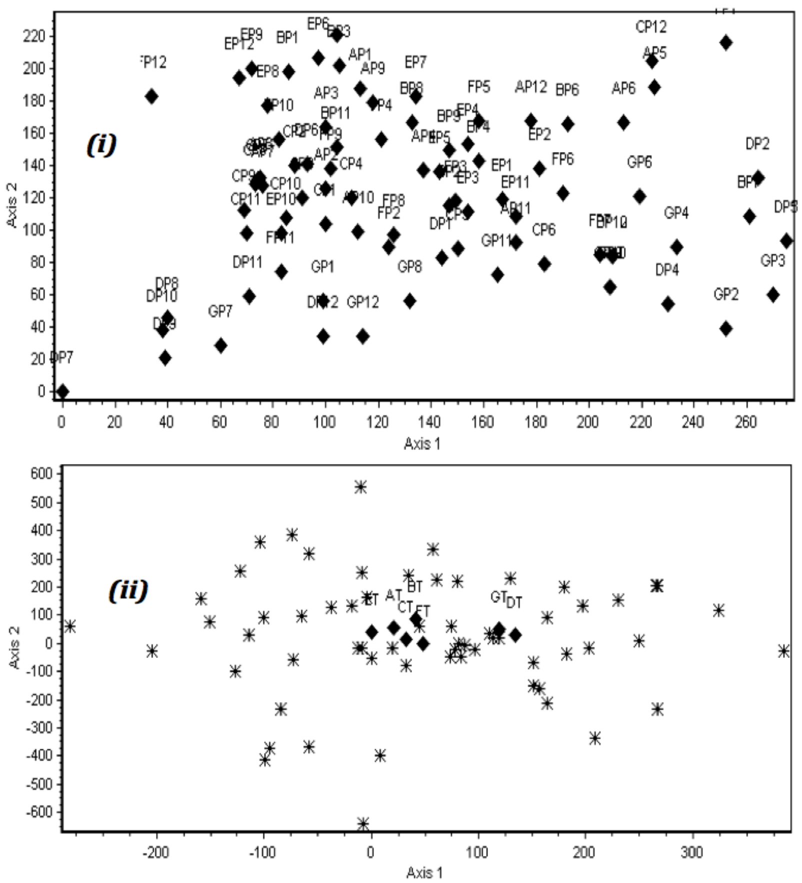
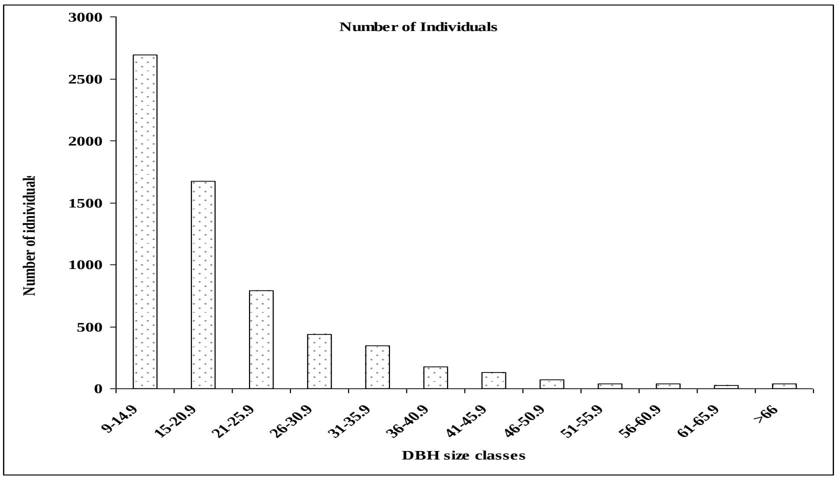


Figure 4: An ordination of (i) 84(0.1 ha) vegetation sample plots and (ii) species and sites of the seven sites (A through G) to show dispersion of plots. Note:◆Represents vegetation plots and * represents species.

DISCUSSION

Tree species composition and diversity in Ihang'ana Forest Reserve

Species diversity was higher along transects A, B and C than the rest of transects (Figure 3). Transects D and G were located on the border of open grassland and therefore probably the microhabitat conditions here restrict the number and types of species growing compared to other transects. Although assessments of soil conditions and related factors were beyond the scope of this study, data from such kinds of analyses could also explain the reasons for the differences observed between different transects. Furthermore, fire from the neighbouring farms and grassland frequently escapes and enters the forest, hence impacting negatively on species composition and diversity. Shannon's diversity indices of between 1.334 and 2.865 reported from this forest are within the range of those reported from other EAM though inclined to the lower side of the range. For example, Ndangalasi (2004) reported Shannon's diversity indices of between 2.139 and 3.609 from Uzungwa Scarp FR. This difference in species diversity can be attributed to variations in habitat conditions. Uzungwa Scarp FR is much wetter than Ihang'ana FR due rain shadow effect to the latter. In addition, Ihang'ana FR is surrounded by human settlements. The population in these villages has expanded since 1974 at the time of villagization when these villages were established (Bureau of Statistics 1988, 2002), an implication that forest resources have continuously been exploited to meet human needs. According to information from the local forest officer, prior to the 1980 people were issued licences to harvest timber trees from this forest, and this might also have affected the species composition and diversity.



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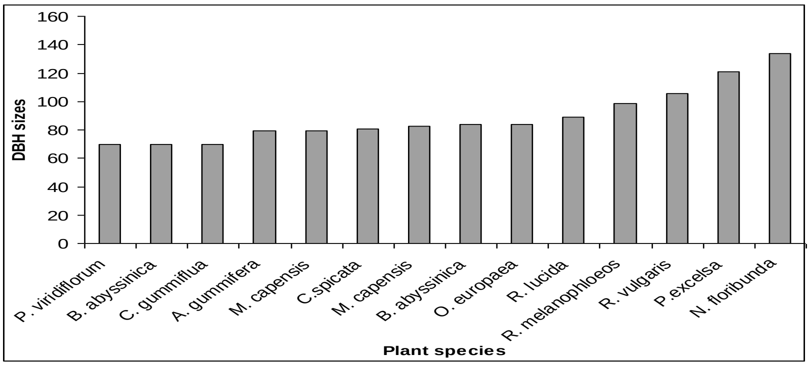

b

Figure 5: Population structure and DBH size class distribution (a) The DBH size class distribution for all trees and (b) Average DBH size classes for the 14 most dominant tree species, Ihang'ana Forest Reserve, Tanzania.

On the other hand, *Aphloia theiformis* and *Nuxia floribunda* scored high IVI values implying that the two species were the most frequent and with high dominance and density. The reason for high performance for the two species is not clear, but perhaps they are most favoured by the habitat and/or are less exploited by the local communities. High abundance of *Macaranga capensis var. capensis* at higher DBH size classes and lack of lower DBH size classes is a reflection of past disturbance in this forest. Note that *Macaranga capensis* is an early successional species sometimes referred to as pioneer species, and therefore, is regarded as an indicator of forest disturbance. It was ranked 6th among the dominant trees in the forest whereas other known pioneer species from the area ranked low, e.g., *Polyscias fulva* (with an IVI of 8.7) ranked 34th. This can be an indication of reduced disturbance from human activities in the forest following the change in management of the forest from the local government to central government in the early 1990s, as reported by Mr. Msungu a forest officer in Kibengu village. Elsewhere, it has been reported that tree species with low IVI can be an indication of their vulnerability to exploitation (Githae et al. 2007). The most important timber trees such as *Ocotea usambarensis, Podocarpus latifolius, Faurea saligna* and *Chrysophyllum gorungosanum* ranked relatively low in IVI scores possibly because they were over-exploited from this forest in the past when licences were issued for logging. *Prunus africana*, a valuable medicinal plant was represented by only few individuals. Lack of baseline data makes it difficult to ascertain whether the low number is due to exploitation pressure through debarking or not.

DBH size class structure of tree species in Ihang'ana Forest Reserve

Observations of the vegetation structure showed that most of trees were in DBH class sizes below 65 cm portraying reversed J-shaped curves. This is an indication of a healthy community which shows that the population is expanding (Diekmann 1994, Peters 1994) and possibly the forest is recovering from previous disturbance. Tree species with DBH size class of above 120 cm were rare possibly because of over-exploitation for timber especially for preferred species such as *Ocotea usambarensis*, and *Podocarpus latifolius*. On the other hand, this can be a result of survival filters which progressively reduce the number of individuals as they advance to large size classes (Muhanguzi et al. 2007) or a combination of the two. According to Argaw et al. (1999), a regenerating population becomes stable when there is more recruitment of individuals in the lower DBH sizes class declining subsequently to higher DBH size classes.

Although the individual trees in the forest might have survived from the episode of the previous disturbance, overall Ihang'ana FR is at a potential stage of regeneration and skewed towards stable population (Figure 5). A well-represented adult population maintains a continuous addition of seedlings, saplings and poles in its population (Seydack 1995). Co-existence of small and large trees is common among successional guilds (Muhanguzi et al. 2007). The seedlings of most indigenous tree species established could co-exist with adults with different canopy-sizes or crown cover.

As reported in the results, we noted differences in total basal areas among different transects despite the fact that the total sampled area for each transect was the same. Transects C and F in particular recorded the lowest total basal area. This difference in the total basal areas can be attributed to the fact that, overall trees from the two transects on the average had smaller DBH size classes than those from transects A, B, D, and E and G. Reasons for these differences were not investigated during the study but it might be due to inherent microhabitat conditions such as soil, moisture etc, or might be due to the anthropogenic factors, hence a need for further investigation.

Variations in tree species compositions among habitats based on DCA

Similarity among sites based on DCA ordination resulted into two clusters of transects, A, B, C, E and F formed one cluster while transects D and G formed the other (Figure 4ii). The reason for this separation is based on species composition and that there appeared to be very little species overlap between the two clusters. This can partly be explained by the fact that transects D and G are located on the western side, a rain-shadow area where the amount of precipitation is relatively lower than the eastern and central parts of the forest. This is likely to have influenced the microhabitat and in turn the species supported. *Catha edulis* and *Garcinia buchananii* were the most dominant species in the two transects (D and G), but were uncommon in other sites. Differences in abiotic factors possibly have led to variations in species compositions, hence separation of transects D and G from the rest in DCA ordination diagram (Figure 4).

CONCLUSION

This study revealed with few exceptions that, Ihangana FR is still in a pristine condition and recovered from anthropogenic interference. The exceptions being for instance the effects of fires that originate from the surrounding grassland and encroaches the forest edge. Fire has become a big threat to the forest, given the fact that the forest reserve is surrounded by grassland and farmlands all around its borders. So far, maintenance of fire breaks by the local communities under the directives of villages' forest officers has helped to minimize the problem. Also the local communities have been involved in the management conservation of the forest which has contributed much to the recovery of the degraded parts in the forests since the 1980s when licensed timber extraction was stopped. It is recommended that the central government should continue supporting the local communities in conservation management of the forest, maintaining the existing fire breaks and timing for clearing the fire breaks is crucial. Generally, given an opportunity and under the current management the forest will recover from those minor disturbances.

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Appendix 1: List of tree species identified in Ihang'ana Forest Reserve

Name	**Author**	**Family**
Scolopia stoltzii var. riparia	Gilg	Flacourtiaceae
Ochna holstii	Engl.	Ochnaceae
Osyris lanceolata	Hochst. and Stendel	Santalaceae
Shrebera alata	(Hochst) Welw	Oleaceae
Syzygium guineense	(Willd) DC	Myrtaceae
Teclea nobilis	Del	Rutaceae
Turraea holstii	Gurke	Meliaceae
Turraea nilotica	Kotschy & Pegr	Meliaceae
Agauria salicifolia	(Lam) Hook.f.	Ericaceae
Albizia gummifera	(J.F.Gumel) CA SM	Mimosoideae
Allophyllus africanus	P.Beauv	Sapindaceae
Antidesma venosum	Tul.	Euphorbiaceae
Aoranthe pendulifora	K.Schum.	Rubiaceae
Aphloia theiformis	(Vahl) Bennt	Flacourtiaceae
Apodytes dimidiata	Arn	Icacinaceae
Bersama abyssinica	Fressen	Melianthacea
Bridelia micrantha	(Hochst) Baill	Euphorbiaceae
Casearia battiscombei	R.E.F.R.	Flacourtiaceae
Cassipourea gummiflua	Tul.	Rhizophoraceae
Catha edulis	Lam.	Celastraceae
Chrysophyllum gorungosum	Engl.	Sapotaceae
Croton macrostachyus	Del	Euphorbiaceae
Cryptocarya libertiana	Engl.	Lauraceae
Cussonia spicata	Thub	Araliaceae
Diospyros whyteana	F.White	Ebanaceae
Dombeya rotundifolia	(Hochst) Planch	Sterculiaceae
Dovyalis abyssinica	(A.Rich) Warb	Flacourtiaceae
Dracaena laxissima	Engl.	Dracaenaceae
Faurea saligna	Harv	Proteaceae
Ficus lutea	Vahl.	Moraceae
Garcinia buchananii	Bak.	Guttiferae
Heteromorpha trifloliata	(Wendl) Eck and Zeyh.	Umbelliferae
Ilex mitis	Radlk.	Aquifoliaceae
Ixora scheffleri ssp scheffleri	K.Schum	Rubiaceae
Lannea schweinfurthii	(Engl) Engl.	Anacardiaceae
Lannea welwitschii	(Hiern) Engl.	Anacardiaceae
Lasianthus kilimandscharicus	K.Schum	Rubiaceae
Macaranga capensis var. capensis	(Baill) Sim	Euphorbiacea
Maesa lanceolata	Forsk.	Myrsinaceae
Maytenus acuminata	(Linnf)Loes	Celastraceae
Maytenus undata	(Lam)Loes	Celastraceae
Mesogyne insignis	Engl.	Moraceae

Olea europaea subsp. africana	Mill	Oleaceae
Olea capensis	L.	Oleaceae
Kiggelaria africana	L.	Flacourtiaceae
Morella salicifolia	Hochst. ExA.Rich	Myrcacaea
Myrsine africana	L.	Myrsinaceae
Mytenus acuminata	(Linnf)Loes	Celastraceae
Nuxia floribunda	Benth	Loganiceae
Ocotea usambarensis	Engl.	Lauraceae
Olea europaea ssp. cuspidata	Mill	Oleaceae
Olea capensis	L.	Oleaceae
Oncoba spinosa	Forsk.	Flacourtiaceae
Parinari excelsa	Sabine	Rosaceae
Pittosporum viridiflorum	Sim	Pittosporaceae
Podocarpus milanjiana	Rendle	Podocarpaceae
Polyscias fulva	(Hiern) Harms	Araliaceae
Prunus africana	Lam.	Rosaceae
Myrsine melanophloeos	(L) Mez	Myrsinaceae
Rawsonia lucida	Harv & Sond.	Flacourtiaceae
Rhamnus prinoides	L. Hiert.	Rhamnaceae
Rhus pyroides var. pyroides	Meik	Anacardiaceae
Rothmannia manganjae	(Hiern) Kray	Rubiaceae
Stephania abyssinica	(Dillon & A.Rich) Walp	Menispermaceae
Syzygium cordatum	Krauss	Myrtaceae
Tecomaria nyassae	L.	Bignoniaceae
Trichocladus ellipticus	Eckl & Zeyh	Hamamelioliceae
Xymalos monospora	(Harv) Warb	Monimiaceae
Flacourtia indica	(Burnman) Merr.	Flacourtiaceae