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Woody plant communities of isolated Afromontane cloud forests in Taita Hills, Kenya

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Abstract

In the Taita Hills in southern Kenya, remnants of the original Afromontane forest vegetation are restricted to isolated mountain peaks. To assess the level of degradation and the need for forest restoration, we examined how forest plant communities and their indicator species vary between and within remnant patches of cloud forest. We used ordinal abundance data to compare plant communities in eight forest fragments. We also analyzed data on the diversity and abundance of trees in 57 0.1 ha plots to compare tree communities within and between the largest two of these fragments, Ngangao (120 ha) and Mbololo (220 ha). The extant vegetation of the Taita Hills at landscape scale consists of secondary moist montane to intermediate montane forest. There was a high species dissimilarity between fragments (69%). Variation in species composition coincided with an abiotic gradient related to elevation. At plot level, secondary successional species and species of forest edges were most abundant and most frequent. Inferred clusters of plots almost entirely coincided with the two forest fragments. Indicator species associated with forest margins and gaps were more frequent in the smaller of the two forest fragments, while indicators for the larger fragment were more typical for less disturbed moist forest. Abiotic site variability but also different levels of disturbance determine site-specific variants of the montane forest. Conservation efforts should not only focus on maintaining forest quantity (size), but also on forest quality (species composition). Late-successional rainforest species are underrepresented in the woody plant communities of the Taita Hills and assisting restoration of viable populations of cloud forest climax tree species is urgently needed.

Key words

Eastern-Arc Mountains, Fragmentation, Montane forest, *Ocotea*, Taita Hills, Relict vegetation

Introduction

Habitat loss and climate change pose increasing threats for biological communities worldwide (Thomas et al. 2004; Ewers and Didham 2006). In Africa, patterns of biodiversity and human population show remarkable similarity, and this often causes land use conflicts (Balmford et al. 2001; Fjeldså and Burgess 2008; Lewis 2009). In particular, forests are at stake: from 2000 to 2005 the continent lost about 4 million hectares of forest annually, close to one-third of the area deforested globally (FAO 2009). With these forests, many plant communities and their associated fauna and ecosystem services are being lost (Lewis 2009).

Deforestation affects biological forest communities in various ways. Cutting forest reduces the amount of habitat, isolates the remaining patches (habitat fragmentation) and alters the local or regional microclimate (Lawton et al. 2001; Fahrig 2003). In remaining forest fragments, selective logging (Berry et al. 2008; Ruger et al. 2008) and the subsequent invasion of alien or early-successional species (Devlaeminck et al. 2005; Heckmann et al. 2008) further degrade habitat quality. Consequently, biological communities in fragmented forests are expected to differ from the original, pre-fragmentation situation (temporal effect). They are also expected to vary between and within remaining forest patches.

Abiotic site conditions are responsible for natural variation of vegetation patterns. In disturbed ecosystems, processes such as soil erosion may affect abiotic site conditions, for instance through nutrient losses (de Koff et al. 2006). Differences in size, shape and degree of disturbance may have additional effects on the vegetation (spatial effect). Species in the altered communities may facilitate, tolerate or inhibit the recruitment of the original climax species. The invasion of forest clearings by *Pteridium aquilinum* (Bracken fern) and the subsequent arrested succession is a typical example of inhibition (e.g. Rodrigues Da Silva and Matos 2006). Ecological restoration must therefore acknowledge the present site potential and the remaining vegetation, because both may pose constraints for restoring plant communities.

In this study, we investigate the variation in forest plant communities in an extremely fragmented Afromontane cloud forest in the Taita Hills, southern Kenya. The Taita Hills form the northeastern part of the Eastern Arc Mountains, a mountain range with an exceptionally high degree of endemism and conservation value (Myers et al. 2000; Burgess et al. 2007; Hall et al. 2009). Because of favorable climate and soil, most of the forests of the Taita Hills have been cleared for agriculture more than 100 years ago (Pellikka et al. 2009). Consequently, existing forest fragments have been isolated from one another and embedded in agricultural rural landscape for over 100 years (Newmark 1998; Pellikka et al. 2009). At present only three relatively large forest patches (86–200 ha) and less than ten small forest patches (< 1–16 ha) remain. With the purpose of conserving and restoring Afromontane cloud forest in southern Kenya, the primary objectives of this paper are to identify forest plant communities of the Taita Hills and their indicator species. We compare species lists of different forest fragments accumulated over a long time period to assess the potential natural vegetation at landscape level. We then compare recent survey data within two large forest patches to evaluate if the present plant communities still represent the potential natural vegetation, and to evaluate local species composition variability.

Methods

Study sites

The Taita Hills forests (3°25'S, 38°20'E) are located in southeast Kenya, 25 km west of Voi in the Taita-Taveta District (Fig. 1). The Taita Hills rise abruptly from the semi-arid Tsavo plains at 600-700 m to a series of ridges, reaching 2208 m at Vuria peak. The plains isolate the hills from other mountains and highland blocks, the closest being Mount Kasigau (ca. 50 km to the southeast), North Pare (ca.70 km southwest), Mount Kilimanjaro (ca. 110 km west) and the West Usambara mountains (ca.120 km south) (Birdlife International 2007).

Rainfall follows a bimodal pattern alternated with a long (June–September) and a short (February) dry period (Lehouck et al. 2009b). The area receives between 600 mm and 2300 mm rainfall per year. Precipitation varies between years and locations, decreasing from east to west (Beentje and Ndiang'ui 1988; Lehouck et al. 2009b). Moist forest in the Taita Hills depends on cloud precipitation brought in by southeast trade winds originating from the Indian Ocean (Beentje and Ndiang'ui 1988). Cloud forests are restricted to sites receiving over 900 mm of annual precipitation. In the Taita hills, such sites are located above 1400 m altitude on the southeastern slopes and above 1700 m altitude on the northwestern slopes (Pellikka et al. 2009).

Indigenous forest fragments are found on two isolated hills and a main massif. The isolated hills are Mount Sagalla and Mbololo Hill. The patch on

Mount Sagalla is located at an altitude between 1350 and 1450 m. On Mbololo Hill, at 1200-1750 m, one of the three larger fragments (Mbololo, indigenous forest area 220 ha) and two very small patches occur (a patch within Ronge plantation, < 1 ha; a patch near Mwabirwa forest station, < 1 ha). The massif is known as Dabida Hill, with an elevation of 1400–2200 m. Forest patches on Dabida Hill included in this study are Ngangao (120 ha), Chawia (86 ha), Yale (16 ha) and Vuria (< 1 ha). Ngangao is located on a steep eastern slope of a north-south oriented ridge at 1700–1952 m. Chawia is located at the top of a cliff and has gentle slopes between 1470 and 1600 m. Yale is located on a north-south oriented mountain ridge with very steep slopes between 1750 and 2104 m (Pellikka et al. 2009). Five other forest fragments in the Dabida massif were not included in this study because compatible vegetation data were not available (Fururu, 8 ha; Macha, 3 ha; Mwachora, 2 ha; Ndiwenyi, < 1 ha; Kichuchenyi, < 1ha). All fragments are partly to heavily disturbed, mixed with or surrounded by plantation forest of exotic species (including *Eucalyptus saligna*, *Pinus patula*, *Cupressus lusitanica*, *Grevillea robusta* and *Acacia mearnsii*). The landscape matrix consists of smallholder agricultural land, where coffee, mangoes, cassava, tomatoes, banana, maize and beans are the main crops (Beentje and Ndiang'ui 1988; Bytebier 2001; Pellikka et al. 2009).

Data collection

We used ordinal abundance data to compare species composition of eight forest fragments. We also analyzed data on the diversity and abundance of trees in 57 0.1 ha plots to compare tree communities within and between the largest two of these fragments.

For the comparison between fragments, we used species lists of all higher plants recorded in the forests of Taita Hills between 1877 and 1985 (Faden et al. 1988). More rare and vagrant species may be included in species lists compiled over long periods and thus, differences in composition between locations may be weakened. Therefore, we assume that these data are most useful at landscape scale. It is also the only existing reference for the assessment of the potential natural vegetation. Species occurring only outside the forests were not taken into account. Forest fragments included in the species list were the larger fragments Mbololo, Ngangao and Chawia, the smaller fragment Yale, and the patches of Vuria, Mwabirwa, Ronge and Sagalla. Frequency symbols in Faden et al. (1988) followed a modified Tansley scale ((locally) abundant, (locally) common, frequent, uncommon and rare) and were converted to presence/absence data. This transformation meant losing information about relative abundances, but allowed for calculating distance measures. For analysis of woody plant communities, we used trees (100 species), woody climbers (6 species) and shrubs (46 species).

For the comparison within and between the two largest forest fragments (Mbololo and Ngangao), we used woody species data from a recent survey (Mbuthia 2003). Trees and palms measuring ≥ 10 cm diameter at 1.30 m height were recorded in 57 sample plots. The plots measured 50 × 20 m^2 and were laid out along stratified random east-west transects in Mbololo (26 plots) and Ngangao (31 plots) (Mbuthia 2003). The relative importance values recorded by Mbuthia (2003) were the average of the relative frequency, relative density and relative basal area of a species in percent. These scores were converted to presence/absence data. After omitting 11 unidentified species that occurred only in a single plot each, 73 woody species were retained for further analysis.

Plant species names follow the Flora of Tropical East Africa. Primary sources for plant species information (autoecology) were Beentje (1994), Maundu et al. (2005) and the African Plants Initiative (www.aluka.org).

Data analysis

We used the Sørensen dissimilarity index to evaluate pairwise differences in species composition between forests fragments (species list data). Mantel statistics were used to relate differences in species composition between fragments to geographical distances. Forest fragments were clustered into groups using a Sørensen distance measurement and flexible beta linkage ($\beta = -0.25$) (McCune and Mefford 1999). Indicator Species Analysis (Dufrêne and Legendre 1997) was applied to calculate indicator values for all species and their significance for the emerging groups. Homogeneity within groups was tested with a multiresponse permutation procedure (MRPP) test. For MRPP, we used the Sørensen distance measure and a natural group weighing factor $n_i/\sum n_i$ (where n_i is the number of samples in each group). In MRPP, the chance-corrected within group agreement *A* describes within-group homogeneity compared to random expectation. If the emerging groups are significantly more homogeneous than expected by chance, then $1 > A > 0$ (McCune and Mefford 1999). Non-metric multidimensional scaling (NMS) based on the Sørensen distance measure, which is the most appropriate method for community analysis, was used to investigate indirect gradients influencing species distribution (Faith et al. 1987; Minchin 1987). We first removed outlier species (by use of a cut-off point of two standard deviations from the grand mean Sørensen distance measure). NMS was run using six starting dimensions, 40 iterations, an instability criterion of 10^{-5} and a rotation for maximum variance (McCune and Mefford 1999). Community composition was compared to species lists of the different forest types of Kenya (Beentje 1990; Trapnell 1997; Kindt et al. 2007).

We also used the Sørensen dissimilarity index and NMS to evaluate pairwise differences in species composition between plots (plot data). Plots were clustered into groups. Indicator values for all species and their significance were calculated for the emerging groups. Homogeneity within groups was tested with a multiresponse permutation procedure (MRPP) test. We used the same procedures as those described for fragments. Before analysis, four outlier plots (including two plots near a water tank and a school) were omitted from the dataset.

Classification, ordination and statistical tests were conducted using PC-ORD 5.0 for Windows (McCune and Mefford 1999) and SPSS 15.0 for Windows (SPSS Inc., Chicago, IL).

Results

Plant communities at landscape scale

There was a high species dissimilarity between the forest fragments (overall mean Sørensen dissimilarity 69%). Floristic dissimilarities (Sørensen distances between fragments) were not related to geographical (Euclidian) distances between fragments (Mantel r = –0.230, P = 0.345).

Clustering the fragments in three groups provided the most informative number of clusters, with more homogeneity within groups than expected by chance (MRPP A = 0.18, P = 0.013). Three woody species communities were identified, containing 19 to 126 species: remnants of riverine forest (Mwabirwa and Ronge), high altitude forest remnants (Vuria and Yale), and moist montane forests (Sagalla, Chawia, Ngangao and Mbololo) (Table 1).

For the NMS ordination, the best solution was two-dimensional (final stress 0.002, mean stress in real data 7.94, P = 0.004). The ordination isolated the high altitude forest remnants from the other fragments along one axis and the other two communities along a second axis. Within communities, individual fragments occupied nearly identical positions in the two-dimensional space of the ordination (Fig. 2).

Plant communities at patch scale

Eight species were found in more than 50% of all plots (overall relative frequency > 0.5): *Tabernaemontana stapfiana* (relative frequency 0.88), *Macaranga conglomerata* (0.81), *Strombosia scheffleri* (0.73), *Craibia zimmermannii* (0.69), *Newtonia buchananii* (0.65), *Albizia gummifera* (0.62), *Rapanea melanophloeos* (0.58) and *Syzygium sclerophyllum* (0.56). These species also had the highest relative importance values in both forests (Fig. 3), indicating that plant communities of both forest fragments are dominated by a few widespread species.

There was a high species dissimilarity between the two forest fragments (Sørensen dissimilarity 64%). Clustering the plots into two groups almost perfectly coincided with the separation between the two forests. A first group comprised all but one plot in Ngangao plus five plots from the southern edge of Mbololo. The second group comprised most plots of Mbololo (minus the five plots in the south) and a single plot in the center of Ngangao. The groups showed a high species dissimilarity (67%) and were more homogenous within groups than can be expected by chance (MRPP $A = 0.09$, $P < 0.001$). For the NMS ordination, the best solution was two-dimensional (final stress 25.52, mean stress in real data 27.26, $P = 0.004$). Ngangao forest was clearly separated from Mbololo in the two-dimensional space of the ordination (Fig. 4, white symbols versus black symbols). Similarly, both plant communities were separated in the ordination (Fig. 4, circles versus triangles). The species with the highest, significant indicator values for the first group (most of Ngangao and south Mbololo) included three species associated with forest margins and edges and disturbance. The indicators for the second group (most of Mbololo) were more typical for less disturbed moist forest (Table 2).

Discussion

Natural vegetation of the Taita Hills

Results of this study (species list data) show that the potential natural vegetation of the Taita Hills consists of moist montane forest. The natural moist montane forest type is *Ocotea* forest, which is also known as upland rainforest (Greenway 1973), Afromontane rainforest (White 1983) and *Ocotea-Podocarpus* forest (Lind and Morrison 1974). It has strong affinities with that of other mountain isolates in the Eastern Arc Mountains (Beentje and Ndiang'ui 1988; Lovett 1993). Within Kenya, forest communities that share keystone species with the Taita Hills forests are found on (mainly south and southeast) slopes and peaks at Mount Kasigau, Machakos Hills, Ol Doinko Sabuk, Kiangombe, the Aberdares (Nyeri), Mount Kenya, Mukinduri, Nyambeni, Mau, Tinderet Peak and Cherangani Hills (see Beentje 1990 for a description of these forests). These forests are *Ocotea* and *Newtonia* forests, or *Pouteria (Aningeria)-Strombosia-Drypetes* forest and *Albizia-Neoboutonia-Polyscias* forest. The latter two forest types can be seen as degraded and marginal variants of *Ocotea* forest (Beentje 1990).

Plant communities at landscape scale

At the landscape level (species list data), the different isolated forest fragments in the Taita Hills are characterized by one plant community despite the relatively large barriers between the different peaks. Based on the indicator species (Table 1), the forest type can be identified as (secondary) moist montane to intermediate montane forest. In Taita Hills, this forest type is represented on the four main peaks (Mbololo, Ngangao, Chawia and Sagalla). The keystone species, *Ocotea usambarensis* and *Podocarpus latifolius*, have been extracted for timber in the past and now only occur in small diameter classes (Bytebier 2001; Mbuthia 2003). Vuria and Yale may be high altitude, degraded variants. These small fragments show poorer structural quality, species richness and diversity than the larger fragments (Wilder et al. 1998; Chege and Bytebier 2005; Githiru et al. 2005). The patches at Mwabirwa and Ronge are two special variants at lower altitude representing riparian phases of the montane forest community – not because all lower altitude forest types would be riparian forest types, but because the only natural vegetation left in these fragments was located at wetter sites.

Plant communities at patch scale

Differentiation of the plant communities between the two largest forest remnants in the Taita Hills, Mbololo and Ngangao, may be related to differences in abiotic site conditions or precipitation. However, the distribution of indicator species over both fragments show that different levels of anthropogenic disturbance may have contributed too (Table 2). In Ngangao, the tree species with the highest relative importance (*T. stapfiana*, *M. conglomerata* and *A. gummifera*; Fig. 3) are early-successional species typical of edges and gaps. These species are also important in Mbololo, but two other species (*S. scheffleri* and *N. buchananii*; Fig. 3) have the highest importance. These species are not typically associated with disturbance, but neither with primary cloud forest. Low evenness (strong dominance of few species) and indicator species suggest that both forests are disturbed, but Mbololo forest is less disturbed than Ngangao forest (see also Wilder et al. 1998).

Potential causes for high dissimilarity between communities

The high dissimilarity between the Taita Hills forest fragments may be an effect of historical or recent isolation. The Taita Hills have been isolated at the landscape scale (the Eastern Arc Mountains) and on a geological time scale (290–180 M yr BP). Isolation could have shaped the plant communities when comparing the Taita Hills to other mountain isolates. Within the Taita Hills, the role of historical isolation is less evident. The Taita Hills may have been covered by continuous cloud forest (Pellikka et al. 2009), but detailed information about pre-disturbance forest cover is insufficient to conclude that historical isolation has shaped the plant communities of individual fragments.

More recently, the efficiency of seed dispersal of different tree species between fragments has decreased. These species are experiencing difficulties in maintaining stable populations in all forest fragments (Cordeiro et al. 2009; Lehouck et al. 2009a; Lehouck et al. 2009c). This implies that some fragments could have an extinction debt (Tilman et al. 1994). As habitat quality deteriorates some tree species will eventually become locally extinct after repeated failure of recruitment (Lehouck et al. 2009b). This is expected to occur sooner in small than in large fragments. Depending on what species will go extinct, this process may further increase or rather decrease pairwise differences between fragments. As highly sensitive and specialized species are more susceptible to local extinction, future extinctions may lead to biotic homogenisation and increased dominance by generalist or early-successional species (Lewis 2009).

Implications for conservation

While at the landscape level, the potential natural vegetation of the Taita Hills is moist montane forest, secondary species and species of gaps and edges are dominating the remnant vegetation. The various degraded states of the fragments require adapted management strategies. In the most degraded forests, restoring a form of secondary forest as an interim nurse stand may be a more realistic method than trying to restore pristine *Ocotea* forest immediately (see also Wright and Muller-Landau 2006). Such a restoration may already be ongoing in stands of planted trees surrounding the fragments of indigenous forests. The planted trees may facilitate the recruitment of native forest trees by acting as safe sites for seedlings (see e.g. Chapman and Chapman 1996; Lemenih and Teketay 2005; Zamora and Montagnini 2007). In other cases, planting or sowing indigenous trees may be needed to diversify impoverished forests or species-poor plantations (Aerts et al. 2006; Aerts et al., 2009). Planted trees may attract seed-dispersing animals (Elliot et al. 2003) and can act as a nurse crop for more demanding tree species by providing shade and improving soil conditions (Farwig et al. 2009).

Conservation-related intervention in the Taita Hills is urgent because only a small area of the forests remains (Brooks et al. 1998; Rogo and Oguge 2000). To preserve the biological richness of the Taita Hills, and in broader perspective, of the Eastern Arc, it is necessary to conserve indigenous forest over its entire elevation range (Hall et al. 2009). In the Taita Hills, this means conserving all indigenous forest fragments, including the very small and degraded patches. But conservation efforts should not only focus on maintaining forest quantity (size and number of patches), but also on forest quality (species composition). Species of old-growth cloud forest, such as *Ocotea usambarensis*, *Pouteria adolfi-friederici* and *Podocarpus latifolius* are underrepresented in the communities of the Taita Hills. Assisting restoration of viable populations of such cloud forest climax tree species is urgently needed.

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Figures

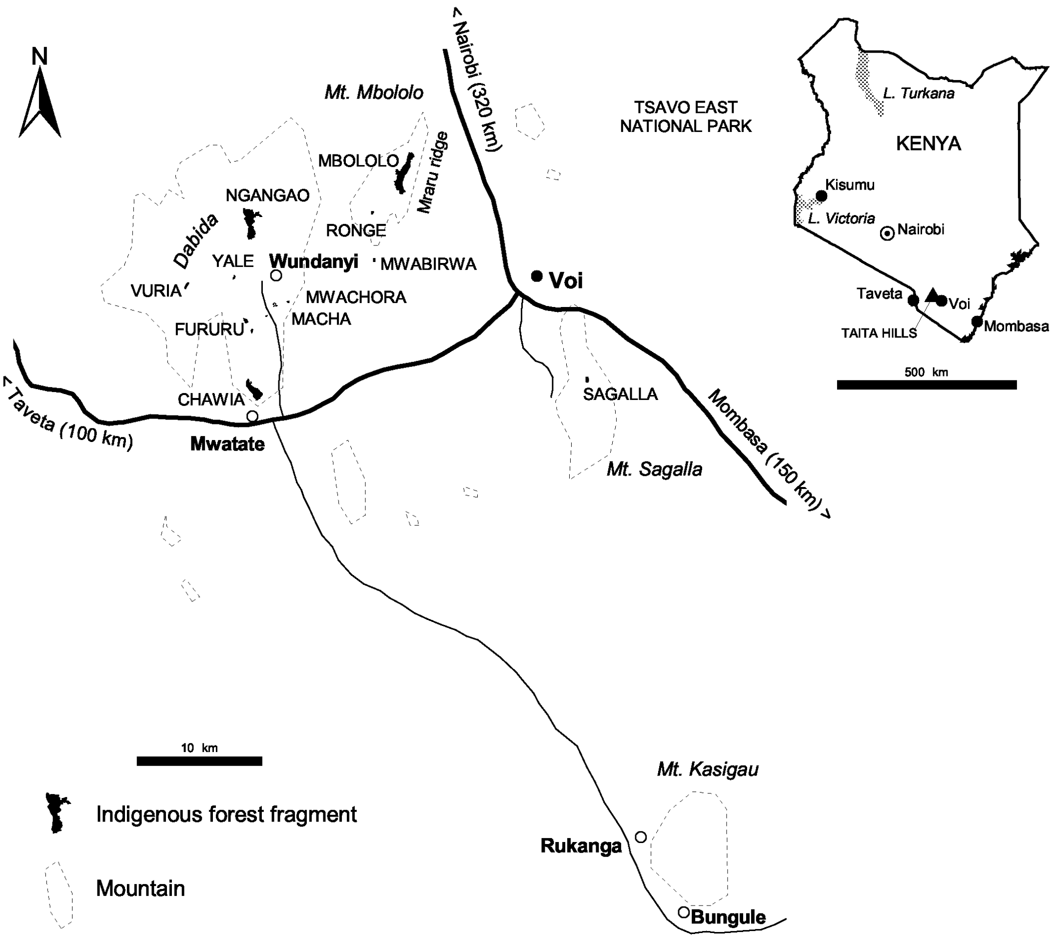

Fig. 1 Forest fragments in the Taita Hills, Taita Taveta District, Kenya. Source data for boundaries, roads, contour lines, cities and lakes © ILRI 2007 (available from www.ilri.org/gis)

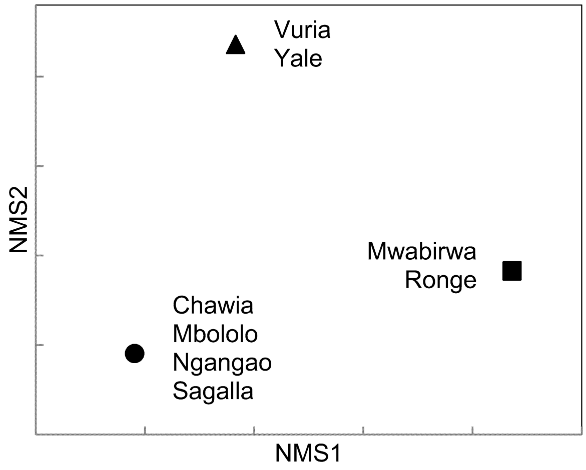

Fig. 2 Nonmetric multidimensional scaling (NMS) ordination of eight forest fragments in the Taita Hills, Kenya. Fragments are labeled according to woody plant species communities produced by cluster and indicator species analysis: moist montane forest (●), high altitude forest remnants (▲), and remnants of riverine forest (■)

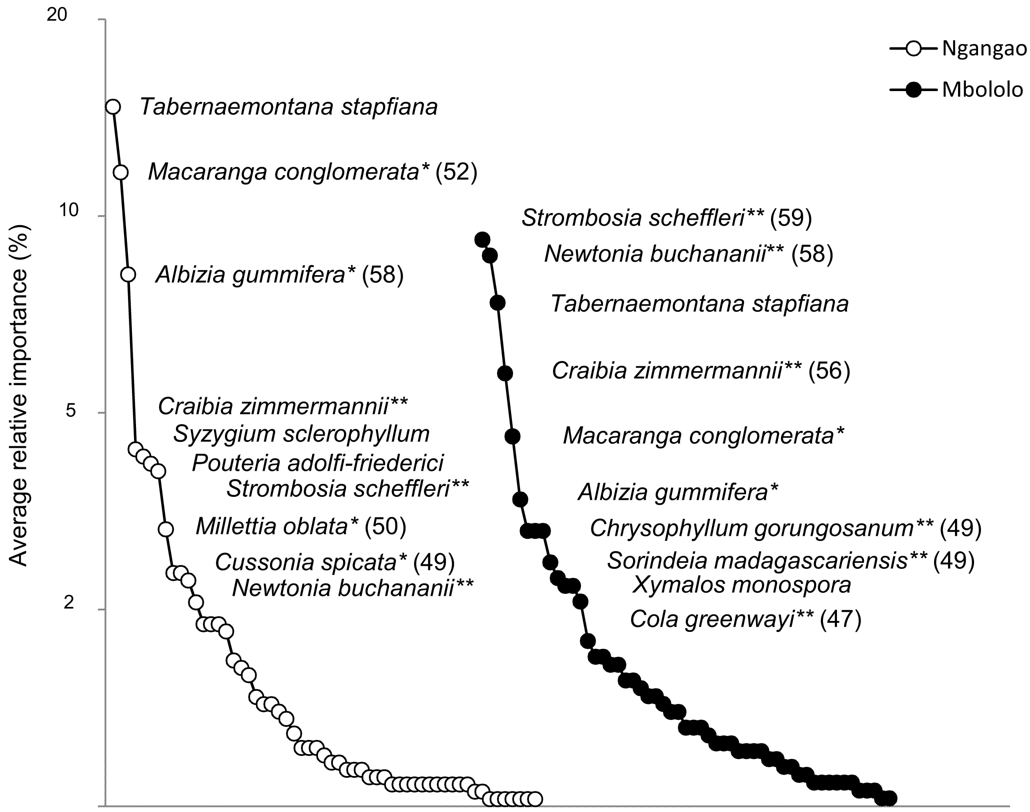

Fig. 3 Rank-abundance curves of tree communities of moist montane forest in Taita Hills, southern Kenya. Curves are drawn for two fragments, Ngangao and Mbololo. Steep curves indicate low evenness of species. Species followed by indicator values (in parentheses) are significant indicator species ($P < 0.05$) for woody species communities determined by cluster and indicator species analysis: * Community I, ** Community II. Indicator values range from zero (no indication) to 100% (perfect indication). Species are ranked according to relative importance (only the first ten species are labeled).

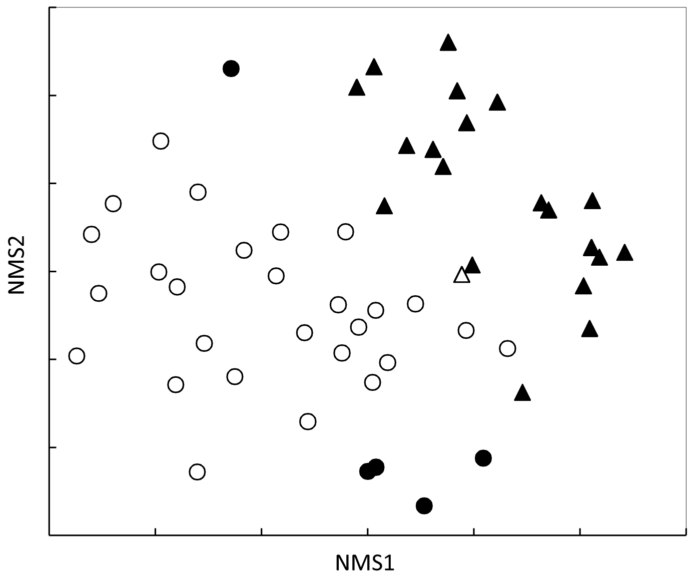

Fig. 4 Nonmetric multidimensional scaling (NMS) ordination of 53 plots in Mbololo forest (black) and Ngangao forest (white) in the Taita Hills, Kenya. Shapes indicate woody plant species communities produced by cluster and indicator species analysis: Community I (circles), Community II (triangles) (see Table 2).

Table 1

Important species of forest communities of woody species in eight isolated forest fragments in Taita Hills, southeast Kenya, determined by indicator species analysis

Indicator species	IV	*P*	Habit	Habitat
<u>Moist montane forests (Sagalla, Chawia, Ngangao, Mbololo; 126 species)</u>				
Tiliacora funifera	100.0	0.013	Liana	Moist and riverine forest
Chassalia parviflora	100.0	0.013	Shrub	Moist forest
Ochna holstii	100.0	0.013	Subcanopy tree	Dry forest (remnants), mist forest
Craibia zimmermannii	100.0	0.013	Canopy tree	Mist forest
Landolphia buchananii	100.0	0.013	Liana	Riverine and moist forest
Cola greenwayi	100.0	0.013	Canopy tree	Moist forest
Newtonia buchananii	100.0	0.013	Canopy tree	Riverine and moist forest
Tabernaemontana stapfiana	100.0	0.013	Canopy tree	Moist forest; common in disturbed forest
Strombosia scheffleri	66.7	0.073	Canopy tree	Moist forest
Nuxia floribunda	66.7	0.073	Tree	Forest (drier types) or forest remnants
Rauvolfia mannii	66.7	0.073	Shrub or tree	Moist forest, especially in margins and disturbed sites
Syzygium sclerophyllum	66.7	0.073	Canopy tree	Moist forest, mist forest
Macaranga conglomerata	66.7	0.073	Understorey tree	Moist forest; early-successional species in forest margins
Keetia gueinzii	66.7	0.073	Liana	Moist forest and forest margins, secondary bushland, riverine

Table 1

(continued)

Riverine forests fragments (Mwabirwa, Ronge plantation; 19 species)				
Anthocleista grandiflora	80.0	0.138	Canopy tree	Along rivers in forest areas
Macaranga capensis	80.0	0.138	Understorey tree	Moist forest, especially near streams
High altitude forest fragments (Vuria, Yale; 27 species)				
Prunus africana	57.1	0.215	Canopy tree	Moist forest
Philippia pallidiflora	57.1	0.409	Tree	Rocky forest edges

Indicator values (IV) range from zero (no indication) to 100% (perfect indication). *P*-values are calculated from a Monte Carlo permutation test for each species. For moist montane forest, only species with an indicator *P*-value < 0.10 are shown. For the other two communities, all indicator *P*-values were > 0.10; only species with the highest IV for each community are shown.

Table 2

Important species of forest communities of woody species in Ngangao and Mbololo in Taita Hills, southeast Kenya, determined by indicator species analysis

Indicator species	IV	*P*	Habit	Habitat
Community I (Most of Ngangao and southern edge in Mbololo, *n* = 32)				
Albizia gummifera	57.6	0.001	Canopy tree	Dry or moist forest (margins), riverine forest
Cussonia spicata	48.8	0.001	Tree	Moist and dry forest and forest margins, riverine forest; early-successional
Macaranga conglomerata	52.2	0.070	Understorey tree	Early-successional tree in edges of wet montane forest
Maesa lanceolata	38.9	0.018	Shrub or tree	Moist forest
Millettia oblata	50.0	< 0.001	Canopy tree	Moist forest (subsp. *teitensis*, endemic to Taita hills)
Oxyanthus speciosus	40.6	0.002	Shrub or tree	Moist forest
Polyscias fulva	46.9	0.001	Tree	Moist forest, riverine forest
Community II (Most of Mbololo except southern edge and one plot in Ngangao, *n* = 21)				
Bequaertiodendron natalense	53.8	< 0.001	Canopy tree	Moist mixed evergreen forest
Chrysophyllum gorungosanum	49.1	< 0.001	Canopy tree	Moist forest
Coffea fadenii	37.7	0.007	Understorey tree	Understorey of moist forest; endemic to Mbololo forest
Cola greenwayi	46.9	0.009	Understorey tree	Evergreen forest
Craibia zimmermannii	55.8	0.008	Canopy tree	Moist forest
Diphasiopsis fadenii	42.1	0.001	Shrub or tree	Moist forest
Ilex mitis	19.0	0.022	Shrub or tree	Evergreen mountain forest
Maytenus acuminata	28.6	0.003	Shrub or tree	Moist forest, especially with *Ocotea*
Newtonia buchananii	58.3	0.004	Canopy tree	Riverine forest, moist forest

Nuxia congesta	23.4	0.043	Shrub or tree	Forest and woodland; common where disturbed
Ocotea usambarensis	23.8	0.008	Canopy tree	Moist forest
Pleiocarpa pycnantha	44.7	< 0.001	Shrub or tree	Wide range
Psychotria crassipetala	38.1	< 0.001	Shrub or tree	Moist forest; endemic to Taita Hills
Sorindeia madagascariensis	49.1	< 0.001	Canopy tree	Riverine forest
Strombosia scheffleri	58.7	0.003	Canopy tree	Moist forest
Strychnos henningsii	51.5	< 0.001	Shrub tree	Dry forest, riverine
Syzygium guineense	28.6	0.002	Large tree	Mountain rainforest

Indicator values range from zero (no indication) to 100% (perfect indication). *P*-values are calculated from a Monte Carlo permutation test for each species.

Only species with an indicator *P*-value < 0.05 are shown.