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VEGETATION STRUCTURE AND COMPOSITION OF THE TAITA HILLS FORESTS

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ABSTRACT

The structure and composition of the indigenous forest fragments of the Taita Hills of south-east Kenya were analysed. We collected data in all of the large forest fragments using Point Centred Quarter extensive surveys, supplementing these data with intensive surveys of 20 x 20 m plots. Our structural data on basal area per unit area, stem density, canopy cover, shrub density, stratification and extent of herbaceous ground cover clearly show that the largest fragment, Mbololo, is also the least disturbed. The next largest fragment, Ngangao, has suffered from intermediate levels of disturbance, and all other fragments have been very heavily impacted. Tree size class distributions show that nearly all of the large circumference trees have been lost from the smallest fragments, while the Chawia forest is selectively losing its small, easily-cut trees. Finally, we mapped the Importance Values (combined standard measures of abundance, biomass and dispersion) of each forest's tree species. The map indicates the forest biogeography of the region but also shows the extent to which all of the fragments except Mbololo and Ngangao are dominated by a very few secondary successional sub-canopy species. Only Mbololo and Ngangao may be viable forests in the long term.

INTRODUCTION

The remaining forests of the Taita Hills, south-east Kenya, are poorly known botanically. A number of historical collections exist from the area, but there have been only three recent

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species inventories (Beentje, 1987; Mwangangi & Mwaura, 1992–3; Imboma, 1997). These show that many of the forests' tree species are shared with both the Kenyan Highlands and the Eastern Arc Mountains, although they are distinct from either, having no less than 13 endemic plant taxa (Beentje, 1987). However, only one study, limited to the single site of Ngangao, has assessed forest structure (Tetlow, 1987). In this paper, we present data on the vegetation of the eight largest surviving forest fragments of the Taita Hills: Sagalla (03°30'S, 38°35'E), 1,500 m, 4 ha; Ronge (03°21'S, 38°25'E), 1,200 m, 1 ha; Mbololo (03°20'S, 38°26'E), 1,800–2,200 m, 200 ha; Ngangao (03°22'S, 38°20'E), 1,700–2,100 m, 92 ha; Chawia (03°28'S, 38°28'E), 1,500 m, 50 ha; Fururu (03°24'S, 38°20'E), 1,400 m, 5 ha; Vuria (03°24'S, 38°17'E), 2,000 m, 1 ha; and Mwachora (03°25'S, 38°22'E), 1,400 m, 2 ha.

METHODS

In the five largest forests we established transects with 40 equally spaced points (three forest fragments, Fururu, Vuria and Mwachora, were too small to hold 40 independent points). In most forests these transects had to be oriented to fit the shape and size of the patch; therefore point spacing varied from 20 m between points in the smallest forests to 100 m in the largest. We surveyed each of the 40 points using the Point Centred Quarter method (Cottam & Curtis, 1956). After measuring the distance from the point to the closest tree >45 cm circumference, *i.e.* >15 cm diameter at breast height in each of the four quadrants NE, SE, SW and NW, we identified the trees and measured their circumferences at 120 cm height.

Following Kent & Coker (1992), we used these data to calculate the Shannon-Wiener diversity index, H':

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

where

s = the number of species

p_i = the total basal area of the i^{th} species as a proportion of the total basal area of all trees

We also calculated the Shannon-Wiener equitability index, J, using:

$$J = H'/\ln s$$

The Importance Values (IVs) for each species (as percentages) were determined by the following formula (Curtis & McIntosh, 1950, 1951):

IV = (Relative density + Relative dominance + Relative frequency)/3

where:

Relative density = Number of individuals/Number of individuals of all species

Relative dominance = Total basal area/Total basal area of all species

Relative frequency = Number of quadrants occurring/Total number of quadrants

These IVs give a combined standard measure of abundance, biomass and dispersion for each species (Kent & Coker, 1992).

At each point in our Point Centred Quarter surveys, we estimated canopy cover and took half-sight measurements of shrub layer density at 1 m and 2 m height (Wight, 1938). For each measurement we counted the number of squares more than half visible on a board that was divided into 25 squares of 8 cm x 8 cm, held at a 5 m distance from the observer. Finally, we counted the number of saw-pits near each point.

In addition, we chose three points in a stratified random manner at which to establish large (20 m x 20 m) plots. In these, we identified and counted every shrub (1–5 m tall); and identified every tree (>5 m tall), measured its circumference at 120 cm and classified its status (e.g., as dead, artificially cut, etc). We noted the presence of buttresses for trees >15 m tall, the heights and dominant species of each vegetation stratum, and the plot's disturbance and slope. Finally, we established five 1 m x 1 m subplots in the centre and in each corner of the plot, within which we estimated the % cover of bare ground, leaf litter and herbaceous growth, and measured the leaf litter depth. For the three smallest forest fragments, we surveyed a single large plot in the centre of the patch and measured half-sights in the five subplots of this plot. All identifications were made with reference to Beentje (1994) and to specimens in the East African Herbarium, Nairobi, Kenya.

RESULTS

Forest structure: Point Centred Quarter surveys

Table 1 presents the summary results of our Point Centred Quarter surveys and figure 1 illustrates the frequency distributions of size classes of trees as revealed by these surveys. Mbololo is clearly the least disturbed forest, with the highest mean basal area per m^2 (an indicator of live standing biomass), stem density and canopy cover, and the most open understorey (as indicated by the high half-sight values). It also retains the largest trees of the Taita Hills, although it holds less intermediate-sized trees than do Ngangao and Chawia, and its mean tree size is lower as a consequence. Ngangao has suffered an intermediate level of disturbance. There are numerous small trees at this site, which have presumably regenerated since the termination of pit-sawing here in the 1970s (Brooks *et al.*, 1998), although Ngangao also holds some very large trees. Likewise, some large trees survive in Chawia, but heavy selective logging of easily-transported small trees at this site has prevented regeneration, as indicated by its low number of small trees, high mean tree size, and low canopy cover. Sagalla and Ronge have both been very heavily disturbed, having the lowest basal area per m^2, mean tree sizes and stem densities, the fewest large trees, and the densest under-storeys.

Forest structure: large plots

Table 2 presents the summary results from our surveys of large (20 m x 20 m) plots. These data are derived from small samples (1,200 m^2 for large forests and only 400 m^2 for small

Table 1. Structural data collected from Point Centred Quarter surveys (n = 40 for each forest fragment). Our samples of mean basal area/tree are highly skewed (figure 1) and so standard deviations are uninformative measures of dispersion for these samples. For these, we instead give values of skewness (in parenthesis). As a result, values of biomass (mean basal area/m^2) also lack standard deviations, but we give standard deviations for all other mean values.

Parameter	Sagalla	Ronge	Mbololo	Ngangao	Chawia
Mean basal area/m^2 (cm^2/m^2)	33	25	77	58	61
Mean basal area/tree (cm^2)	858(2.8)	827(4.6)	1,358(4.5)	1,536(2.9)	2,041(1.9)
Stem density/ha	386±116	301±116	578±148	380±134	297±95
Mean canopy cover (%)	57±32	60±31	72±34	60±32	51±34
Mean half-sight: 1m	13±8	10±8	18±6	16±9	12±9
Mean half-sight: 2m	12±9	11±8	19±6	12±9	11±9
Total pit-saws	1	0	2	12	2

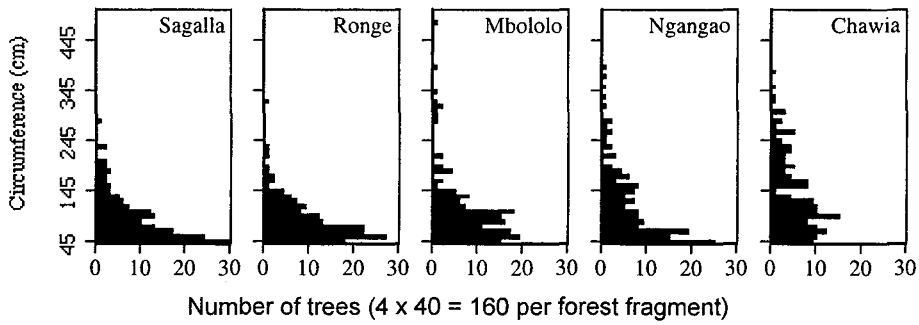

Figure 1. Frequency distribution of size classes of trees surveyed by Point Centred Quarter survey.

forests) and should therefore be interpreted with caution. In particular, the basal area per m^2 of 86 cm^2/m^2 for Ngangao is greatly influenced by a single huge tree, and that for Mwachora is vastly inflated by a large *Phoenix reclinata* Jacq. clone. However, it can be seen that the two lowest altitude and therefore most level sites (Ronge and Chawia) have the deepest leaf litter, despite the degree to which they have been disturbed. The high stratification and number of buttressed trees attest to the quality of the forest in Mbololo and Ngangao. There are also non-significant tendencies for the more disturbed sites to have a more extensive herb layer and proportionately less leaf litter, higher proportions of dead and cut trees, and more trails.

Forest composition

Table 3 gives three measures of forest composition derived from our Point Centred Quarter surveys. Mbololo and Ngangao clearly have higher tree species richness (*i.e.* variety of species) and diversity indices (*i.e.* variety of species biomass across total biomass) than do the other forests. They also have higher equitability indices (*i.e.* evenness of biomass distribution across species) than does Chawia, indicating their healthy distribution of diverse tree species. Sagalla and Ronge have equitability indices as high as Mbololo and Ngangao; however, this is largely a product of their low species richness.

Table 2. Structural data collected from 20 m x 20 m plots. Our samples of mean litter depth are highly skewed and so standard deviations are uninformative measures of dispersion for these samples. For these, we instead give values of skewness (in parenthesis). We give standard deviations for all other mean values.

Parameter	Sagalla	Ronge	Mbololo	Ngan-gao	Chawia	Fururu	Vuria	Mwa-chora
Range of slopes (°)	0–38	5–11	34–48	24–36	4–14	30	56	10
Range of strata	2–3	3	3–4	2–4	2–3	3	2	3
Mean litter depth (mm)	15(1.7)	30 (3.7)	14(1.3)	13(2.7)	25(1.8)	12 (-1.7)	10(0.6)	6(0.3)
Mean litter cover (%)	57±30	81±30	75±19	58±29	47±25	60±29	78±3	17±24
Mean herb cover (%)	30±25	14±21	11±12	34±28	53±25	37±32	11±9	81±26
Dead trees (%)	14	12	9	12	13	8	22	0
Artificially cut trees (%)	2	0	1	4	2	0	13	0
Buttressed trees /1,200 m^2	0	4	10	6	2	0	3	3
Number of trails /1,200 m^2	0	1	1	3	5	3	3	6
Basal area /m^2 (cm^2/m^2)	25	43	63	86	53	45	41	281

Figure 2 presents IVs of > 9 % for tree species in the five large forests as determined by our Point Centred Quarter survey. The isolation of Sagalla and the low altitude of Ronge set the composition of these two forests apart from the rest of the Taita Hills (figure 2). Thus important trees in Sagalla (*e.g. Newtonia buchananii* (Bak.) Gilb. & Bout.) and Ronge (*e.g. Anthocleista grandiflora* Gilg.) are scarce elsewhere in the Taita Hills, which are instead characterised by species like *Albizia gummifera* (J.F. Gmel.) C.A. Sm., *Tabernaemontana stapfiana* Britten and *Strombosia scheffleri* Engl. This pattern is reflected in the avian biogeography of the forests, with the drier, lower altitude forests of Sagalla and Ronge holding very different bird communities to the moist high forests (Brooks *et al.*, this volume).

Table 3. Measures of forest composition data collected from Point Centred Quarter surveys (n = 40 for each forest fragment).

Parameter	Sagalla	Ronge	Mbololo	Ngangao	Chawia
Number of species	15	22	36	32	17
Shannon-Wiener diversity, H'	2.18	2.24	2.75	2.44	1.68
Shannon-Wiener equitability, J	0.81	0.73	0.77	0.70	0.59

Nevertheless, the heavy disturbance the forests have suffered has clearly impacted their composition as well as their structure, overlying the background patterns of biogeography. The degree to which Chawia, Ronge and Sagalla have been disturbed is shown by the importance in these forests of just a few tree species, especially early successional subcanopy species of little economic importance like *T. stapfiana* and *P. reclinata*. In contrast, Ngangao and especially Mbololo have a more even distribution of species IVs and much greater species diversity.

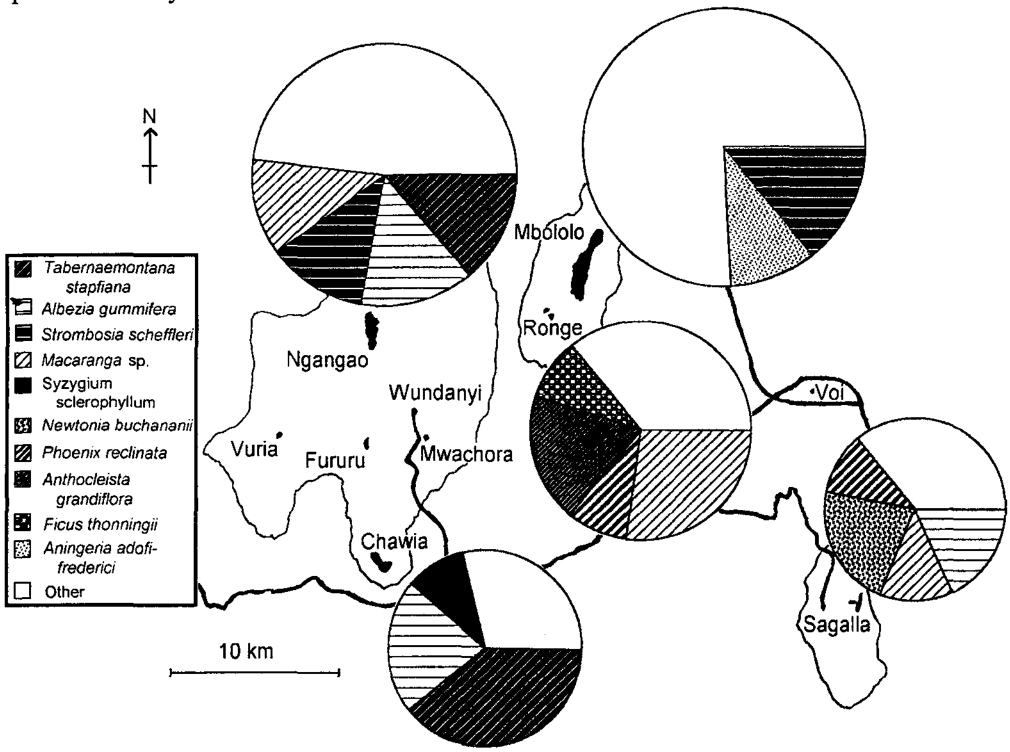

Figure 2. Importance Values (IVs) > 9 % for tree species in the five large forests as determined by the Point Centred Quarter survey. Areas are proportional to species numbers, with stripes for subcanopy and shading for canopy trees. The thin lines delimit the area above 1,200 m, the thick lines show main roads, and the solid areas show indigenous forests.

DISCUSSION

The structure and composition of the Taita Hills forests indicate the high levels of disturbance suffered here. In the future, only Mbololo and Ngangao, with their relatively natural forest structure and composition, are likely to persist. The dominance of the other forests by a few species and the former heavy cutting of young (in Chawia) and old (in Sagalla and Ronge) trees may well compromise their viability in the long term.

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