TREE SPECIES COMPOSITION AND POTENTIAL TIMBER PRODUCTION OF A COMMUNAL MIOMBO WOODLAND IN HANDENI DISTRICT, TANZANIA

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Key words: Species diversity – species importance – commercial and non-commercial timber species – timber harvesting

MALIONDO, S. M. S., ABELI, W. S., OLE MEILUDIE, R. E. L., MIGUNGA, G. A., KIMARO, A. A. & APPLEGATE, G. B. 2005. Komposisi spesies pokok dan potensi penghasilan balak di hutan kebun miombo kauman di daerah Handeni, Tanzania. Tiga tapak dipilih berhampiran Madebe iaitu sebuah kampung di daerah Handeni yang menguruskan hutan kebun miombo di Tanzania. Sepuluh blok segi empat sama setiap satunya bersaiz 4 ha ditubuhkan. Setiap blok disubbahagikan pula kepada 16 plot segi empat sama, setiap satu seluas 2.5 ha. Dalam setiap blok, semua pokok dengan diameter aras dada (dbh) > 30 cm dikenal pasti dan diukur dbhnya. Semua pokok > 10 cm dan

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< 30 cm dbh direkod dalam enam plot yang dipilih secara rawak dalam setiap blok. Ketumpatan batang meningkat secara linear (r^2 = 0.58) daripada 142 pokok ha^{-1} di tapak A kepada 223 pokok ha^{-1} di tapak C dengan kebanyakan daripada batang (77%) berada dalam kelas < 30 cm. Purata luas pangkal dirian adalah 11.0 m^2 ha^{-1} dan 8.52 m^2 ha^{-1} daripadanya adalah bagi spesies komersil. Tapak A mempunyai isi padu dirian 57.1 m^3 ha^{-1} berbanding 50.9 m^3 ha^{-1} di tapak lain. Spesies pokok komersil > 50 cm dbh merupakan 4% daripada jumlah stok, 23% daripada luas pangkal dan 25% daripada isi padu. Sebanyak 16 famili yang mengandungi 48 spesies pokok dikenal pasti di kawasan kajian yang seluas 40 ha ini dan 34% dan 25% daripada batang adalah masing-masing dalam famili Caesalpiniaceae dan Papilionaceae. *Brachystegia boehmii* dan *Julbernardia globiflora* merupakan spesies dominan. Ini menunjukkan kedua-dua spesies ini tidak banyak dibalak dan mempunyai kerintangan api yang agak tinggi. *Combretum amiculatum, Diplorhynchus condylocarpon, Brachystegia microphylla* dan *Pseudolachnostylis maprouneifolia* juga banyak didapati.

Introduction

The miombo, which is the largest woodland under the auspices of the Southern Africa Development Countries (SADC) covering 3.8 million km^2, affects the livelihood of about 55 million people (Campbell *et al.* 1996). Besides local interest, the woodland is also of global significance with respect to environmental and biodiversity conservation. This ecosystem varies greatly both spatially and temporally due to the complex interaction of a range of influences including climatic, edaphic, fire and anthropogenic factors.

The importance of the miombo to the local inhabitants cannot be overemphasized. It provides a source of food including wild vegetables, and animal and plant protein . It also provides fuelwood, charcoal, grass, wood and building poles for shelter and medicinal plants for human and animal health (Monela *et al.* 2001).Environmental services produced by the miombo include protection of water catchments and biodiversity conservation. The production and marketing of timber, wildlife and honey harvested from the miombo woodland contribute significantly to the income of local communities and individuals through local and overseas trading (Monela *et al.* 2001).

Unsustainable use of the miombo including its conversion to agriculture, overgrazing, clearing for settlement and unplanned harvesting of forest products such as timber and fuelwood and uncontrolled fires leading to environmental degradation and reduction in biodiversity are of national and global concern. While the timber harvesting operations in many parts of the miombo currently cover a small area, there is huge potential for providing large quantities of timber on a sustainable basis. However, sustainable timber production is impeded by poor timber harvesting practices and improper silvicultural regimes. This has destroyed plant and animal biodiversity and caused soil degradation and erosion, as well as degradation of the residual stand and impaired adequate regeneration. Development and adoption of efficient, environmentally friendly harvesting techniques for industrial and community-based harvesting of the miombo woodland can contribute to its sustainable management.

This paper provides information on a miombo woodland earmarked to be harvested by industrial timber harvesting companies under the control of the local authorities, namely Madebe Village Authority in collaboration with the Handeni District Forest Catchment Office, Tanzania. Current stocking rates, species composition and biodiversity indices are provided as baseline information required for comparing the impact of improved timber harvesting with the current conventional timber harvesting.

Timber harvesting in miombo woodlands of Tanzania

The miombo woodlands in Tanzania are dominated by the genera *Brachystegia, Julbernardia* and *Isoberlinia* (White 1983) and comprise about 75% of the total forest cover. Apart from these genera, which characterize the miombo, these woodlands contain other valuable timber tree species such as *Pterocarpus angolensis, Afzelia quanzensis* and *Brachylaena huillensis* that are extensively harvested for processing by sawmills located within the miombo areas. The miombo woodland in Handeni district is the main source of wood for several sawmills and two parquetry factories in Tanga. *Pterocarpus angolensis, B. huillensis* and *A. quanzensis* are the most favoured commercial timber species, but since bigger sizes of these tree species have been exhausted, other commercial species including *Brachystegia* spp., *Julbernardia* spp., *Isoberlinia* spp. and *Sterculia* spp. are now being harvested for timber, railway sleepers and plywood production.

Handeni district, like many other areas in Tanzania, has a relatively low human population, practising mainly shifting cultivation. Large areas of the woodland are periodically cleared for planting maize, millet, sorghum, cassava and pigeon peas, and are abandoned when the soil becomes unproductive. These woodlands are also the major source of building poles, fuelwood, medicinal plants, fruits and vegetables (Mwihomeke & Mabula 1994).

Timber harvesting is undertaken using semi-mechanized logging methods, which include chainsaws for felling and de-limbing, and modified farm tractors for skidding the logs. The current timber harvesting practices are environmentally unfriendly and have negative impact on the residual woodlands. There are no planned skidding trails, no directional felling of trees to facilitate skidding and logs are dragged haphazardly on the ground by logging tractors, leading to unnecessary soil disturbance and soil erosion. There is damage to, or destruction, of the residual commercial trees but regeneration damage also occurs. Piling of logging slash around felled trees sometimes results in intense fires during the dry season, killing or suppressing young seedlings, root-suckers and coppice regrowth.

Pit sawing is also prevalent in some areas which involves sawing logs into boards on the logging site and transporting the sawnwood by hand or with the use of animals. While this operation normally has less environmental impact where it is carried out haphazardly, or unplanned, it may also cause damage to the residual trees. Pit sawing moreover leads to a low recovery of utilizable wood from each log and can also lead to depletion of a particular tree species when controls on the logging operations are non-existent.

Materials and methods

The study area

The study site was located in Kang' ata ward close to Madebe village in Handeni district, in Tanga Region, Tanzania. The area lies between 5°40'–5°45' S and 37°55'–38°05' E at an altitude of about 600 m above sea level. The topography consists of undulating plains intersected by valleys and isolated hills. Soils vary from dark reddish brown, sandy clay loam at the surface to dark red clayey subsoil. Soil pH is strongly acidic (4.1–6.0). The soil belong to Oxisols order of the Soil Taxonomy System of Soil Classification (Soil Survey Staff 1999). The area has a subhumid climate (Mwihomeke & Mabula 1994) with a mean annual rainfall of 854 mm, which falls between November and May (Hathout & Sumra 1974). The natural vegetation consists of dense miombo woodland dominated by *Brachystegia* spp., *Julbernardia* spp., *P. angolensis, B. huillensis* and *A. quanzensis.* The area is a public forest/woodland loosely managed by four villages in the Kang' ata ward in consultation with the District Forest Authority. Details of the villages in the ward are provided in Table 1 (Mwihomeke & Mabula 1994).

Site selection and plot layout

Three sites were selected within the miombo woodland for tree vegetation analysis. A multidisciplinary research team selected this area as being suitable to provide both socio-economic information as well as logging data as this part of the woodland had been earmarked for timber harvesting. The data collected is part of the pre-harvest inventory.

The sites were located at varying distances from Madebe village, which is 27 km away from Handeni township. Site A is 6 km from Madebe village; sites B and C are 12 and 13 km respectively from the village. The sites had been selectively logged in the past with the largely uncontrolled operations removing most of the large trees of *P. angolensis.*

Ten blocks, each measuring 200 x 200 m, were established. The 4-ha plot size was considered sufficient to cover the variability encountered in this woodland and as being representative of the public woodland in the area. Sites A and B had

Table 1 Villages in the Kang'ata ward, Handeni district, Tanzania

Village	Number of households	Population (number)
Madebe	190	897
Gole	34	147
Kilima Mzinga	255	898
Nyasa	245	350
Total	724	2292

three blocks each, and site C had four blocks (total sample area – 40 ha). Four instead of three blocks were used in site C to accommodate more variability observed on that site. Each block was subdivided into 16 plots of 50 x 50 m. All trees with diameter at breast height (dbh) > 30 cm were identified and recorded. From each block, 6 plots were selected at random, and all trees with dbh ≥10 cm and ≤ 30 cm were identified and measured for dbh.

Calculations

The number of stems ha^{-1} *(N)* and basal area *(G)* of the stands on the three sites using trees ≥10 cm dbh were calculated. Gross stem volume *(V)* of all trees ≥10 cm dbh to the stem tip was calculated using the following volume equations developed for a similar miombo woodland in another part of Tanzania (Malimbwi *et al.* 1994). These data were then converted to volume ha^{-1}, expressed as m^3 ha^{-1}.

(1) For trees ≥15 cm dbh:
$\text{Ln } Y = -10.965 + 2.8\ 5 \text{ Ln} X \qquad r^2 = 0.89$

(2) For trees <15 cm dbh:
$\text{Ln } Y = -7.06\ 06 + 1.80 \text{ Ln} X \qquad r^2 = 0.84$

where Y is volume (m^3) and X is dbh (cm) and Ln is the natural log.

It should be noted that the above equations were based on trees of dbh 8–43 cm and hence use of these models for larger trees (> 43 cm) is likely to overestimate the actual volume. To correct the volume of large trees, Nduwamungu (pers. comm.) has suggested a correction factor of 0.5.

The following biodiversity indices for trees ≥10-cm dbh were calculated according to standard formulae (Kent & Coker 1992) for each of the three sites.

(i) Frequency *(f)*
$f =$ number of occurrences of a species.

(ii) Relative frequency *(rf)*
$rf =$ (number of occurrences of the i^{th} species / number of occurrence of all species) * 100.

(iii) Relative density *(rD)*
$rD =$ (density of the i^{th} species / density of all species) * 100.

(iv) Relative dominance *(rd)*
$rd =$ (basal area of the i^{th} species/ total basal area of all species) * 100

(v) Importance value index (IVI)
$\text{IVI} = rf + rD + rd$

(vi) Shannon-Wiener diversity index (H')

$$H' = -\sum_{i=1}^{s} p^i \ln p^i \qquad (1)$$

where:

H' = Shannon-Wiener diversity index

s = number of species

p_i = the proportion of individuals

(vii) Equitability (evenness) (J)

$$J = H'/\ln S \qquad (2)$$

where, J = equitability (evenness) index
S = total number of species
H' =Shannon diversity index

The three pre-harvest sites were compared using the calculated indices.

Results

Stem density, basal area and volume

The mean stem density, basal area and standing volume for the three sites were 183 stems ha^{-1}, 11.0 $m^2\,ha^{-1}$ and 52.97 $m^3\,ha^{-1}$ respectively (Table 2). Most stems (77%) were in the small dbh class (10–30 cm) while 63% of the basal area and 70% of the volume were in trees larger than 30-cm dbh. Notably, the number of trees and basal area increased linearly with distance from Madebe village.

Table 2 Mean values for stems (*N*), basal area (*G*) and standing volume (*V*) in Handeni, Tanzania

Site	Stocking		Basal area		Standing volume	
	N (stems ha^{-1})	% (dbh ≤ 30 cm)	*G* ($m^2\,ha^{-1}$)	% (dbh ≤ 30 cm)	*V* ($m^3\,ha^{-1}$)	% (dbh ≤ 30 cm)
A	142	73	9.61	29	57.15	22
B	182	79	10.75	42	49.11	34
C	223	79	12.64	42	52.65	33
Mean	183	77	11.00	37	52.97	30

Note: Sites A, B and C are 6, 12 and 13 km respectively from Madebe village.

Basal area varied significantly between sites in dbh classes 21–30 cm and > 50 cm ($p < 0.050$). Both number of stems ha^{-1} and standing volume differed significantly between sites for trees with dbh > 50 cm, accounting for 8% of the stocking and 35% of the basal area in site A. The corresponding figures for the other two sites averaged 3 and 18%. The proportions of the total volume in the large trees with dbh > 50 cm) were 46, 27 and 24% for sites A, B and C respectively.

Commercial and non-commercial trees

The number of commercial species (Bryce 1999) in the area was eleven. These species accounted for 56, 60 and 43% of the total stocking in sites A, B, and C respectively. The size distribution of commercial and non-commercial tree species (Bryce 1999) followed a reversed " J " shape on the three sites (Figures 1a, b, c) but in site C, the commercial species had a similar number of trees in the 10–40 cm dbh class decreasing thereafter (Figure 1c). Site B supported more commercial species than the other two sites, of which 71% were in small diameter classes (dbh < 30 cm) compared with 55% in the other two sites (Table 3). The number of small trees (< 20-cm dbh) of commercial species was much lower (37%) than in the non-commercial species (80%).

Table 3 Mean values for stocking (*N*), basal area (*G*) and standing volume (*V*) of commercial tree species in Handeni, Tanzania

Site	Stocking		Basal area		Standing volume	
	N (stems ha^{-1})	% (dbh ≤ 30 cm)	*G* ($m^2 ha^{-1}$)	% (dbh ≤ 30 cm)	*V* ($m^3 ha^{-1}$)	% (dbh ≤ 30 cm)
A	80	54	7.96	16	49.93	13
B	111	71	8.18	31	38.04	25
C	96	57	9.43	29	42.25	22
Mean	96	61	8.52	25	43.39	30

Note: Sites A, B and C are 6, 12 and 13 km respectively from Madebe village.

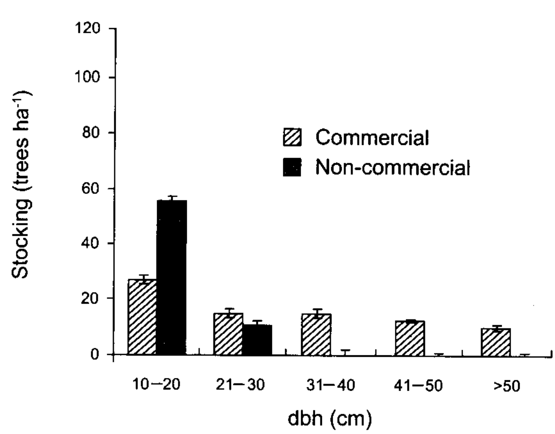

Figure 1(a) Stocking distribution of commercial and non-commercial tree species in site A

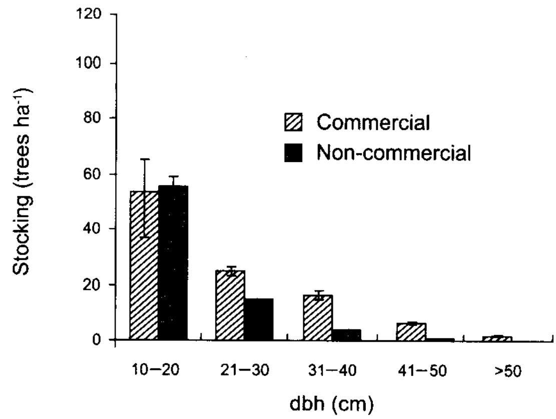

Figure 1(b) Stocking distribution of commercial and non-commercial species in site B

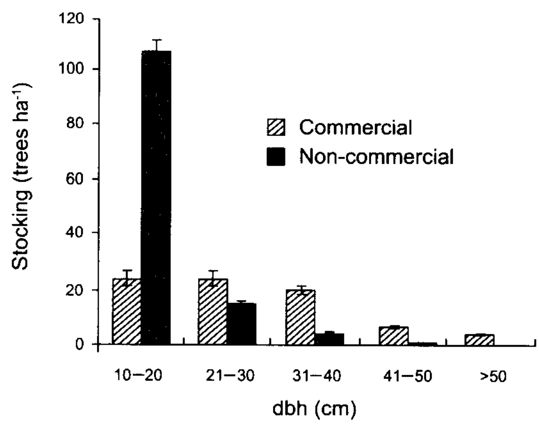

Figure 1(c) Stocking distribution of commercial and non-commercial tree species in site C

The basal area of commercial species is concentrated in larger diameter size class while non-commercial species followed a reversed pattern for sites A and B (Figures 2a, b). On site C, commercial stems in the intermediate diameter class (31–40) had higher basal area than the other diameter classes (Figure 2c).

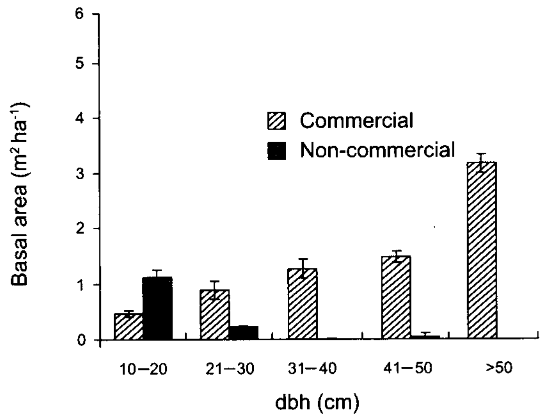

Figure 2(a) Basal area distribution of commercial and non-commercial tree species in site A

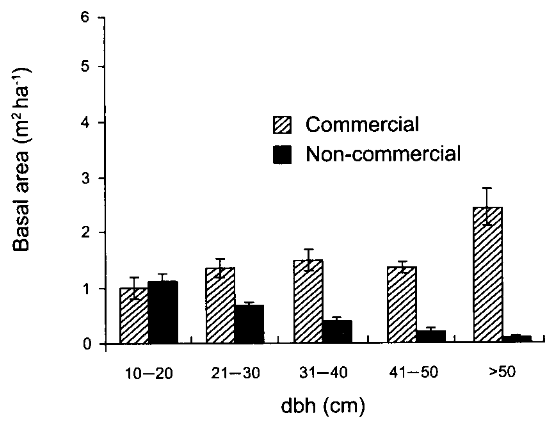

Figure 2(b) Basal area distribution of commercial and non-commercial tree species in site B

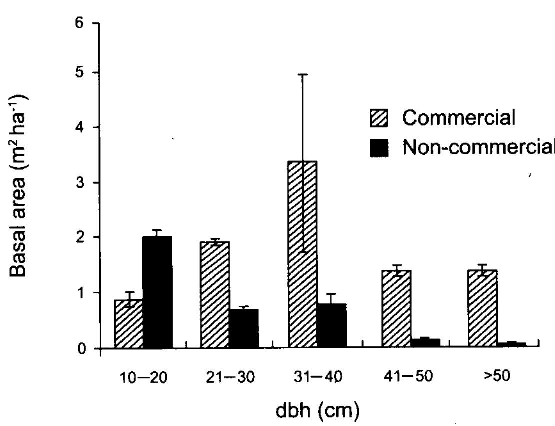

Figure 2(c) Basal area distribution of commercial and non-commercial tree species in site C

Commercial species accounted for 83, 76 and 73% of the total basal area in sites A, B and C respectively. About 73% of the basal area in non-commercial species was in small diameter classes < 20-cm dbh in site A, 46% in site B and 60% in site C. The corresponding values for the commercial species were 6, 13 and 8% respectively.

Figures 3a, b, c show that the volume of commercial species increased with diameter class, but that of the non-commercial species decreased with size class. This may be due to the fact that most of the commercial timber species are legally protected and can only be harvested after obtaining a government licence. Most of the total volume was in commercial species (87% in site A, and 79% in the other two sites). Table 3 shows that site A supported a higher volume of commercial species (49.9 $m^3 ha^{-1}$) than the other two sites (40.0 $m^3 ha^{-1}$). About 53% of the commercial volume in site A was in large commercial trees (> 50 cm), compared with 31% in the other two sites. The proportions of the volume of non-commercial species in small trees (< 20-cm dbh) were 73, 63 and 42% for sites A, B and C respectively.

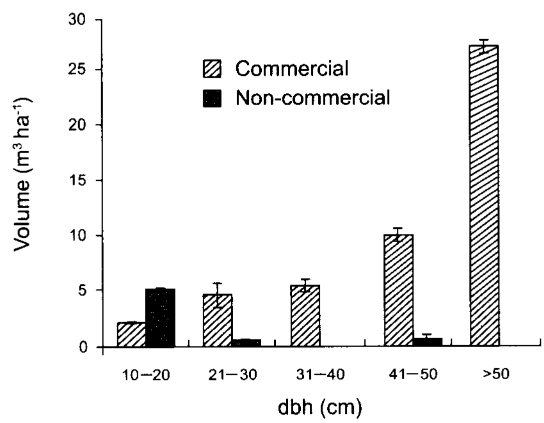

Figure 3(a) Volume distribution of commercial and non-commercial tree species in site A

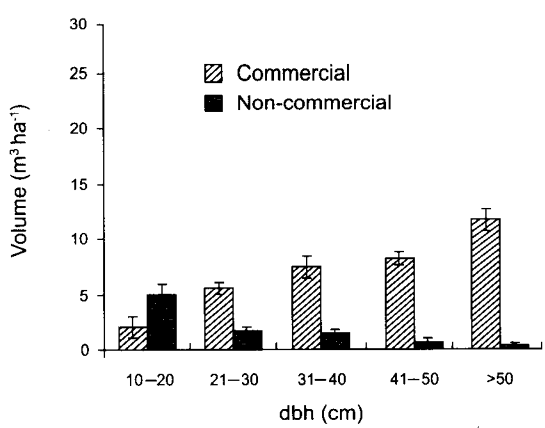

Figure 3(b) Volume distribution of commercial and non-commercial tree species in site B

Tree species composition and richness

A total of 48 tree species above 10-cm dbh were identified in the three sites. The complete list of identified species with both local and scientific names is provided in Appendix 1.

The tree species were in 16 plant families. The dominant families were Caesalpiniaceae and Papilionaceae, which occupied about 34 and 25% respectively of all recorded trees as shown in Table 4. Trees from families Euphorbiaceae and Combretaceae were subdominants, contributing 10 and 7% respectively. The least represented families were Sterculiaceae (0.29%), Sapindaceae (0.2%), Verbanaceae (0.1%) and Rubiaceae (0.1%).

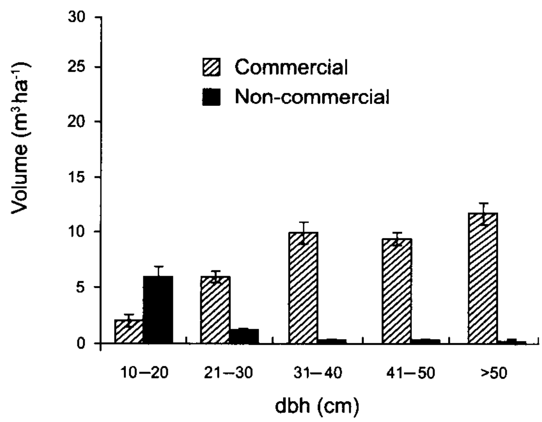

Figure 3(c) Volume distribution of commercial and non-commercial tree species in site C

Table 4 Distribution of individual trees per family and site (> 10 cm dbh) in Handeni, Tanzania

S/No.	Family	Site A	Site B	Site C	Total	%
1	Caesalpiniaceae	107	103	138	348	34.22
2	Mimosaceae	24	9	19	52	5.11
3	Euphorbiaceae	24	36	41	101	9.93
4	Papilionaceae,	64	90	99	253	24.88
5	Combretaceae	27	17	30	74	7.28
6	Bignoniaceae	4	9	2	15	1.47
7	Loganiaceae	11	1	1	13	1.28
8	Apocynaceae	0	16	24	40	3.93
9	Capparidaceae	5	13	30	48	4.72
10	Ochnaceae	1	5	6	12	1.18
11	Sapindaceae	0	2	0	2	0.20
12	Burseraceae	0	0	1	1	0.10
13	Anacardiaceae	8	1	2	11	1.08
14	Sterculiaceae	2	0	1	3	0.29
15	Rubiaceae	0	0	1	1	0.10
16	Verbenaceae	1	0	0	1	0.10
	Total	279	302	395	975	

Species diversity

Table 5 indicates the diversity of species as determined by the Shannon-Wiener index. Site A was the most diverse with a Shannon-Wiener index of 2.35 followed by site C (2.23).

The distribution of individual trees between species within the three sites (i.e. evenness) was very similar (Table 5). Analysis of variance showed that species diversity and equitability did not differ significantly between sites ($p < 0.05$).

Species importance

Species importance value index (IVI) was used to assess species importance on the three sites. Table 6 indicates the four dominant species in each site ranked according to their IVI. Generally, the dominant species were *Brachystegia boehmii, Julbernardia globiflora* and *Combretum amiculatum,* with the overall IVI of 60.79, 60.49 and 45.97 respectively. In sites B and C, the dominant species was *B. boehmii* with an IVI of 96.62 and 52.36 respectively. The dominant species in site A was *J. globiflora* (88.15). *Combretum amiculatum* was common in all three sites.

Table 5 Species diversity and equability indices (> 10 cm dbh) in miombo woodland, Handeni, Tanzania

Site	Shannon-Wiener index (H)	Equitability or evenness (J)	Total number of species
A	2.3475	0.7390	24
B	2.1746	0.6916	23
C	2.2290	0.7326	23

Table 6 Average importance value indices (IVI) of the four dominant tree species (> 10 cm dbh) on the three sites in miombo woodland, Handeni, Tanzania

Site	Species name	IVI
Site A	*Julbernardia globiflora*	88.15
	Combretum amiculatum	52.76
	Brachystegia boehmii	36.39
	B. microphylla	28.32
Site B	*B. boehmii*	96.62
	J. globiflora	41.81
	C. amiculatum	39.42
	Pseudolachnostylis maprouneifolia	21.88
Site C	*B. boehmii*	52.36
	Julbernardia. globiflora	51.30
	C. amiculatum	45.72
	Diplorhynchus condylocarpon	30.95

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Discussion

Species diversity

The Shannon-Wiener index of diversity for the three sites is high, indicating high species diversity. This high species diversity is a result of diverse habitat types found in miombo woodlands (Campbell *et al.* 1996). The similarity in equitability index of the three sites shows that the plant community in this woodland is dominated by few species (Kent & Coker 1992), perhaps reflecting the widespread human influence throughout the woodland, though variations in edaphic factors may also contribute.

Family and species diversity

As with other parts of the miombo, the leguminous families of Caesalpiniaceae, Papilionaceae and Mimosaceae dominate the woodland. These families constituted about 50% of all the trees measured. Temu (1985) reported that the miombo woodland contained at least 175 tree species, most of which belong to the families Caesalpiniaceae and Papilionaceae. Although the two families dominate the study area, there were 48 species (27%) recorded on the sites covering 40 ha.

Dominance

On the basis of IVI, the dominant species on all three sites were *J. globiflora* and *B. boehmii*. This suggests that these species regenerate well under existing conditions and are likely to remain dominant in the absence of a catastrophic event. Desanker and Prentice (1994) pointed out that *B. spiciformis, B. boehmii* and *J. globiflora* are often the only dominant species present in dry miombo where rainfall is less than 1000 mm year^{-1}.

Abundance of large trees of *B. spiciformis, B. boehmii* and *J. globiflora* on the other hand, reflects less harvesting pressure on these, but also their less susceptibility to annual fires. According to Bryce (1999), the wood of *J. globiflora,* and to a lesser extent, of *Brachystegia* spp., is difficult to work by hand or machine, and is used mainly as heavy construction works, mining timber, and railway sleepers. Although in other areas these species are used to produce charcoal (Monela *et al.* 1993, Malimbwi *et al.* 1994, Luoga *et al.* 2002), this was not the case in Madebe. Because of sawing difficulties and lack of markets for these species, sawmill owners in this area do not prefer these species. Instead they prefer *P. angolensis.* This has resulted in the overharvesting of *P. angolensis* trees leaving very small-sized trees of this highly valued species.

Timber production

The distribution of stem sizes of all trees follows the reversed "J" shape, common in natural forests and shown in Figure 1. This is generally an indication of good recruitment into larger size classes and satisfactory regeneration. However, the average stand density of 183 stems ha^{-1} recorded in this study is much lower than the 762 stems ha^{-1} (Rees 1974), 520–645 stems ha^{-1} (Malaisse 1978), 444 stems ha^{-1} (Ek 1994) and 691 stems ha^{-1} (Nduwamungu 1997) reported from other studies in miombo woodland in Zambia and Tanzania. The fewer trees in this study is due to the fact that only those $\geq$ 10 cm dbh were measured unlike in other studies cited above which included stems of dbh less than 10 cm. It may also be indicative of the high rate of exploitation of poles and valuable timber species. Destruction of fire-susceptible species by hot intense late dry season fires resulting from the accumulation of high fuel load of dry tall grasses, and previous logging slash in these woodlands could be another reason.

The mean basal area obtained in this study (9.93 $m^2 ha^{-1}$) is slightly higher than the 8.8 $m^2 ha^{-1}$ reported for Iringa (Bystrom *et al.* 1987), and even higher than the 6.8 m^2 ha^{-1} reported for Kitulaghalo, near Morogoro, Tanzania (Malimbwi *et al.* 1994). The mean total volume obtained in this study (50.9 m^3 ha^{-1}) is lower than the 60 m^3 ha^{-1} obtained in the miombo woodland of Tabora, Tanzania (Temu 1980), and much higher than the 38.7 m^3 ha^{-1} reported by Malimbwi *et al.* (1994) from Morogoro. This high timber volume is associated with the many large *J. globiflora* and *B. boehmii* trees (> 50 cm dbh) found on the three study sites.

The volume equations used for estimating total tree volume (Malimbwi *et al.* 1994) did not include trees above 43 cm dbh, making comparisons with other studies difficult. Furthermore, use of these models for larger trees is likely to underestimate the total volume. For example, a comparison of volume predicted by these equations with that from the tree volume tables for indigenous tree species (Schultz 1973) was attempted. It showed that the volume obtained by the current equations was higher by a factor of 1.46 for trees of dbh 15–50 cm, 1.18 for trees of dbh 55–80 cm and 0.85 for trees of dbh 85–125 cm. We suggest a modification of the equations of Malimbwi *et al.* (1994) by collecting and incorporating data on larger trees than currently included as proposed by Nduwamungu (pers. comm.).

There were differences in the number of stems ha^{-1}, basal area ha^{-1} and standing volume ha^{-1} for dbh class > 50 cm between the three sites, with site A having relatively more trees in this class (and most likely taller trees) compared with the other two sites. This might account for the slightly higher volume in site A despite its lower stocking and basal area than in the other two sites (Table 2). It should further be noted from Table 2 that 71% of the basal area in site A was in large trees (> 30-cm dbh) compared with 53% in the other two sites. However, considering the great variability within sites, these differences may not be of practical significance. The proportion of trees < 30-cm dbh increased from 73% for site A to 79% for the other two sites (i.e. larger trees in site A). This, together with the linear increase (r^2=0.58) in the total number of trees from sites A to C, suggests that more regeneration is taking place, or there is less harvesting pressure of small trees as distance from Madebe village increases.

The number of commercial species (Bryce 1999) in the area is eleven. Similar to the size class distribution, volume and basal area distributions of non-commercial tree species follow a reversed "J" shape, while the commercial species have a typical "J" shape curve (Figures 2 and 3). The number of small trees (< 20 cm dbh) in commercial species was much lower (37%) than in the non-commercial species (80%) indicating more regeneration of the latter. Similarly, only 9% of the basal area of commercial species was in small trees, compared with 60% in the non-commercial species. By contrast, commercial trees dominated the large trees (> 50 cm) accounting for 99% of the stocking, 95% of the basal area and 97% of the volume in that class, reflecting the poor representation of non-commercial species in this class. This is because the *Julbernardia* and *Brachystegia* genera that dominated the large trees have not been harvested for timber or charcoal. The decrease of basal area and volume in non-commercial tree species (Figures 2 and 3) suggests that most of these species are naturally small, and thus are less represented in the large diameter classes. Regulated harvesting of the large commercial trees should be undertaken soon to encourage future regeneration and ingrowth.

Conclusions

The communally managed miombo woodland in Kang'ata ward, like other parts of Handeni, has been overharvested with respect to the preferred species such as *P. angolensis, B. huillensis* and *A. quanzensis*. Only few trees of these species with a dbh > 30 cm were recorded in the study sites. There is, however, a high stocking of large trees of formerly less preferred species such as *B. boehmii, J. globiflora, C. amiculatum, D. condylocarpon, B. microphylla* and *P. maprouneifolia*. Extensive harvesting of *J. globiflora* and *B. boehmii* is currently being undertaken in the region and is likely to increase as the availability of the more valued species decreases, and markets for the former increase, particularly for railway sleepers. However, because many private sawmill owners face financial constraints, they use less capital-intensive logging methods. Most use unskilled labour and poor harvesting practices. These practices contribute to high rates of wood waste in the forest, environmental degradation and low productivity. There is a need to study the current harvesting practices in detail from a productivity and environmental viewpoint and provide cost-effective recommendations for improving industrial timber harvesting operations, which will improve productivity and at the same time reduce environmental degradation.

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Appendix 1 Tree species identified in miombo woodland, Handeni, Tanzania

Local name	Botanical name	Family name
Mseni*	*Brachystegia microphylla*	Caesalpiniaceae
Mkambala*	*Acacia nigrescens*	Mimosaceae
Mtondoro*	*Julbernardia globiflora*	Caesalpiniaceae
Myombo*	*Brachystegia boehmii*	Caesalpiniaceae
Mnyinga*	*Xeroderris stuhlmanii*	Papilionaceae
Msolo*	*Pseudolachnostylis maprouneifolia*	Euphorbiaceae
Mninga*	*Pterocarpus angolensis*	Papilionaceae
Mlama	*Combretum amiculatum*	Combretaceae
Muyuyu	*Markhamia obtusifolia*	Bignoniaceae
Mtongafyala	*Strychnos innocua*	Loganiaceae
Mtogo	*Diplorhynchus condylocarpon*	Apocynaceae
Mkongowe	*Acacia tortilis* ssp. *spirocarpa*	Mimosaceae
Mtusi	*Acacia polyacantha* ssp. *campylacantha*	Mimosaceae
Mgoji	*Pteleopsis myritifolia*	Combretaceae
Mguluka	*Boscia salicifolia*	Capparidaceae
Muhuga	*Dalbergia nitidula*	Papilionaceae
Muwenge	*Syzygium guineense*	Myrtaceae
Msangazi	*Dalbergia commiphoroides*	Papilionaceae
Mparatanyani*	*Brachystegia* sp.	Caesalpiniaceae
Mtoyo	*Azanza garckeana*	Malvaceae
Kikwindilakwima	*Bridelia cathartica*	Euphorbiaceae
Msisimizi	*Albizia harveyi*	Mimosaceae
Mtonte/Mnkhatakwa	*Brackenridgea zanguebarica*	Ochnaceae
Mbwewe	*Blighia unijugata*	Sapindaceae
Mfumbiri	*Lonchocarpus bussei*	Papilionaceae
Mkungugu	*Acacia tortilis*	Mimosaceae
Msinga	*Sesbania micrantha*	Papilionaceae
Msenekanga*	*Ochna* spp.	Ochnaceae
Mdadalika	*Newtonia paucijuga*	Mimosaceae
Mtwintwi	*Commiphora africana*	Burseraceae
Mkingu	*Albizia versicolor*	Mimosaceae
Mkwakwa	*Strychnos spinosa*	Loganiaceae
Mselegembe	*Dichrostachys cinerea*	Mimosaceae
Mselekhanga	*Pseudolachnostylis maprouneifolia*	Euphorbiaceae
Mkwaju	*Tamarindus indica*	Cesalpiniaceae
Msasa	*Cordia goetzei*	Boraginaceae
Mnyumbunyumbu/mumbu	*Lannea schweinfurthii* ssp. *stuhlmanii*	Anacardiaceae
Mdaula	*Zanha africana*	Sapindaceae
Mngo'ngo	*Sclerocarya birrea* ssp. *caffra*	Anacardiaceae
Mboza	*Sterculia africana*	Sterculiaceae
Mgunga	*Acacia nilotica*	Mimosaceae
Kirumbu	*Ormocarpum kirkii*	Papilionaceae
Mviru	*Vangueria infausta*	Rubiaceae
Mpingo*	*Dalbergia melanoxylon*	Papilionaceae
Mcheje	*Albizia zimmermannii*	Mimosaceae
Mkwizingi	*Cassia abbreviata*	Caesalpiniaceae
Mluati	*Dombeya shupangae*	Sterculiaceae
Mgobe*	*Vitex doniana*	Verbenaeae

*Commercial timber species (Bryce 1999)