DEPENDENCE ON FOREST AND ITS IMPACTS ON SPECIES COMPOSITION AND COVER IN DINDILI FOREST RESERVE, MOROGORO TANZANIA

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Abstract
The specific objectives of the study were to: identify forest human disturbance, identify forest products used for house construction by adjacent communities, assess stand density and diameter distribution and hence basal area and wood volume. Other objectives were to assess: species composition, regeneration and forest cover changes over time. Systematic sampling design involving post-stratification of the forest reserve into dry evergreen forest and miombo woodland was used in the inventory. Microsoft Excel spreadsheet software and, remote sensing and GIS technologies were used to analyze quantitative data for various forest parameters and forest cover respectively. Identified human disturbances included charcoal production, cultivation and logging especially in miombo woodland stratum evidenced by higher number of stumps, observed pit-sawing platforms and charcoal kilns. Results from forest inventory showed that in the woodland stratum of the study area, stocking levels were 365 ± 72 stems ha $^{-1}$*, 7.74 ± 1.82 m*^{2} *basal area and volume of 52.76 ± 14.48 m*^{3} *ha*$^{-1}$*. In dry evergreen forest, values of 1256 ± 105 stems, 25.48 ± 2.34 m*^{2} *basal area and volume of 200.75 ± 25 m*^{3} *ha* $^{-1}$ *were observed. Values of Shannon-Wiener index of diversity (H') of 3.05 and Index of Dominance (ID) value of 0.065 were observed in miombo woodland stratum. In dry evergreen forest stratum, values of 3.18 and 0.064 respectively were observed. It was also observed that the original closed forest cover of the study area declined by 14% between 1991 and 2000. The most tree species extracted included* ***Afzelia quanzensis****,* ***Dalbergia melanoxylon****,* ***Julbernardia globiflora*** *and* ***Pterocarpus angolensis****. Stocks of tree species such as* ***Burkea africana*** *and* ***Milicia excelsa*** *were depleted. It was concluded that Dindili Forest Reserve had been highly affected by forest dependence, reflected by the lower stocking levels, diversity indices and reduced forest cover. In order to subjugate the current scenario, special efforts are needed to promote regeneration of the over-exploited species and put in place sound management plans for Dindili Forest Reserve which encourage full participation of the communities around it.*

Key Words: Miombo, degradation, communities, Fulwe, Kitulanghalo

1.0 INTRODUCTION

Tanzania has about 33.5 million ha. of forests and woodlands which is nearly 38% of the total land area in the mainland (MNRT, 2001). In 1989, the forestry sector was estimated to contribute 2 - 3% of GDP and 10% of the country's registered exports. In 1998 the sector contributed 3.3% of the country's GDP and it also employed 3% of paid labour (MNRT, 2001). However, the real contribution of this sector has always been underestimated due to unrecorded daily labour in collection and household consumptions, of particularly Non-Timber Forest Products and services (Ruffo *et al.*, 2002).

Worldwide, local communities depend inevitably on forests to meet an array of domestic needs (Scoones *et al.*, 1992) cited by Roe and Elliot, 2004). This dependence is mainly dictated by poverty, lack of alternatives (Katigula, 1999; Dudenhoefer, 2004) and inadequate social services (Weaver *et al.*, 2003). According to Roper and Roberts (1999), wood fuel dominate the energy economies of virtually all African countries, accounting for 80% of all wood used. In Tanzania, wood fuel accounts for 92% of the total energy consumption (MNRT, 1998). The dependence on forest products causes forest degradation and shrinkage in forest cover (Rudel, 2006). Thus, biodiversity conservation and poverty reduction need to be tackled together (Bawa, 2006; Sodhi *et al.*, 2006) since they are interlinked (Mariara, 2003). Such dependence is a reason for degradation of a number of catchment forest reserves in Tanzania, including Dindili in Morogoro Region (Lovett and Pócs, 1993; Ngaga *et al.*, 2004; Burgess *et al.*, 2004). According to Malimbwi *et al.* (2005) some of the reserves in Morogoro such as Mafleta and Magotwe have been turned into agricultural land. In part, encroachment problems have been attributed by land scarcity and on the other hand by the lack of government control (Nsolomo and Chamshama, 1990).

The study aimed at assessing the impacts of forest dependence on species composition and forest cover in Dindili Forest Reserve, Morogoro Tanzania. The activities carried out were: identification of forest human disturbance, identification of forest products used for house construction by adjacent communities, assessment of stand density and diameter distribution and hence basal area and wood volume. Other activities were assessment of species composition, regeneration and temporal cover changes of the forest.

2.0 METHODOLOGY

2.1 Description of the study area

This study was conducted in Dindili Forest Reserve and Fulwe village which is adjacent to this forest. This area is located in Morogoro Rural District Tanzania, at between $37^{o}52'$ E and 6^{o} 42' S, about 25 kilometers North East of Morogoro Town. The forest is 1,005 ha large, located at between 450 - 864 m.a.s.l. and receives rainfall of between 700 - 1,000 mm $year^{-1}$ with temperatures of between $21^{o}C$ in July and $26^{o}C$ in December. The forest is subdivided into two distinct vegetation types; dry evergreen forest accounting for 60% of the entire forest reserve on the wetter eastern slopes and summit ridge and miombo woodland occupying 40% mostly on the lower ridges and the drier western slopes (Lovett and Pócs, 1993).

2.2 Sampling and data collection

Systematic sampling design was used to lay plots, in which the forest was subdivided into 11 transects, located 500 m apart. A total of 72 concentric circular plots of 0.07 ha each were laid along transects, 270 m apart. Each plot had four subplots of 2 m, 5 m, 10 m and 15 m radii. In each plot the following parameters were recorded:

(a) Within 2 m radius subplot: all seedlings, saplings, coppices and trees with Diameters at Breast Height (DBH) < 4 cm were identified and counted as regenerants,
(b) Within 5 m radius subplot: identification and measurements of diameters and heights of all trees/shrubs with DBH ≥ 4 cm,
(c) Within 10 m radius subplot: identification and measurements of diameter and heights of all trees/shrubs with DBH ≥ 10 cm,
(d) Within 15 m radius subplot: identification and measurements of diameter and heights of all trees/shrubs with DBH > 20 cm,
(e) In each plot, all human disturbances were recorded. Stumps were considered new when intact in shape without signs of decay, whereas old stumps were those with rotting signs and disintegrating shapes. Stump sizes ranged from 2 cm diameter and above to cover all removals for different uses.

A total of 472 (21%) out of 2,257 households were sampled at random from Fulwe sub-village registers. At each household picked, all houses were inspected to determine the materials used in walling and roofing and the duration from which the houses were constructed. Remote sensing and Geographical Information System (GIS) were used to acquire information over time and used to assess spatial and temporal cover changes. Landsat TM images of 1991 and 2000 covering the study area were used to gather spatial and temporal information for cover change detection.

2.3 Data analysis

2.3.1 Forest stocking

Analysis of forest stocking levels involved computation of basal area ha^{-1} (G) basing on basal area of individual trees, $g_i = (\pi D^2)/40{,}000$ in m^2; stems ha^{-1} (N); and Volume ha^{-1} (V) in m^3. A form factor of 0.5 was used to calculate total volume of individual trees (Kielland-Lund, 1990). The formulae used in calculations were;

(i) $N = \Sigma\, i/(a * n)$ (ii) $G = \Sigma\, gi/(a * n)$. (iii) $V = \Sigma\, vi/(a * n)$.

Where: i = individual tree, gi = basal area of a tree ($=(\pi * D^2)/40{,}000$) (m^2), vi = volume of a tree ($= gi * H * f$) (m^3), f = form factor (0.5), a = plot/sub-plot area/size (where radius = 2 m, 5 m, 10 m or 15 m) and n = number of sample plots.

2.3.2 Regeneration potential

Number of average regenerations ha^{-1} (N) was computed from the counted regenerations in each 2 m radius sub-plot. Analysis of number of regenerations ha^{-1} (N) included all trees with DBH < 4 cm. The formula used to compute regenerations ha^{-1} was;

$N = \Sigma\, i/(a * n)$

Where: i = individual regenerant or stem and a = sub-plot area/size (where radius = 2 m).

2.3.3 Average number of stumps

Number of stumps ha^{-1} (S) was computed based on counted stumps $plot^{-1}$. The formula used to calculate number of stumps (S) ha^{-1} was;

$S = \Sigma\, s_i/(a * n)$

Where: s_i = individual stump and a = plot area/size (where radius = 15 m).

2.3.4 Diversity indices

Shannon-Wiener-index of diversity was used to calculate species diversity (H') and evenness ($E_{H'}$) (Magurran, 1988) and Simpson's Index of Dominance (ID) was used to determine species dominance (Misra, 1989). The formulae used to calculate these indices were:

(i) $H' = -\sum_{i=1}^{s} \rho_i \log_a \rho_i$, (ii) $E_{H'} = H'/\ln S$ and (iii) $ID = \Sigma(n_i/N)^2$

Where: ρ_i = is the proportion of individuals of species $_i$, **S =** Number of species ha^{-1} and **N =** Number of stems ha^{-1}

2.3.5 Household survey data

Microsoft excel program was used to analyze data from household survey. A two-tailed t-test at 5% level of significance was used to compare the different parameters.

2.3.6 Forest cover changes

Assessment of cover changes combined digital and visual image interpretation techniques. Prior to image analysis, field observations were conducted to establish different cover classes, assess temporal-spatial dynamics and monitor environmental degradation and land cover changes (Consiglio *et al.,* 2006; Mbilinyi *et al.,* 2007; Mumford *et al*., 2007). Three major classes were identified: closed forest, open forest and shrubs. Other classes identified were grassland, woodland and cultivation or fallow. Two Landsat TM scenes from 1991 and 2000 covering the study area were registered to a map co-ordinate system (UTM zone 37 South, Datum Arc 1950) prior to change detection analysis. A supervised image classification using Maximum Likelihood Classifier was performed in ERDAS image software by making use of field identified training fields.

3.0 RESULTS AND DISCUSSION

3.1 Forest human disturbance

Abundant pit-sawing platforms, stumps and charcoal kilns were observed as evidence of human disturbances in the forest. This is similar to observations reported by Nduwamungu (1997), Luoga *et al.* (2000a), Zahabu (2001) and CHAPOSA (2002) who observed same human activities in Kitulanghalo FR, just about 10 km from Dindili FR.

3.1.1 Stump count

Observed stump sizes based on butt diameters ranged from 2 cm to above 40 cm. Distribution of stumps by size both in dry evergreen forest and woodland strata showed that on average: 60% of all counted stumps fall in 2 < 10 cm diameter class; 30% in 10 ≤ 20 cm and 10% fall in > 20 cm diameter classes. In the woodland stratum, a mean of 912±132 stumps ha^{-1} with 793±123 old and 118±56 new stumps ha^{-1} were observed. Average butt diameter distributions of all counted stumps in woodland stratum were: 61% found in 2<10 cm; 28% in 10≤20 cm and 11% in > 20 cm diameter class. These results suggest that trees of smaller sizes are more cut than bigger size trees.

The observed stump numbers are higher than those from other studies, possibly due to the inclusion of the lowest diameter class (2<10 cm) which most researchers exclude. In Kitulanghalo FR, Morogoro and in the adjacent open access forest, Luoga *et al.* (2002) recorded 55 and 182 stumps ha^{-1}, respectively. Nduwamungu (1997) obtained only 23 stumps ha^{-1} at Kitulanghalo. However, this researcher included cut stumps with butt diameters >20 cm only. Silayo *et al.* (2006) reported 46 and 14 fairly fresh stumps between 10.1 cm and less than 30 cm butt diameters in the public lands of miombo woodlands in Bagamoyo District and Uzigua FR in Handeni District, Tanzania.

In this study, there was a highly significant difference between the number of old and new stumps in miombo woodland stratum (Table 1), suggesting a higher forest products extraction in previous years than at the time of the study. The declining trend in stump numbers may have been caused by the fact that most tree species with high timber values, such as *Pterocarpus angolensis*, *Afzelia quanzensis*, *Burkea africana* and *Dalbergia melanoxylon*, that previously attracted commercial timber harvesting have been exhausted (Lovett and Pócs, 1993). Important tree species extracted in the woodland according to stumps contribution included: *Acacia polyacantha* subsp. *campylacantha* (6%), *Albizia* spp. (8%), *Dichrostachys cinerea* (5%), *Dombeya* spp. (11%), *Julbernardia globiflora* (10%), *Markhamia zanzibarica* (6%) and *Milletia usaramensis* (8%).

Table 1: Comparison of means between old and new stumps in woodland and dry evergreen forest strata in Dindili Forest Reserve

Miombo woodland		Dry evergreen forest	
Stumps category	Stumps ha^{-1}	Stumps category	Stumps ha^{-1}
Old	793±123	Old	202±43
New	118±56	New	120±32
$t_{0.05}$,df30	5.0089	$t_{0.05}$,df52	1.525
t-tabulated	2.042	t-tabulated	2.006
Significance	**	Significance	N.S

** Significant different at 5% level. N.S = Non-significant at 5% level

In dry evergreen stratum, a mean of 322±63 stumps $ha^{-1}$was observed with 202±43 old stumps and 120±32 new stumps ha^{-1}. On average, 57% fall in 2 < 10 cm, 31% in 10 ≤ 20 cm and 12% fall in > 20 cm diameter classes. Just like in woodland stratum, more cuts were observed in smaller size trees than bigger size trees. Statistical comparison between old and new stumps in dry evergreen forest stratum showed no significant difference (Table 1). Out of 39 tree species observed to contribute in stumps count in dry evergreen forest stratum, 8 species were found to be more prominent. These included: *Brachylaena huillensis* (9%), *Combretum stuhlmanii* (8%), *Croton sylvaticus* (8%), *Erythroxylum emarginatum* (8%) and *Manilkara sulcata* (5%). Other prominent species according to stumps contribution were *Milletia usaramensis* (11%), *Scrodophloeus fischeri* (25%) and *Spirostachys africana* (6%).

Statistical comparison of old stumps between miombo woodland (793±123) and dry evergreen forest (202±43) strata also showed highly significant difference as shown in Table 2. This suggests that forest extraction in previous years concentrated more in miombo woodland stratum than in the dry evergreen forest. Comparison of new stumps between miombo woodland (118±55.6) and dry evergreen forest (120±32) strata are statistically non-significant. This probably indicates that the current forest products extraction is more or less evenly distributed throughout the whole forest reserve.

Table 2: Comparison of means between woodland and dry evergreen forest strata of Dindili Forest Reserve

Vegetation types	Parameters	
	Old stumps ha^{-1}	New stumps ha^{-1}
Miombo woodland	793±123	118±56
Dry evergreen forest	202±43	120±32
$t_{0.05}$,df41	5.4066	0.025
t-tabulated	2.0195	2.0195
Significance	**	N.S

** Significant different at 5% level, N.S = Non-significant different at 5% level

3.2 Forest products used for house construction

The survey showed that out of 472 houses sampled, 68% had their walls erected by forest products and 32% by bricks. The survey also found that 94.5% of all houses surveyed had their roof rafters made of forest products of different tree species from Dindili FR and the balance had roof rafters made of exotic sawn timber from *Cupressus lusitanica* and *Pinus patula*. These observations are higher than what Katigula (1999) recorded in the East Usambara, Tanzania where 79% of the sampled houses had roof rafters extracted from the adjacent forest.

The assessment revealed that most of the houses were temporary, making communities in the village to continue depending on forest products from the reserve. Clarke *et al.* (1996) observed the same situation in Malawi.

The dominant tree species used in house construction included *Brachylaena huillensis* and *Scrodophloeus fischeri* (more than 50% of walling material), *S. fischeri* and *Manilkara sulcata* (over 60% of roofing material), *Spirostachys africana*, *Markhamia zanzibarica*, *Albizia gummifera* and *Terminalia sambesiaca*. These observations suggest that the demand for forest products for house construction could be the reason for high stump count in the study area for the listed tree species that are not common for sawn timber and charcoal production.

3.3 Stand density and diameter distribution

In the woodland stratum of the study area, 365±72 stems $ha^{-1}$was observed (Table 3). This observation is lower than most results reported from various miombo woodlands. Nduwamungu (1997) obtained 691 stems ha^{-1} at Kitulanghalo FR while Zahabu (2001) obtained 618 stems ha^{-1} in the same forest and 1,405 stems ha^{-1} in the public lands nearby the reserve; and Mohamed (2006) obtained 817 stems ha^{-1} in miombo woodland stratum of Handeni Hill FR in Tanga. Other researchers include Mafupa (2006) who reported 722 stems ha^{-1} in undisturbed stratum of Igombe River FR in Tabora and Malimbwi *et al.* (2005) who obtained values between 338 and 1,134 stems ha^{-1} in Morogoro and Mvomero districts, respectively.

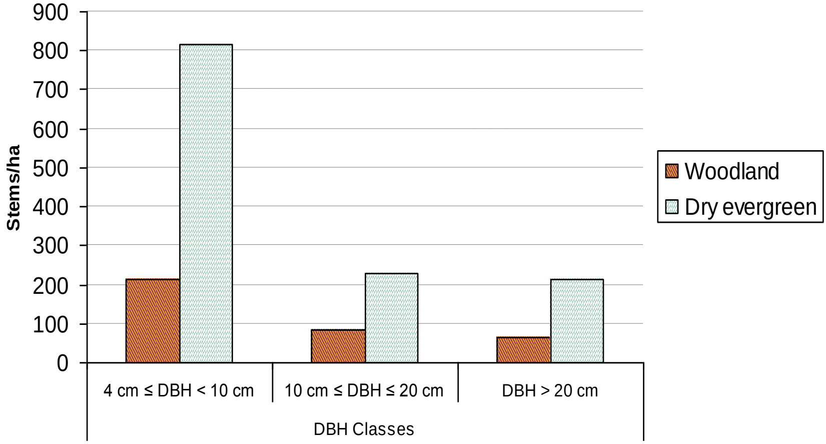
The probable reason for the lower stand density in the woodland stratum in this study was over-exploitation, reflected by the abundant number of stumps observed.

Table 3: Distribution of number of stems, basal area and wood volume in miombo woodland stratum of Dindili Forest Reserve

Diameter classes	Number of stems ha^{-1}	Basal area ha^{-1} (m^2)	Volume ha^{-1} (m^3)
4 cm ≤ DBH < 10 cm	215 ± 57	0.61 ± 0.16	1.11 ± 0.38
10 cm ≤ DBH ≤ 20 cm	84 ± 27	1.21 ± 0.44	4.97 ± 2.31
DBH > 20 cm	66 ± 19	5.93 ± 1.64	46.68 ± 14.03
Total	365 ± 72	7.74 ± 1.82	52.76 ± 14.48

Of all stems in miombo woodland stratum, 59% were found in the first diameter class (4 cm ≤ DBH < 10 cm), 23% in 10 cm ≤ DBH ≤ 20 cm and 18% in DBH > 20 cm diameter class (Table 3). The plausible explanation for the high regeneration is human disturbance as also noted by Luoga *et al.* (2004) that when miombo woodlands are disturbed, trees respond by producing profuse coppice shoots and root suckers.

Figure 1: Distribution of number of stems by diameter classes



The observation of 215 stems ha^{-1} in DBH < 10 cm diameter class is lower than results from other studies reported in miombo woodlands. Zahabu (2001) reported mean stems $ha^{-1}$of >300 in Kitulanghalo FR; Mohamed (2006) obtained >500 stems ha^{-1} in Handeni Hill FR and Mafupa (2006) reported >400 stems ha^{-1} in Igombe River FR in Tabora. Likewise, the values of 84 and 66 stems ha^{-1} in 10 cm ≤ DBH ≤ 20 cm and DBH > 20 cm diameter classes respectively in miombo woodland stratum are lower than results from other similar studies (Table 3). Mohamed (2006) reported >100 stems ha^{-1} in 10 cm ≤ DBH ≤ 20 cm and about 100 stems ha^{-1} in DBH > 20 cm diameter classes in Handeni Hill FR in Tanga; Zahabu (2001) reported >100 stems ha^{-1} in 10 cm ≤ DBH ≤ 20 cm in Kitulanghalo FR and Malimbwi and Mugasha (2002) reported about 100 stems ha^{-1} in both 10 cm ≤ DBH ≤ 20 cm and DBH > 20 cm diameter classes in Handeni Hill FR. The apparent reason for the lower values of stems ha^{-1} in the all three diameter classes of the woodland stratum is human disturbance.

Trees in the diameter class > 20 cm in miombo woodland were more preferred for sawn timber as most stumps of such sizes were associated with pit-sawing platforms, whereas charcoal kilns were observed to be near stumps in diameter classes between 10 cm and above. This could be the explanation for the much lower stems ha^{-1} in higher diameter classes in the woodland area.

In the dry evergreen forest, 1,256 ± 105 stems ha^{-1} were recorded as shown in Table 4. This observation is higher than results from other studies conducted in semi-evergreen and dry evergreen forests. Mohamed (2006) reported 1,083 ± 184 stems ha^{-1} in Handeni Hill FR; Mgeni and Malimbwi (1990) obtained 401 stems ha^{-1} in Mazumbai FR in Lushoto District, Tanzania and Kajembe *et al.* (2004) reported 665 stems ha^{-1} in Mamiwa-Kisara FR in Kilosa District, Tanzania. This could mean that there had been less human disturbance in the dry evergreen forest stratum as compared to miombo woodland stratum. The other probable reason is the dominance of the lesser known timber species compared to miombo woodland stratum of Dindili FR.

Table 4: Distribution of forest stock in dry evergreen forest stratum of Dindili Forest Reserve

Diameter classes	Number of stems ha^{-1}	Basal area ha^{-1} (m^2)	Volume ha^{-1} (m^3)
4 cm ≤ DBH < 10 cm	816 ± 101	3.1 ± 0.66	9.4 ± 2.76
10 cm ≤ DBH ≤ 20 cm	228 ± 23	3.72 ± 0.41	20.67 ± 2.76
DBH > 20 cm	212 ± 19	18.66 ± 2.33	170.68 ± 24.95
Total	1256 ± 105	25.48 ± 2.34	200.75 ± 25

In this stratum, scattered pit-sawing platforms observed were associated with stumps of diameters ≥ 20 cm. This could be the explanation for lower number of stems in higher diameter classes in the dry evergreen stratum (Table 4). This is a reflection of high forest products dependence from the study area, resulting into high impact on stocking levels, especially trees of bigger sizes.

3.4 Basal area and wood volume

The mean basal area of 7.74 ± 1.82 m^2 was observed in miombo woodland stratum (Table 3), whereas Strang (1974) and Malimbwi (2000) indicated the basal area in miombo woodlands to stabilize at a range of between 10 and 20 m^2.

In Kitulanghalo FR, Nduwamungu (1997) and Zahabu (2001) reported mean basal area values of 10.4 m^2 and 10 m^2 ha^{-1} respectively and in Kilosa, Nduwamungu (2001) reported mean basal area of 10.9 m^2 ha^{-1}. Other researchers include: Malimbwi and Mugasha (2002) and Mohamed (2006) who reported basal area of 11.21 ± 3.38 m^2 ha^{-1} and 12.7 ± 1.55 m^2 ha^{-1} respectively in Handeni Hill FR; Mafupa (2006) who reported 11.24 ± 0.76 m^2 in undisturbed stratum and 2.44 ± 0.48 in disturbed stratum of Igombe River FR in Tabora. Outside Tanzania, Strang (1974) recorded 10 – 11 m^2 ha^{-1} in Zimbabwe and Malaisse (1978) obtained 12 to 25 m^2 in Katanga, DRC. The likely explanation for the lower value of basal area in this study is human disturbance and over-exploitation of forest products, reflecting the high forest dependence by communities around Dindili FR.

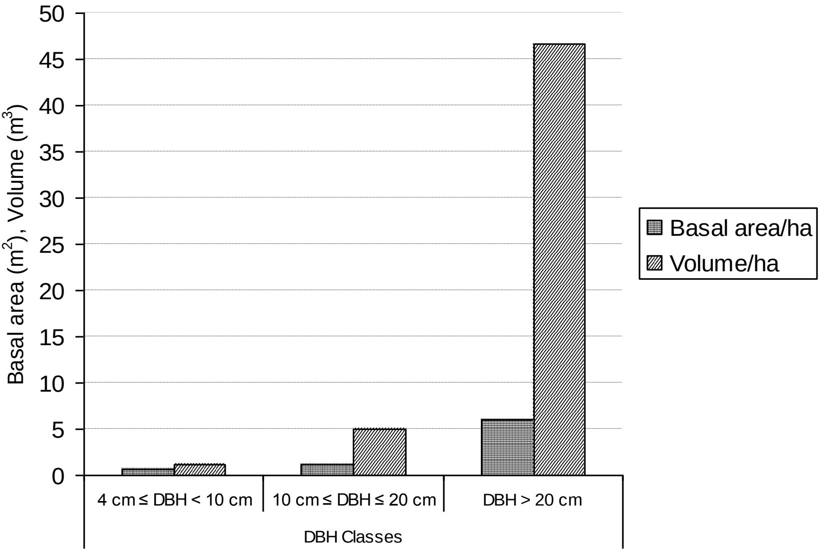
The wood volume of 52.76 ± 14.48 m^3 ha^{-1} was recorded in the woodland stratum of Dindili FR as shown in Table 3. Like for basal area, the mean volume is lower than those from other studies in different miombo woodlands. Nduwamungu (1997) and Zahabu (2001) reported 71 m^3 ha^{-1} and 78.8 m^3 ha^{-1} respectively at Kitulanghalo, Nduwamungu (2001) had 83.5 m^3 ha^{-1} in Kilosa and Malimbwi and Mugasha (2002) recorded 108.99 m^3 ha^{-1} in Handeni Hill FR. Other observations include 111.34 m^3 ha^{-1} by Mohamed (2006) in Handeni Hill FR and 87.14 m^3 ha^{-1} by

Mafupa (2006) in Igombe River FR, Tabora Tanzania. These also suggest further that the woodland stratum of Dindili FR is highly impacted by human disturbance.

The distribution pattern of volume and basal area in the woodland stratum of Dindili FR is common in natural forest with good regeneration and recruitment (Philip, 1983). This is a strong evidence of human disturbance to the forest.

In the dry evergreen forest stratum of Dindili FR, the mean basal area of 25.48 ± 2.34 m^2 ha^{-1} and mean volume of 200.75 ± 25 m^3 ha^{-1} were recorded as shown in Table 4. The both values are higher than most observations from other studies as Malimbwi and Mugasha (2002) and Mohamed (2006) reported basal area of 10.94 m^2 and volume of 125.24 m^3 ha^{-1} and 15.06 m^2 and 153.52 m^3 ha^{-1} respectively in semi-evergreen forest stratum of Handeni Hill FR. Also, Kajembe *et al.* (2004) had mean basal area and volume of 22.41 m^2 ha^{-1} and 246.89 m^3 ha^{-1} respectively in Mamiwa-Kisara FR in Kilosa.

Figure 2: Distribution of basal area and volume in woodland stratum of Dindili Forest Reserve



3.5 Species composition

3.5.1 Number of species

A total of 106 trees and shrubs species were identified in Dindili FR, 72 being identified as both standing trees and regenerations, and the remaining 34 species in regeneration count only. Overall, 44 species were found to be common in both woodland and dry evergreen forest strata. In miombo woodland stratum, a total of 80 species were recorded, out of which 39 species were standing trees or shrubs and the remaining were regenerations. The dominant species according to number of stems contribution in the woodland stratum included: *Albizia gummifera, Acacia polyacantha subsp. campylacantha, Combretum zeyheri, Diplorhynchus condylocarpon, Dombeya rotundifolia,* *Erythrococca kirkii* and *Julbernardia globiflora*. Lovett and Pócs (1993) reported *Pterocarpus angolensis, Heteromorpha arborea, Ozoroa reticulata, Pavetta crassipes* and *Sclerocarya caffra* as among the canopy tree species in miombo woodland of the study area. Conversely, none of these species were recorded as standing trees in this study. With exception of *Pterocarpus angolensis* which was recorded in regenerations and stump counts, other species were not recorded at all. Tree species such as *Dalbergia melanoxylon* which were reported by the same authors to be rich in Dindili FR, did not appear so in this study, its stock seemed to be exhausted. All these are indications of human disturbance and over exploitation, reflecting forest dependence.

The most expected important timber species from miombo woodlands were *Pterocarpus angolensis, Afzelia quanzensis, Brachystegia* spp. and *Julbernardia* spp. Others included *Dalbergia melanoxylon, Swartzia madagascariensis* and *Pericopsis angolensis*. While *Dalbergia melanoxylon* was scantly observed, *Pterocarpus angolensis* was recorded in regeneration and stump count only and the other species were not recorded at all. These observations suggest that such common timber species have been depleted.

In regards to wood volume contribution, the dominant species were *Acacia polyacantha subsp. campylacantha, Brachystegia boehmii, Brachystegia spiciformis, Julbernardia globiflora, Manilkara sulcata* and *Pterygota mildebraedii*. In the dry evergreen forest stratum, a total of 70 trees and shrubs species were recorded out of which 59 species were classified as standing trees or shrubs and the remaining as regenerations. The dominant species based on number of stems in this stratum included: *Brachylaena huillensis, Combretum schumanii, Croton dichogamus, Croton sylvaticus* and *Erythroxylum emarginatum.* The other dominant species were *Manilkara sulcata, Millettia* *usaramensis, Vepris nobilis* and *Scrodophloeus fischeri.* According to wood volume contribution, the dominant tree species were *Brachylaena huillensis, Combretum schumanii, Commiphora pteleifolia, Cussonia zimmermannii, Lannea schimperi, Manilkara sulcata, Ricinodendron heudelotii, Scrodophloeus fischeri* and *Terminalia sambesiaca.*

Apart from the species above, Lovett and Pócs (1993) reported such species as *Afzelia quanzensis, Commiphora madagascariensis, Euphorbia candelabrum, Teclea simplicifolia, Chazaliella abrupta* and *Excoecaria madagascariensis* to be among the dominant tree species in dry evergreen forest stratum. However, none of them was recorded in this study with exception of *Afzelia quanzensis* which though, was recorded in stump count only. The observations suggest that Dindili FR has been highly impacted by human disturbance in terms of species composition.

3.5.2 Diversity indices

(i) Shannon-Wiener Index of Diversity (H')

In the miombo woodland stratum of Dindili FR, H' value of 3.05 was recorded. This value is lower than values 3.79, 3.56 and 3.26 obtained in diameter classes <10cm, 10-20cm and >20 cm respectively by Nduwamungu (1997) and value of 3.13 by Zahabu (2001) both in Kitulanghalo FR in Morogoro. The obtained value in Dindili FR is also lower than the value of 3.10 recorded by Mohamed (2006) in Handeni Hill FR in Tanga. Compared to these observations, Dindili FR has low species diversity which could be a reflection of biotic disturbances (Misra, 1989). Other observations include H' values of 2.90 in woodlands of public lands nearby Kitulanghalo (Zahabu, 2001), 2.40 by Mafupa (2006) in Igombe River FR and 2.42 by Malimbwi and Mugasha (2002) in Handeni Hill FR in Tanga.

In dry evergreen forest of Dindili FR, H' value of 3.18 was observed. Compared to observations in miombo woodland stratum, this indicates that the dry evergreen forest stratum of the study area is relatively less disturbed. However, compared to other studies, dry evergreen forest stratum of Dindili FR has also experienced biotic disturbances. In Handeni Hill FR, Mohamed (2006) obtained H' value of 3.39.

(ii) Index of Dominance (ID)

In woodland stratum of Dindili FR, ID value of 0.065 was observed. This value of ID is comparable to the values obtained from other studies in miombo woodlands. Malimbwi and Mugasha (2002) and Mohamed (2006) reported ID values of 0.073 and 0.063 respectively in miombo woodland stratum at Handeni Hill FR in Tanga, Tanzania. At Igombe River FR in Tabora Tanzania, Mafupa (2006) obtained ID values of 0.088 and 0.135 in undisturbed and disturbed strata respectively; Zahabu (2001) reported ID values of 0.092 and 0.065 in public lands and Kitulanghalo FR respectively in Morogoro, Tanzania. This low value of ID observed indicates high species diversity in miombo woodland stratum of the study area (Misra, 1989; CHAPOSA, 2002). This suggests that species diversity in Dindili FR is not highly impacted by human disturbances. This situation could be contributed by the high regenerations observed that cushioned human impact on species diversity.

The dominant species according to ID values in the woodland stratum included *Albizia gummifera* (0.0119), *Combretum zeyheri* (0.0107) and *Julbernardia globiflora* (0.0102). This shows that *Albizia gummifera* is the most dominant tree species in woodland stratum and *Julbernardia globiflora* the least dominant of the three. This is not common in miombo woodlands where in most observations reported, *Julbernardia globiflora* is the most dominant species. Observations in this study suggest that *J.*

globiflora has been highly impacted by human disturbance and over exploitation.

In dry evergreen forest stratum, ID value of 0.064 was observed. This observation is comparable to the study conducted by Malimbwi and Mugasha (2002) who reported ID value of 0.062 in semi-evergreen forest at Handeni Hill FR in Tanga, Tanzania. This indicates that human disturbances have had no influence on species diversity. Like in miombo woodland stratum, high regeneration could be the reason for low ID value that reflects high species diversity. Dominant species in this stratum according to ID values are *Scrodophloeus fisceri* (0.02344), *Millettia usaramensis* (0.01086), *Croton dichogamus* (0.00578) and *Combretum schumanii* (0.00564).

3.6 Regeneration

A mean value of 15,915 stems ha^{-1} of regenerants was observed in the woodland stratum of Dindili FR from 46 tree species with DBH < 4 cm. This observation is higher than observations reported from other studies in miombo woodlands. Mohamed (2006) reported mean of 3,334 stems ha^{-1} regenerants from 44 species with DBH < 5cm in Handeni Hill FR in Tanga, Tanzania; Malimbwi and Mugasha (2002) obtained average of 8,752 stems ha^{-1} from a total of 12 different tree species with DBH < 5 cm in miombo woodland stratum at Handeni Hill FR, Tanga, Tanzania. This high regeneration could be due to human disturbances as noted by Chidumayo and Frost (1996) and Luoga *et al.* (2004). The regenerants are dominated by *Acacia polyacantha subsp. campylacantha, Albizia gummifera, Dalbergia boehmii, Dichrostachys cinerea, Diplorhynchus condylocarpon, Erythroxylum emarginatum* and *Milletia usaramensis*. No regenerations of *Brachystegia boehmii, B. microphylla* and *B. spiciformis* were recorded.

In dry evergreen forest stratum, mean value of 51,342 regenerants with DBH < 4 cm were observed from 26 different tree species. Like in the woodland stratum, this observation is higher than results reported from other studies. Malimbwi and Mugasha (2002) reported average regenerations of 6,546 stems ha^{-1} from 23 different tree species with DBH < 5cm in the semi-evergreen forest at Handeni Hill FR in Tanga, Tanzania. Six species dominated the regenerants namely; *Catunaregam spinosa*, *Croton dichogamus*, *C. sylvaticus*, *Erythroxylum emarginatum*, *Scrodophloeus fischeri* and *Vepris nobilis*. These species contributed 90% of all regenerants recorded in which *Scrodophloeus fischeri* alone contributed about 50%.

3.7 Forest cover changes

Forest cover analysis and change detection of Dindili FR between 1991 and 2000 are shown in Table 5 and 6. The results show that Dindili FR has undergone both positive and negative cover changes in terms of area. Overall, closed forest declined by 14% between 1991 and 2000. This represents annual decline of 11 ha (Table 5). In the same period of time, the open forest has increased by 54%. The increase in open forest has been contributed by 123 ha that has degraded from closed forest, 31 ha regeneration from shrubs and 12 ha from other cover categories. The probable reason for declining closed forest cover and a consequential increase in open forest cover is human disturbance and over-exploitation of forest products.

Table 5 also shows that the overall shrub cover type increased by 39% between 1991 and 2000, while other cover categories increased by 41%.

Table 5: Forest cover changes by area in Dindili Forest Reserve

Land cover/use	Years			
	1991 Acreage (Ha)	2000 Acreage (Ha)	1991-2000 Area change (Ha)	1991-2000 % Change
Closed forest	780	670	-110	-14
Open forest	136	210	+74	+54
Shrubs	59	82	+23	+39
Others	32	45	+13	+41

These results imply that there is high dependence of communities on forest products and that cultivation has insignificant contribution in forest degradation, reflected by the size of other cover categories which remained more or less the same between 1991 and 2000.

As shown in Table 6 and 7, change detection of covers between 1991 and 2000 showed that, of 780 ha of closed forest in 1991, 80% remained unchanged, while 16%, 3% and 1% degraded to open forest, shrubs and other covers respectively. In the open forest category, of 136 ha in 1991 only 32% remained unchanged, while 27% regenerated to closed forest and, 36% and 5% degraded to shrubs and other covers respectively by 2000.

Table 6: Dindili Forest Reserve change detection matrix between 1991 and 2000

Covers in 1991 (Ha)	Covers in 2000 (Ha)				
	CF	OF	S	O	Total
CF	623	123	20	14	780
OF	37	44	48	7	136
S	8	31	10	10	59
O	2	12	4	14	32
Total	670	210	82	45	1007

CF = Closed forest, OF = Open forest, S = Shrubs, O = other covers (Cultivation, grassland and woodland)

Of the shrub category, 14% and 53% regenerated to closed forest and open forest respectively by 2000, while 17% had been converted to cultivation, woodland and grassland and, 17% remained unchanged. Change detection matrix (Table 6) shows that 2 ha of other cover categories regenerated to closed forest. This change is not possible in a period of 10 years. Probably this could be caused by either miss-classification of images or inaccurate registration into map co-ordinate system.

The forest temporal dynamics between 1991 and 2000 showed that regeneration potential of Dindili FR is substantial. Of 670 ha of closed forest in 2000, 6% had been contributed by regenerations from open forest and 1% from shrubs. Of 210 ha of open forest in 2000, 15% was contributed by regeneration from shrubs and 6% from cultivation, grassland and woodland (Table 7).

CHAPOSA (2002) in Kitulanghalo and Mbwewe study areas, both in Tanzania, and Chongwe study area in Zambia observed similar results. The causes of forest cover changes in both countries were agriculture and charcoal production. In

Kitulanghalo and Mbwewe, agriculture and charcoal production resulted into 25% of closed woodland (119,000 ha) to be degraded to open woodland; 20% to bushland and 5% to mixed cropland between 1991 and 1998. In Chongwe study area in Zambia, agriculture was reported to account for 70% of the total deforestation, while charcoal production contributed 35% of deforestation. Cover change detection in Chongwe study area showed that open scrubland increased by 7.6% annually between 1991 and 1998.

Luoga *et al.* (2002) and Mbilinyi *et al.* (2007) also reported human disturbances such as agriculture and charcoal production to be reasons for forest cover changes at Kitulanghalo FR in Morogoro, Tanzania. In the eastern part of Tanzania, Mbilinyi *et al.* (2007) reported 25% of 116,803 ha of closed woodland to have been degraded to open woodland; 23% to thicket, bushland, bushed grassland and grassland; 5.0% had been converted to cultivation between 1991 and 1998. The same author in the same study area reported 53% of 177,102 ha of open woodland present in 1991 to have been degraded to thicket, bushland, bushed grassland and grassland; and 9% to cultivation.

Table 7: Dindili Forest Reserve temporal dynamics between 1991 and 2000

	Unchanged forest	
Cover	Acreage (Ha)	% of the cover in 1991
CF	623	80
OF	44	32
	Forest degradation	
Change	Acreage (Ha)	% of the cover in 1991
CF - OF	123	16
CF - S	20	3
CF - O	14	1
OF - S	48	35
OF - O	7	5
	Forest regeneration	
Change	Acreage (Ha)	% of the cover in 2000
OF - CF	37	6
S - CF	8	1
O - CF	2	0
S - OF	31	15
O - OF	12	6

CF - OF = closed forest to open forest, CF - S = closed forest to shrubs, CF - O = closed forest to other covers, OF-S = open forest to shrubs, OF-O = open forest to other covers, OF-CF = open forest to closed forest, S-CF = shrubs to closed forest, O-CF = other covers to closed forest, S-OF = shrubs to open forest, O-OF = other covers to open forest.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Dindili FR has been highly impacted by human disturbance and over-exploitation. Over-exploitation of high value timber species coupled with such other uses as charcoal production are the reasons for the depleted stocks of *Pterocarpus angolensis, Milicia excelsa, Burkea africana* and *Afzelia quanzensis* which could be described as endangered in the area. Human disturbances and over-exploitation were also the reasons for the low stocks observed in terms of stand density, diameter distribution, basal area and wood volume, specifically to such species as; *Dalbergia melanoxylon, Brachystergia* spp.*, Acacia* spp. and *Albizia* spp.

Human disturbance and over-exploitation in Dindili FR has also increased the population of regenerants, dominated by six species only namely; *Catunaregam spinosa, Croton dichogamus, C. sylvaticus, Erythroxylum emarginatum, Scrodophloeus fischeri* and *Vepris nobilis*.. The other impact of forest dependence is on forest cover change in which the closed forest declined by 14% and the open forest increased by 54% between 1991 and 2000.

The following recommendations are put forward:

Special efforts are needed to promote regeneration of the endangered species and more and close studies need to be in place to explore regeneration potential of such species which did not register any regeneration as *Manilkara sulcata*, *Brachystegia boehmii* and *B. spiciformis.*

Dindili forest reserve is within the Dar es Salaam catchment area for forest products supply. Without sound management plans, degradation of this reserve and others in the area is expected to continue. Communities adjacent to this forest should be encouraged to fully participate in forest reserve protection from within themselves and outsiders.

The above can be achieved through: definition of communities' rights and incentives; formulation of village by-laws and enforcement; and strengthening of existing village natural resources committees by defining their roles and powers as well as entitled incentives. In most cases, the committee members bear the opportunity cost of their own personal livelihood activities without assured benefits from their participation in forest patrolling. In addition to the above, close follow-ups by the government is also crucial as an incentive to the village natural resources committees on one hand, and to the village government on the other. This will help resolve conflicts of power which usually surface between the village governments and village natural resources committees.

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