Journal of Tropical Forest Science 12(2):336–347 (2000)

PREVALENCE AND STANDING VOLUME OF *DALBERGIA MELANOXYLON* IN COASTAL AND INLAND SITES OF SOUTHERN TANZANIA

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Received January 1998

MALIMBWI, R. E., LUOGA, E. J., HOFSTAD, O., MUGASHA, A. G. & VALEN, J. S. 2000. Prevalence and standing volume of *Dalbergia melanoxylon* in coastal and inland sites of southern Tanzania. In order to determine the prevalence and standing volume of *Dalbergia melanoxylon*(mpingo), 120 sample plots were laid out in each of two districts, Kilwa and Nachingwea, representing coastal and inland woodlands in Lindi Region, southern Tanzania. Using data from felled trees, volume equations for various utilisation classes were constructed. Also estimated were the basic density of mpingo, the percentage content of heartwood, sapwood, and heartrot, and the thickness of bark and sapwood.The basic density values for mpingo were 1.14, 0.76 and 1.06 g cm^{-3} for heartwood, sapwood, and both heartwood and sapwood. These are multiplier factors to obtain biomass values from volume. The heartwood content of mpingo is 83% of the total volume and the rest (17%) is sapwood and bark. Based on a few logs observed 13% of the total volume may be expected to have heartrot. The sapwood thickness is 1.1 cm with little variation irrespective of log diameter. The bark is thin (3.7 mm) and soft making the tree susceptible to damage by bruising and fire.The inland forests have twice as much overbark volume of mpingo as the coastal forests with 10 and 5 m^3 ha^{-1} respectively. The merchantable volume to 20 cm top diameter overbark is 4.4 and 1.7 m^3 ha^{-1} accounting for only 43 and 33% of the total volume per hectare respectively. Since regeneration of mpingo is easy, there is no immediate need to classify mpingo as an endangered species provided fire control is enhanced as an important conservation measure. It is, however, appropriate to regard the species as threatened.

Key words: *Dalbergia melanoxylon* - standing volume - basic density - Tanzania

MALIMBWI, R. E., LUOGA, E. J., HOFSTAD, O., MUGASHA, A. G. & VALEN, J. S. 2000. Penyebaran dan isipadu dirian *Dalbergia melanoxylon* di tapak di pantai dan di darat bahagian selatan Tanzania. Untuk menetukan penyebaran dan isipadu dirian *Dalbergia melanoxylon* (mpingo), 120 petak sampel diwujudkan di setiap dua daerah, Kilwa dan Nachingwea, mewakili hutan jarang di pantai dan di darat Lindi Region, di selatan Tanzania. Menggunakan data daripada pokok-pokok yang ditebang, persamaan isipadu bagi pelbagai peringkat penggunaan telah dibina. Turut dianggarkan ialah ketumpatan asas mpingo, peratus kandungan teras kayu, kayu gubal dan reput teras, ketebalan kulit dan kayu gubal. Nilai ketumpatan asas bagi mpingo ialah 1.14; 0.76 dan 1.06 g cm^{-3} bagi teras kayu, kayu gubal dan kedua-dua teras kayu dan kayu gubal. Ini merupakan faktor pengganda untuk memperoleh nilai biojisim daripada isipadu. Kandungan teras kayu bagi mpingo ialah 83% daripada jumlah isipadu dan selebihnya (17%) ialah kayu gubal dan kulit. Berdasarkan beberapa jenis kayu balak yang dicerap, 13% daripada jumlah isipadu dijangka mempunyai reput teras. Ketebalan teras kayu adalah 1.1 cm dengan sedikit perubahan tanpa mengambil kira garis pusat kayu balak. Kulit adalah nipis (3.7 mm) dan lembut menyebabkan pokok rentan terhadap kerosakan disebabkan oleh luka dan kebakaran. Hutan darat mempunyai dua kali sama banyak isipadu kulit luar mpingo di hutan pantai dengan masing-masing ialah 10 dan 5 m^3 ha^{-1}. Isipadu boleh niaga bagi 20 cm garis pusat atas kulit luar ialah 4.4 dan 1.7 m^3 ha^{-1} menunjukkan masing-masing hanya 43 dan 33% daripada jumlah isipadu sehektar. Memandangkan pemulihan mpingo adalah senang, tiada keperluan segera untuk mengklasifikasikan mpingo sebagai spesies yang telah pupus dengan syarat kawalan kebakaran dipertingkatkan sebagai satu cara pemuliharaan yang berkesan. Bagaimanapun, spesies ini boleh dianggap sebagai spesies yang terancam.

Introduction

Dalbergia melanoxylon Guill. & Perr. belongs to the family Leguminosae and sub-family Papilionaidae. It has a wide range of occurrence in at least 20 countries in sub-Saharan Africa, and is locally known as "mpingo" (Kiswahili), or East African blackwood (trade name). It is ecologically and economically a very important component of many African woodlands. (Marshall 1995).

Dalbergia melanoxylon is a small, usually multi-stemmed and heavily branched shrub or tree with stem and branches armed with spines or thorns. The crown is low and irregularly shaped (Gillet *et al.* 1971). The tree height ranges from 4.5 to 7.5 m tall but occasionally reaches 15 m. The bole is fluted with narrow ribs separated by deep indentations. The bole length occasionally reaches up to 3.6 m, but normally ranges from 1.2 to 1.8 m.

In its natural habitat *D. melanoxylon* grows slowly. According to Nshubemuki (1993), for intensively managed stands the rotation age may range from 50 to 80 y depending on site quality to produce mature trees of dbh 38–40 cm. Although *D. melanoxylon* has a potential as a plantation species, it has not been planted extensively either in Tanzania (Hansen 1996) or other countries.

Dalbergia melanoxylon reproduces easily through seedlings, root suckers and cuttings (Mugasha 1983). In a field study in Southern Tanzania, Hansen (1996) found an average of 4638 regenerating seedlings per hectare in coastal (Kilwa) miombo woodland and 268 seedlings in inland (Nachingwea) miombo. Only 8.9% of the total regeneration were actual seedlings while the remaining were due to root suckers and from stumps. Few seedlings attain sapling/pole size stages. There was evidence that survival may be improved considerably by fire protection specially during the early years of growth (Hansen 1996).

At up to £12 000 m^{-3}, timber of *D. melanoxylon* probably commands the highest price of any wood in the world (Fauna & Flora International 1995). In addition to its international value where the end use is largely the manufacture of musical instruments, especially woodwind instruments, *D. melanoxylon* has a great local importance in wood carvings (Bryce 1967, Mbuya *et al.* 1994). Local uses of *D. melanoxylon* include firewood, charcoal, pestles, combs, knife hafts and cups (Bryce 1967). Other uses of *D. melanoxylon* include fodder, bee forage, mulch and nitrogen fixation (Mbuya *et al.* 1994). The plant is also used as medicine to treat wounds, abdominal pains, worms, and venereal diseases (Marshall 1995).

In many countries where *D. melanoxylon* occurs, over-exploitation over the last few decades has caused scarcity of this species. Because of the fear that *D. melanoxylon* might become extinct, the governments of Kenya and Germany in 1993/94 proposed to place the species on Appendix II of the Convention on International Trade in Endangered Species of Wild Life Fauna and Flora (CITES) (Kabuye 1995, Koning 1995). The implementation of the proposal was halted due to lack of adequate supportive data. This research was carried out to provide much needed data on the species.

Export of logs or sawn timber of *D. melanoxylon* is still an important economic activity in northern Mozambique and southern Tanzania. The dilemma then is to balance the international community's concern for the preservation of this species against the economic interests of forest workers and industrialists in the exploiting countries. Also there are both cultural and economic interests tied to the production of musical instruments in the affluent societies of the north.

An objective and scientific assessment of any natural resource is a prerequisite for sustainable management. There is hardly any inventory carried out for *D. melanoxylon* in Tanzania. Prescribing a sustainable harvesting regime for *D. melanoxylon* requires adequate information on the distribution, standing volume and growth rates of the resource. It was against this background that an inventory was carried in southern Tanzania (Kilwa and Nachingwea Districts) where it is believed the species is still plentiful. The sites may not necessarily be representative of the habitats of the species in the country.

Materials and methods

The study sites

Two locations were investigated, the inland and coastal sites. Lionja Forest Reserve (38°20'–38°30'E, 10°12'–10°20' N) and the surrounding public lands were sampled in Nachingwea District representing inland miombo woodlands. Mitature Forest Reserve (38° 53'–39° 14' E, 8° 45'–9° 03'N) and the surrounding public land in Kilwa District were sampled representing coastal miombo woodlands.

Data collection and analysis

Inventory

In each district 120 sample plots were located. Half of these plots formed one parcel and were laid out in the forest reserve while the other plots were in public land. In each location 3000 m long transects were laid out at an interval of 500 m. Fifteen plots were laid out along each transect at an interval of 200 m. The sample plots were circular with a radius of 20 m.

In each plot, all *D. melanoxylon* trees with dbh ≥ 4 cm were measured for dbh to the nearest 0.1 cm and total height to the nearest 0.1 m. Due to multiple stems and flutes on the trees, standard mensurational techniques had to be followed strictly to minimise measurement errors. For example, for a tree forking below 1.3 m from the ground, each stem was treated as an individual tree. For trees with flutes diameter was recorded as the average of two measurements taken at right angles. A basal area count was taken for all tree species using a relascope with a basal area factor of 1.

Construction of volume equations

A total of 24 *D. melanoxylon* trees were measured for the construction of volume equations. The tree sizes ranged from 7 to 50 cm in dbh and 6 to 16 m in height. Length of the billets (including branches) ranged from 1.5 to 6.0 m and their mid-diameters were measured for volume calculation using Huber's formula. The minimum merchantable diameter was 20 cm. The bark thickness was also measured.

Four utilisation categories of *D. melanoxylon* were considered for volume equations construction:

- Total volume overbark
- Total volume underbark
- Merchantable volume overbark
- Merchantable volume underbark

Four volume models were fitted as follows:

1. $\ln V = b_0 + b_1 \ln D + b_2 \ln H$
2. $\ln V = b_0 + b_1 \ln D$
3. $V = b_0 + b_1 D^2$
4. $V = b_0 + bD^2H$

Where ln = base of natural logarithms
V = volume (m^3)
b_i = constants to be estimated
D = dbh (cm)
H = total tree height (m)

Estimation of basic density

Twenty wood samples from twenty trees (15 from inland and 5 from the coast) were taken for basic density measurement.

A disk of about 2 cm thickness was cross-cut from within the lower 1 m of the stem. In the laboratory, from each disk a block measuring 4 cm width was cut from bark to pith. A similar block was cut and its sapwood was separated from the heart-wood. The blocks were soaked in water for a week to regain green volume, after which they were measured for green weight and volume by water displacement. The blocks were then dried in an oven at 103 ± 2 °C for four days to constant weight and the oven dry weight recorded. The basic density was computed as the ratio of oven dry weight to green volume.

Estimation of heartwood and sapwood volume percentage

To estimate the volume ratio of heartwood and sapwood that might be expected in a log, six logs were measured for diameter, heartwood and sapwood thickness.

Results and discussion

Volume equations for Dalbergia melanoxylon

Table 1 shows coefficients of the regression equation and the goodness of fit as indicated by R^2 and standard error of estimate.

For all categories of *D. melanoxylon*, model 1, the logarithmic equation with dbh and height as independent variables, is superior considering the goodness of fit in terms of R^2 and SE. The model gives almost a perfect fit ($R^2 = 0.99$) for total volume overbark and underbark. However, model 2 which has also high R^2 (0.97) has been adopted for both total volume overbark and underbark on the basis of its simplicity to use as it requires only dbh on its application.

Table 1. Coefficients of the regression equations and their goodness of fit for the different utilisation categories of *Dalbergia melanoxylon* in southern Tanzania

Dependent variable	Model	Regression estimator b_0	b_1	b_2	R^2	SE
Total volume overbark	1	- 9.887	1.824	1.155	0.99	0.15
			(0.088)*	(0.20)		
(VTOB)	2	- 8.375	2.231	-	0.97	0.23
			(0.82)	-		
Total volume underbark	1	- 10.127	1.824	1.188	0.99	0.14
			(0.080)	(0.182)		
(VTUB)	2	- 8.572	2.262	-	0.97	0.23
			(0.081)			
Merchantable volume over-	1	- 13.132	2.385	1.409	0.87	0.24
			(0.291)	(0.359)		
bark (VMOB)	2	11.010	2.804	-	0.77	0.32
			(0.364)	-		
	3	1.445	- 0.092	0.00172	0.79	0.18
			(0.049)	(0.0006)		
	4	- 0.154	0.0000324	-	0.85	0.14
			(0.00000321)			
Merchantable volume under-	1	- 12.93	2.367	1.335	0.86	0.25
			(0.305)	(0.376)		
bark (VMUB)	2	- 11.30	2.867	-	0.77	0.32
			(0.371)	-		
	3	1.43	- 0.092	0.00172	0.80	0.18
			(0.0488)	(0.0006)		
	4	- 0.157	0.000031	-	0.85	0.14
			(0.000003)			

*Numbers in brackets are the standard errors of the coefficients.

Model 1 has still to be adopted for merchantable volume on the basis of its significantly high R^2. The selected equations are therefore as follows:

- Total volume overbark

  $$V_{TOB} = 0.00023D^{2.231}$$

- Total volume underbark

  $$V_{TUB} = 0.000189D^{2.262}$$

- Merchantable volume overbark

  $$V_{MOB} = 0.00000198D^{2.385}H^{1.409}$$

- Merchantable volume underbark

  $$V_{MUB} = 0.00000242D^{2.367}H^{1.335}$$

Percentage content of different parts of Dalbergia melanoxylon

Table 2 shows the volume percentages of bark, sapwood, heartwood, and the thickness of the bark and sapwood of some samples of *D. melanoxylon*. In Table 2, standing *D. melanoxylon* trees were estimated to contain heartwood of 83% of total volume, the rest (17%) being sapwood and bark. The sapwood thickness was 1.1 cm with little variation (0.9–1.5 cm) often caused by damage on the stem. It was later observed in other logs that the reported sapwood thickness is stable within this range regardless of variation in log diameter.

Table 2. Volume percentage of heartwood, sapwood and thickness of bark and sapwood of some samples of *D. melanoxylon* in southern Tanzania

	Average	Range	SE	Remarks
Heartwood (%)	83	73–89	2.4	Six samples
Sapwood (%)	17*	10–26	2.4	"
Sapwood thickness (cm)	1.1	0.9–1.5	0.087	235 samples
Back thickness (cm)	3.7	1.5–8.0	0.104	"

*Includes bark.

The bark of *D. melanoxylon* is very thin (3.7 mm) and soft making the tree susceptible to damage by bruising and fire. On a live tree open scars exposing the wood are a common feature. If the fire is severe enough the trees will die and perhaps regenerate from root suckers during the next rainy season.

The form factor of total volume overbark is 0.53 with a range of 0.41 to 0.73 (Table 2). This is well within the expected range (Philip 1994).

Table 3. Basic density (g cm^{-3}) of different parts of *D. melanoxylon* in southern Tanzania

Source		Average	Range	Std. error	Remarks
Inland	Heartwood	1.12	1.03–1.19	0.012	15 samples
	Sapwood	0.77	0.71–085	0.012	"
	Sapwood/heartwood	1.07	1.0–1.17	0.010	"
Coast	Heartwood	1.15	1.1–1.28	0.011	5 samples
	Sapwood	0.75	0.7–0.81	0.011	"
	Sapwood & heartwood	1.06	1.0–1.1	0.019	"
All sites	Heartwood	1.14	1.0–1.1	0.015	15 samples
	Sapwood	0.76	0.7–0.85	0.012	"
	Sapwood & heartwood	1.06	1.0–1.17	0.013	"

Basic density of Dalbergia melanoxylon wood

The basic density of the heartwood, sapwood, and both sapwood and heartwood is shown in Table 3. There was no difference in basic density of heartwood or sapwood between coastal and inland *D. melanoxylon* trees. The average values for coastal and inland *D. melanoxylon* were 1.14, 0.76 and 1.06 g cm^{-3} for heartwood, sapwood and both heartwood and sapwood respectively. The basic density of timber of *D. melanoxylon* exported from Cabo Delgado province in Mozambique is reported as 0.849 g cm^{-3} (Hofstad 1997), indicating a much lighter wood than that from southern Tanzania.

Standing volume

The inland forests have twice as much *D. melanoxylon* volume (overbark) as the coastal forests with 10 and 5 m^3 ha^{-1} respectively (Table 4) while the merchantable volume to 20 cm top diameter overbark is 4.4 and 1.7 m^3 ha^{-1} respectively. This accounts for only 43 and 33% of the total volume per hectare in inland and coastal areas respectively. In Cabo Delgado province, Mozambique, Macome (1996) reported a total overbark volume of 2.2 m^3 ha^{-1}.

Table 4. Volume standing volume of *D. melanoxylon* (m^3 ha^{-1}) in southern Tanzania

Location	Total volume overbark	Mechantable volume used overbark	Volume % unused*	Volume %
Coastal area				
Parcel 1	4.2 ± 2.0	1.2 ± 0.7	28	72
Parcel 2	5.9 ± 1.1	2.2 ± 0.4	37	63
Mean	5.0	1.7	33	68
Inland area				
Parcel 1	8.4 ± 1.4	8.4 ± 1.4	46	54
Parcel 2	12.4 ± 2.5	4.9 ± 1.2	40	60
Mean	10.4	4.4	43	57
Overall mean	7.7	3.2	38	63

Hansen (1996) observed more abundant *D. melanoxylon* regeneration of 4638 seedlings ha^{-1} in coastal woodlands as compared to 267 seedlings ha^{-1} in the inland. In this study (Table 4) the percentage of non-merchantable volume is higher for coastal forests (68%) than inland forests (57%). These figures, however, are relative to the total standing volume. The actual tree merchantable volume is 63% if the tree is used to 20 cm top diameter. According to Temu (1979), only about 40% or less of the total tree volume in miombo woodland is utilisable as saw logs due to poor tree form. The results in this study shows that there is less wastage of *D. melanoxylon* wood than with other miombo woodland species. The equivalent biomass of the merchantable part of the tree is 4.7 and 1.5 t ha^{-1} for inland and coastal *D. melanoxylon* respectively. If we exclude sapwood (which normally is not used), the net biomass is 3.9 and 1.2 t ha^{-1}.

Proportion of Dalbergia melanoxylon in relation to other species

Table 5 shows there is no difference in overall basal area for all tree species between the two localities (about 10 m^2 ha^{-1}). This may be expected for a typical miombo woodland (Malimbwi *et al.* 1994), although lower than that of 34 m^2 ha^{-1} reported from Mozambique (Malleux 1981). However, inland miombo has twice as much *D. melanoxylon* basal area as the coastal forests and similarly the occurrence of *D. melanoxylon* is higher inland (Table 6). Since there is prolific *D. melanoxylon* regeneration the differences in stocking at older age may be attributed to ecological factors such as fires and other growth conditions. The easy accessibility of coastal woodland which enhances harvesting may be another factor.

Table 5. *Dalbergia melanoxylon* (mpingo) basal area (m^2 ha^{-1}) in relation to other species in southern Tanzania

Location	Basal area of all species	Basal area of mpingo	Mpingo basal area (%)
Coastal area			
Forest reserve	10.0 ± 4.4	0.7 ± 0.3	7
Public land	11.4 ± 1.1	0.9 ± 0.2	8
Mean	10.5	0.8	7.5
Inland			
Public land	10.2 ± 0.9	1.3 ± 0.2	13
Forest reserve	9.8 ± 1.7	1.9 ± 0.4	19
Mean	10.0	1.6	16
Overall mean	10.2	1.2	12

Table 5 shows further that there is no difference in basal area between forest reserves and public lands. Although forest reserves are expected to have a higher stocking of *D. melanoxylon* as harvesting is controlled, this status does not seem to improve the stocking which apparently has been poor for a long time. Ackhurst (1970) reported that the major miombo species in Lionja Forest Reserve (inland) were *Pterocarpus angolensis, Brachystegia* and *Julbernardia* spp.

Occurrence of Dalbergia melanoxylon

Table 6 shows that in the plots surveyed *D. melanoxylon* was spotted more frequently inland than in the coast. Hawkins *et al.* (1995) in Mikumi National Park found that the species constituted 0.7% of the total mean density of 20 trees per hectare and these were in clusters, individual trees being within 10 m from each other. In Mozambique, Macome (1996) reported highly clustered *D. melanoxylon* trees in open forests. The clustering characteristic was also observed during this study, and this was more pronounced in coastal area where only 10% of all visited plots had *D. melanoxylon* compared to 44% of the inland plots. Field observations also showed that *D. melanoxylon* clusters were found on ant hills, where the undergrowth vegetation had been suppressed, thus providing a natural fire-break when the surrounding vegetation is burnt. It is difficult to say which came first, the ants or *D. melanoxylon.* The termitalia soils on ant hills are known to be generally more fertile than the surrounding areas, thus they could have attracted mpingo with other species. Since *D. melanoxylon* usually grows in marginal areas as it cannot compete with other species (Mugasha 1983), we prefer to reason that it came first and survived fire for the early years and the ants followed to enjoy the fire protected area as a result of grasses being suppressed.

Table 6. Occurrence of *D. melanoxylon* (mpingo) in southern Tanzania

Location	Total number of plots visited	Plots with mpingo	
		Number	%
Coastal area			
Forest reserve	60	4	7
Public land	59	8	13
Mean	60	6	10
Inland			
Forest reserve	60	28	47
Public land	59	24	41
Mean	60	26	44

Table 7. Volume of *D. melanoxylon* licensed for cutting in southern Tanzania 1990–95 (m^3)

Region	1990	1991	1992	1993	1994	1995
Lindi	n.a	1006	370	249	723	388
Mtwara	138	121	56	107	28	n.a
Sum	-	1127	426	356	751	-

Source:Valen (1996).

Conclusion

Dalbergia melanoxylon occurs frequently over a large part of the southern provinces in Tanzania. We have noted that the inland woodlands contain more mpingo or blackwood than coastal woodlands (basal area, 1.6 and 0.8 m^2 ha^{-1}, and total volume, 10.2 and 5.0 m^3 ha^{-1} respectively). The difference in standing volume is even more pronounced when we compare merchantable volume (4.4 and 1.7 m^3 ha^{-1} respectively). These differences are probably caused by a combination of ecological factors and commercial exploitation. The coastal area has always been more easily accessible. Hansen (1996) showed that there is, however, more abundant natural regrowth of seedlings of the species in the coastal woodland (4638 plants ha^{-1}) than in the inland (267 plants ha^{-1}). Those observations may indicate that there is no immediate threat to the existence of *D. melanoxylon* in this part of its natural habitat. This does not, however, mean that the species may not be threatened in other parts of its range.

The average licenced removal of *D. melanoxylon* in southern Tanzania from 1991 to 1994 is 665 $m^3 y^1$ (Table 7). It is thought that this figure is only a small portion of actual removals as it ignores all kinds of illegal harvesting (Puhakka 1991). Even with this underestimation, considering the low standing volume and the long rotation age (up to 200 y) required to get mature blackwood in unmanaged forest (Sharman 1995), sustainable production of blackwood is doubtful.

From general resource economic theory and observations of felling operations in the region we tend to think that exploitation will cease when blackwood population density per hectare has reached a minimum threshold. Selective felling would then become unprofitable even without regulatory intervention. Environmentalist, however, may not be satisfied with such low population densities and insist on regulation of harvesting at a much earlier stage. Also, low quality specimens may remain as a result of dysgenic selection.

Although *D. melanoxylon* is a savannah species, it does not appear to be fire resistant. The stems are frequently damaged by fire. Substantial heartrot worthy of further research was observed in some logs and this could be linked with fungal infection following fire damage. Since there is evidence of adequate regeneration, control of fires and harvesting would appear to be important conservation measures.

Acknowledgement

This research was financed by the Royal Norwegian Ministry of Foreign Affairs under the North-South Programme.

References

ACKHURST, P. W. 1970. Reconnaissance Inventory of Lionja Forest Reserve. Ministry of Natural Resources and Tourism, Dar es Salaam. Unpublished report.

BRYCE, J. M. 1967. *The Commercial Timbers of Tanzania.* URT, Forest Division. 139 pp.

FAUNA & FLORA INTERNATIONAL. 1995. *Proceedings of the Maputo Workshop : Towards Conservation and Responsible Use of Dalbergia melanoxylon.* Maputo, 6–9 November 1995. 82 pp.

GILLET, J. B., POLHILL, R. M. & VERDCOURT, B. 1971. Leguminosae (Part 3). Sub-family Papilionoidaea (1). Pp. 100–102 in Milne-Redhead, I.S.O & Polhill, B.A. (Eds.) *Flora of Tropical East Africa.* Crown Agent for Overseas Government and Administration.

HANSEN, M. B. 1996. Natural Regeneration of *Dalbergia melanoxylon* in South-east Tanzania. Cand. Agric. thesis, Department of Forest Sciences, Agricultural University of Norway, Ås .96 pp.

HAWKINS, D. M., LYARUU, H. & NORTON, G. W. 1995. *Dalbergia melanoxylon* in Mikumi National Park, Tanzania. Pp. 44–50 in *Proceedings of the Maputo Workshop: Towards Conservation and Responsible Use of Dalbergia melanoxylon.* Maputo, 6–9 November, 1995.

HOFSTAD, O. 1997. Protection of African blackwood in Tanzania and Mozambique through CITES. Saastamoinen, O. & Tikka, S. (Eds.) Proceedings of the biennial meeting of the Scandinavian Society of Forest Economics. Mekrijarvi, Finland, March 1996. *Scandinavian Forest Economics* 36:443–452.

KABUYE, C. 1995. Presentation from Kenya. Pp. 25–26 in *Proceedings of the Maputo Workshop: Towards Conservation and Responsible Use of Dalbergia melanoxylon*. Maputo, 6–9 November, 1995.

KONING, DE J. 1995. CITES. Pp. 23–25 in *Proceedings of the Maputo Workshop : Towards Conservation and Responsible Use of Dalbergia melanoxylon*. Maputo, 6–9 November, 1995.

MACOME, E. 1996. *Report on Exploratory Inventory of Dalbergia malanoxylon in the Province of Cabo Delgado*. National Directorate of Forests and Wildlife. Centre of Forestry Experiments - Marracuene. 9 pp.

MALLEUX, J. 1981. *Evaluacion de los recurses florestales de la Republica Popular de Mozambique*. FO: MOZ/ 76/007, FAO, Maputo. 9 pp.

MALIMBWI, R. E., LUOGA, E. G. & SOLBERG, B. 1994. Estimation of biomass and volume in miombo woodland at Kitulangalo Forest Reserve, Tanzania. *Journal of Tropical Forest Science* 7(2):230–242.

MARSHALL, N. 1995. Trade in *Dalbergia melanoxylon*. Pp. 30–38 in *Proceedings of the Maputo Workshop: Towards Conservation and Responsible Use of Dalbergia melanoxylon*. Maputo, 6–9 November, 1995.

MBUYA, L. P., MSANGA, H. P., RUFFO, C. K., BITNIE, A. & TENGNAS, B. 1974. *Useful Trees and Shrubs for Tanzania. Identification, Propagation and Management for Agricultural and Pastoral Communities*. Regional Soil Conservation Unit, Swedish International Development Authority. 542 pp.

MUGASHA, A. G. 1983. *The Effect of Planting Season, Different Planting Materials, and Weeding Methods on Early Performance of Dalbergia melanoxylon at Kwamarukanga, Korogwe, Tanzania*. Tanzania Silviculture Technical Note (New Series) 43.

MUGASHA, A. G. & MRUMA, S. O. 1983. *Growth of Dalbergia melanoxylon in Natural Woodland and Trial Plots in Tanzania*. Tanzania Silviculture Technical Note (New Series) 59. 11 pp.

NSHUBEMUKI, L. 1993b. *NFT Highlights: Dalbergia melanoxylon : Valuable Wood from a Neglected Tree*. The Nitrogen Fixing Tree Association, Hawaii, USA.

PHILIP, M. S. 1994. *Measuring Trees and Forests*. CAB International, U.K. 310 pp.

PUHAKKA, M. 1991. *Inventory of Dalbergia melanoxylon in the Mtwara Region: Present State of Resources and Perspectives for its Sustainable Use in the Future*. Project report of the Turka-Mtwara Friendship Association. 20 pp.

SHARMAN, H. 1995. Investigation into the Sustainable Management of a Tropical Timber Tree Species Using *Dalbergia melanoxylon* as a Case Study. A dissertation presented for the degree of Master of Science, University of Edinburgh. 85 pp.

TEMU, A. B. 1979. *Fuelwood Scarcity and Other Problems Associated with Tobacco Production in Tabora Region, Tanzania*. University of Dar es Salaam, Division of Forestry Record No. 12, Morogoro. 12 pp.

VALEN, J. S. 1996. Exploitation of blackwood in southern Tanzania. Unpublished manuscript, Noragric Aas. 6 pp.