Uganda Journal of Agricultural Sciences, 2005, 11: 2 -8
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ISSN 1026-0919
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Differences in basic density and strength properties of *Milicia excelsa*, *Maesopsis eminii*, *Cynometra alexandri* and *Celtis gomphophylla* from Budongo forest, Uganda

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Abstract

Strength properties of four species comprising two that were less desirable (*Cynometra alexandri* and *Celtis gomphophylla*) and two desirable species (*Maesopsis eminii* and *Milicia excelsa*) from Budongo Forest Reserve, Uganda were studied. Three trees of each species were sampled in the diameter size classes: 60-69 cm, 70-79 cm and 80-89 cm, respectively. The preparation of samples and determination of basic density and strength properties followed the standard procedures of wood strength testing. The less desirable species had higher strength properties than the desirable species. The mean basic density for *C. alexandri* and *C. gomphophylla* categorised as less desirable were: 738 and 519 kg/m^3 compared to the preferred *M. eminii* and *M. excelsa* (BD: 359 and 463 kg/m^3). High values of basic density and strength properties of wood for species considered less desirable for timber shows that utilisation of these species should be promoted to save the desirable species.

Key words: *Basic density, Budongo, desirable species, less desirable species, strength properties*

Introduction

Overexploitation of desirable timber species and underutilisation of the species considered less valuable is a major problem confronting sustainability of the timber industry in the tropics. The desirable species are those normally preferred for commercial timber production based on such qualities as, appearance of timber and ease of preparation. The selection of desirable species is also influenced by the market prices. The problem of selecting timber species also confronts the timber industry worldwide. In the United States and Canada, the dense hardwoods such as, red and white oak, maple and hickory are preferred, and grading is based on structural uses and appearance (Haygreen & Bowyer, 1996). In the tropical natural forests, the desirable species constitute less than 5% of the total species. In the Philippines, for example, 97% of the species occurring in natural forests are not commonly processed by wood using industries because they are considered less desirable (Youngs & Hammett 2000).

In Uganda, the Budongo Forest Reserve contains more than 300 tree species that are considered less desirable for the timber industry. Some of the desirable timber species in Budongo are *Entandrophragma angolense* Welw., *E. cylindericum* Sprague, *E. utile* Dawe & Sprague, *Khaya anthotheca* Welw., and *Milicia excelsa* (Welw.) C. Berg Plumptre, 1996). Kityo & Plumptre (1997) reported that the most important criteria used to determine desirable timbers were attractive appearance, moderate density and strength, ease of sawing and durability. The same authors indicated that much of the pressure on relatively few commonly used species results from ignorance about the strength properties and potential uses of the less preferred species. For instance, *Celtis* species are abundant and yield high-grade timber, yet they are under-utilised. Another Species *Cynometra alexandri* Wright is five times as abundant as other preferred species in Budongo Forest Reserve (Kityo & Plumptre, 1997) yet it remains under-utilised.

Youngs and Hammett (2000) stated that improved utilisation of under-utilised species might offer opportunities on a global scale for both needed products and maintaining healthy and sustainable forest management. In Uganda no assessments have been done to compare the desired and less desired species in terms of strength properties. The objectives of this study were, to compare basic density and strength properties of *Milicia excelsa*, *Maesopsis eminii* Engl. (desired) and *Celtis gomphophylla* Bak., *Cynometra alexandri* (less desired); 2) assess the relationships between basic density and strength properties, and diameter class; and 3) to investigate variations in basic density and strength properties within and between species.

Materials and Methods

Test samples were collected from compartment N2 of Budongo Forest Reserve, because it was a utilization compartment and easily accessible. Budongo Forest

Reserve is a medium altitude moist semi deciduous forest. It is located in western Uganda between 1°37'-2°00 N and 31°22'-31°46'E and covers an area of 825 km², making it Uganda's biggest forest reserve (Hamilton, 1984). The Budongo Forest Reserve is divided into five blocks; Biso, Nyakafunjo, Waibira, Kaniyo pabidi and Siba. Each of these blocks is sub-divided into compartments. Compartment N2 was logged in the periods between 1945-47. The soils throughout this area are tropical red earths (*Ferralitic*) and are regarded as the final stage in tropical weathering (Paterson, 1991). The mean annual precipitation over the forest centre usually exceeds 1400 mm but the surrounding savannas rarely attain 850 mm.

Three trees of each species; *M. excelsa*, *M. eminii*, *C. gomphophylla* and *C. alexandri* were selected. Individuals selected were in the diameter at breast height over bark (DBHOB) classes 60-69 cm, 70-79 cm and 80-89 cm (Elliot, 1966). The trees were cut to 2 m long logs (at breast height) and sawn to 75 mm thick central planks, which were divided along the pith and sawn into 30 mm sticks and then machined to 20 mm pieces. Basic density was determined in accordance with ISO 3131 (1975). Determination of strength properties was done using a monsato tensomenter machine and deflection curves were plotted manually. The techniques described by Lavers (1969) were used to determine the following strength properties:

- Compression (MCS)
- Static bending
- Modulus of elasticity (MOE)
- Modulus of rupture (MOR)
- Shear parallel to grain (MSS)
- Cleavage (CLR)

Data analyses

Analysis of variance (ANOVA) general linear model was used to determine the variation of basic density and the strength properties among and between species. Repeated ANOVA was used to evaluate the variation of the properties with diameter classes, and radial positions (from pith to bark). Simple linear regression analysis was used to study relationships between basic density and strength properties. All the tests were done at 5% level of significance using Minitab programme (Version 13) (Minitab Inc., 2000).

Results

Variation of density within species

The mean basic densities of the four species were 738 kg/m³, 519 kg/m³, 359 kg/m³ and 463 kg/m³ for *C. alexandri*, *C. gomphophylla*, *M. eminii* and *M, excelsa* respectively. Basic density varied significantly ($P<0.05$) between individual trees of each of the four species. The regression and correlation analysis of basic density and diameter class showed a weak relationship between the two with low R-squares i.e R^2 = 33.2%, 12.9%, 15.7% and 11.7% for *C. alexandri*, *C. gomphophylla*, *M. eminii* and *M. excelsa*, respectively (Table 1).

Table 1: Regression equations and correlation coefficients of the relationship between basic density and tree diameter classes.

Species	Regression equation (BD = a + bD)	R-square (%)	P	Significance
Cynometra alexandri	BD = 675 + 31.7D	33.2	0.001	*
Celtis gomphophylla	BD = 472 + 23.8D	12.9	0.031	*
Maesopsis eminii	BD = 402 – 22.1D	15.7	0.03	*
Milicia excelsa	BD = 514 – 25.9D	11.7	0.069	NS

Variation of density in individual trees

Basic density did not differ significantly with radial positions (from pith to bark) $F_{1,26} = 0.87$ and $F_{1,32} = 1.2$, $P>0.05$ (GLM ANOVA) for *C. alexandri*, and *C. gomphophylla* respectively. However basic density varied

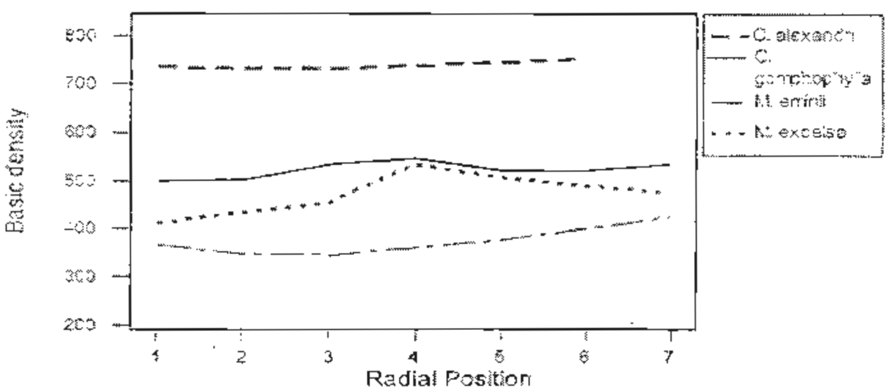


Figure 1. Radial variation in basic density for Cynometra, alexandri, Celtis gomphophylla, Maesopsis eminii and Millica excelsa

significantly with radial positions $F_{1,26} = 9.78$ and $F_{1,25} = 11.00$, $P<0.05$ (GLM) for *M. eminii* and for *M. excelsa* (Figure 1.)

Variation of density between species

Significant differences were observed in basic density of the four species $F_{3,119} = 130.41$, $P<0.05$ (GLM). Basic density was significantly lower ($F_{1,122} = 129.97$, $P < 0.05$) for desirable tree species (*M. eminii* and *M. excelsa*) than less desirable species (*C. alexandri* and *C. gomphophylla*).

Variation of strength properties within species

There were significant differences in MOE, MOR and Wmax but MCS, MSS and CLR were not significantly different between individual trees of *C. alexandri*. Significant differences ($P < 0.05$) between trees for MOR, Wmax and MSS were observed between individual trees of *C. gomphophylla,* but MOE, MCS and CLR did not differ significantly. For *M. eminii* there were significant differences in Wmax, MCS and MSS. Differences in MOE, MOR and CLR were not significant. *M. excelsa* had significantly different values of MOR, Wmax and MSS but not MOE, MCS and CLR (1-4). The variations of strength properties between trees are demonstrated (Figure 2 a-f).

Variation of strength properties within individual trees

There were significant differences of MOR, Wmax and MSS in radial positions for *C. alexandri* ($P<0.05$), but MOE, MCS and CLR did not show significant differences ($P>0.05$).

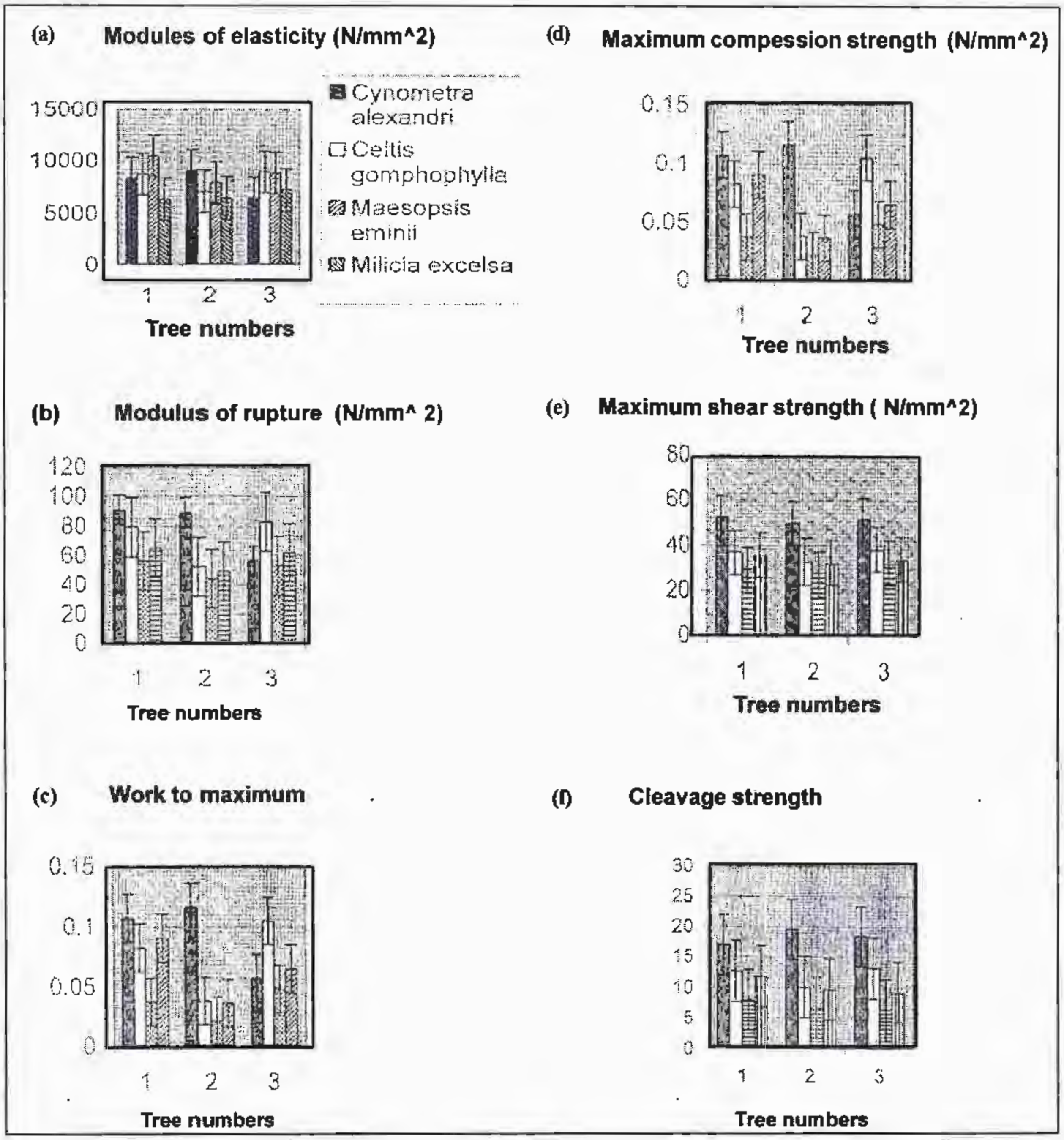


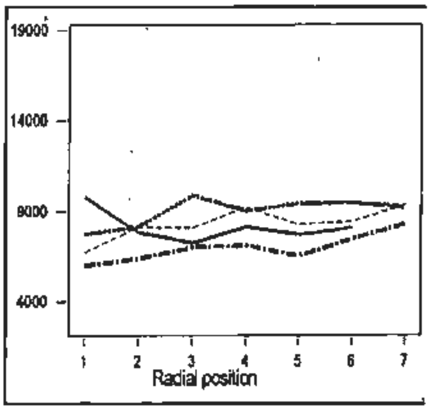
***Figure 2**. a-f: Variation in MOE, MOR, Wmax, MCS, Mss and CLR in individual trees of Cynometra alexandri, Celtis gomphophylla, Maesopsis eminii and Milicia excelsa*

For *C. gomphophylla*, there were significant differences (P<0.05) in values of MOR and W_{max} with radial position. All the strength properties did not show significant differences (P > 0.05) with radial position for *M. eminii*. Only MOE, MOR and MCS were significantly different (P<0.05) with radial position for *M. excelsa*. These variations are illustrated in Figure 3 a-f.

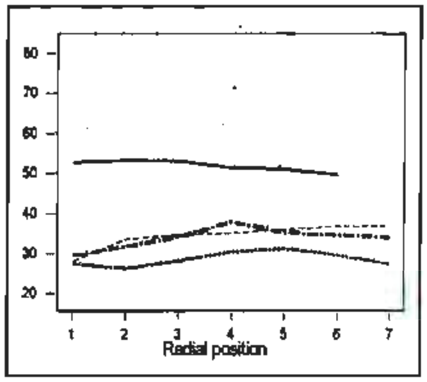
Variation of strength properties between species

There were significant differences in strength properties (P < 0.05) between species (Table 2). The less desirable species (*C. alexandri* and *C. gomphophylla*) had significantly higher values (P < 0.05) than the desirable species (*M. eminii* and *M. excelsa*) except for MOE, which did not differ (P> 0.05) in between the two categories (Table 3).

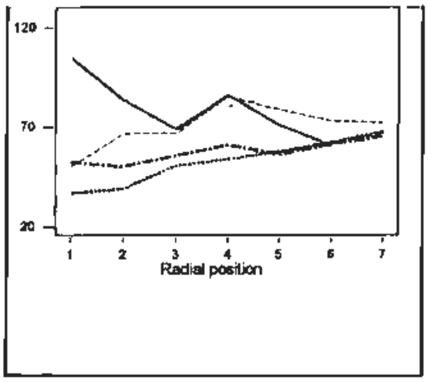
(a) Modulus of elasiticity (N/mm^2



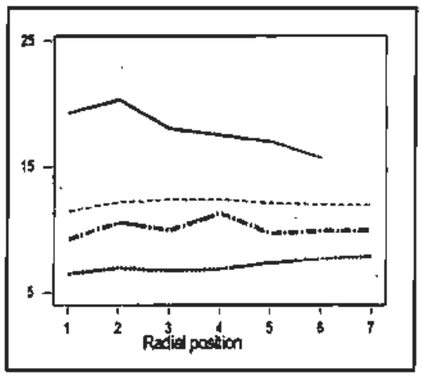
(d) Maximum compression strenth (N/mm^2)



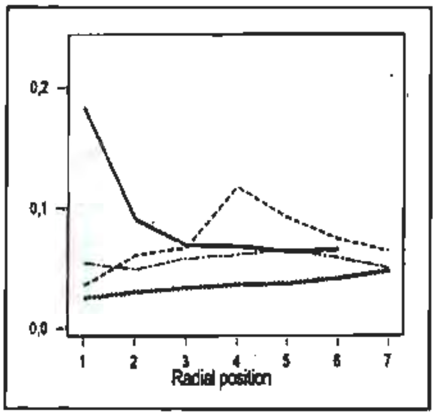
(b) Modulus of rupute (N/mm^2)



(e) Masimum shear strength (N/mm^2)



(c) Worl to maximum load (N/mm^2)



(f) Maximum cleavage strength (N/mm)

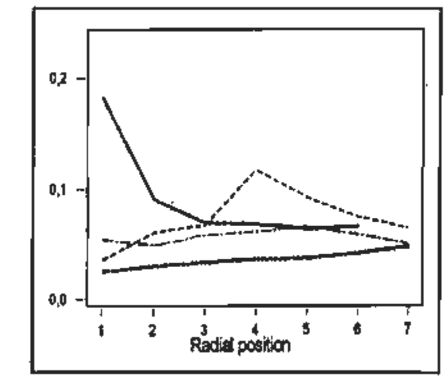


Figure 3a-f: *Radial variation of MOE, MOR, Wmax, MCS, and CLR in Cynometra alexandri, Celtis* ***omphophylla,*** *Maesopsis eminii and Milicia excelsa*

Discussion

The variation in basic density within species, could be due to environmental factors affecting tree growth such as elevation, air temperature, solar radiation, humidity and soil characteristics, while differences between trees of the same species could be attributed to ontogenic and genetic factors (Ishengoma & Nagoda, 1991). Size and age are also important determinants of the variation. The radial variation of basic density observed in *M. eminii* and *M. excelsa* was

Table 2: Analysis of Variance for strength properties showing species to species variation

Property	DF	Sum of Squares	Mean Square	F	P
MOE	3	90970980	30323660	5.79	0.001
MOR	3	13910.7	4636.9	9.74	0.000
W_{max}	3	0.054956	0.018319	9.17	0.000
MCS	3	8085.7	2695.2	62.42	0.000
MSS	3	2041.77	680.59	57.85	0.000
CLR	3	2526.20	842.07	60.62	0.000

Table 3: Analysis of Variance for strength properties showing species to species variation

Property	Sum of Squares	Mean square	F	P
MOE	1970307	1970307	0.33	0.564
MOR	11894	11894	24.52	0.000
W_{max}	0.037808	0.037808	17.96	0.000
MCS	4073.3	4073.3	53.86	0.000
MSS	1250.7	1250.7	116.03	0.000
CLR	2103.6	2103.6	122.64	0.000

NS = No significant difference, * = Significant difference

Table 4: Regression and R-square for the relationship between strength properties and basic density for the four species under study

Strength properties at 12% MC	Species	Regression equation (y = a + bx)	R-square (adj.)
MOE (N/mm^2)	Cya	y = 10135 – 2.97x	0.0
	Ms	y = 1333 + 21.5x	0.3
	Cdu	y = 4146 + 7.94x	8.3
	Me	y = 3025 + 7.80x	9.5
MOR (N/mm^2)	Cya	y = 188 – 0.148x	2.7
	Cdu	y = 2.0 + 0.132x	5.1
	Ms	y = - 10.5 + 0.171x	18.7
	Me	y = - 2.9 + 0.131x	20.1
Wmax (N/mm^2)	Cya	y = 0.126 –0.000044x	0.0
	Cdu	y = - 0.0658 +0.000271x	4.8
	Ms	y = 0.0203 +0.000039x	0.0
	Me	y = - 0.0847 +0.000314x	20.8
MCS (N/mm^2)	Cya	y = 59.1 – 0.0109x	0.0
	Cdu	y = 44.6 – 0.0171x	0.0
	Ms	y = 34.4 – 0.0144x	0.0
	Me	y = 13.5 + 0.0437x	28.1
MSS (N/mm^2)	Cya	y = 4.37 + 0.0189x	72
	Cdu	y = 7.53 + 0.00860x	1.5
	Ms	y = 2.04 + 0.0138x	18.5
	Me	y = 5.47 + 0.0102x	6.3
CLR (N/mm^2)	Cya	y = 18.7 + 0.0026x	0.0
	Cdu	y = 12.0 + 0.0083x	0.0
	Ms	y = 3.96 + 0.0130x	5.3
	Me	y = 2.59 + 0.0193x	14.4

Species = cya: Cynometra alexandri, cdu: Celtis gomphophylla, Ms: Maesopsi eminii, Me: Milicia excelsa
Other symbols: x: basic density, y: strength values, a: y-intercept, b: regression coefficient.

affected by the width of growth rings and the percentage of the dense latewood (Ishengoma & Nagoda, 1991). Basic density at the pith is usually lower than that at the outer wood. This variation may be explained by the presence of juvenile wood at the pith and mature wood towards the bark (Hamza *et al*, 2001). Differences in diameter classes could explain only small percentages of the observed variation in basic density.

According to Ishengoma & Nagoda (1991), the variation in basic density between different species is due to the differences in amount of cell wall substance and extraneous materials present per unit volume. This is determined by the structural characteristics of wood such as size and proportional amounts of different cell types present and cell wall thickness. The latter is the major determinant.

The variation of strength properties within species shows that within any species there is considerable variation in wood strength properties that corresponds to the variation in density and to the density-strength relationship of that property (Haygreen & Bowyer, 1996).

The superior strength properties of the less desired species as compared to the desirable species shows that underutilization of species is not based on inferior wood properties but due to lack of markets (Youngs & Hammett, 2000). Other reasons for underutilizing certain species may be appearance and ease in sawing. Bangura *et al* (2001) noted that the price of wood depended partly on its colour.

The weak correlation between basic density and strength properties was contrary to findings of Haygreen & Bowyer (1996) showing that the strength of wood was closely correlated to density and it was possible to make good estimates of strength based only on density. This could be due to the small number of individual tree tested. However, the results agree with the fact that mechanical properties were not affected to the same degree by changes in density (Haygreen & Bowyer, 1996).

Conclusions

The results from this study showed that basic density and strength properties varied significantly from species to species and from each individual tree to another of the same species. Not all properties however, varied significantly between and within species. *C. alexandri* and *C. gomphophylla*, although underutilized, had higher basic density and strength property values than *M. eminii* and *M. excelsa*. This indicates that the species desired for timber production (i.e *M. eminii* and *M. excelsa)* do not necessarily have better strength properties. The less desired species, (e.g *C. alexandri* and *C. gomphophylla*) had high potentials for timber production owing to their relatively higher strength properties. Effective use of underutilized species is an integral element in forest conservation. Processing of wood is a key element and both technology and marketing are more important than is generally considered (Youngs & Hammett, 2000). In order to broaden the resource base and attain sustainable utilization of timber, the underutilized or less desired species have to be utilized hand in hand with the desired species. From the basic density alone, precise predictions about the strength properties of the species could not be made. It is recommended that strength properties be used as one of the major criteria for harvesting timber species. The strength of timber required varies with the purpose and this should be considered. A balance of appearance and strength properties is essential, in this case lamination should be considered to utilise species with low properties but good appearance.

Acknowledgements

The authors extend their sincere thanks to NORAD and the Faculty of Forestry, Makerere University for sponsoring this research, the department of Wood Utilisation, Sokoine University of Agriculture-Morogoro whose equipment was used for the wood tests.

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