# DETERMINATION OF BASIC DENSITY AND STRENGTH PROPERTIES OF *CORDIA AFRICANA* LAM. GROWN IN AGROFORESTRY SYSTEM IN LUSHOTO, TANGA

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## ABSTRACT

Basic density and strength properties of *Cordia africana* Lam. grown in agroforestry systems in Lushoto, Tanga were determined. Six sample trees were randomly selected in the same farm at Shashui village near Soni. After measuring dbh the trees were felled and total tree height recorded. Four discs were cut at breast height, 30%, 60% and 90% of the total tree height for basic density determination. A one metre long log was cut above 1.3m for strength properties determination. A central plank measuring 6cm including pith was sawn in east-west direction from each log. Standard methods were used in determination of basic density and strength properties. The main findings of this study were as follows:

Basic density was 0.40g/cm$^3$; Basic density increased moderately from the pith to a certain point after which it remained more or less constant; Basic density decreased from the butt to the top of the tree. Mean values for modulus of rupture, modulus of elasticity, maximum crushing stress and shear parallel to grain, compression stress and cleavage perpendicular to grain were lower than those for common hardwoods such as *Ocotea usambarensis* and *Albizia spp*. found in Lushoto. There was positive correlation between basic density and strength properties.

It was recommended that, wood from *C. africana* grown in Lushoto and other areas with similar soil and climatic conditions could be used for light construction work and furniture making. It was further recommended that, more studies should be done in other geographical conditions where the species is grown so as to make concrete conclusions on efficient utilization of the species.

## INTRODUCTION

*Cordia africana* (East African cordia) is a resplendent forest, woodland and bush tree. In most cases the tree reaches a height of 10m but occasionally achieves a height of 24 m. In Tanzania, it is common in pastureland at 1200-2000 m a.s.l., particularly in Arusha and Kilimanjaro regions. The tree is found in Kenya, Uganda, Sudan, Ethiopia, Zaire and Malawi (Blundel 1987). It tolerates a wide variety of soils and is often found in cropland where it is managed as a shade tree. *C. africana* is used for firewood, furniture, roof shingles, beehives, household utensils, medicine (bark and roots), fodder (leaves in dry season), bee forage, shade in coffee plantation, mulch, soil conservation and boundary demarcation (Mbuya *et al.* 1994. It is one of the tree species grown in agroforestry systems in Lushoto.

According to Rocheleau *et al.* (1988), agroforestry is a collective name for land use systems and technologies in which woody perennials (trees, shrubs, palms, bamboo etc) are deliberately combined on the same land management unit with herbaceous crops and/or animals either in some form of spatial arrangement or temporal sequence. This system has been practised for a long-time in certain parts of Tanzania like Kilimanjaro, Kagera and Tanga regions. A number of researches have been conducted in agroforestry systems to determine the right tree species and agricultural crops combination (Lulandala *et al.* 1989). In most cases selection of species used in agroforestry was based on silvicultural and biological factors such as fast growth, multiple land use etc. Little or no emphasis was put on wood properties required for end uses of these species. Studies of wood properties grown in plantations and from natural forests indicate that management practices and the environment have effect on wood properties of most tree species (Zobel & van Buijtenin 1989). It is therefore expected that *C. Africana* grown in agroforestry will produce wood of different properties compared to that grown in natural conditions.

This study was carried out to determine basic density and strength properties of *C. africana* grown in agroforestry in Lushoto. Results from this study will form a basis for recommendations for efficient utilization of *C. africana*.

## MATERIALS AND METHODS

### Description of study area

Samples were collected in Shashui village near Soni in Lushoto district. Lushoto is one of the six districts in Tanga region. It is located in the North-Eastern part of Tanzania, bordering the republic of Kenya to the north, Kilimanjaro region to the north-west and Korogwe district to the South. The district lies between latitude $4^{\circ}24'$ - $5^{\circ}00'$ S and longitudes $38^{\circ}10'$ - $38^{\circ}36'$ E and occupies an area of $4500km^2$. Altitude in Lushoto ranges from 800 to 2300 m. a.s.l. Seventy percent of the total land area is under cultivation (Kerkhof 1990). National forest reserves occupy 36,000ha, while 170ha of forests are under local government and the area for afforestation in public land is 10% of the total area of the forest (District Forest Office 1998).

Msangi (1990) reported that Lushoto district receives rainfall in a bimodal pattern, with short rains in October to December and long rains in March to June. Monthly rainfall distribution ranges from 600 mm to more than 1200 mm. Mean annual temperatures vary with altitude: at 500 m. a.s.l. it is in the range of 25 to $27^{\circ}C$ while on the plateau, at 1500-1800m; the range is 17 to $18^{\circ}C$ (Wiersum *et al.* 1985).

West-Usambara mountains which form the main part of Lushoto district and where Shashui is located is consisted of an uplifted block of highly folded and metarmophosed volcanic rocks (Msangi 1990). The mountains rise from the surrounding plains at approximately 600 m. The altitude ranges from 1300 to 1900 m. a.s.l. and have maximum altitude of 2300 m. (Wiersum *et al.* 1985). The main rock types are igneous, with varying amounts of pyroxene, hornblende and biotite. The rocks are intruded by quartzite vein. Soils derived from these rocks are latosols. In lower wetter areas, soils are humic ferralitic due to higher precipitation and humic ferrisols in the drier, cooler areas (FAO/UNESCO 1979). Soil pH in forests varies between 3 and 5 but in areas under cultivation is higher (Wiersum *et al.* 1985).

Lushoto district has three main forest types: lowland evergreen, intermediate evergreen and high evergreen forests (Inversen 1989). The lowland evergreen forests below 750 m altitude, occur as the eastern foothills of the East Usambara mountains, the intermediate evergreen (submontane) forests occur between 750 and 1400 m altitude, and is dominated by pencilwood *(Juniperus procera*), and *Olea hochstetteri* and the high evergreen (montane rainforest) occurs above 1400m. The montane rainforest is dominated by podo (*Podocarpus* spp), and Ocotea (*Ocotea usambarensis*), with co-dominants such as Albizia (*Albizia* spp), *Cassipourea* spp, *Chrysophylum* spp, *Ficalhoa laurifolia, Makaranga kilimandscharica, Olea* *hochstetteri, Parinari excelsa, Polycias* spp, *Pygeum africanum* and *Syzygium guineense*.

**Collection of study material**

Six sample trees were randomly selected in the same farm in Shashui village near Soni. The trees were 30 years old. The trees were mixed with coffee and bananas and their spacing was not regular. Pruning up to three meters and weeding were done regularly. Standard methods for sample collection and data recording described by Hughes and Plumptre (1976) were followed. After felling, for basic density determination, four discs were cut from each sample tree at 1.3m, 30%, 60% and 90% of total tree height. The samples were put in plastic bags to prevent fast drying.

For strength properties determination, a one-meter log was cut at 1.3m upward. A central board including pith was sawn from each log. The discs and the boards were transported to Sokoine University of Agriculture in Morogoro for determination of basic density and strength properties.

**Basic density and strength properties determination**

A wedge extending from pith to bark was cut from each disc. Four samples were cut at 1%, 33%, 66% and 100% of total wedge length. Basic density was determined using water displacement method.

Data for strength properties were determined on a Monsanto tensiometer machine and deflection curves were plotted manually. Determination of strength properties was done according to Lavers (1969). The strength properties determined were static bending (modulus of rupture and modulus of elasticity) compression (maximum crushing stress parallel to grain and compression stress perpendicular to grain), shear parallel to grains, cleavage perpendicular to grain.

**Data analysis**

Simple statistics were done to determine mean values and standard deviations of all studied properties. ANOVA was conducted to determine variation in basic density in both radial and axial direction. Regression analysis was conducted to establish the relationship between basic density and strength properties.

**RESULTS AND DISCUSSION**

**Basic density**

Mean basic density of C. *africana* was 0.40g/cm$^3$ with standard deviation of 0.07. According to Panshin and de Zeew (1970), wood with a density 0.36g/cm$^3$ or less is considered to be light, whereas one with 0.36 – 0.50g/cm3 is medium and above 0.50g/cm$^3$ is considered to be heavy. The wood of *C. africana* can be classified as medium. Basic density reported from this study was higher than those reported by Mosha (1999) and Mahonge (2001) for the same species grown in agroforestry in Moshi, which were 0.33g/cm$^3$ and 0.37 g/cm$^3$ respectively. On the other hand, the value obtained from this study was lower than those for some hardwood species growing naturally in Lushoto like *Afzelia quanzensis* (0.83g/cm$^3$), *Sephalosphaela usambarensis* (0.56g/cm$^3$) and *Ocotea usambarensi* (0.59g/cm$^3$) (Bryce, 1999).

**Variation of basic density**

Radial variation in basic density of *Cordia africana* is presented in figure 1. Basic density increased from 0.37g/cm$^3$ at the pith up to certain point where it reached maximum value of 0.41g/cm$^3$ then it decreased slightly towards the bark. The difference in basic density between wood near the pith and that near the bark was statistically significant ($p<0.05$). Iddi *et al.* (1998) reported a similar trend for *Eucalyptus maidenii* and *Eucalyptus saligna* grown at Sao Hill. The pattern of variation observed in this study is in agreement with type III described by Panshin and de Zeeuw (1970), which states that, "basic density increases moderately for the first five years followed by a more or less constant plateau or sometimes decrease in the last formed increment near the bark".

Figure 2 shows variation in basic density for *C. africana.* Grown in Shashui, Lushoto. Basic density decreased from base to top of the tree. The trend is similar to type I pattern reported by Panshin and de Zeeuw (1970) which states that "density decreases uniformly from base to top of the tree".

**Strength properties**

Mean strength properties and their standard deviation are presented in Table 1. It can be noted that, for almost all wood properties the studied *C. africana* has lower strength properties values. However, work to maximum load for the studied species was higher than those reported by Mosha (1999) and Mahonge (2001) for the same species grown under agroforestry in Moshi and Arumeru respectively. In addition to that, the studied *C. africana* had higher compression value than that reported by Mahonge (2001). This might be caused by genetic and environmental differences. Furthermore, the values obtained in this study were lower compared to those for some hardwood species grown naturally in Lushoto such as *A. quanzensis, C. usambarensis* and *O. usambarensis* reported by Bryce (1999).

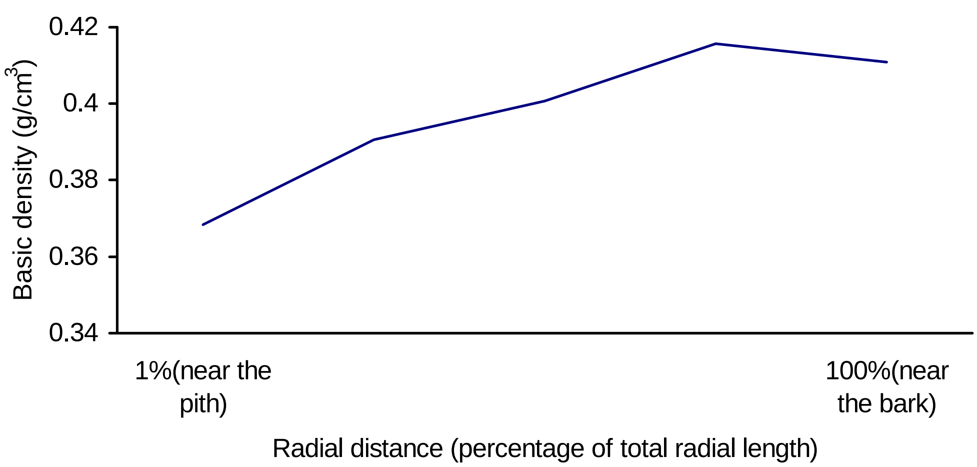


Figure 1. Radial variation in basic density for *C. Africana*

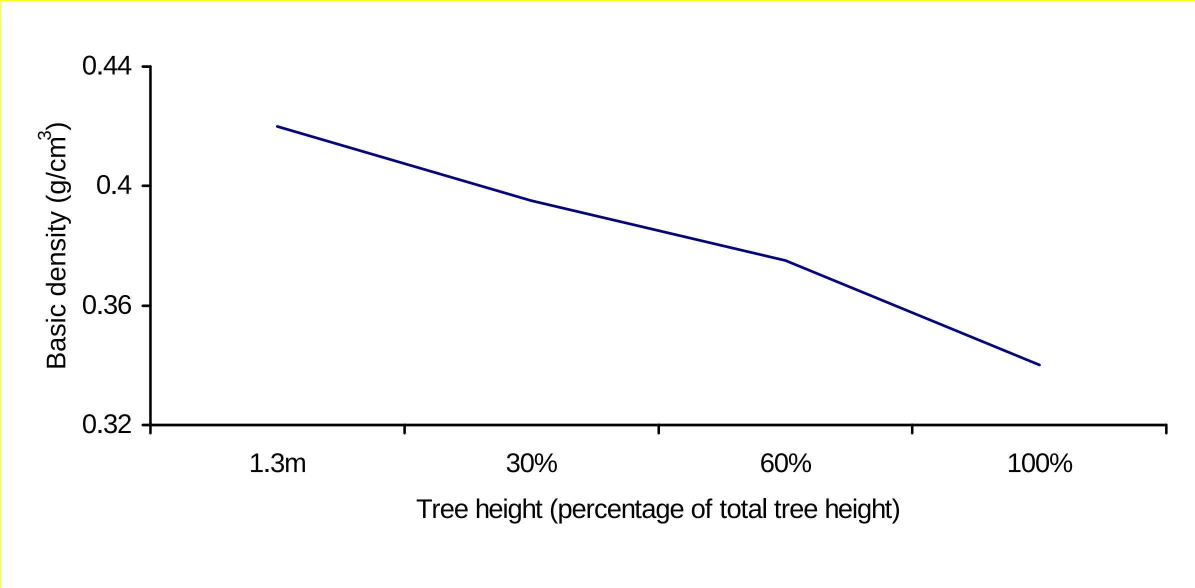


Figure 2. Axial variation in basic density for *C. Africana.*

Since density is the major factor in determining the strength of wood as pointed out by Desch (1981) i.e. wood with high density has corresponding high strength values. Therefore low strength values of *C. africana* which has low basic density compared to some hardwood species growing naturally in Lushoto reported by Bryce (1999) should be expected.

**Relationship between basic density and strength properties**

Positive correlation was found between strength properties and basic density (Table 2). This means that as basic density increases, strength properties also increase. It can be noted in table 2 that the regression equations for Modulus of elasticity, Modulus of rupture, Work to maximum load and compression parallel to grain have positive Y-intercepts while those for Shear parallel to grain and Cleavage in radial direction have negative Y-intercepts. The negative Y-intercepts indicate that there were factors, which have negative influence i.e. reducing strength values of *C. africana*. These factors include arrangement of individual cells and the physico-chemical composition of cell wall especially the degree of lignification of the cell wall (Desch 1973).

Table 1: Comparison of strength properties of agroforestry grown *Cordia africana* from this study with those of the same reported by other researchers

| Strength property | Mean strength values of *C. Africa* reported by: | | |
|---|---|---|---|
| | This study | Mahonge (2001) | Mosha (1999) |
| Compression ($N/mm^2$ ) | 23.50 | 22.64 | 27.11 |
| Shear ($N/mm^2$) | 5.86 | 7.97 | 7.34 |
| Cleavage (N/mm ) | 9.94 | 10.96 | 12.35 |
| Modulus of elasticity ($N/mm^2$) | 2468. | 6003.83 | 4711.3 |
| Modulus of rupture ( $N/mm^2$ ) | 37.04 | 41.74 | 47.46 |
| Work to maximum load ($N/mm^2$) | 0.08 | 0.0443 | 0.06 |

Table 2: Regression equations for the relation between basic density and studied strength properties for *C.africana*.

| Strength property (12 % m.c ) | Regression equation ( Y = a + bx ) | r |
|---|---|---|
| Compression | Y = 14.45 + 28.67x | 0.55 |
| Shear | Y = -3.29 +29x | 0.86 |
| Cleavage | Y = -0.12 +31.9x | 0.81 |
| Modulus of elasticity | Y = 1824.89 +3120.19x | 0.60 |
| Modulus of rupture | Y = 21.77 +68.21x | 0.51 |
| Work to maximum load | Y = 0.07 +0.06x | 0.80 |

Note: Y = Strength property
a = Y intercept
b = regression coefficient
x = basic density

## CONCLUSION AND RECOMMENDATION

*C. africana* grown in agroforestry in Lushoto has average basic density of 0.40g/cm$^3$ and it can be classified as medium density wood. The density increased from the pith to a certain point where it reached maximum value then it remains more or less constant near the bark. Basic density of *C. africana* decreased from the butt to the top of the tree. Values for the strength properties of *C. africana* are lower than those for some hardwood species growing naturally in Lushoto. There was a positive correlation between basic density and studied strength properties for *C. africana.*

It is recommended that, *C. africana* be used for light construction furniture and utensil making and as well as fuel wood. It is further recommended that, in order to come up with comprehensive recommendations, more studies should be done for different ages and in other areas where the species is grown in agroforest systems.

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