**JUNE 2015**
**VOLUME 84(2)**

**ISSN 2408 – 8129**

# TANZANIA JOURNALOF FORESTRY ANDNATURE CONSERVATION

**SPECIAL ISSUE**

**PROCEEDINGS OF RESEARCH FINDINGS DISSEMINATION WORKSHOP OCEANIC BAY HOTEL AND RESORT, BAGAMOYO**

**11th– 12th JUNE, 2015**

**EDITORS**

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Published by
Faculty of Forestry and Nature Conservation
Sokoine University of Agriculture
Morogoro, Tanzania

# TANZANIA JOURNAL OF FORESTRY AND NATURE CONSERVATION

**Background**

The Faculty of Forestry and Nature Conservation of the Sokoine University of Agriculture in Morogoro, Tanzania, inaugurated the Tanzania Journal of Forestry and Nature Conservation in order to elevate the former publication of the then Faculty of Forestry, Faculty of Forestry Records, to a status of an International Journal. The last issue of the Faculty of Forestry Records was volume 72 and this Journal took over beginning with volume 73. The list of the ‘Records’ is given at the last pages of this issue and can be ordered from the office of the Dean using the address given under the sub-heading ‘Subscription’ at the bottom of this page.

**Scope**

The Tanzania Journal of Forestry and Nature Conservation accommodates the current diverse and multidisciplinary approaches towards ecosystem conservation at national and global levels. Published biannually, the Journal will accept research and review papers covering the technological, physical, biological, social and economic aspects of management and conservation of tropical flora and fauna.



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# PREFACE

One of the key functions of Tanzania Forest Fund (TaFF) is to support adaptive and applied research into forestry. Since the Fund became operational in July 2011, a total of 22 research projects have been funded. Out of these, 11 have been completed. A two day ($11^{th}$ and $12^{th}$June 2015) workshop was organized by TaFF at Oceanic Bay and Resort, Bagamoyo Tanzania to disseminate findings of these projects.

The workshop was attended by 54 participants from government institutions including Local Government Authorities, Ministry of Natural Resources and Tourism, Agencies, Research and Training Institutions, Non-governmental Organizations and other Conservation Trust Funds.The participants also included researchers whose projects are funded by TaFF.

The workshop was officially opened by the Permanent Secretary of the Ministry of Natural Resources and Tourism, Dr. Adelhelm Meru and closed by the Acting Director of the Forestry and Beekeeping Division, Mrs Gladness Mkamba.

During the workshop, comments were made on the presented papers. After the workshop, all papers were peer reviewed. Only positively reviewed papers appear in these proceedings. We are grateful to the contributers to the first TaFF research findings dissemination workshop and congratulate TaFF for organizing the workshop.

# Some physical and strength properties of immature *Pinus patula* trees harvested in Iringa and Njombe regions, Tanzania

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## ABSTRACT

A study was conducted to determine physical and strength properties of immature *Pinus patula* grown in Iringa and Njombe regions of Tanzania. Sample trees aged 5 to 15 years were collected from farmers' woodlots. The trees were categorized into 5 age classes: 5 - 7, 8 - 10, 11 - 12, 13 - 14 and 15 years. Four trees from each age class were selected and marked for felling. Diameter at breast height and stem length for each tree were measured before and after felling respectively. Three disks and planks each measuring 5 cm thick and 120 cm long respectively were cut at 1.3 m, 50% and 75% of total tree height from each sample tree for determination of wood basic density and strength properties using standard procedures. Analysis of variance was used to compare means of wood basic density and strength properties of pine wood between age classes. Results showed that *P. patula* wood at 5-15 years had relatively lower basic density, modulus of rupture (MOR), modulus of elasticity (MOE) and compression strength than 25 year old wood. Basic density varied significantly ($p<0.05$) between tree ages and increased with increase of tree age. Strength properties increased with increase in tree ages with exception of MOE and MOR in Njombe region. It was concluded that wood basic density and strength properties of *P. patula* at 5 - 15 years had inferior properties compared to *P. patula* at 25 years. It was therefore recommended that farmers should not harvest their trees for structural use purposes at the age of 15 years and below but may be for other uses like pulp and paper making. A similar study is needed for trees aged 16 to 24 years to determine the age at which farmers can start harvesting trees for structural use. However, the harvesting time should not based on physical and strength properties of wood alone but other factors such as current and mean annual increment and economic aspects.

**Keywords:** Wood properties; immature trees; woodlots; *Pinus patula*; Tanzania.

## INTRODUCTION

Wood basic density and mechanical/strength properties are basic factors which determine the end use of wood. Density of wood is a measure of the proportion of cell wall material in the wood and hence is dependent on the ratio of cell wall thickness and cell wall diameter. Density of wood is directly related to other properties and is therefore an important index of wood quality (Dinwoodie 1981, Tsoumis 1991, Walker 1993). In that regard, wood with high density is expected to have high mechanical properties.

In Tanzania, pioneering attempts to establish forest plantations started in the 1890s (Schabel 1990, Nshubemuki *et al.* 2001). This was followed by large scale industrial forest plantations establishment between 1920 and 1961. Forest plantations in Tanzania are dominated by pines and currently its wood is widely used for construction as well as furniture making. In order to have economical use of wood, a thorough understanding of its physical and mechanical properties is inevitable (Iddi *et al.* 1998). The versatility of wood as raw material is due to its structural properties and chemical composition (Tsoumis 1991). The knowledge of structure is of multiple and practical importance as it explains the behaviour of wood as a material due to the close relationship of structure, properties and utilization (Hamza *et al.* 1999).

Most of softwood timber available in the markets are produced from individual woodlots. These timbers are sawn from immature trees i.e. before recommended utilisation age of 25 years because of poverty as farmers have no alternative sources of income. Other factors accelerating early harvesting of trees include market forces (high demand of softwood timber) and high costs of stand tending practices. The objective of this study was therefore to determine basic density, modulus of rupture, modulus of elasticity, shear and compression strength of wood of *P. patula* harvested at 5 to 15 years from farmers' woodlots in Iringa and Njombe regions. The results from this study are important for improving harvesting and utilization guideline, technical notes and technical orders for sustainable management and utilization of forest plantations in Tanzania.

## MATERIALS AND METHODS

### Study areas

Sample trees were collected from farmers' woodlots in Iringa and Njombe regions, specifically in Kilolo and Njombe Rural districts respectively. In Kilolo district, samples were collected from Kidabaga village located in Dabaga ward. The district is located in western part of Udzungwa escarpment at 7$^o$ 55' to 8.3$^o$ S and 34$^o$ to 37$^o$ E (Chi-son and Renvoize 1989). Altitude ranges between 1,800 and 2,500 m a. s. l. The disrict receives rainfall from November to April ranging from 500 to 2700 mm. The average annual temperature experienced in the area is 15$^o$ C in highlands and 30$^o$ C in lowlands. Topography of the areas is mainly undulated hills with lowlands and highlands..

In Njombe Rural district, samples were collected in Matembwe village, Matembwe ward in Lupembe division. Njombe Rural district is located between 8.80º and 9.80º S and 34.50º to 35.80º E. The altitude of Njombe Rural district ranges between 1,000 and 2,000 m.a.s.l. Precipitation ranges from 1,000 to 2000 mm per year and the temperature averages 15$^o$ C in the highlands. Lowlands receive rainfall ranging between 600 and 1,000 mm per year and temperature ranging between 15$^o$ C and 20$^o$ C (Kaduvage and Timbula 2011).

### Tree sampling and sample preparation

Tree sampling was done purposively. Only trees with good form and free from visible defects were selected for sample collection. Trees were categorized into five age classes: 5 - 7, 8 -10, 11- 12, 13 - 14 and 15 years. Four trees from each age class were selected and marked for felling. Diameter at breast height (DBH) and stem length for each sampled tree were measured before and after felling respectively. For each felled sample tree, three disks measuring 5 cm thick and three planks measuring 120 cm long were cut at 1.3 m, 50% and 75% of total tree height. The disks and planks were labelled to indicate the region, tree number, age and position in the stem. The samples were immediately wrapped in polythene bags and transported to the Wood Utilization Laboratory at Moshi Timber Utilization Research Centre where laboratory work was carried out.

### Determination of Properties

#### *Basic density*

Basic density was determined according to ISO 3131 (1975) using green volume and oven dry weight of the sample. The test specimens were immersed in distilled water for 24 hours in order for the wood voids to be filled with water. Green volume was obtained using the displacement method in accordance with Archimedes' Principle. The test specimens were then oven dried at a temperature of 103 ±2°C until they attained constant weight and cooled in desiccators. They were then reweighed and the weights recorded. Basic density in kg/m$^3$ was then calculated using equaation 1:

$$BD\ (kg/m^3) = \frac{\text{Oven dry weight (grammes)}}{\text{Green volume } (cm^3)} \times 100 \qquad (1)$$

***Strength properties***

Strength properties were determined according to BS 373 (1957), ISO 3131 (1975). Samples were prepared according to the required tests. The moisture content in each test sample at the time of test was calculated based on ISO 3131 (1975). Monsanto Tensometer wood testing machine and Impact bending machine were used to test strength properties. The following strength properties were determined:

*Static bending strength (Modulus of Elasticity (MOE)and Modulus of Rupture (MOR))*

Specimens measuring 20 x 20 x 300 mm were taken and loaded using centre loading method to the Monsanto Tensometerwood testing machine using a feeding speed of 0.635 mm/min and 500 kg deflection beam. Graph plotting was done manually following the mercury column along the scale in Newtons. The load at which failure occurred was recorded on graph paper. MOR was calculated from the maximum load at which each specimen failed. MOE was calculated using load to deflection curve plotted on a graph by the machine. MOE and MOR were calculated using equations 2 and 3:

$$MOR = 3PL/2BD^2 \qquad (2)$$

$$MOE = P^1L^3/4YBD^3 \qquad (3)$$

Where
- $P$ = Maximum load in Newton's (N)
- $L$ = Span length (mm)
- $P^1$ = Load in Newton's to limit of proportionality
- $B$ = Width of the test sample (mm)
- $D$ = Depth of the test sample (mm)
- $Y$ = Deflection in mm at mid length at limit of proportionality

*Compression strength parallel to the grain*

Each test specimens measuring 20 x 20 x 60 mm was taken and loaded to the Monsanto Tensometer machine on a parallel grain basis using a feeding speed of 0.635 mm/min and 2000 kg deflection beam. Then, the maximum crushing load was recorded by plotting the graph following the rise of the mercury in the column until failure occurs. The maximum crushing strength was then calculated from maximum crushing load and recorded in $N/mm^2$. Crushing strength was calculated using equation 4:

$$\text{Crushing strength} = \frac{P_{(max)}}{A} \qquad (4)$$

Where $P_{(max)}$ = Maximum crushing load in Newton's (N)
$A$ = Cross-sectional area ($mm^2$)

*Shear strength parallel to grain*

Each test specimen measuring 20 mm x 20 mm x 20 mm was taken and mounted on the Monsanto Tensometer machine with a 2000 kg deflection beam and a speed of 0.635 mm/min were used. Maximum shear strength was recorded graphically straight from the rise of the mercury along the column until failure occurred. Shear strength was calculated using equation 5:

$$\text{Shear strength at maximum load} = \frac{P}{A} \quad \text{.........................}(5)$$

Where; P = Maximum load (N) and
A = Area in shear ($mm^2$)

For uniform comparison of results, the strength properties were adjusted to their equivalents at 12% moisture content (Desch 1981).

**Data analysis**
Analysis of variance (ANOVA) in Statistical Analysis Software (SAS) package was used to compare mean basic density and mechanical properties of pine wood between age classes. Least Significant Differences were used to separate differing means.

## RESULTS

**Basic density**
Results showed that mean wood basic densities of *P. patula* collected from both districts increased with increase in age of trees (Figure 1). In Kilolo district, the lowest mean basic density was 312 kg/ $m^3$ for trees in age class 5 - 7 years and highest mean basic density was 444 $kg/m^3$ recorded for trees in age class 13 - 14 years. The difference between the two age classes was significant ($p = 0.015$). In Njombe Rural district, the lowest mean basic density was 339 $kg/m^3$ recorded in pines of age class 5 - 7 years and the highest was 375 $kg/m^3$ recorded for pines aged 15 years and there was significant difference ($p = 0.042$).

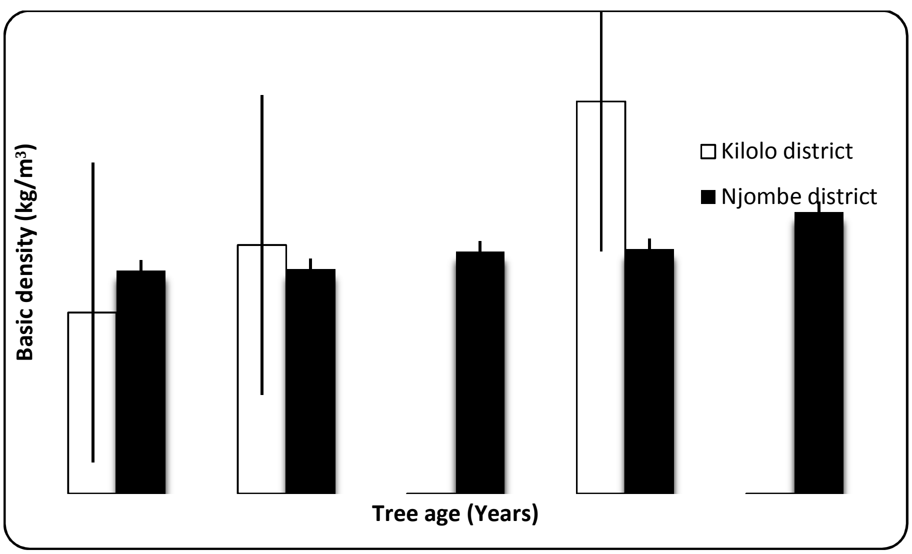


Figure 1. Basic density of *Pinus patula* growing in Kilolo and Njombe Rural districts.

**Modulus of Elasticity (MOE)**
Results shows that MOE values of *P. patula* wood collected from Kilolo district increased with increase in tree age. It ranged from 5535.4 $N/mm^2$ to 5820.1 $N/mm^2$ for trees aged 5 - 7 and 13 - 14 years respectively (Table 1). There were no significant ($p > 0.05$) differences in MOE values between tree ages. MOE values of *P. patula* wood collected from Njombe Rural district ranged from 5074.9 $N/mm^2$ to 5338.9 $N/mm^2$ for trees aged 5 - 7 and 11 - 12 years respectively (Table 1). MOE values increased from trees aged 5 - 7 to 11 - 12 years and then decreased for trees aged 15 years. There were no significant (p

> 0.05) differences in MOE values between tree ages.

Table 1. Mean MOE of *Pinus patula* trees at different ages in Kilolo and Njombe Rural districts.

| Age classes (years) | MOE (N/mm²) | |
|---|---|---|
| | Kilolo district | Njombe Rural district |
| 5-7 | 5535.4 | 5074.9 |
| 8-10 | 5592.4 | 5258.8 |
| 11-12 | | 5338.9 |
| 13-14 | 5820.1 | 5299.8 |
| 15 | | 5288.4 |

**Modulus of Rupture (MOR)**
MOR of wood of trees from Kilolo district increased with increase in age and ranged between 18.4 N/mm$^2$ and 22.7 N/mm$^2$ for trees aged 5 - 7 and 13 - 14 years respectively (Table 2). There were no significant ($p > 0.05$) differences in MOR mean values between tree age classes. MOR of wood of trees from Njombe Rural was found to increase for trees in age classes 5 - 7 and 13 - 14 years and thereafter decreased at the age of 15 years (Table 2). The differences were not statistically significant ($p > 0.05$).

**Table 2.** Mean MOR of *P. patula* growing in Kilolo and Njombe Rural districts

| Age classes (years) | MOR (N/mm²) | |
|---|---|---|
| | Kilolo district | Njombe Rural district |
| 5-7 | 18.4 | 18.4 |
| 8-10 | 19.5 | 18.9 |
| 11-12 | | 19.04 |
| 13-14 | 22.7 | 21.1 |
| 15 | | 20.9 |

**Shear strength**
The mean maximum shear strength parallel to grain of wood aged 5 to 7 and 13 to 14 years in Kilolo district ranged between 7.95 N/mm$^2$ and 13.87 N/mm$^{2.}$ while for wood from Njombe Rural district ranged between 6.78 N/mm$^2$ and 9.98 N/mm$^2$ for wood of trees aged 8 - 10 and 15 years for both tangential and radial sides (Table 3). Results show that shear strength in tangential side was relatively higher than in radial side in all years.

Table 3: Mean Shear strength parallel to grain (N/mm$^2$) of *P. patula* wood at different ages in Kilolo and Njombe Rural districts.

| **Age clases (years)** | **Shear (N/mm²)** | | | |
|---|---|---|---|---|
| | **Kilolo district** | | **Njombe Rural** | **district** |
| | **Tangential** | **Radial** | **Tangential** | **Radial** |
| 5-7 | 9.83 | 7.95 | 7.87 | 7.85 |
| 8-10 | 11.61 | 9.48 | 7.09 | 6.78 |
| 11-12 | | | 8.76 | 7.67 |
| 13-14 | 13.87 | 11.41 | 8.01 | 7.03 |
| 15 | | | 9.98 | 9.50 |

**Compression strength**

The compression strength of *P. patula* wood from Kilolo and Njombe Rural districts ranged from 7.1 to 14.3 N/mm$^2$ in the tangential direction and from 4.4 to 8.4 N/mm$^2$ in radial direction for wood aged 5 to 15 years.

## DISCUSSION

The basic densities recorded in this study are in keeping with that of Bryce (1967) who reported a wood basic density of 366 – 442 kg/m$^3$ for *P. patula* aged 15 years. Similar results were recorded by Laswai *et al*. (2015) who reported a wood basic density of 388 kg/m$^3$ for *P. patula* aged 15 years grown in North Kilimanjaro forest plantation. However, the mean basic densities for *P. patula* wood of 5 – 15 years recorded in this study were lower compared to 518 kg/m$^3$ for trees aged 25 years reported by Bryce (1967). According to FAO (2010), wood with basic density less than 400 kg/m$^3$ is classified as weak, 401 – 500 kg/m$^3$ fairly strong, 501 – 640 kg/m$^3$ strong and above 640 kg/m$^3$ very strong. Therefore, wood of *P. patula* trees from Kilolo woodlots aged 5 - 10 years was classified as weak and that from trees age 13 - 14 years was classified as fairly strong. *P. patula* trees from Njombe Rural aged 5 - 15 years classified as weak wood. The plausible reason for these differences in mean basic densities between the two districts could be attributed to differences in environmental factors and seed source.

The MOE was lower compared compared to 7000, 7500, 7800 and 9000 N/mm$^2$ recordedfor *P. patula* aged 15, 16, 18 and 20 years respectively grown in North Kilimanjaro forest plantation (Laswai *et al*. 2015). Similarly, the MOE values recorded in this study were lower compared to 8317 N/mm$^2$ for *P. patula* aged 25 years reported by Bryce (1967). According to FAO (2010), wood with MOE = 4000 N/mm$^2$ is classified as weak, 4000 < MOE < 6000 N/mm$^2$ fairly strong, 6000 <MOE < 7500 N/mm$^2$ strong and MOE > 7500 N/mm$^2$ as very strong. Therefore, wood from trees aged 5 to 15 in this study were considered as fairly strong. These woods cannot be used for construction purposes such as construction of bridges where toughness is required. Acording to Kityo and Plumptre (1997), wood for structural use should have MOE of 6860 - 14700 N/mm$^2$.

The MOR was lower compared to 52 N/mm$^2$ reported by Bryce (1967) at 25 years. According to FAO (2010), wood with MOR of 10 to 15 N/mm$^2$ is designated as weak, 15 < MOR < 20 N/mm$^2$ fairly strong, 20 <MOR < 30 N/mm$^2$ strong and MOR > 30 N/mm$^2$ as very strong. Therefore, wood aged 5 to 12 years from both districts was considered as fairly strong while wood aged 13 years and above were considered as strong. However, Kityo and Plumptre (1997) reported that wood for structural use should have MOR ranging between 39 and 132 N/mm$^2$. Therefore, these woods had relatively lower MOR values than the recommended value for structural use.

The mean shear strength parallel to grain of 10.3 N/mm$^2$ for *P. patula* wood at age of 25 years recorded by Bryce (1967) is within the range of shear strength recorded in this study in Kilolo district but relatively higher than shear strength for wood recorded in Njombe Rural district. Similarly, results from this study were within the range of 10 -13 N/mm$^2$ of *P. patula* aged 15 – 20 years (Laswai *et al*. 2015). Results recorded in this study were in agreement with FAO (2010) which reports shear strength of various woods of between 5 and 20 N/mm$^2$.

The compression strengths recorded in this study were lower compared to 33.2 N/mm$^2$ reported by Bryce (1967) for *P. patula* aged 25 years. This implies that wood from these age groups can only be used in areas which need lower tension strength due to easeness of being compressed when load is applied. The strength is different when the load is applied in parallel or transverse to the grain. It has been observed that in softwoods, tangential compression strength is higher than radial, where as in hardwoods the situation is opposite. Axial compression strength is higher up 15 times and varies between 25 to 95 N/mm$^2$ where as transverse values vary between 1 to 20 N/mm$^2$ (Panshin and de Zeeuw 1980). Low density wood is easily compressed and frequentlty tears out than high density wood (Mbwambo *et al*. 2006).

## CONCLUSIONS AND RECOMMENDATIONS

Wood basic density and strength properties of *P. patula* at 5 - 15 years had inferior properties compared to *P. patula* at 25 years. It was therefore recommended that farmers should not harvest their trees for structural use purposes at the age of 15 years and below but may be for other uses like pulp and paper making. A similar study is needed for trees aged 16 to 24 years to determine the age at which farmers can start harvesting trees for construction purposes. However, the harvesting time should not based on physical and strength properties of wood alone but other factors such as current and mean annual increment and economic aspects.

## ACKNOWLEDGEMENT

The authors are grateful to the Tanzania Forest Fund (TaFF), for the financial support. The technical staff of Moshi Timber Utilisation Research Centre, Tanzania Forestry Research Institute (TAFORI) are acknowledged for facilitating the experimental work.

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