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Density and Mechanical Properties of *Casuarina equisetifolia* Wood Grown in Oromia Regional State, Bishoftu, Ethiopia

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ABSTRACT

Ethiopia's rapid expansion of urbanization, industrialization, modernization, and population growth has led to an insistently increase in the demand for wood for construction, furniture, and other end products. This study aimed to investigate the effect of tree height and the diameter tree section (sapwood and heartwood) on the density and mechanical properties of *Casuarina equisetifolia* timber. For this study, ten sample of *C. equisetifolia* trees were selected and harvested from Bishoftu, Oromia Regional State, Ethiopia. The collected sample logs were sawn into 3-cm-thick lumber, and sample specimens were prepared for density and mechanical properties testing. Sample specimens of heart and sapwood sections were prepared from the bottom, middle, and top portions of the tree for testing density, static bending (MOE and MOR), compression strength parallel to the grain, impact bending strength, and hardness strengths in tangential and radial directions according to ISO standards. The results revealed that tree height had significantly affected density and hardness strengths in tangential and radial directions. On the other hand, the diameter section (heart and sapwood) significantly affected the density, impact bending, and hardness strength in the radial direction. On the contrary, tree height and tree diameter section didn't show a significant effect on MOE, MOR, and compression strength parallel to the grain. Due to the high density of *Casuarina equisetifolia* wood, it is very hard to convert into lumber, and the lumber is also difficult to machine. Based on the basic properties studied, *Casuarina equisetifolia* wood could be used for wood flooring, chipwood, particleboard, furniture, and other products such as tool handles.

INTRODUCTION

Australia, the Indian subcontinent, Southeast Asia, and the islands of the western Pacific Ocean are the native habitats of *Casuarina equisetifolia* (Orwa et al., 2009). Commonly referred to as Ironwood, Beefwood, Bull-oak, or Whistling pine, this member of the Casuarinaceae family may reach a height of 20 meters in just 12 years and can flourish in a range of soil types (Bakewell-Stone, 2023). It grows mostly on sands and sand loams that are well-drained and have a gritty texture in semi-arid to sub-humid climates. *Casuarina equisetifolia* timber species may be grown in areas with mean annual temperatures of 10 to 35 ^{0}C, mean annual rainfall of 200 to 3500 mm, and elevations ranging from 0 to 1400 m (Tiwari and Talreja, 2023; Bakewell-Stone, 2023). According to Orwa et al. (2009), it has a single trunk with an open, irregularly shaped crown that is straight, cylindrical, and typically branchless up to 10 meters in height.

Casuarina equisetifolia wood has an air dry density of 900–1000 kg/m^3, making it a highly heavy hardwood (Orwa et al., 2009; Bakewell-Stone, 2023). Its heartwood is either dark red-brown, pale brown, or mildly to strongly red, while the sapwood is yellowish or pale yellow brown with a tinge of pink. Grain might be wavy, straight, or somewhat interlocked; texture is even and fine to moderately fine.

The timber of *C. equisetifolia* is very hard and strong (Chowdhury et al., 2009). It has served as the main raw material for making tool handles, rafters, electric poles, and house supports (Orwa et al., 2009). It has also been utilized for charcoal and fuel wood because of its high calorific values and density (Tiwari and Talreja, 2023). Sometimes it has been called 'the best firewood in the world'. The calorific value of the wood is 4950 kcal/kg, and that of the charcoal exceeds 7000 kcal/kg (Orwa et al., 2009; Tiwari and Talreja, 2023). Moreover, because of its fiber properties, *C. equisetifolia* timber can be used as a source of wood fiber for the manufacturing of pulp and paper (Warrier et al., 2015; Dechamma et al., 2020).

The quality of lumber produced from this timber is not studied, and there is a limited amount of information on the utilization of lumber produced from *C. equisetifolia* timber species grown in Ethiopia. Two major important properties, such as physical and mechanical properties, should be tested to evaluate the quality and appropriate utilization of *C. equisetifolia* lumber. Evaluating density and mechanical properties helps to analyze the behaviors of lumber products when designing structures and subjected to loads (Desalegn, 2012; Kaba et al., 2022). Based on the results of physical and mechanical properties, it's possible to identify the end uses of any timber species that may be used for industrial applications and other wood products (Desalegn, 2012; Vishnu, 2013). The physical and mechanical qualities of hardwoods vary depending on the species, age, growth rate, climatic and edaphic conditions, moisture content, anatomy, and extractive content of wood (Chowdhury et al., 2009; Sahoo, 2018; Bessa et al., 2022; Raobelina et al., 2025). The objective of this paper was to evaluate the effect of tree height and diameter section on the physical and mechanical properties of *C. equisetifolia* lumber and its potential utilization.

METHODS

Description of Study Area and Sample Tree Harvesting

Casuarina equisetifolia sample trees were collected from Bishoftu, Oromia Regional State, Bishoftu Agricultural Research Center. Bishoftu is located in the East Shewa Zone of Oromia Regional State, 47 km south-east of Addis Ababa, the capital city of Ethiopia. The geographical location of the study area is 8°44'4.74"N and 39°0'30.726"E with an elevation of 1920 meters above sea level. Its annual rainfall is about 702.1 mm, mostly falling between June and September. The temperature typically varies from 12.22°C to 26.67°C and is rarely below 9.44°C or above 29.44°C. From the study site, ten representative samples of *C. equisetifolia* trees were selected and felled. The harvested sample trees were debranched, and thereafter sectioned into three portions (bottom, middle, and top) along the tree height, and transported to the Addis Ababa Forest Products Innovation Center of Excellence (FPICE) for further processing for testing.

Specimen Preparation

The collected sample logs were sawn tangentially into 3 cm thickness of lumber using a circular saw machine. Then, sample boards, which are knot-free, straight-grained, and represent the maximum quality, were selected and air-dried to a moisture content level of about 12% and then sample specimens were prepared for the determination of density and mechanical properties of the wood. Sample specimens used for density and mechanical properties tests were prepared separately for heartwood and sapwood sections from the bottom, middle, and top portions of *C. equisetifolia* wood.

Sample specimens with a dimension of 20 x 20 x 300 mm^3 were prepared for heart and sapwood sections from bottom, middle, and top portions of *C. equisetifolia* used to evaluate static bending (modulus of elasticity and modulus of rupture) and impact bending strength according to ISO 3133 (1975) and 3348 (1975) standards, respectively. Specimens with a dimension of 20 x 20 x 60 mm^3 and 20 x 20 x 45 mm^3 were prepared for heart and sapwood sections from bottom, middle, and top portions of *C. equisetifolia* to evaluate compression strength parallel to the grain and hardness strengths according to ISO 3387 (1975) and ISO 3350 (1975) standards procedures, respectively.

Determination of Density and Mechanical Properties

The density of wood was determined based on air-dry mass (Ross, 2010). The dimensions of specimens were measured at an air-dried wood of 12% moisture content level using a digital caliper to determine their volumes. After that, the samples were weighed with an electronic balance. Density at 12% moisture content (MC) is calculated using equation 1:

$$\rho_{12} = \frac{M_{12}}{V_{12}} \text{ .... (eq1)}$$

Where ρ_{12} is the density at 12% MC, M_{12} is the mass at 12% MC, and V_{12} is the volume at 12% MC level.

Modulus of Elasticity and Modulus of Rupture

Using the Universal Strength Testing Machine (UTM), model FM2750, with maximum loads of 50 Kilo Newton (KN), the MOE and MOR were tested and calculated in accordance with ISO 3133, 1975. The span length of the specimen, or the separation between the suspension point, was 280 mm. The specimen's center on the radial face was subjected to a load at a steady rate of 0.11 mm/s. Modulus of elasticity and Modulus of rupture are calculated using equations 2 and 3, respectively.

$$\text{Modulus of elasticity} = \frac{P^1L^3}{4d^1bh^3} \text{ .... (eq2)}$$

$$\text{Modulus of rupture } = \frac{3PL}{2bh^2} \text{ .... (eq3)}$$

Where Modulus of elasticity is in (N/mm^2), Modulus of rupture is in (N/mm^2): modulus of rupture, P^1: is load at the limit of proportionality in 'N', P: maximum load in 'N', L: the span length in 'mm', and d: deflection at the limit of proportionality.

Compression Strength Parallel to the Grain

The compression parallel to the grain test was done based on the ISO 3387, 1975 standard. The specimens were tested using a Universal Testing Machine with a speed of loading of 0.01 mm/sec. The maximum crushing strength (MCS) is calculated using equation 4:

$$\text{Maximum crushing strength} = \frac{C}{bh} \text{ .... (eq4)}$$

Where MCS: Maximum crushing strength (N/mm^2), C: Maximum load (N), b: width of the specimen (mm), h: Thickness of the specimen (mm)

Impact Bending Strength

Impact bending strength was determined based on the ISO 3348 (1975) standard. The specimens were set up on a pendulum hammer, a type of Impact bending Testing Machine model PW5-S. The test machine's force plate was used to read the joule value, whereas the load was applied to the center. The impact bending strength was calculated using equation 5:

$$\text{Impact strength} = \frac{P}{bh} \text{ .... (eq5)}$$

Where P is the Joule value in Nm, b is the specimen's width in mm, and h is the specimen's thickness in mm.

Hardness Strength

Hardness is determined based on the ISO 3348, 1975 standard. It is measured by the force required to embed an 11.3 mm ball one-half its diameter into the wood. Hardness values were obtained based on the Janka method. The specimens in both radial and tangential faces were loaded at a rate of 0.11 mm/s using the UTM machine.

Experimental Design and Statistical Analysis

A completely randomized design (CRD) with factorial experiment was used to conduct this experiment. The statistical analysis of the data was conducted using version 24 of the Statistical Package for the Social Sciences (SPSS). Statistical analysis of variance (ANOVA) was used to evaluate density and mechanical properties at three tree height levels and two diameter sections of *C. equisetifolia*. The mean comparisons were carried out by Tukey HSD to determine the suitability of *C. equisetifolia* for various value-added products.

RESULTS AND DISCUSSION

Density and Mechanical Properties

In this study, density, static bending, compression strength parallel to the grain, impact bending strength, and tangential/radial hardness strength tests were conducted and evaluated for the end uses of *C. equisetifolia* timber for various applications. Evaluating the density and mechanical properties of *C. equisetifolia* helps to analyze the behaviors of lumber products when designing structures and subjected to loads. Therefore, the density and mechanical properties information obtained from this study may be used to identify the end uses of *C. equisetifolia* timber for various applications.

The statistical analysis of variance in Table 1 shows the effects of tree height and diameter section on the density and mechanical properties of *C. equisetifolia* wood. As depicted in Table 1, tree height and diameter section had significant impacts on the density and tangential/radial hardness strengths. However, tree height and diameter section didn't show significant effects on MOE, MOR, and compression strength parallel to the grain (Table 1).

Density

Density is one of the important parameters that influence the quality, strength, and utilization of the solid wood products that appear to influence machinability, conversion, strength, and several other wood properties (Malkoçoglu, & Özdemir, 2006; Dadzie et al., 2016; Adebawo et al., 2019; Sori et al., 2023). On the other hand, it could be used to estimate the suitability of wood for wood-based products and end-products (Vishnu, 2013; Girma & Abate, 2021). As indicated in Table 1, tree height had a significant impact on the density of *C. equisetifolia* wood. According to the Tukey HSD mean comparison, density was significantly increased from the bottom towards the middle portion and then decreased to the top of *C. equisetifolia* timber (Table 2). On the other hand, the highest value of density (806.69 kg/m^3) was observed in the middle portion, followed by the top (760.10 kg/m^3) and bottom (754.61 kg/m^3) portions of *C. equisetifolia* wood (Table 2). This pattern of variation was confirmed in another hardwood of *Petersianthus macrocarpus* (Poku et al., 2001). This variation could be due to the complex interactions among many factors, including site, climate, geographic location, and age, position in the stem, growth rate, and auxin gradient formation (Poku et al., 2001).

Table 1. Statistical analysis of variance for density and mechanical properties of *C. equisetifolia* wood

Source of variation	Dependent variables	DF	Sum Squares	Mean Squares	F value	P value
Tree height	Density (Kg/m^3)	2	48399	24199	13.245	0.000
	MOE (N/mm^2)	2	8711800	4355900	0.819	0.445
	MOR (N/mm^2)	2	1436	718	1.450	0.240
	Comp. (N/mm^2)	2	297	148	1.307	0.276
	Impac. (Nm/m^2)	2	1531	765	0.542	0.583
	Hard. Tan. (N)	2	25861842	12930921	7.664	0.001
	Hard. Rad. (N)	2	8365876	4182938	4.026	0.021
Tree diameter	Density (Kg/m^3)	1	52589	52589	28.784	0.000
	MOE (N/mm^2)	1	5165982	5165982	0.972	0.327
	MOR (N/mm^2)	1	270	270	0.546	0.462
	Comp (N/mm^2)	1	55	55	0.485	0.488
	Impac (Nm/m^2)	1	15933	15933	11.290	0.001
	Hard. T (N)	1	4290250	4290250	2.543	0.115
	Hard. R (N)	1	19311734	19311734	18.586	0.000
Tree height x Tree diameter	Density (Kg/m^3)	2	30330	15165	8.300	0.001
	MOE (N/mm^2)	2	12314905	6157452	1.158	0.319
	MOR (N/mm^2)	2	1463	732	1.478	0.234
	Comp (N/mm^2)	2	99	50	0.437	0.648
	Impac (N/mm^2)	2	7115	3558	2.521	0.086
	Hard. T (N)	2	17199420	8599710	5.097	0.008
	Hard. R (N)	2	5861929	2930964	2.821	0.065

Source: The data for this research article was analysed and generated the result using Statistical Package for the Social Sciences (SPSS) version 24.

As depicted in Table 3, the heartwood section of *C. equisetifolia* wood had a higher density (798.27 kg/m^3) than the sapwood section (749.93 kg/m^3). A similar variation pattern to this finding was reported for *Acacia burkea* and *Spirostachays africana* (Mmoloti et al., 2013). Density significantly varies along the tree height and across the diameter of the tree. According to Ross (2010), density variation in most hardwood trees along tree height is more pronounced than across the diameter section. The difference is attributed to the presence of extractives deposited in the heartwood part of timber species (Aguilera and Zamora, 2009).

Regardless of tree height and diameter sections, the density value obtained was in the range of 757 to 806 kg/m^3. Chowdhury (2012) found air-dried density in *C. equisetifolia* wood with a value of 800 kg/m^{3,} which is in the range of this finding. Kumar et al. (2011) also reported a density value of 750 kg/m^3 in the same species of this finding, which is comparable to this finding. However, a higher value than this finding was observed in the same species of this finding with a density value of 830 kg/m^3 by Petro et al. (2015). According to Panshin & de Zeeuw (1980), the mean value of density obtained in this finding is categorized under heavy wood density. Our result that *C. equisetifolia* wood is a high-density wood is supported by findings of other authors (Chowdhury et al., 2007; 2012; Petro et al., 2015).

Compared to commercially known and endangered timber species in Ethiopia, the density value of this finding obtained in *C. equisetifolia* wood, which is 774.10 kg/m^{3,} is greater than the density reported in *Hagenia abyssinica* (560 kg/m^3) and *Pouteria adolfi-friederici* (600 kg/m^3) as shown in Table 4. On the other hand, comparable to this finding observed in *E. globulus* wood (780 kg/m^3), as shown in Table 4.

Modulus of Elasticity and Modulus of Rupture

Evaluating stiffness (MOE) and bending strength (MOR) is helpful to determine the resistance of an applied external load on the wood (Arriaga et al., 2023). As depicted in Table 1, tree height had no significant impact on MOE and MOR. The density of wood is a reliable indicator of its strength.

Thus, variability in wood mechanical properties for *C. equisetifolia* wood also followed a similar pattern to that of wood density. The mean values of MOE and MOR were slightly increased from the bottom to the middle and then decreased to the top of the tree (Table 2). This variability may be associated with the inherent variability within trees, growth and environmental conditions, and the presence of high extractive contents in the wood (Adebawo et al., 2019).

The result demonstrated that the MOE and MOR values were lower in the lower part of the *C. equisetifolia* wood than in the upper part (Table 2). The variation pattern of MOE along the tree height of this finding was confirmed in another hardwood of *Petersianthus macrocarpus* (Poku et al., 2001). On the other hand, the sapwood section had higher MOE and MOR values than the heartwood section of *Casuarina equisetifolia* wood. Similar trends of variation were reported in hardwood of Poplar wood (Boktas et al., 2020).

Regardless of tree height and diameter section, MOE values fall within the range of 9361 MPa to 9928 MPa, and MOR falls within the range of 122 MPa to 128 MPa. The result shows that *C. equisetifolia* wood has lower stiffness values than other hardwood timbers used for lumber production. The MOE value result for C. *equisetifolia* wood was comparable to that of *Cordia africana* wood (6996 N/mm^2), as shown in Table 4. However, higher MOE values were reported for *E. globulus* (11655 N/mm^2) and *Prunus africana* wood (12070 N/mm^2) (Desalegn et al., 2012; Desalegn et al., 2015).

Table 4 shows that the MOR value observed in *C. equisetifolia* wood was superior to the MOR reported in *Cordia africana* (64 N/mm^2). The MOR value obtained in this finding of the wood was comparable to MOR values reported in other hardwoods of *E. camaldulensis*, *E. globulus*, *Olea capensis*, and *Olea welwitschii* (Table 4).

Compression Parallel to the Grain

Analyzing compression strength parallel to the grain helps to determine the deformation resistance of lumber compressed or distorted under applied load (Shmulsky & Jones, 2019). As indicated in Table 1, tree height and diameter sections did not show significant impacts on compression strength parallel to the grain. The variation of pattern observed along the stem height of the wood was an inconsistent pattern, which is slightly increased from the bottom to the middle and then decreased to the top of *C. equisetifolia* wood. A similar pattern of variation was reported in another hardwood of *Petersianthus macrocarpus* (Poku et al., 2001).

Table 3 shows that the heartwood section has a higher value of compression strength parallel to the grain (60.03 MPa) than the sapwood section of the tree (58.47 MPa). Similar variation to this finding was reported in Eucalyptus grandis and Poplar wood (Bektas et al., 2020). Regardless of tree height and diameter section, the compression strength parallel to the grain value falls within the range of 57 MPa to 61 MPa. In relation to commercially known and endangered tree species in Ethiopia, the MCS of this finding was higher than that of *Cordia africana* (29 N/mm^2), E. grandis (45 N/mm^2), and *E. globulus* (52 N/mm^2), as shown in Table 4.

Impact Bending Strength

Measuring impact bending strength helps to determine the amount of work expanded in breaking a piece of wood or resistance to sudden force. Based on impact bending results, it's possible to determine whether wood can be used for tool handles (Mayo, 2015). As depicted in Table 1, tree height did not show a significant impact on impact bending strength. Table 3 shows that the sapwood section had higher impact bending strength (13786 Nm/m^2) than the heartwood section of the tree (11125 Nm/m^2). The different values of impact bending obtained in sap and heartwood sections of this finding were agreed with by other scholars reported in *Eucalyptus grandis* and Poplar wood (Bektas et al., 2020).

Regardless of tree height and diameter section, impact bending strength values fall within the range of 11904 Nm/m^2 to 12896 Nm/m^2. The mean value of this finding was comparable to other hardwood timber species *E. saligna* (12873 Nm/m^2), but greater than the finding reported in *Grevillea robusta* (18094 Nm/m^2) as reported by Desalegn et al. (2012 and 2015).

Hardness Strength

Analyzing hardness property is important when timber is selected for paving blocks, floor ship decking, and bearing blocks (Ross, 2010). As depicted in Table 1, tree height and diameter section had significant impacts on tangential/radial hardness strengths. The hardness strengths value variations in the three tree height levels of *C. equisetifolia* show a similar trend of pattern to the density value variations obtained in the three tree height levels of this finding. According to several scholars (Nicholas and Brown, 2002), the density of wood is significantly correlated with the mechanical properties of wood. They also noticed that the value of density in the wood could predict the mechanical properties of the wood.

The heartwood section had higher tangential and radial hardness strengths values than the sapwood section of *C. equisetifolia*. Hardness strengths values variations between heart and sapwood reported in Hardwoods of White and Red Oak tree species showed comparable patterns of variation to this finding observed in *C. equisetifolia* wood (Merela and Cufar, 2013).

According to Shmulsky & Jones (2019), a higher concentration of extractives and infiltration materials is found in the heartwood part of timber compared to the sapwood part of timber species. These led to an increase in density and mechanical properties in the heartwood part compared to the sapwood part of timber species (Muhammad et al., 2018).

Regardless of tree height and diameter section, the tangential hardness values fall in the range of 3920 N to 4343 N, and the radial hardness strength falls within the ranges of 3695 N to 4274 N. The result of this finding, tested in radial direction, was higher than radial hardness found in other hardwood species of *Cordia africana* (2213 N) and *Hagenia abyssinica* (3036 N), as shown in Table 4. On the other hand, the values of radial and tangential hardness observed in this finding were higher than the values of radial (2045 N) and tangential (2127 N) hardness strengths reported in *Grevillea robusta* (Shanavas and Kumar, 2006). Comparable to this finding was found in *Acacia auriculiformis* wood with the values of radial (3856 N) and tangential (4220 N) hardness strengths (Shanavas and Kumar, 2006).

Table 2. The effect of tree height on average values of density and mechanical properties

Tree height	N	Density (Kg/m^3)	MOE (MPa)	MOR (MPa)	Comp. (MPa)	Impac. (Nm/m^2)	Hard. Tan. (N)	Hard. Rad. (N)
Bottom	30	754.61^a	9335.97^a	118.41^a	56.92^a	128.96^a	6178.67^a	6584.33^a
Middle	30	806.69^b	9808.45^a	128.12^a	61.35^a	119.04^a	7222.67^b	6627.67^{ab}
Top	30	760.10^a	9054.37^a	124.29^a	59.48^a	125.67^a	6011.00^a	5960.33^{ac}

Source: The data for this research finding was analysed and the mean results generated using Statistical Package for the Social Sciences (SPSS) version 24, and the comparisons between the means are done based on Tukey HSD.

Table 3. The effect of tree diameter on average values of density and mechanical properties

Tree section	N	Density (Kg/m^3)	MOE (MPa)	MOR (MPa)	Comp. (MPa)	Impac. (Nm/m^2)	Hard. Tan. (N)	Hard. Rad. (N)
Heart	45	798.27^a	9160.02^a	121.87^a	58.47^a	11125^a	6689.11^a	6854.00^a
Sap	45	749.93^b	9639.18^a	125.33^a	60.03^a	13786^b	6252.44^a	5927.56^b

Source: The data for this research finding was analysed and the mean results generated using Statistical Package for the Social Sciences (SPSS) version 24, and the comparisons between the means are done based on Tukey HSD.

Table 4. Comparison of mean values of density and mechanical properties in Casuarina equisetifolia wood with other timbers species studied in Ethiopia

Scientific name	Density (Kg/m^3)	MOE (N/mm^2)	MOR (N/mm^2)	Comp. (N/mm^2)	Impac. (Nm/m^2)	Hard. Tan. (N)	Hard. Rad. (N)
Casuarina equisetifolia#	774	9400	124	59	12456	6471	6391
Cordia africana	410	6996	64	29	6588	–	2213
Eocatyptus camaldulensis	853	14177	131	71	12209	–	5887
Eocatyptus globulus	780	11655	124	52	16114	–	8743
Eocatyptus grandis	560	10308	92	45	10021	–	3036
Eucalyptus saligna	680	11604	106	53	12873	–	4507
Grevillea robusta	530	8899	83	41	18094	–	6737
Hagenia abyssinica	560	9563	86	43	6436	–	3814
Olea capensis	990	13197	124	72	17576	–	9338
Olea welwitschii	820	14194	124	67	16274	–	7434
Pouteria adolfifriederici	600	10029	93	46	8677	–	4535
Prunus Africana	850	12070	125	59	13941	–	10399

is indicates the result of this finding

Source: Desalegn et al., 2012; Desalegn & Teketay; 2015; Desalegn et al., 2015

CONCLUSION

The effect of tree height and diameter section (heart and sapwood) on density and mechanical properties of *C. equisetifolia* wood has been studied. The density and hardness strengths values tested in the tangential and radial direction of *C. equisetifolia* wood varied considerably along the tree height. However, MOE, MOR, and compression strength parallel to the grain did not vary with increasing height from the bottom to the top of the tree. On the other hand, density, impact bending, and hardness radial of *C. equisetifolia* wood significantly vary radially between the heart and sapwood sections. Nonetheless, MOE, MOR, compression strength parallel to the grain, and hardness strength in the tangential direction did not vary between the heart and sapwood sections of *C. equisetifolia* wood. The density of *Casuarina equisetifolia* wood is high and could be put to useful purposes where heavy wood is required for construction, such as wood flooring, chipwood, particleboard, furniture, and other products, such as tool handles, etc. Because of its similar mechanical qualities to those of other hardwood species, the wood may be used as a replacement for overused species that are rapidly going extinct in the building and construction industry, such as chipwood, particleboard, furniture, etc. There would be a need to investigate the anatomical and chemical properties of the wood and how this relates to strength properties, as well as its usage for pulp and paper applications.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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