

Comparative evaluation of calorific value, wood density, and moisture content for sustainable bioenergy production of major tree species in Pakistan



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Article Info

Abstract

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Biomass energy, Fuelwood favorable characteristics that might produce sustainable biomass fuels. In this regard, ten widespread quality, Calorific value, Wood and extensively distributed species from Punjab, Pakistan, were investigated for fuel properties such density, Moisture content

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The growing need for alternative energy sources underlines the need to identify woody species with favorable characteristics that might produce sustainable biomass fuels. In this regard, ten widespread and extensively distributed species from Punjab, Pakistan, were investigated for fuel properties such as calorific value, wood density, and moisture content. For the experimental study, mature trees were chosen, and wood samples were obtained and analyzed for calorific value using an oxygen bomb calorimeter. Similarly, wood density and moisture content were measured using standard methods, followed by one-way ANOVA, Tukey's Honestly Significant Difference (HSD), and Pearson correlation. For all the factors evaluated, the results revealed statistically significant differences across species. *Prosopis cineraria* (4484.9 kJ/kg), *Vachellia nilotica* (4377.3 kJ/kg), and *Eucalyptus camaldulensis* (4254.2 kJ/kg) had the highest calorific value, while *Bombax ceiba* (2087.5 kJ/kg) had the lowest calorific value. Similarly, *Vachellia nilotica* (820 kg/m³) and *Prosopis cineraria* (790 kg/m³) had the highest wood densities, which ranged from 300 to 820 kg/m³. The moisture content of chosen species ranged from 6.3 to 19.3%, with *Vachellia nilotica* and *Prosopis cineraria* having the lowest moisture content values. This study found a significant positive correlation ($r = 0.928$, $P < 0.001$) between wood density and calorific value, indicating that dense wood contains more energy. Thus, *Prosopis cineraria*, *Vachellia nilotica*, *Dalbergia sissoo*, *Casuarina equisetifolia* and *E. camaldulensis* have outstanding fuel qualities, therefore, could be promising for plantations of fuelwood and biomass energy generation programs in Pakistan.

1 Introduction

With rising global energy consumption and growing concerns about fossil fuel depletion and climate change, renewable and sustainable energy sources are gaining widespread popularity. Among the available sustainable energy alternatives, biomass is one of the leading resources. Biomass accounts for nearly 10% of the world's primary energy consumption, making it the most significant renewable source globally (IEA, 2023). Woody biomass, being one of the primary sources of household and industrial use, has historically dominated household fuel supply in many developing countries. It represents a carbon-neutral alternative to fossil fuels if managed sustainably, offering benefits such as rural livelihoods and climate change mitigation (IPCC, 2022).

Pakistan faces numerous energy-related issues, including a rapidly growing population, increasing energy needs, and an increased reliance on imported fossil fuels, despite investments being made in its energy sector. Fuelwood is still the most consumed household energy source, especially in the rural areas of Pakistan, where commercial sources are inaccessible. Increasing pressure on woody biomass due to rapid demand has necessitated the need to study Fast Growing Species (FGS), which yield better quality biomass for sustainable energy. Fuelwood quality is essentially evaluated on the basis of several physicochemical properties, of which calorific value (often called the higher heating value (HHV)), wood density and moisture content are the most critical ones. Calorific value represents the amount of energy released from the complete combustion of biomass. High density implies greater mass per volume, leading to higher energy release per unit volume, prolonged burn duration, and enhanced combustion efficiency. High moisture content

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reduces fuel quality as combustion energy would be consumed for its evaporation before effective burning begins (Demirbaş, 2001; Telmo and Lousada, 2011; Asif *et al.*, 2023).

It is well documented that the calorific value of biomass varies among species. Differences in chemical compositions (lignin, cellulose and hemicellulose, extractives, and ash content) and anatomical structure result in different calorific values. For instance, higher lignin content is typically associated with a higher calorific value, as it is richer in carbon-based aromatic compounds compared to other carbohydrate structures (Parikh *et al.*, 2005; Vassilev *et al.*, 2010; Saleem *et al.*, 2024). Similarly, wood density and moisture content are two of the important physical properties of fuel, closely related to its energy yield and combustion characteristics. Hence, assessing fuel quality in terms of these parameters could provide suitable species for efficient energy production.

The traditional species utilized in Pakistan, such as Kikar (*Vachellia nilotica*) and Shisham (*Dalbergia sissoo*), are known to be excellent fuelwood species due to their high energy value. However, the availability and yield of these species have significantly diminished in many regions owing to overexploitation, change in land use, and pest attacks, with shisham dieback being an infamous example. In recent times, several Fast-Growing Tree (FGT) species have gained popularity and have been extensively planted across Pakistan, especially in the province of Punjab. These species include *Conocarpus lancifolius*, *Eucalyptus camaldulensis*, *Casuarina equisetifolia*, *Tamarix aphylla*, *Terminalia arjuna*, *Prosopis cineraria*, *Bombax ceiba*, and *Salvadora oleoides*. To date, comparative information regarding the fuel quality (calorific value, density and moisture content) of these widely planted tree species has remained sparse.

Thus, the objective of this study was to investigate the fuelwood quality (calorific value, wood density, and moisture content) of ten common tree species grown in Punjab, Pakistan. Specifically, we aimed to: (i) determine the calorific value (HHV) of these tree species; (ii) characterize variation in wood density and moisture content; (iii) investigate relationships between calorific value, wood density and moisture content; and (iv) identify promising tree species for the sustainable production of biomass energy for fuel use and future development of bioenergy resources in Pakistan. The outcomes of this study are expected to provide essential insights to forestry managers, researchers, and policymakers on renewable energy and land management in Pakistan.

2 Materials and Methods

2.1 Study area

The research was performed at the Department of Forestry and Range Management, University of Agriculture, Faisalabad (31° 26' N, 73° 06' E), Faisalabad, Punjab, Pakistan. These trees belonged to mature age and developed under the same growing conditions, the University of Agriculture, Faisalabad (UAF), Lyallpur Park Faisalabad and Punjab Forestry Research Institute (PFRI), Gatwala National Park Faisalabad. These were situated in semi-arid irrigated plains of central Punjab and possess hot summers and moderate winters and receive an annual average rainfall of 300-400 mm. The average annual temperature ranges between 20-27°C.

2.2 Tree species selection

In this study, ten common tree species generally and locally used as fuelwood and as agro-forestry resources in Pakistan were enumerated; namely, *Vachellia nilotica* (Kikar), *Dalbergia sissoo* (Shisham), *Conocarpus lancifolius* (Conocarpus), *Salvadora oleoides* (Van), *Tamarix aphylla* (Frash), *Terminalia arjuna* (Arjun), *Casuarina equisetifolia* (Casuarina), *Prosopis cineraria* (Jand), *Bombax ceiba* (Simal) and *Eucalyptus camaldulensis* (Sufaída). The selected tree species were generally preferred for fuel and planted in agroforestry practice across Punjab province. For each species, three healthy mature trees were selected and regarded as replicates in their respective categories.

2.3 Sample collection

The samples for wood cores were collected at breast height (1.3m from ground level) by employing the increment borer. Great care was exercised in the collection of sound and clean samples from the heartwood. Samples were labelled and kept in a polyethylene bag at the time of sampling to minimize moisture loss and delivered to the lab for analysis in the Department of Forestry and Range Management, University of Agriculture Faisalabad.

2.4 Moisture content determination of wood

The weight of each wood core sample was recorded immediately after collection using a digital analytical balance (0.001 g). The samples were dried in a forced-air oven at 105±2°C until they achieved constant weight according to the standard wood moisture determination procedure. The cooled overdried samples were weighed in a desiccator, and moisture content was calculated on an oven-dry basis using the following formula:

Formula for Moisture Content (Dry Basis)

$$\text{Moisture Content (\%)} = \frac{W_f - W_d}{W_d} \times 100$$

Where:

W_f = Fresh (green) weight of the wood sample (g)

W_d = Oven-dry weight of the wood sample (g)

Figure 1. Equation for calculating moisture content (dry basis) of wood samples, where W_f is the fresh (green) weight (g) and W_d is the oven-dry weight (g). Moisture content is expressed as a percentage of oven-dry weight.

2.5 Determination of wood density

Oven-dry weight divided by green volume gave wood density. Sample length was measured with a precision ruler, and the diameter of the core wood was measured using a digital Vernier caliper. Sample volume was computed: Wood density is already accepted as one significant biomass quality characteristic because it affects energy density, combustion period, and transportation costs.

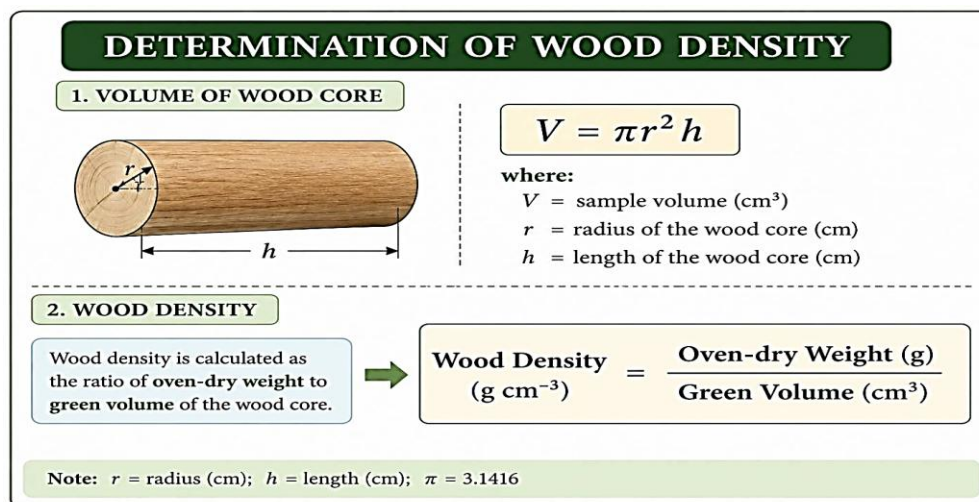


Figure 1. Schematic illustration of the determination of wood density. The volume of the cylindrical wood core was calculated using the equation $V = \pi r^2 h$, where r is the radius and h is the length of the wood core. Wood density (g cm⁻³) was subsequently determined as the ratio of oven-dry weight (g) to green volume (cm³).

2.6 Determination of calorific value

The calorific value for each species was calculated using an oxygen bomb calorimeter, following the standard procedure for analyzing solid biomass fuels. The dried wood samples were ground to a fine, homogenized powder in a laboratory mill. About 1.0 g of this sample was pressed into a disk pellet and burned in pure oxygen at about 30 bar pressure. Prior to sample analysis, the bomb calorimeter was calibrated against a benzoic acid standard. Temperature increase of the surrounding water jacket during combustion was automatically measured and recorded, and high heating value (HHV) was calculated following appropriate correction of the combustion heat to account for energy contribution from igniter wire and the acid (manufacturer protocol). Calorific value was reported as kcal kg.

2.7 Statistical analysis

The experiment was conducted in a completely randomized design (CRD). Calorific value, wood density, and moisture content data were analyzed for differences among tree species using one-way analysis of variance (ANOVA). For significant treatments ($P < 0.05$), differences among means were analyzed by Tukey's Honestly Significant Difference (HSD) test. The relationship between

calorific value, wood density and moisture content was analyzed by Pearson's correlation coefficient. Statistical software used was R statistical software (R Core Team, 2025), and all statistical calculations and graphs were generated using Microsoft Excel.

3 Results

3.1 Variation in calorific value among tree species

Tree species used for experiments show differences of calorific value which were statistically significant ($P < 0.05$) and were between 2087.5 to 4484.9 kJ kg (Table 1 & Table 2). The highest calorific value was recorded for *Prosopis cineraria* (4484.9 kJ kg) which was very much close to *Vachellia nilotica* (4377.3 kJ kg) and *Eucalyptus camaldulensis* (4254.2 kJ kg) and then *Dalbergia sissoo* (4247.5 kJ kg) and *Casuarina equisetifolia* (4221.1 kJ kg) that belonged to first statistical group (Figure 3). *Conocarpus lancifolius* (4109.2 kJ kg), *Tamarix aphylla* (3928.3 kJ kg), and *Terminalia arjuna* (3654.5 kJ kg) showed medium calorific value. These belong to the second statistical category for moderate fuelwood quality. *Bombax ceiba* has the lowest calorific value of any species (2087.5 kJ kg), followed by *Salvadora oleoides* (3268.4 kJ kg). The calorific value of the tree species investigated varied greatly, as demonstrated by the fact that *P. cineraria*, *V. nilotica*, *E. camaldulensis*, *D. sissoo*, and *C. equisetifolia* were better suited for use as fuel wood than others as compared to *Bombax ceiba* that exhibited low calorific value.

Table 1. Analysis of variance (ANOVA) showing the effect of tree species on calorific value, moisture content, and wood density of major fuelwood tree species in Pakistan.

Character	SOV	df	Sum of Squares (SS)	Mean Square (MS)	F-value	P-value
Calorific Value (kcal kg ⁻¹)	Species	9	14,082,903	1,564,767	23.23**	1.06×10^{-8}
	Residuals	20	1,347,436	67,372	—	—
Moisture Content (%)	Species	9	0.10121	0.011245	37.61**	1.33×10^{-10}
	Residuals	20	0.00598	0.000299	—	—
Wood Density (g cm ⁻³)	Species	9	1.977	0.2197	122.10**	1.72×10^{-15}
	Residuals	20	0.036	0.0018	—	—

Table 2. Ranking of major fuelwood tree species of Pakistan based on calorific value, wood density, and moisture content. Values followed by different lowercase letters within each column are significantly different according to Tukey's HSD test at $P \leq 0.05$.

Sr. No.	Species	Calorific value	Species	Wood density (Kg/m ³)	Species	Moisture Percentage
1	<i>Prosopis cineraria</i>	4484.9 a	<i>Vachellia nilotica</i>	820 a	<i>Bombax ceiba</i>	19.3 a
2	<i>Vachellia nilotica</i>	4377.3 ab	<i>Prosopis cineraria</i>	790 a	<i>Eucalyptus camaldulensis</i>	15.2 b
3	<i>Eucalyptus camaldulensis</i>	4254.2 ab	<i>Dalbergia sissoo</i>	670 b	<i>Terminalia arjuna</i>	13.3 b
4	<i>Dalbergia sissoo</i>	4247.5 ab	<i>Casuarina equisetifolia</i>	660 b	<i>Conocarpus lancifolius</i>	10.3 c
5	<i>Casuarina equisetifolia</i>	4221.1 ab	<i>Tamarix aphylla</i>	640 b	<i>Tamarix aphylla</i>	10.0 c
6	<i>Conocarpus lancifolius</i>	4109.2 abc	<i>Conocarpus lancifolius</i>	640 b	<i>Dalbergia sissoo</i>	8.0 d
7	<i>Tamarix aphylla</i>	3928.3 bc	<i>Salvadora oleoides</i>	620 b	<i>Casuarina equisetifolia</i>	7.3 d
8	<i>Terminalia arjuna</i>	3654.5 cd	<i>Terminalia arjuna</i>	620 b	<i>Salvadora oleoides</i>	6.7 d
9	<i>Salvadora oleoides</i>	3268.4 d	<i>Eucalyptus camaldulensis</i>	600 b	<i>Prosopis cineraria</i>	6.5 d
10	<i>Bombax ceiba</i>	2087.5 e	<i>Bombax ceiba</i>	300 c	<i>Vachellia nilotica</i>	6.3 d

3.2 Variation in Wood Density among Tree Species

There were significant variances in mean wood density between 10 selected species, ranging from 300 to 820 kg/m³ (Figure 4), indicating a wide range in wood physical attributes among tree species. *Vachellia nilotica* had the highest wood density (820 kg/m³), and together with *Prosopis cineraria* (790 kg/m³), it formed the statistically superior group of trees (group a), with considerably higher wood density than all other species ($P < 0.05$). These species had a high density, indicating a more compactly packed woody structure and making them suitable candidates for construction wood, as their wood energy properties may have a higher heating value.

The tree species forming an intermediate group (*Dalbergia sissoo*, 670 kg/m³; *Casuarina equisetifolia*, 660 kg/m³; *Conocarpus lancifolius*, 640 kg/m³; *Tamarix aphylla*, 640 kg/m³; *Terminalia arjuna*, 620 kg/m³; *Salvadora oleoides*, 620 kg/m³; and *Eucalyptus camaldulensis*, 600 kg/m³) do not show statistically significant differences among them; hence group 'b' showed similar significance. Although numerical variations within this group were seen, their woods had not significantly different characteristics from each other for the wood density in addition. Conversely, *Bombax ceiba* had the least wood density (300 kg/m³) and it had also shown significant difference from all other species (group c, $P < 0.05$). Its wood density was about 63% less than *Vachellia nilotica* and 62% less than *Prosopis cineraria*, which had low wood density and thereby possessed poor packing characteristics and lower stored energy per unit of volume.

3.3 Variation in Moisture Content among Tree Species

Moisture contents in all studied tree species range from 6.3 to 19.3 percent, showing a significant variance in water storage capacity and fuel wood production capability (Figure 5). *Bombax ceiba* had the highest average value of 19.3%, indicating a significant difference from other species ($P < 0.05$). The high percentage of *Bombax ceiba* is responsible for a large amount of combustion energy released during the processes having to be wasted in evaporating the water, resulting in a lower net heating impact and a longer time to ignite the fuel. The next highest moisture content value was found in *Eucalyptus camaldulensis* (15.2%), which belongs to statistical group (b). This value is significantly different from the others, apart from *Bombax ceiba* and *Terminalia arjuna* (13.3%), which also belong to statistical group (b) and were found to have similar conditions. They have a somewhat higher moisture content, which needs drying before being used. *Conocarpus lancifolius* (10.3%) and *Tamarix aphylla* (10.0%) belong to statistical group (c), where the moisture value was average among the other species. Both species have a moderate moisture content and could be a good option if the seasoning process was completed quickly. *Dalbergia sissoo* (8.0%), *Casuarina equisetifolia* (7.3%), *Salvadora oleoides* (6.7%), *Prosopis cineraria* (6.5%), and *Vachellia nilotica* (6.3%) had the lowest moisture contents. The statistical group (d) includes all these species. The species in the same group (d) did not differ significantly from one another. They are said to be useful for producing firewood because of their low moisture content, which implies that the less moisture they have, the more energy they will release when heating or burning and suitable for ignition.

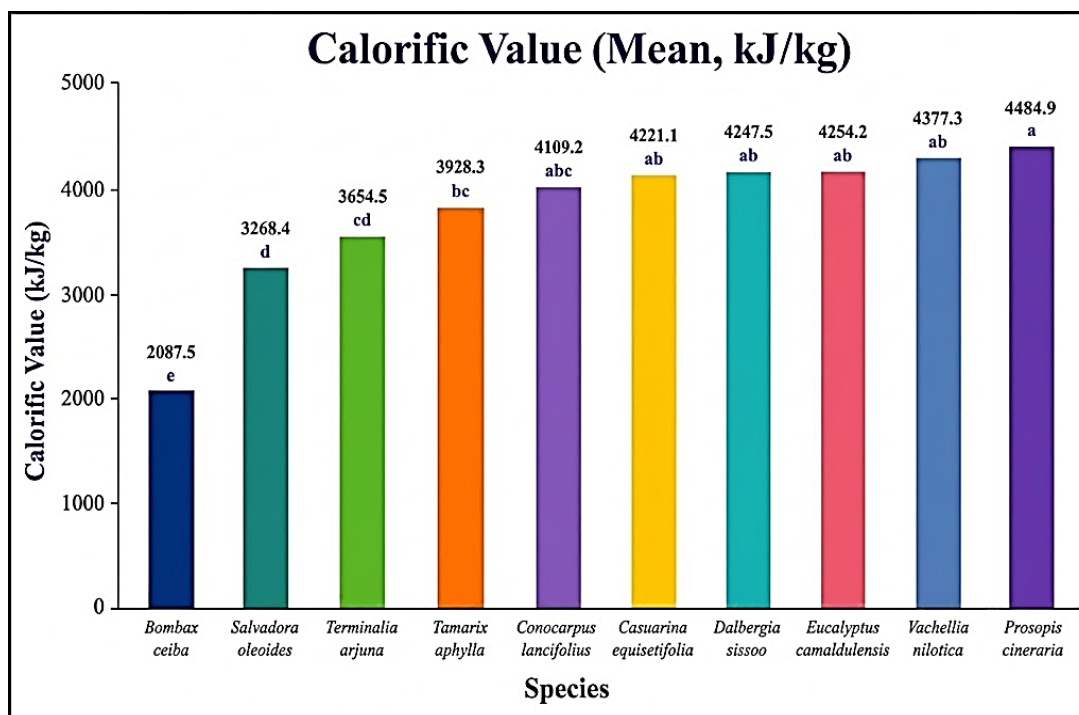


Figure 3. Average calorific value (kcal kg⁻¹) of the selected tree species arranged in ascending order. Values represent the mean higher heating value (HHV) of each species, highlighting interspecific differences in fuelwood energy potential.

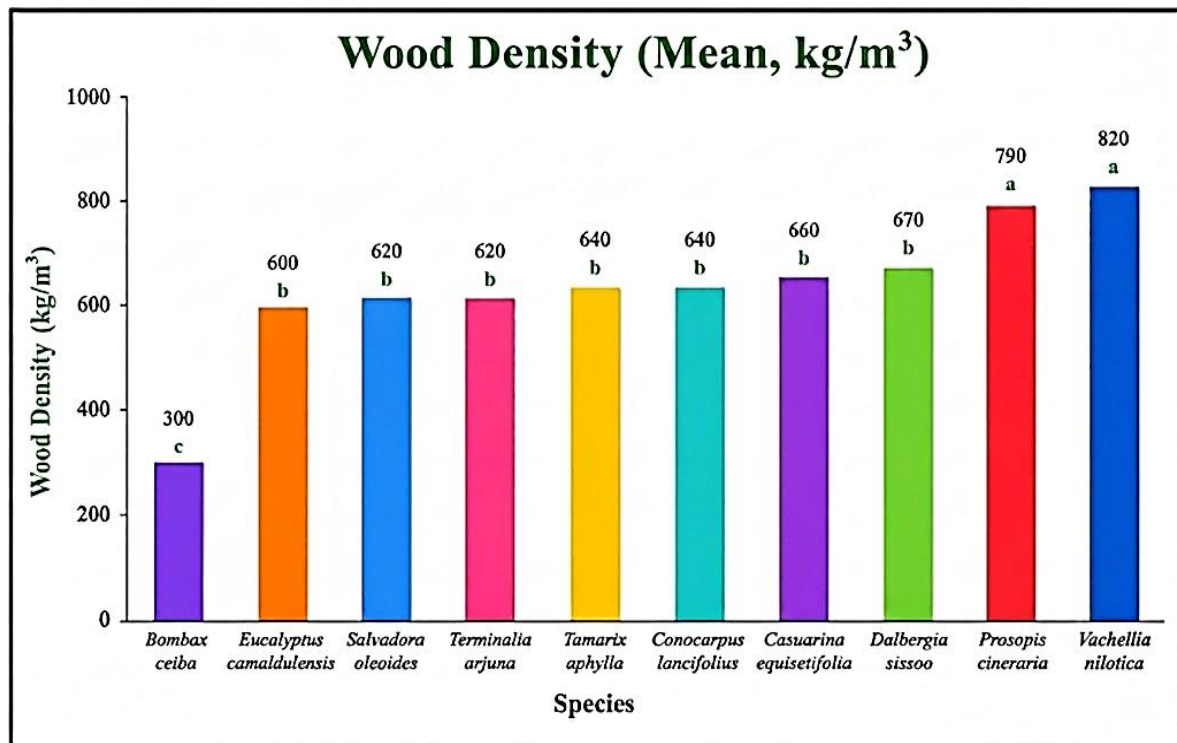


Figure 4. Mean wood density (g cm^{-3}) of the selected tree species arranged in ascending order. Values represent the average wood density for each species, highlighting the variation in wood compactness and potential energy density among the evaluated woody biomass resources.

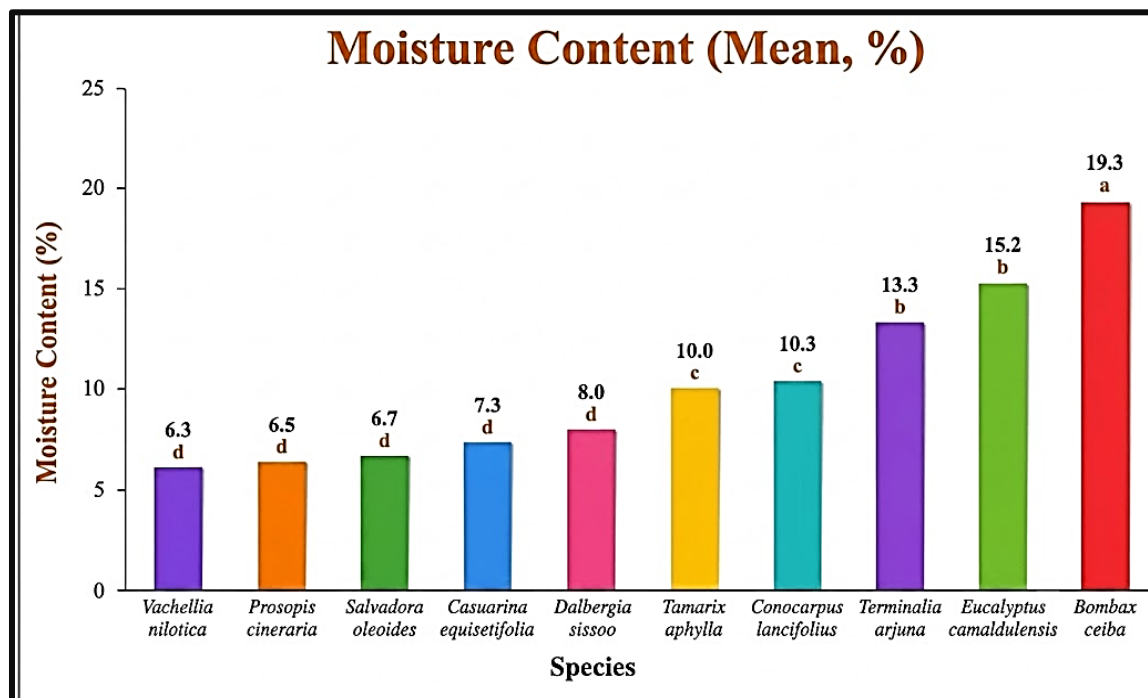


Figure 5. Average moisture content (%) of the selected tree species arranged in ascending order. Values represent the mean moisture content of each species, highlighting differences in wood moisture characteristics that influence fuel quality and combustion efficiency.

3.4 Correlation among Calorific Value, Wood Density, and Moisture Content

The investigation shows that the three fuelwood characteristics of calorific value, moisture content, and wood density have a strong positive association (Figure 6). Wood density and calorific value have the strongest positive connection ($r = 0.928$, $p < 0.001$). The outcome shows that species with dense forests typically have greater calorific values and, thus, larger energy yields. Given the strong association between wood density and calorific value, wood density may be a more accurate measure of the fuel energy potential of wood species. There was significant positive correlation between wood density and moisture content ($r = 0.748$, $p < 0.01$). Although not as strong as that between wood density and calorific value, it indicates that woody species with superior fuel qualities after adequate drying, comparably higher densities typically have somewhat higher moisture contents, perhaps because of species structural variations with higher binding water inside cell walls. Additionally, a somewhat significant association between calorific value and moisture content was found ($r = 0.653$, $P < 0.01$), indicating that species with greater calorific values typically have somewhat higher moisture content. The correlation was lower for wood density than for moisture content, suggesting that intrinsic woody characteristics like wood density, composition, lignin, cell walls, and extractable organic materials would be significant factors in determining fuel energy potential. In general, there was a strong positive association between the three variables, and wood density seemed to have a greater impact on the calorific value. Therefore, it implies that the primary element influencing the energy yield of tree species is wood density, and species with high wood density will provide the maximum energy content after seasoning.

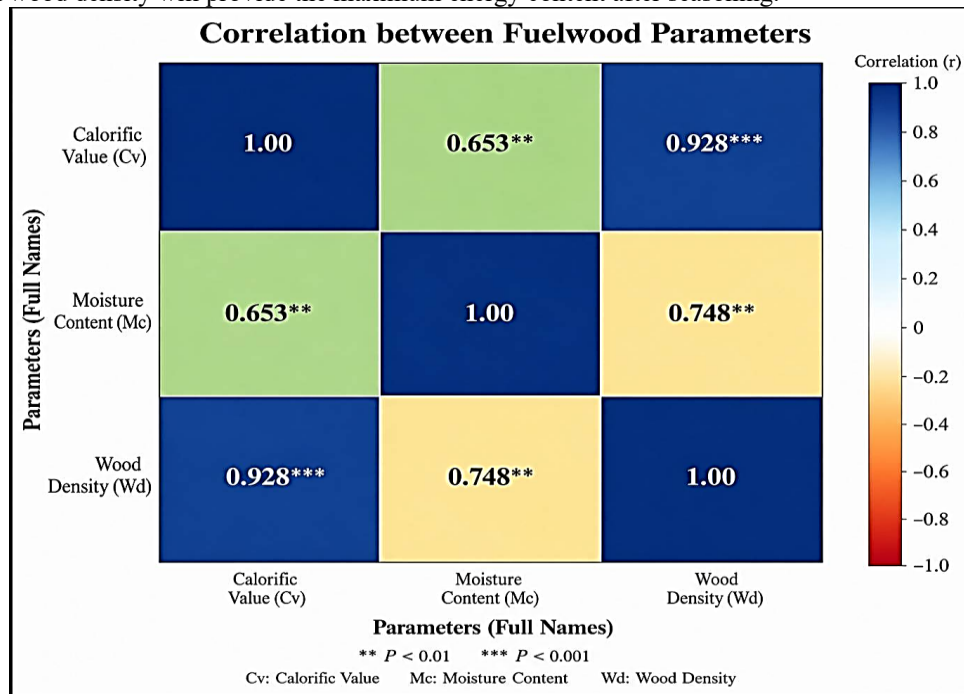


Figure 6. Pearson correlation heatmap illustrating the relationships among calorific value (Cv), moisture content (Mc), and wood density (Wd). Values within the cells represent correlation coefficients (r), while color intensity indicates the strength of positive correlations. $P < 0.01$; * $P < 0.001$.

4. Discussion

4.1 Interspecific variation in calorific value of tree species

In the current study, significant differences in calorific value were found between the species tested. The species *P. cineraria*, *V. nilotica*, *E. camaldulensis*, *D. sissoo*, and *C. equisetifolia* had the highest energy content. These changes were unsurprising given that the calorific value of wood is mostly determined by its chemical composition (carbon, lignin, extractives, and minerals (ash), which varies by species. It is widely accepted that woods with high carbon content and low ash have a higher heating value (Zafar *et al.*, 2023; Nautiyal, 1995). The superior performance of *P. cineraria* and *V. nilotica* in this study is consistent with previous research on wood fuels in arid and semi-arid parts of South Asia. Puri *et al.* (1994) had previously selected *V. nilotica*, *Casuarina equisetifolia*, and other native hardwood species as desirable fuelwood woods due to their higher calorific values, larger wood density, and high Fuelwood Value Index (FVI). Later, Kataki and Konwer (2002) identified *V. nilotica* as one of the best local indigenous fuel woods based on calorific value, density, and other fuel wood qualities. More recently, Amrat and Chandio (2022) analyzed the indigenous woody species of Thar Desert Pakistan and found that *P. cineraria* had a greater calorific value and wood density than *S. oleoides*, indicating that *P. cineraria* is a more viable local biomass resource for energy uses. Their findings are consistent with current research, demonstrating that *P. cineraria* regularly outperform other indigenous species across Pakistan's many ecozones due to the desirable characteristics of its wood. *B. ceiba* has the lowest calorific value of all the species invested. This is also consistent with previous fuelwood valuation studies, which found that species with low wood density had a lower calorific value and a lower Fuelwood Value Index (FVI) than high

density hardwoods. Although *B. ceiba* has a variety of applications, both economic and ecological, it's extremely low energy content precludes it from commercial bioenergy applications requiring substantial heat generation.

4.2 Variation in wood density among tree species

Wood density varied greatly among the species examined, with *V. nilotica* and *P. cineraria* having the highest densities. Wood density is a universally essential indicator of fuelwood quality, since it estimates the amount of flammable material in each volume. Woods with high densities burn for longer periods of time and provide more heat per unit volume, while also saving transportation and storage space. Higher density values obtained for *V. nilotica* are consistent with findings in India, where the species had a higher wood density and gave a superior heat value (Kataki & Konwer, 2002). Puri *et al.* (1994) identified *V. nilotica* as one of the most important indigenous fuel woods due to its high density. Similarly, higher wood density in *P. cineraria* in the current study supports prior results from Pakistan (Amrat & Chandio, 2022), in which *P. cineraria* demonstrated favorable wood attributes such as higher density and improved burning characteristics. The extremely low density observed for *Bombax ceiba* is consistent with studies by Kataki & Konwer, (2002) and Amrat & Chandio, (2022), which showed that low density woods produce reduced calorific values and FVI. Low density species burn quickly and need to be refilled more frequently than dense hardwood species. These conditions, together with *B. ceiba*'s low calorific content, resulted in poor performance as fuel wood.

4.3 Variations in moisture content among tree species

Moisture is a major limiting factor for the usage of biomass fuels since it takes more energy to evaporate water before it evaporates. It is critical in biomass energy studies that fuel woods be dried for an extended period before usage. Moisture content in different tree species in the current study follows a nearly same trend in terms of species ranking on the Fuelwood value index. *B. ceiba* has substantially higher moisture content than *V. nilotica* and *P. cineraria*. These species demonstrate that species with lower moisture content require less energy to evaporate water prior to combustion, allowing them to burn more readily and at a greater rate of combustion. Similar to the findings of this investigation, increased moisture content has frequently been identified as a major negative factor influencing fuel attributes (Kataki & Konwer, 2002; Amrat & Chandio, 2022). While *E. camaldulensis* had the highest moisture content, it also had a significant calorific value, indicating that moisture content does not govern fuel value solely; other factors such as wood density, ash content, chemical constituents (extractives, lignin, etc.) influence the calorific value, and drying wood is a practical practice for efficient use.

4.4 Relationship between calorific value, wood density and moisture content

A strong positive association ($r=0.928$) was found between calorific value and wood density. Wood density is also regarded as a valid indication of fuel quality because it represents a fraction of combustible biomass per unit volume, determining the potential energy production. A favorable relationship was found between wood density and moisture content ($r=0.211$), but not as significant as with calorific value. This can be explained by the fact that dense hardwoods often have a higher fraction of cell walls carrying bound water, and they may also have had higher moisture levels in recent wood tissue. Studies found comparable relationships between wood density and moisture content (Manj *et al.*, 2024; Amrat and Chandio, 2022). A somewhat good relationship was found between calorific value and moisture content ($r=0.469$). However, a higher moisture content is not advantageous for a larger calorific content of wood; rather, it is a result of the unique structure and composition of wood across different species. In practical terms, moisture content is a quantity that, by absorbing energy for its elimination, would restrict the total effective energy production during combustion. Considering these limitations, the study concluded that *V. nilotica*, *P. cineraria*, *D. sissoo*, *C. equisetifolia*, and *E. camaldulensis* might be appropriate for biomass energy applications in Pakistan due to their higher calorific value, wood density, and moisture content values, which are comparable to similar earlier research carried out in the region.

5. Conclusion

This study reveals significant variations in the fuelwood properties of ten common woody tree species found in plantations in Punjab, Pakistan. Due to their higher calorific value, higher wood density, and lower moisture content, *P. cineraria* and *V. nilotica* had the maximum energy potential. As a result, these species are better suited for high-energy wood fuels. However, *B. Ceiba* performed worse because of its increased moisture content, lower calorific value, and wood density. Wood density and calorific value have a strong positive connection ($r = 0.928$), suggesting that wood density can be a reliable indicator of biomass energy content and used to forecast and evaluate the quality of tree species for fuelwood. *P. cineraria*, *V. nilotica*, *D. sissoo*, *casuarina equisetifolia*, and *E. camaldulensis* were the fuelwood quality species in order of calorific value, wood density, and moisture content. In Pakistan, these plants could be used for crops and energy production. This study would provide forest managers, scientists, and policymakers with essential information on key woody species to meet our needs for renewable biomass and energy, as well as to plan for afforestation and agroforestry.

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