# NOTES

## WOOD DENSITY OF TROPICAL TREE SPECIES IN THE PHILIPPINES: STATE OF KNOWLEDGE AND DATABASE DEVELOPMENT FOR TREE BIOMASS ESTIMATION

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Wood density is a measure of the amount of cell wall substance per unit volume of wood. It is expressed in terms of mass over volume units (g $cm^{-3}$, kg $m^{-3}$). Wood density is a complex physical property, depending on the tree species and its interaction with the environment (Ilic *et al.* 2000) as well as silvicultural measures (Tsoumis 1991). It is an important index for estimating the strength and mechanical properties of wood to determine its suitability for various uses (Tamolang *et al.* 1995).

Variations in wood density values within and between tree species and sites exist as a result of the varying needs of trees for structural support under different circumstances (Fearnside 1997). Density varies in trees from pith to bark (lateral variation) and from base to apex (vertical variation) depending on the species and its locality of growth. Pith-to-bark gradients in wood density values occur because of varying growth rates as trees mature. Studies conducted in Australia by Ilic *et al.* (2000) showed a reduction in density with height for softwoods and a gradual increase with height for hardwoods. Tsoumis (1991) reported that a reduction in density with increasing height is common in softwoods, although not in all cases. Hairiah and Sitompul (2000) developed an equation to estimate the relative wood density of a tree at a particular height because density varies along the length of the trunk.

The most common method for determining wood density is by taking 25 × 25 × 25 mm wood samples from discs at least 153 mm thick at 3- and 6-m heights above the tree stump. The volume of the samples is then determined by the liquid displacement method. Subsequently, the samples are oven-dried at a temperature range of 101–105 °C to constant weight. When density is computed as the ratio of oven-dry weight to oven-dry volume, the value is termed oven-dry density. When it is computed using fresh or green volume, it is termed relative density or basic density. Air-dry density, on the other hand, is usually computed at a volume with 12 or 15% moisture content (MC). In estimating tree biomass, relative density data are used. When only air-dry density values are available, relative density can be computed from available equations relating MC of wood to density or vice-versa. These equations are discussed in Tsoumis (1991) and Simpson (1993). In general, the MC of wood is negatively correlated with its density, which means decreasing MC increases

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wood density. Conversely, increasing MC from zero to the maximum moisture that wood can absorb from the atmosphere or the fibre saturation point (fsp) decreases relative density. The fsp value of wood is usually at 25–30% MC.

To improve the accessibility and provide information on wood density to researchers, a database was developed from reviewed literature in the Philippines. Data sets by Tamolang *et al.* (1995) and Rocafort *et al.* (1983) were used as the main sources of data. The wood density values included in the database are in terms of green, 12% and oven-dry (OD) MC conditions of wood volume.

The wood density database is written in Microsoft Access 2000 and contains linked tables pertaining to botanical taxonomic classification (family, scientific and common names), location and site characteristics (annual rainfall, soil type, agroclimatic zone) where the samples were taken, and wood density values at green, 12% and OD MC volume conditions. Data contained in the different tables can be edited and viewed from various interfaces of the database.

Currently, the wood density database contains 542 entries, representing 59 families and 243 species. The families were arranged according to number of entries in the database with Dipterocarpaceae having the most (187) entries (Table 1). Dipterocarps are valuable timber sources in the Philippines, providing 94% of the country's total volume of timber exports (PROSEA 1994). Important dipterocarp species in the Philippines are *Shorea negrosensis* (red lauan), *S. contorta* (white lauan) and *Dipterocarpus grandiflorus* (apitong). Other families with the most entries in the database that are also important timber groups are Leguminosae (39 entries), Meliaceae (38), Euphorbiaceae (19), Moraceae (16), Sapindaceae (15), Sterculiaceae (15), Anacardiaceae (14), Sapotaceae (14) and Ebenaceae (12).

The frequencies of wood density classes of the green, 12% and OD MC data sets are shown in Figure 1. The most frequent wood density values for the green and 12% MC data sets are the 0.4 to 0.6 classes. In contrast, the wood density values in the 0.5 to 0.7 classes are more dominant in the OD MC data set. The dominant wood density classes of the three data sets presented here are within the range of 0.4 to 0.8 reported in Reyes *et al.* (1992). This range represents the dominant classes of a much larger data set covering tree species from tropical regions of Asia, America and Africa. The patterns shown in Figure 1 reflect the bias of the literature sources used here for commercial and timber tree species, as also shown in Table 1. Increasing the number of samples to include other non-timber tree species in the future may reflect a more even distribution of wood density classes.

The mean wood density values for the green, 12% and OD MC volume conditions are 0.54, 0.60 and 0.64 g $cm^{-3}$ respectively (Table 2), and are comparable with global mean values of 0.57 g $cm^{-3}$ for tropical Asia, 0.50 g $cm^{-3}$ for tropical Africa and 0.60 g $cm^{-3}$ for tropical America (Reyes *et al.* 1992). Uhl *et al.* (1988) and Brown (1997) reported 0.71 g $cm^{-3}$ while Brown and Lugo (1984) obtained 0.62 g $cm^{-3}$ as global mean values for tropical forests. Further studies are needed for a more confident national mean wood density for Philippine tree species. This can be achieved by conducting an extensive wood density inventory to include all trees, whether commercial or not, taking note of wood density variation of the whole tree for a given species at a given site.

Various reports were consulted to provide the basic environmental characteristics describing the sites where the wood samples were taken. These include soil type (Fernandez & Clar de Jesus 1980), annual rainfall (PAGASA 2000) and agroclimatic zones (BSWM 1975). Wood density data were gathered from 54 different sites scattered across the country's main island groups of Luzon (32 entries), Mindanao (18 entries) and the Visayas (4 entries). The mean annual rainfall values for these three islands range from 1590 to 2700 mm. Soil types recorded are mostly of the clay loam, clay and loam types.

Generally, the sample sites fall under three different climatic zones, namely, moist zones with two to four dry months per year (23 sites), wet zones with less than two dry months per year (19 entries) and dry zones with five to six dry months per year (12 entries). The means of the green, 12% and OD MC values under various climatic types show that trees from dry zones have higher densities (Table 3). Similar results have been observed by Barajas-Morales (1987) in drier regions of Mexico, where tropical species produce wood of higher density. The results presented here may be insightful although not conclusive. However, site conditions do not exert a clear influence on wood density (Tsoumis 1991).

**Table 1** Botanical families represented in the database and number of entries (n) reported per family

| Family | n | Family | n |
|---|---|---|---|
| Dipterocarpaceae | 187 | Ulmaceae | 4 |
| Leguminosae | 39 | Apocynaceae | 3 |
| Meliaceae | 28 | Casuarinaceae | 3 |
| Euphorbiaceae | 19 | Magnoliaceae | 3 |
| Moraceae | 16 | Thymelaeaceae | 3 |
| Sapindaceae | 15 | Alangiaceae | 2 |
| Sterculiaceae | 15 | Betulaceae | 2 |
| Anacardiaceae | 14 | Cornaceae | 2 |
| Sapotaceae | 14 | Datiscaceae | 2 |
| Ebenaceae | 12 | Icacinaceae | 2 |
| Guttiferae | 10 | Lythraceae | 2 |
| Lauraceae | 10 | Polygalaceae | 2 |
| Myrtaceae | 10 | Rhamnaceae | 2 |
| Burseraceae | 8 | Theaceae | 2 |
| Combretaceae | 8 | Aceraceae | 1 |
| Lecythidaceae | 8 | Araliaceae | 1 |
| Podocarpaceae | 8 | Cunoniaceae | 1 |
| Verbenaceae | 8 | Elaeocarpaceae | 1 |
| Amygdalaceae | 7 | Flacourtiaceae | 1 |
| Annonaceae | 7 | Myrsinaceae | 1 |
| Araucariaceae | 6 | Nyctaginaceae | 1 |
| Fagaceae | 6 | Ochnaceae | 1 |
| Bombacaceae | 5 | Olacaceae | 1 |
| Dilleniaceae | 5 | Pittosporaceae | 1 |
| Pinaceae | 5 | Rhizophoraceae | 1 |
| Rubiaceae | 5 | Sabiaceae | 1 |
| Rutaceae | 5 | Sonneratiaceae | 1 |
| Tiliaceae | 5 | Staphyleaceae | 1 |
| Bignoniaceae | 4 | Taxaceae | 1 |
| Malvaceae | 4 | Total species | 542 |

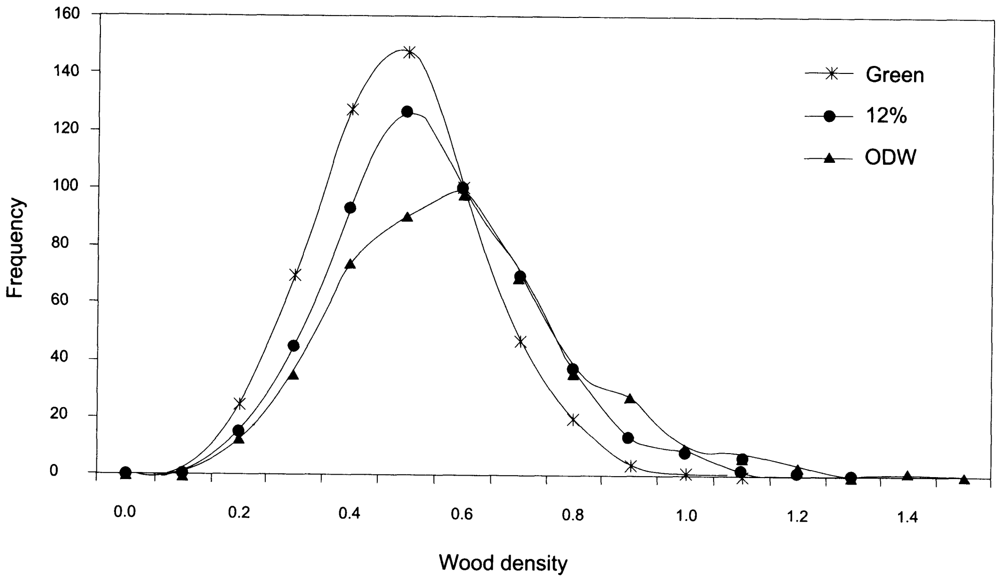


**Figure 1** Frequency distributions of database entries by relative density classes at various moisture content conditions (green, 12% and OD) of wood

**Table 2** Mean, standard deviation, range and number of entries of mean relative density values (g $cm^{-3}$) at various moisture content conditions

| Parameter | Mean relative density at various moisture contents | | |
|---|---|---|---|
| | Green | 12% | OD |
| Mean | 0.537 | 0.595 | 0.637 |
| Standard deviation | 0.144 | 0.172 | 0.199 |
| Minimum value | 0.204 | 0.211 | 0.216 |
| Maximum value | 1.043 | 1.255 | 1.452 |
| Count (n) | 542 | 516 | 468 |

**Table 3** Summary data showing number of samples (n) and mean relative density values (g $cm^{-3}$) at various moisture contents per climate type

| Climate type | n | Mean relative density at various moisture contents | | | Mean relative density per climate type |
|---|---|---|---|---|---|
| | | Green | 12% | OD | |
| Dry | 40 | 0.630 | 0.704 | 0.763 | 0.699 |
| Moist | 299 | 0.530 | 0.586 | 0.628 | 0.581 |
| Wet | 203 | 0.528 | 0.584 | 0.625 | 0.579 |

The information on wood density in the database can be used as an accessible index of wood quality. There is a direct relationship between density and other wood properties. Density affects wood shrinkage and swelling as well as the mechanical, thermal, acoustical and other properties related to wood processing (Tsoumis 1991). Density is also an important index of quantitative production that is of interest to the pulp, paper and fibre industries.

This paper has reviewed the current state of knowledge of wood density values for tropical tree species based on existing literature in the country. Although available data are not lacking, further research is needed to explain the effects of environmental factors on wood density. As most research on wood density in the Philippines has focused on commercial purposes, an inventory on wood density for use in biomass studies should be conducted to include all tree species. Protocols must be designed to account for variations in density values for more accurate and reliable tree biomass estimates.

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