Bulk Density (Scaling Factor) of 14 Hardwood Species in Arkansas

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Abstract

With the monetary exchange for hardwood trees and logs changing from log-scale board feet to tons, it is important that bulk density values (also called scaling factors) be developed to aid in determining the value of standing trees and logs. This study included 14 species of hardwoods and a total of 325 trees. Ten species were oak, which were divided into a red oak group (seven species) and a white oak group (three species). The red oak group had an average bulk density of 80.7 lb/ft^3, and the white oak group had an average bulk density of 79.2 lb/ft^3. A significant difference was found between the groups, as were significant differences between species within each group. Southern red oak (*Quercus falcate*) had the highest value (83.0 lb/ft^3), and white oak (*Quercus alba*) had the lowest (77.0 lb/ft^3). Three hickory types had an average bulk density of 79.4 lb/ft^3. Sweetgum (*Liquidambar styraciflua*) had a bulk density of 78.3 lb/ft^3.

In the Mid-South, timber has long been bought and sold by log scale, a method of estimating the board feet of lumber that can be sawn from the tree or log. Today, however, timber in the Mid-South is often bought and sold by the ton (2,000 lb). Timber Mart-South (2011) reported the average delivered price for the first quarter of 2011 in Arkansas was \$51.86/ton for oak sawtimber and \$37.43/ton for mixed hardwood sawtimber. Guides have been published to aid landowners and procurement personnel in estimating the weight of the merchantable portion of both loblolly pine (*Pinus taeda*; Patterson and Doruska 2007) and hardwood (Patterson and Doruska 2008) standing trees.

Another value that aids mill managers is bulk density (sometimes called scaling factor), which is the green log outside-bark weight divided by the inside-bark volume. Numerous bulk density studies have been conducted on various species, such as southern pine (*Pinus* sp.; Patterson and Clark 1988); yellow poplar (*Liriodendron tulipifera*; Patterson and Clark 1992); red pine (*Pinus resinosa*), northern red oak (*Quercus rubra*), and yellow poplar (Patterson and Wiant 1993); bottomland hardwoods (Lenhart et al. 1995); mature loblolly pine (Patterson et al. 2004); and loblolly pine pulpwood (Patterson and Doruska 2005).

Most mill managers know their mill's Lumber Recovery Factor (LRF), which is an indication of the mill's production efficiency. The LRF is calculated by dividing the board feet of lumber produced by the inside-bark cubic foot volume of the logs sawn. If the manager were to divide bulk density by the mill's LRF, the resulting number would be the number of pounds of green, unbarked log required to produce a board foot of lumber. Because of the removal of bark, slabs, edging, end trim, and sawdust during production, the weight of the required log is usually at least twice the weight of the resulting boards (Patterson and Zinn 1990). If the pounds of log per board foot value were divided into the weight of a load of logs, the resulting number of board feet would be a fair estimate of the lumber that would be produced by that mill from the load of logs. The resulting estimate would be mill specific, because it was based on that mill's LRF.

The goals of this study were to determine the bulk density values of the major hardwood species harvested in the study area and to determine if a significant difference existed in bulk density by species.

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Procedures

The data were collected with the aid and assistance of loggers, because loggers had equipment of sufficient size to lift the large hardwood logs involved in the study. Some of the hardwood species sampled grow mainly in the bottomlands, which are inaccessible during wet weather; therefore, the data were collected during the summer and early fall months over several years. Also, elevation greatly influences the species mix of a stand of timber. Arkansas contains both upland and bottomland hardwood forests. Species composition of the two forest types differ based on site conditions and elevation. Species composition of bottomland hardwood forests is particularly sensitive to microsite elevation; changes in elevation as small as 1 to 2 feet can lead to different species composition (Tennant 1989). The hydrologic regimes resulting from those slight differences in elevation lead to very different soil conditions and species composition (Taylor et al. 1990). Taylor et al. (1990) describe a series of six zones to differentiate the hydrologic regimes (Mitsch and Gosselink 1986) and resulting soil conditions (Wharton et al. 1982) of bottomland hardwood forests based on the frequency and nature of flooding events.

To obtain the data size and species mix desired for this study, eight sites were visited: five in southern Arkansas and three in northern Arkansas (Fig. 1). The southern sites consisted of two sites on the Felsenthal National Wildlife Refuge that were 2 miles apart, one site east of the city of Hamburg, one site northeast of the city of Warren, and one site south of the town of New Edinburg. The northern sites were located in the Boston Mountains of the Ozark National Forest, south of the town of Dennard, and southeast of the city of Batesville. In all, 325 trees were included in the study.

The tree data of the red oak group (southern red oak [*Quercus falcate*], northern red oak [*Q. rubra*], cherrybark oak [*Q. falcate* var. *pagodaefolia*], black oak [*Q. velutina*], nuttall oak [*Q. nuttallii*], water oak [*Q. nigra*], and willow oak [*Q. phellos*]) are shown in Table 1. The tree data of the white oak group (overcup oak [*Q. lyrata*], post oak [*Q. stellata*], and white oak [*Q. alba*]) are shown in Table 2. The tree data of the miscellaneous group (mockernut hickory [*Carya tomentosa*], shagbark hickory [*C. ovata*], bitter pecan [*C. aquatica*], and sweetgum [*Liquidambar styraciflua*]) are shown in Table 3.

The research team entered each site ahead of the logger to select the study trees from that site. Species, diameter at breast height (DBH), and total height were recorded for each tree. The trees were painted with many bands of different colors and numbered so that the resulting merchantable log could be identified at the landing after felling and skidding.

At the landing, diameter measurements were taken with calipers. Because of the curve of the butt swell, diameter measurements need to be taken at smaller intervals in that area. Therefore, diameter measurements were taken at the butt and in 1-foot intervals up to and including 8 feet and then in 3-foot intervals to the top. At each point, two diameter measurements were taken 90° apart, and the recorded value was the average of the two measurements. A bark gauge was used to determine bark thickness at various intervals along the length, and the total length of the merchantable log was also recorded. For oak and sweetgum, the bark measurements were taken at the butt, at 4 and 8 feet, and then every 9 feet thereafter. Because of the nature

Figure 1.—Map of the state of Arkansas showing the locations of the study sites.

Table 1.—Summer bulk density values for trees of the red oak group as well as diameter at breast height (DBH) and total height.

Species	Sample size	No. of sites	DBH, mean (range) (in.)	Total height, mean (range) (ft)	Bulk density, mean (SD) (lb/ft^3)
Southern red oak (*Quercus falcate*)	19	2	18.0 (12.7–26.1)	78 (62–105)	83.0 (4.26)
Black oak (*Quercus velutina*)	20	3	16.6 (12.1–29.4)	69 (52–85)	81.9 (3.06)
Northern red oak (*Quercus rubra*)	24	3	19.7 (12.5–30.1)	79 (63–96)	81.6 (3.92)
Willow oak (*Quercus phellos*)	25	2	18.1 (11.7–27.7)	87 (60–120)	80.5 (4.07)
Nuttall oak (*Quercus nuttallii*)	24	2	18.0 (12.5–25.1)	90 (52–106)	80.3 (4.81)
Cherrybark oak (*Quercus falcate* var. *pagodaefolia*)	20	2	18.7 (12.1–29.4)	86 (71–113)	80.0 (2.98)
Water oak (*Quercus nigra*)	24	2	22.2 (15.3–34.0)	92 (68–113)	79.0 (5.59)

Table 2.—Summer bulk density values for trees of the white oak group as well as diameter at breast height (DBH) and total height.

Species	Sample size	No. of sites	DBH, mean (range) (in.)	Total height, mean (range) (ft)	Bulk density, mean (SD) (lb/ft^3)
Post oak (*Quercus stellata*)	20	1	17.7 (14.1–24.0)	68 (56–80)	82.5 (4.49)
Overcup oak (*Quercus lyrata*)	25	2	17.4 (11.8–25.5)	85 (66–105)	80.1 (5.61)
White oak (*Quercus alba*)	40	2	21.4 (12.4–36.4)	92 (71–123)	77.0 (5.50)

Table 3.—Summer bulk density values for miscellaneous trees as well as diameter at breast height (DBH) and total height.

Species	Sample size	No. of sites	DBH, mean (range) (in.)	Total height, mean (range) (ft)	Bulk density, mean (SD) (lb/ft^3)
Mockernut hickory (*Carya tomentosa*)	18	1	18.5 (15.1–24.3)	94 (72–120)	81.5 (3.58)
Shagbark hickory (*Carya ovata*)	12	2	17.4 (14.5–20.8)	83 (62–104)	79.3 (4.74)
Bitter pecan (*Carya aquatica*)	21	2	17.0 (13.1–21.3)	73 (52–89)	77.6 (2.31)
Sweetgum (*Liquidambar styraciflua*)	33	2	16.4 (11.5–21.6)	92 (63–110)	78.3 (4.69)

of hickory bark, bark gauges become inoperable quickly; therefore, measurements were taken at the ends and at two places along the length. The location of the mid-log measurements depended on log length. The weight of the log was obtained using crane-type load cell scales with a maximum capacity of 10,000 pounds, with readings accurate to within 1 pound. The scales were chained to the log loader, with two chains attached to the scales' hook; at the end of chains were large log tongs. The log tongs were attached to the log, and the loader lifted the log free of the ground. If the log was too large for the scales, a merchantable log was cut from the butt end, and each part was weighed separately. It was felt that the loss of one chainsaw kerf would not reduce the log weight significantly.

The inside-bark diameters were calculated by subtracting two bark thicknesses from the outside-bark measurements. The volume of each segment between diameter measurements was estimated using Smalian's equation, and the volume of the log was the sum of the segment volumes. Therefore, the bulk density is the weight of the log in pounds divided by the inside-bark volume of the log in cubic feet.

For determining differences between species within a species group, Tukey's studentized range tests were used, with an alpha of 0.05. Tukey's test controls the Type I experimentwise error. Regression analyses were conducted on each species and species group to determine if any correlation existed between DBH and bulk density. From looking at each species' spreadsheet, it was clear that the bulk density values were not different by site location. When bulk density values for each species were sorted in ascending order, the values from one site location were thoroughly interspersed with the values from the other site location. The data were collected from July through September over several years. Patterson and Doruska (2005) have stated that the bulk density value for pine during these months was the mean for the year. Normally, the bottomlands are too wet to harvest hardwoods during the fall, winter, and spring. Therefore, to operate during the wet months, sawmills stock pile logs during the summer and keep them under water spray.

Results and Discussion

Mean bulk density and standard deviation (SD) values for the species in the red oak group are shown in Table 1. The mean bulk density for the red oak group was 80.7 lb/ft^3. Statistical analysis indicated that the bulk density for water oak was significantly lower than the bulk densities for southern red oak, northern red oak, and black oak.

Mean bulk density and SD values for the species in the white oak group are shown in Table 2. The mean bulk density for the white oak group was 79.2 lb/ft^3. Statistical results indicated that the white oak value was significantly lower than the post oak value.

The difference between the mean red oak group bulk density and the mean white oak group bulk density was 1.5 lb/ft^3. Tukey's test indicated that the white oak value was significantly lower than the red oak value.

Mean bulk density and SD values for the species in the miscellaneous group are shown in Table 3. In this group, three species are in the hickory family, and their mean bulk density was 79.4 lb/ft^3. Analysis indicated that the bitter pecan value was significantly lower than the mockernut hickory value. The other species in the miscellaneous group was sweetgum, which had a mean bulk density of 78.3 lb/ft^3.

Numerous regressions were conducted to see if a correlation existed between tree diameter and bulk density.

The results were mixed. A few species showed a positive correlation, meaning that as DBH increased, so did bulk density; however, most species and species groupings showed a negative correlation, meaning that as DBH increased, bulk density decreased somewhat. Most correlation coefficients (R) were approximately −0.25. The slopes of the regression lines were fairly shallow.

An example of how this information can be used is as follows: A sawmill manager knows that the mill has an LRF of 6.4 board feet per cubic foot of log input. A truckload of ‘‘red oak’’ logs weighing 24.3 tons is coming to the mill. Knowing the elevation of the timber stand, the manager assumes that the load is a mix of water oak and cherrybark oak and so uses a bulk density value of 79.5 lb/ft^3. By dividing the bulk density by the LRF, the manager arrives at a value of 12.4 pounds per board foot. By dividing that value into the weight of the logs in pounds, the manager estimates that approximately 3,900 board feet of lumber will be cut from that load.

Conclusions

The merchantable portion of 325 trees was measured and weighed to determine bulk density values. Fourteen species were involved, and of those studied, southern red oak had the highest bulk density value (83.0 lb/ft^3) and white oak the lowest (77.0 lb/ft^3). If two truckloads of logs had the same-size logs and the same total log weight but one had southern red oak logs and the other white oak logs, the white oak load would have more logs and would produce more lumber than the southern red oak load. For mill managers to make the best financial decisions when buying logs and timber, they need to utilize all of the information available, which includes the mill’s LRF, the species entering the mill, and the bulk density values of those species.

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