ESTIMATING TOP WEIGHTS OF HARDWOOD SAWTIMBER

by Jeffrey L. Wartluft

FOREST SERVICE RESEARCH PAPER NE-427
1978
FOREST SERVICE, U. S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

The Author

JEFFREY L. WARTLUFT earned a bachelor of arts degree in 1965 from Thiel College and a master of forestry degree in 1965 from Duke University. He spent 2 years teaching in the Industrial Forestry Department of a Chilean technical university as a Peace Corps volunteer. For 10 years he has conducted research on markets for forest and mill residues at the Forestry Sciences Laboratory at Princeton, West Virginia.

MANUSCRIPT RECEIVED FOR PUBLICATION 10 JULY 1978

Abstract

For a more efficient use of the hardwood forest resource, tables were developed for estimating the weight of sawtimber tops, a major portion of logging residue. Regressions were developed for green and dry total treetop weight and treetop weight in material greater than 3 inches dob (diameter outside bark) for each of three species groups: soft hardwoods, hard hardwoods, and mixed hardwoods. Estimates of treetop weights (green) ranged from 763 pounds for an 11-inch dbh (diameter at breast height) tree to 4,165 pounds for a 26-inch dbh tree. Moisture content averaged 62 percent (oven-dry basis), and the average percent bark (green-weight basis) was 23.

THE CONCERN

AN INCREASING DEMAND for wood products from our relatively stable forest resource combined with public pressure to improve our forest land esthetically, has made it necessary for forest managers and wood processors to utilize more of the wood from harvested trees. Logging residues, generally overlooked as potential raw material, comprise a significant part of the unused forest resource. For example, Craft (1976) found that total residue weight was 1.8 times the weight of sawlogs removed. His study also showed the potential usefulness of the residues. These residues yielded 4,700 board feet of sawed products and 52 tons of chips per acre.

The development of strategies for using logging residues requires methods for making low-cost estimates of the amounts available. Since much of the potentially useful residue is in small branches, weight is the most practical measurement. Chips made from this material are sold on a weight basis, too. Published information provides weight estimates for whole trees (less than 10 inches dbh) left in clearcuts or damaged during logging (Phillips 1977, Wartluft 1977, Wiant et al. 1977), and weight estimates of material left at woods landings (Goho 1976). But for sawtimber tops—the other major portion of logging residue—estimates are available for only one species, black oak (King and Schnell 1972). This report provides a practical method for estimating sawtimber top weights for the major Appalachian hardwoods under any harvesting situation.

PROCEDURE

We conducted the field work for this study on three oak-hickory sawtimber logging operations in southern West Virginia and southwestern Virginia. Red oak site indexes for the three stands were 50, 60, and 80.

In each stand, we selected the sawtimber tree closest to each intersection on a two-chain grid. A total of 75 hardwood trees of nine commercially important Appalachian species were included in the sample (Table 4). For each sample tree, we recorded tree number, species, dbh to the nearest 1/10 inch, and total tree height to the nearest foot. The commercial logger felled, bucked, and topped the sample trees before logging.

After the tops (including limbs below the tops) were on the ground, we cut them into manageable pieces and weighed them to the nearest 5 pounds with a 500-pound capacity, straight-spring scale (Fig. 1). Weights were recorded separately for two kinds of material: (1) pieces greater than 3 inches dob, and (2) pieces equal to or less than 3 inches dob.

To determine moisture content and percent bark, we cut a sample disk at random from each size portion of each top (two disks per tree).

Figure 1. Weighing treetop residue in the woods with lightweight portable equipment.

ANALYSIS

To arrive at equations for predicting sawtimber top weights from available tree measurements and characteristics, we had to account for known variations that affect weight: species, tree size (dbh and total tree height), moisture content, tree portion (≤ 3 inches dob, >3 inches dob, and leaves), site, and operator (logger).

Sample trees came from three different locations, each logged by different commercial loggers. Therefore the site and operator variables were confounded, which made it impossible to isolate the individual effects. Thus the data on these variables were pooled.

Published information on leaf weights is scarce, but indications are that less than 3 percent of treetop weight is in leaves (King and Schnell 1972). To some extent, the effect of leaves was averaged out as we weighed some trees with leaves and some without. However, we did not consider leaf weight in our prediction equations.

Since we chose our trees at random, several species were represented by one or only a few samples. Therefore, we grouped the data in two categories according to the specific gravities of species, which were based on weight when oven dry and volume when green (U. S. Department of Agriculture 1974). Specific gravities for the soft hardwoods (yellow-popular, cucumbertree, and blackgum) ranged from .40 to .46; the hard hardwoods (white ash, hard maple, hickory, and all oaks) ranged from .55 to .66. We developed separate equations for these two species groups, and one for all hardwoods combined.

We accounted for the effects of moisture content and tree portion by developing separate regressions for green and oven-dry material and for different tree portions.

Results from a series of regression analyses and stepwise regressions indicated that total tree height made no significant contribution to the equations as long as dbh (or a function thereof) was included. Therefore, total tree height was eliminated as a variable.

This left us with dbh as the best predictor for use in the regressions. Dbh is a very practical predictor since it is also used in estimating board-foot volumes in the sawlog portions of the trees.

Plots of treetop weights versus dbh showed that the variance of the weight was not homogeneous. Therefore we tried a number of transformations of the weight to get homogeneous variance. We achieved this with the logarithm of the top weights, and found that a single linear function of dbh gave us the best fit. We developed regressions for green and dry total treetop weight and treetop weight in material greater than 3 inches for each of the three species groups, which made a total of 12 separate regressions (Table 1). From these, we constructed Tables 2 and 3 of treetop weights with corresponding 95 percent confidence intervals for mean estimates for sawtimber with a dbh range of 11 to 26 inches. Table values for the material less than or equal to 3 inches were calculated by subtracting the greater-than-3-inch regression estimates from the total regression estimates. We calculated moisture contents on an oven-dry basis, and bark percentages on a green-weight basis (Table 4).

RESULTS

All regression equations for estimating sawtimber top weights are of the general form: $\ln w = b_0 + b_1 dbh$ (Table 1).

Estimates of sawtimber top green weight ranged from 763 pounds for an 11-inch dbh tree to 4,165 pounds for a 26-inch dbh tree (Table 2); estimates of oven-dry weight ranged from 449 to 2,609 pounds (Table 3). The percent of treetop weight in material greater than 3 inches dob steadily increased from 56 percent to 75 percent as dbh increased from 11 to 26 inches.

Moisture content averaged 62 percent (Table 4). Hard hardwoods had a lower moisture content, 59 percent, than soft hardwoods, 81 percent.

The average percent bark was 23 (Table 4). The 3-inch or smaller material averaged 27 percent, and the material larger than 3 inches averaged 20 percent bark. Soft hardwoods, with an average of

Table 1.—Regression statistics for equations[a] developed in the study (all equations are highly significant)

w (pounds)	b_0	b_1	S.E.	r^2
Soft hardwoods				
Total treetop green weight	5.122	0.1090	0.400	0.51
Total treetop oven-dry weight	4.530	.1092	.379	.53
>3 inch treetop green weight	4.320	.1300	.458	.53
>3 inch treetop oven-dry weight	3.746	.1301	.432	.56
Hard hardwoods				
Total treetop green weight	5.506	.1129	.345	.70
Total treetop oven-dry weight	4.951	.1174	.348	.71
>3 inch treetop green weight	4.700	.1326	.402	.70
>3 inch treetop oven-dry weight	4.166	.1358	.403	.71
Mixed hardwoods				
Total treetop green weight	5.392	.1132	.404	.60
Total treetop oven-dry weight	4.818	.1173	.428	.59
>3 inch treetop green weight	4.590	.1331	.450	.63
>3 inch treetop oven-dry weight	4.038	.1360	.463	.62

[a] All equations are of the form: $\ln w = b_0 + b_1 dbh$, where dbh is diameter at breast height in inches and ln is the natural logarithm function.

Table 2.—Treetop green weights[a] for Appalachian hardwood sawtimber, by dbh class, in pounds[b]

Tree dbh class (inches)[c]	Mixed hardwoods			Hard hardwoods			Soft hardwoods		
	≤3″	>3″	Total	≤3″	>3″	Total	≤3″	>3″	Total
11	337	426 (1.22)	763 (1.19)	379	473 (1.22)	852 (1.18)	241	314 (1.65)	556 (1.54)
12	368	486 (1.19)	854 (1.17)	414	540 (1.19)	954 (1.16)	262	358 (1.55)	620 (1.47)
13	401	555 (1.17)	956 (1.15)	451	617 (1.17)	1068 (1.15)	283	408 (1.47)	691 (1.40)
14	436	634 (1.15)	1071 (1.13)	491	704 (1.15)	1195 (1.13)	306	464 (1.40)	771 (1.34)
15	474	725 (1.13)	1199 (1.12)	534	804 (1.14)	1338 (1.12)	331	529 (1.34)	859 (1.29)
16	515	828 (1.12)	1343 (1.11)	580	918 (1.12)	1498 (1.11)	356	602 (1.29)	958 (1.25)
17	558	946 (1.11)	1504 (1.10)	629	1048 (1.12)	1677 (1.10)	383	686 (1.26)	1069 (1.23)
18	604	1080 (1.11)	1684 (1.10)	681	1197 (1.11)	1878 (1.10)	411	781 (1.26)	1192 (1.22)
19	652	1234 (1.11)	1886 (1.10)	736	1366 (1.12)	2102 (1.10)	439	890 (1.28)	1329 (1.24)
20	702	1410 (1.12)	2112 (1.11)	793	1560 (1.12)	2353 (1.11)	469	1013 (1.31)	1482 (1.27)
21	754	1611 (1.14)	2365 (1.12)	853	1782 (1.14)	2635 (1.12)	499	1154 (1.37)	1653 (1.31)
22	808	1840 (1.15)	2648 (1.14)	915	2034 (1.15)	2949 (1.13)	529	1314 (1.43)	1843 (1.37)
23	864	2102 (1.17)	2966 (1.16)	979	2323 (1.17)	3302 (1.15)	558	1497 (1.51)	2055 (1.43)
24	920	2401 (1.20)	3321 (1.18)	1044	2652 (1.20)	3697 (1.17)	587	1705 (1.60)	2292 (1.51)
25	976	2743 (1.22)	3719 (1.20)	1110	3029 (1.22)	4138 (1.18)	614	1941 (1.69)	2556 (1.58)
26	1032	3133 (1.25)	4165 (1.22)	1175	3458 (1.24)	4633 (1.21)	639	2211 (1.80)	2850 (1.67)

[a] Weights in pounds with 95 percent confidence factors in parentheses for mean estimates. For the upper confidence limit, multiply the mean estimate by the factor. For the lower confidence limit, divide the mean estimate by the factor. Corresponding portions may not add due to rounding.
[b] To convert to kilograms, multiply by 0.454.
[c] To convert to millimeters, multiply by 25.4.

Table 3.—Treetop oven-dry weights[a] for Appalachian hardwood sawtimber, by dbh class, in pounds[b]

Tree dbh class (inches)[c]	Mixed hardwoods			Hard hardwoods			Soft hardwoods		
	≤3″	>3″	Total	≤3″	>3″	Total	≤3″	>3″	Total
11	196	253 (1.22)	449 (1.20)	227	287 (1.22)	514 (1.18)	131	177 (1.60)	308 (1.51)
12	215	290 (1.20)	505 (1.18)	249	329 (1.19)	578 (1.16)	142	202 (1.52)	344 (1.44)
13	236	332 (1.18)	568 (1.16)	273	377 (1.17)	650 (1.15)	154	230 (1.44)	384 (1.38)
14	258	381 (1.16)	639 (1.14)	300	432 (1.15)	731 (1.13)	166	262 (1.37)	428 (1.32)
15	282	436 (1.14)	718 (1.13)	328	494 (1.14)	822 (1.12)	179	298 (1.32)	477 (1.27)
16	308	500 (1.12)	808 (1.11)	359	566 (1.12)	925 (1.11)	193	339 (1.27)	532 (1.24)
17	336	572 (1.12)	908 (1.11)	391	649 (1.12)	1040 (1.10)	207	387 (1.25)	594 (1.21)
18	365	656 (1.11)	1021 (1.10)	427	743 (1.11)	1170 (1.10)	222	440 (1.24)	662 (1.21)
19	397	751 (1.12)	1148 (1.11)	464	851 (1.12)	1316 (1.10)	237	502 (1.26)	739 (1.22)
20	430	861 (1.13)	1291 (1.12)	504	975 (1.13)	1479 (1.11)	253	571 (1.29)	824 (1.25)
21	466	986 (1.14)	1451 (1.13)	547	1117 (1.14)	1664 (1.12)	269	651 (1.34)	919 (1.30)
22	503	1130 (1.16)	1632 (1.15)	592	1280 (1.15)	1871 (1.13)	284	741 (1.40)	1025 (1.35)
23	541	1294 (1.18)	1835 (1.17)	639	1466 (1.17)	2104 (1.15)	300	844 (1.48)	1143 (1.41)
24	581	1483 (1.20)	2064 (1.19)	688	1679 (1.20)	2367 (1.17)	314	961 (1.56)	1275 (1.47)
25	622	1699 (1.23)	2320 (1.21)	738	1923 (1.22)	2661 (1.19)	328	1095 (1.64)	1423 (1.55)
26	663	1946 (1.26)	2609 (1.23)	790	2203 (1.24)	2993 (1.21)	340	1247 (1.74)	1587 (1.63)

[a] Weights in pounds with 95 percent confidence factors in parentheses for mean estimates. For the upper confidence limit, multiply the mean estimate by the factor. For the lower confidence limit, divide the mean estimate by the factor. Corresponding portions may not add due to rounding.

[b] To convert to kilograms, multiply by 0.454.

[c] To convert to millimeters, multiply by 25.4.

Table 4.—Weighted average moisture content and bark percentage, by species, species group, and treetop portion

Item	No. trees	Moisture content[a]	Bark[b]
		- - - Percent	- - -
Mixed (all) hardwoods	75	62	23
Parts greater than 3-inch diameter	75	63	20
Parts 3 inches or less in diameter	75	60	27
Hard hardwoods	57	59	22
Soft hardwoods	18	81	27
Red oak (*Quercus* spp.)	31	67	20
Chestnut oak (*Quercus prinus*)	16	55	25
Yellow-poplar (*Liriodendron tulipifera*)	14	81	28
White oak (*Quercus alba L.*)	6	48	22
Blackgum (*Nyssa sylvatica*)	3	89	24
Hickory (*Carya* spp.)	2	40	26
Cucumbertree (*Magnolia acuminata*)	1	53	26
Ash (*Fraxinus americana*)	1	49	19
Hard maple (*Acer saccharum*)	1	46	28

[a] Oven-dry basis. Weighted according to proportion of treetop weight represented.
[b] Green-weight basis. Weighted according to proportion of treetop weight represented.

27 percent bark, had more than the hard hardwoods at 22 percent.

USE OF RESULTS

A forest manager or logger can make a preharvest prediction or postlogging estimate of the weight left in the tops of hardwood sawtimber once the sawlogs are removed. Knowing the diameter distribution of sawtimber in the sale is all that he needs. The number of trees in each diameter class should be multiplied by the weight per tree shown in Tables 2 or 3. The estimates can be made in either green or oven-dry weights, and can include the entire tops or portions of tops. If the species distribution is also known, separate estimates can be made for hard hardwoods and soft hardwoods.

Suppose a forester wants to predict the total green weight that would be left in treetops after a sawtimber harvest.

The procedure is:

- Identify stand components (e.g., 22-inch dbh hard hardwoods, 18-inch dbh soft hardwoods, etc.)
- Find table value (Table 2) for each stand component (e.g., 22-inch dbh hard hardwoods = 2,949 pounds per top).
- For each stand component, multiply the estimated top weight from the table by the number of trees in that component (e.g., 2,949 pounds per treetop x 3 trees = 8,847 pounds).
- Sum the estimates for each stand component.

If the forester wants an estimate for only the material greater than 3 inches or only the material less than or equal to 3 inches, other columns in Table 2 or 3 are consulted. To determine how much wood fiber can be expected, Table 4 shows the deduction in weight for the percentage of bark. The original moisture contents in Table 4 can be used to estimate weights at any chosen moisture content.

A sensitivity analysis showed that even in the extreme case of a 5 percent error in dbh measurement, the resulting differences in weight estimates in all categories were well within the confidence limits. A more typical error of 3 percent in an 18-inch dbh hard hardwood would result in only a 6.1 percent difference in the total green top weight estimate.

Estimates of whole tree (above ground) weights for hardwood sawtimber can be made by use of these treetop weight estimates in conjunction with sawlog weight estimates presented by Timson (1972). For each tree, the dbh, species, and scaling diameter and length of each sawlog must be known to arrive at a whole tree weight estimate.

LITERATURE CITED

Craft, E. Paul.
1976. **Utilizing hardwood logging residue: A case study in the Appalachians.** U. S. Dep. Agri. For. Serv. Res. Note NE-230, 7 p.

Goho, Curtis D.
1976. **A study of logging residue at woods landings in Appalachia.** U. S. Dep. Agric. For. Serv. Res. Note NE-219, 4 p.

King, W. W., and Robert L. Schnell.
1972. **Biomass estimates of black oak tree components.** Tennessee Valley Authority Tech. Note B 1, 24 p.

Phillips, Douglas R.
1977. **Total-tree weights and volumes for understory hardwoods.** TAPPI 60(6):68-71.

Timson, Floyd G.
1972. **Sawlog weights for Appalachian hardwoods.** U. S. Dep. Agri. For. Serv. Res. Pap. NE-222, 29 p.

U. S. Department of Agriculture.
1974. **Wood handbook: Wood as an engineering material.** U. S. Dep. Agric. Agric. Handb. 72, rev. 415 p.

Wartluft, Jeffrey L.
1977. **Weights of small Appalachian hardwood trees and components.** U. S. Dep. Agric. For. Serv. Res. Pap. NE-366, 4 p.

Wiant, Harry V., Jr., Carter E. Sheetz, Andrew Colanino, James C. DeMoss, and Froylan Castaneda.
1977. **Tables and procedures for estimating weights of some Appalachian hardwoods.** W. Va. Univ. Agric. and For. Exp. Stn. Bull. 649T, 36 p.

ACKNOWLEDGMENT

The author thanks mathematician Ken Whitenack for his contribution to this study.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978— 703-112:63

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania.
- Warren, Pennsylvania.