Total Tree and Its Utilization in The Southern United States

Alexander Clark III

Abstract

Using summaries of data abstracted from other studies, equations for predicting the dry weight of wood and bark in the main stem and crown were developed for red oak, yellow-poplar, and the four major species of southern pine. The equations are used to show, for various methods of harvesting, what proportion of wood and bark is removed and what proportion is left as logging residue. In sawtimber pines and excurrent hardwoods such as yellow-poplar, 85 to 90 percent of all above-stump wood is harvested if the main stem is logged to a 4-inch (10-cm) top; however, in sawtimber deliquescent hardwoods such as oak, logging to a 4-inch top removes only 74 to 80 percent of above-stump wood. When harvesting pulpwood trees and sawtimber deliquescent hardwoods, chipping the total tree above the stump can significantly increase wood yields, compared to logging to a 4-inch top. In plantation pine, logging the stump and taproot as well as the main stem increases wood yields by 20 to 25 percent.

INCREASING DEMANDS for wood, escalating costs, and the energy shortage have forced the wood industry in the southern United States to consider the total tree as a potential source of wood and wood fiber. The concept of utilizing the total tree was an isolated idea 40 years ago (6) but started to receive interest and economic consideration in the 1950s. In 1957, Sproull, Parker, and Belvin (16) examined the general economics of whole-tree harvesting of southern pines and estimated that this practice could increase pulp yields by 30 to 40 percent. In 1964, Youngs (22) introduced the complete-tree concept, which he defined as the biological and technological investigation and utilization of the entire tree from root tips to leaf hairs. During the late 1960s and 1970s the utilization of the whole tree was promoted by several investigators (9, 10, 14, 20, 21), and a comprehensive review of the literature was conducted by Keays (11) in 1971. The whole-tree harvesting concept was first applied on a large scale using mobile whole-tree chippers, feller bunchers, and grapple skidders in 1971 (20). Since then, the number of mobile tree chippers sold to wood-using industries has increased to over 480 with most of the chippers used in whole-tree harvesting operations (15).

The literature indicates that there is significant variation in the amount of additional fiber recovered when trees are harvested under the whole-tree concept (2, 8, 13, 14). Keays (7) reports that full-forest harvesting can increase biomass yields by 30 to 300 percent over

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TABLE 1. — *Means and ranges of tree measurements, by species and location.*

Species	Location	Trees sampled (No.)	DBH (in.) Avg.	DBH (in.) Range	Total height (ft.) Avg.	Total height (ft.) Range	Age (yr.) Avg.	Age (yr.) Range
			NATURAL PINE					
Loblolly	Talladega NF, Ala.	41	13.9	5.6-20.4	83	48-107	42	37- 47
Loblolly	Francis-Marion NF, S.C.	25	15.4	5.6-24.0	87	57-102	58	30- 95
Loblolly	Sumter NF, N.C.	30	11.0	5.6-16.4	66	50- 90	28	22- 36
Shortleaf	Holly Springs NF. Miss.	34	12.3	6.1-19.7	72	48- 87	70	28-110
Slash	Conecuh NF, Ala.	43	12.9	6.0-21.0	73	47- 99	51	28- 68
Longleaf	Conecuh, NF, Ala.	47	13.2	5.9-18.9	80	56- 97	53	32- 69
ALL NATURAL PINE		220	13.1	5.6-24.0	77	47-107	52	22-110
			PLANTATION PINE					
Loblolly	Polk Co., Ga.	20	7.1	3.8-10.0	45	32- 53	18	
Loblolly	Polk Co., Ga.	20	9.1	5.9-12.5	56	46- 63	18	
Slash	Calhoun Co., Fla.	22	9.0	5.7-12.5	64	44- 74	17	
ALL PLANTATION PINE		62	8.4	3.8-12.5	55	32- 74	18	
			NATURAL HARDWOODS					
Yellow-poplar	Pisgah, NF., N.C.	39	13.9	5.8-28.4	99	53-147	56	21- 81
Yellow-poplar	Oconee NF., Ga.	26	13.5	5.5-20.3	84	58-107	60	37- 96
Sweetgum	Oconee NF., Ga.	24	13.1	5.7-20.7	82	48-101	51	32- 79
N. red oak	Pisgah, NF., N.C.	36	8.6	5.9-11.3	71	53- 86	49	35- 55
N. red oak	Pisgah, NF., N.C.	35	17.6	4.7-24.7	97	67-118	76	53-114
White oak	Oconee, NF., Ga.	23	12.8	5.6-20.9	71	47- 92	56	37- 80

conventional merchantable bole harvesting depending on the species, stand density, and site harvested. The purpose of this paper is to discuss the increase in wood and bark utilization that is achieved by whole-tree chipping southern pines and hardwoods, compared to harvesting stems to a 4-inch (10 cm)[1] top. The paper also shows what proportion of wood and bark in the tree is harvested and what proportion is left as logging residue when southern species are logged to other merchantable limits.

Procedure

To evaluate the timber resource in the southern United States, foresters have conducted studies of the four major species of southern pine—loblolly (*Pinus taeda* L.), slash (*P. elliottii* Engelm.), shortleaf (*P. echinata* Mill.), and longleaf (*P. palustris* Mill.) — as well as northern red oak (*Quercus rubra* L.), white oak (*Q. alba* L.), yellow-poplar (*Liriodendron tulipifera* L.), and sweetgum (*Liquidambar sytraciflua* L.)[2] (3, 5, 17, 18, 19) (Table 1). The objective of these studies was to develop equations for estimating the green volume of the total tree and tree components and the green and dry weight. This paper summarizes the data in these papers to show what proportion of the tree is harvested by various harvesting methods. During the collection of these data, the entire above-stump portion of the tree including stem, branches, and foliage (and in some cases, the stump and taproot) was measured and weighed. The saw log and pulpwood portions of the stem, roots, and crown were subsampled to determine the amount of wood, bark, water, and foliage present in each component.

Simple linear regression equations, using diameter breast height (DBH) and total height as independent variables, were developed from the data to predict dry weight of the total tree and tree components for each species. The form of the equations was:

$$Y = b_0 + b_1(D^2Th)$$

where: Y = ovendry (OD) weight (lb.)
D = diameter breast height (in.)
Th = total tree height (ft.).

The equations accounted for 70 to 99 percent of the variation in dry weight of the total tree and tree components. Using these equations, this paper shows what proportion of the wood in a tree can be harvested and what proportion would be left as logging residue when the species sampled are logged to the merchantable limits generally used by the wood industry in the southern United States. The merchantable limits used in this paper are not always met on all timber sales, but the data show what proportion of the total tree is utilized when trees are logged to these limits.

The data on the four species of southern pine growing in natural stands indicate that, although these species differ significantly in weight per cubic foot, similar-size trees growing in closed stands have basically the same proportion of wood, bark, and needles, regardless of species (4). Therefore, in this paper, the data on the four species of pine sampled in natural stands have been combined; the data on plantation-grown loblolly and slash pine have also been combined. In this paper the terms *total tree* or *whole tree* refer to all portions of the tree above the stump[3], and therefore exclude roots and stump.

[1]2.54 cm = 1 in. and 0.305 m = 1 ft.

[2]Articles on predicting total-tree biomass of plantation-grown southern pine, red oak, white oak, and sweetgum are in preparation by Clark and coauthors.

[3]Stump height is 0.5 foot for pulpwood-size trees, and 1.0 foot for sawtimber-size trees.

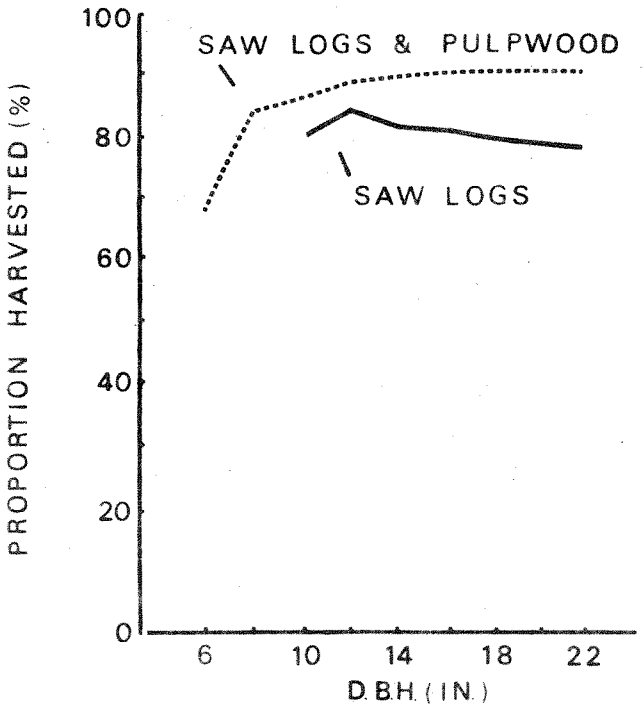

Figure 1. — Proportion of total-tree wood (above stump) harvested when saw logs of natural southern pine are logged to a 6-inch or merchantable top, compared to logging saw logs and pulpwood to a 4-inch top.

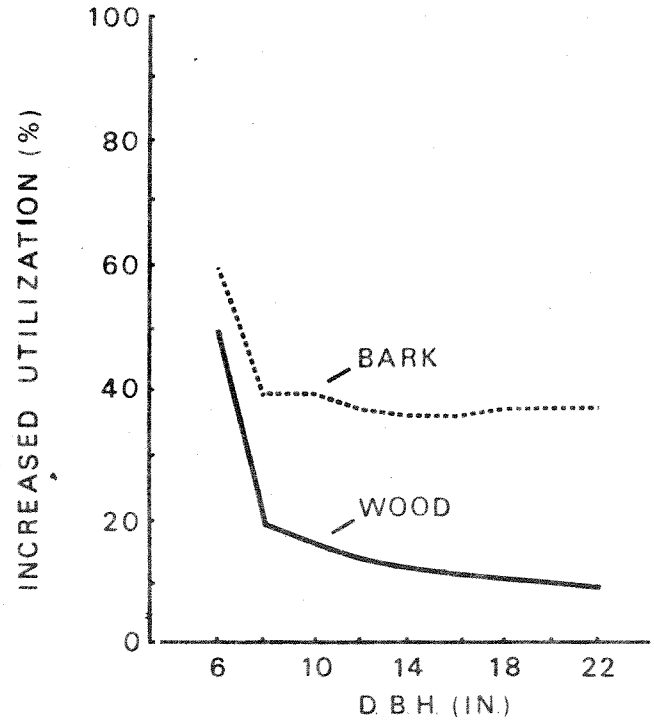

Figure 2. — Percent increase in natural southern pine wood and bark harvested when whole-tree chipping is compared to logging the stem to a 4-inch top.

Results and Discussions

Natural stands of southern pine are currently logged either by removing only saw logs to a 6-inch diameter inside bark (DIB) or merchantable top, or by tree-length logging the entire stem saw logs, and pulpwood to a 4-inch DIB top. Figure 1 shows the proportion of above-stump wood harvested when logging saw logs and pulpwood. When only saw logs are harvested, the average proportion of total-tree wood (above the stump) that can be utilized ranges from 80 percent (for 10-in. trees) to 84 percent (for 12-in. trees), and then decreases as tree size increases. This decrease occurs because a larger proportion of the larger trees is in crown material, and large knots and branches prevent the upper stem from being merchantable. When both saw logs and pulpwood are tree-length logged to a 4-inch top, 67 to 86 percent of all the above-stump wood in pulpwood-size trees (trees 5.0 - 8.9 in. DBH) is utilized, and 85 to 90 percent of all wood in sawtimber-size trees (trees ≥9.0 in. DBH) is utilized.

When natural pine stems are logged to a 4-inch DIB top, 89 percent of the material harvested is wood, and 11 percent is bark. The branches and topwood left in the woods as logging residue will contain, on the average, only 59 percent of their weight in wood, 19 percent in bark, and 22 percent in needles.

Currently some pulp companies are either chipping the entire tree above the stump or removing saw log and veneer material at the landing and chipping the upper stem and crown with whole-tree chippers. Figure 2 shows the percent increase in wood and bark harvested when the total tree above the stump is chipped, compared to tree-length logging the stem to a 4-inch top. In natural pine, whole-tree chipping significantly increases the amount of bark harvested, compared to the increase in amount of wood harvested. Compared to logging trees to a 4-inch top, whole-tree chipping produces an 18 to 50 percent increase in wood utilization for trees of pulpwood size, and an increase of 10 to 15 percent for trees of sawtimber size. Chipping the total tree above the stump increases the amount of bark harvested by 40 to 60 percent in trees of pulpwood size and by about 40 percent in trees of sawtimber size.

The percent increase in bark harvested is nearly twice that of wood because wood and bark are not equally distributed among tree components (Table 2). The stem of a pine tree contains 81 to 91 percent of the above-stump wood in a tree but only 68 to 73 percent of the above-stump bark. In comparison, branches of a

TABLE 2. — *Distribution of total-tree wood and bark in stem[a] and crown of southern pines.*

DBH[b] class (in.)	Proportion of wood		Proportion of bark	
	Stem (%)	Crown (%)	Stem (%)	Crown (%)
6	81	19	68	32
8	84	16	72	28
10	86	14	72	28
12	88	12	73	27
14	89	11	73	27
16	90	10	73	27
18	90	10	73	27
20	91	9	73	27
All classes	87	13	72	28

[a]Stump to 4-inch inside bark diameter.
[b]DBH=diameter at breast height.

TABLE 3. — *Proportion of total-tree wood and bark in crown material of red oak and yellow-poplar.*

DBH* class (in.)	Proportion of tree wood in crown		Proportion of tree bark in crown	
	Yellow-poplar (%)	Red oak (%)	Yellow-poplar (%)	Red oak (%)
6	35	30	39	38
8	23	23	27	35
10	16	21	20	31
12	11	20	16	32
14	8	23	13	35
16	8	24	13	37
18	8	25	13	38
20	9	25	14	39
22	10	26	14	40
24	11	26	15	40
All classes	14	24	18	33

*DBH=diameter at breast height.

significant difference is that yellow-poplars contain, on the average, only 14 percent of their wood and 18 percent of their bark in the crown compared to red oaks, which contain 24 percent of their wood and 33 percent of their bark in crown material (Table 3). If yellow-poplar or red oak are whole-tree chipped when foliage is absent, about 84 percent of the material chipped is wood and 16 percent is bark.

When trees are logged to top diameters larger than 4 inches, whole-tree chipping can increase wood yields even more than indicated. For example, if trees are logged only to a saw log top, whole-tree chipping can increase wood yields up to 45 percent for excurrent species and up to 65 percent for deliquescent species.

Summary

Based on a review and analysis of several studies, it appears as though the wood industry in the southern United States can efficiently harvest a significant majority of the tree by logging to a 4-inch DIB top. Eighty-five to ninety percent of all above-stump wood in sawtimber-size pine and yellow-poplar and about 84 percent of all wood in plantation pine is harvested if the main stem is logged to a 4-inch top; however, this same method removes only 74 to 80 percent of the wood in sawtimber-size deliquescent trees such as red oak. For plantation southern pines, logging the stump and taproot in addition to the stem (to a 4-in. top) increases wood yields by 20 to 25 percent.

Whole-tree chipping increases wood yields most significantly when harvesting pulpwood-size trees and sawtimber-size deliquescent hardwoods. When whole-tree chipping is compared to logging the stem to a saw log top, whole-tree chipping can increase wood yields up to 45 percent for excurrent species and up to 65 percent for deliquescent species.

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