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Sugarberry Volume and Weight Tables

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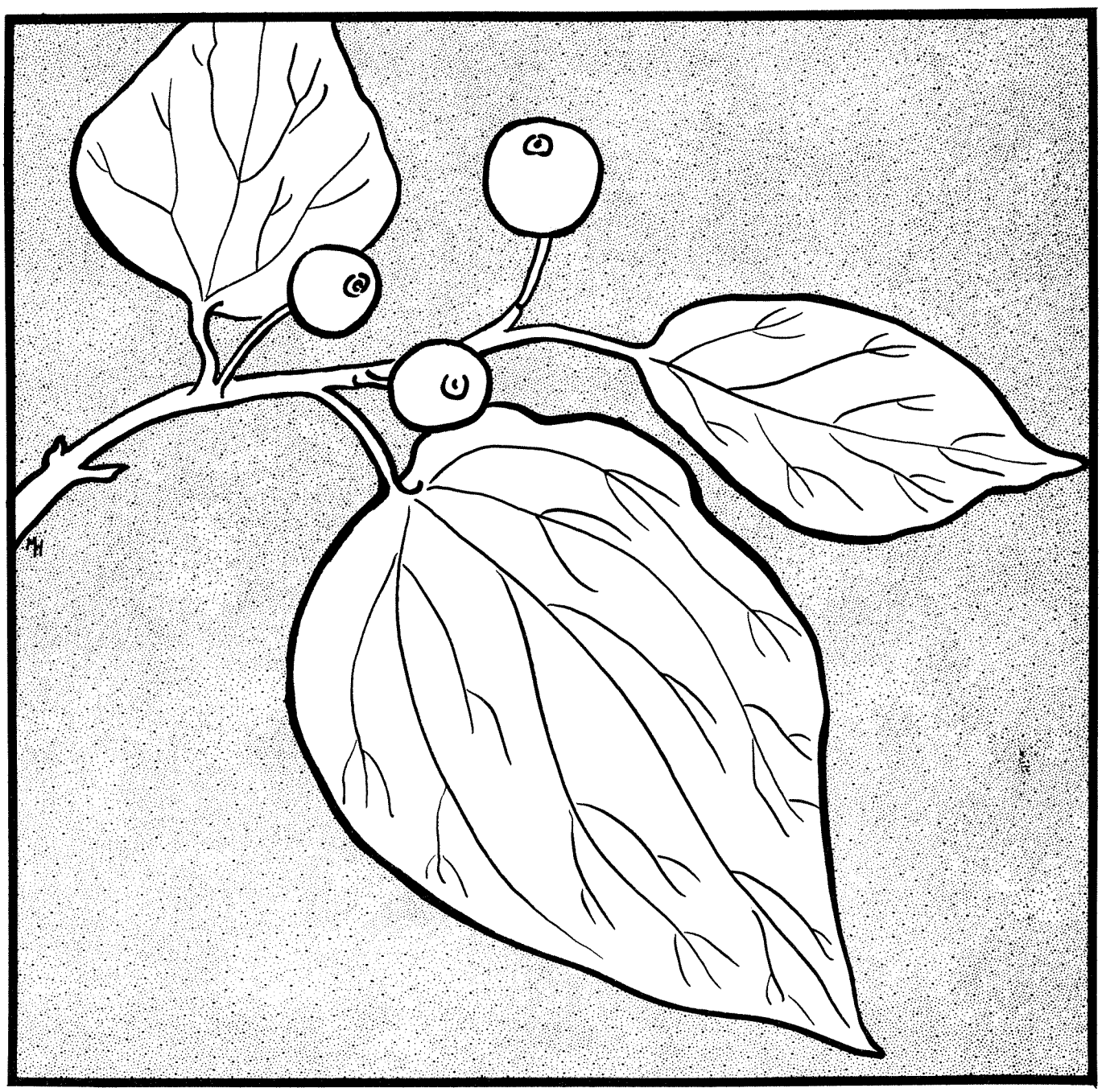

SUMMARY

Volume and weight tables were constructed from a 121-tree sample of sugarberry *(Celtis laevigata* Willd.) taken in the Mississippi Delta. The tables present cubic-foot volume, green weight, and dry weight of bole wood, bole wood plus bark, and total tree excluding leaves above a 1-foot stump as predicted from the allometric model $\text{Ln } Y = b_0 + b_1 \text{Ln}(D^2H)$. Merchantable bole volume and weight estimates can be made to any outside bark diameter limit. More precise bole estimates can be obtained from equations using upper bole diameters taken at relative heights of 25, 33, and 50 percent of total tree height.

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INTRODUCTION

Sugarberry *(Celtis laevigata* Willd.) grows on bottomlands of the Piedmont and Coastal Plain of the southern United States from southeastern Virginia, south to southern Florida, then west along the Gulf Coast into Texas, north to western Oklahoma, Missouri, southern Illinois and Indiana, and western Kentucky (Little 1979) (fig. 1). It is most commonly found on clay soils of broad flats or shallow sloughs within the flood plains of major southern rivers but thrives on various types of soils. This is a slow growing species, with trees reaching 80 feet in height and 20 inches in dbh.

In recent years there has been considerable demand for volume and weight tables for bottomland hardwood species. This paper is the fourth in a series of six giving both volume and weight tables for some of the major bottomland hardwood species. The other five species in the series are willow oak *(Quercus phellos* L.) (Schlaegel 1981), Nuttall oak *(Q. nuttallii* Palmer) (Schlaegel and Willson 1983), overcup oak *(Q. lyrata* Walt.) (Schlaegel 1984a), sweetgum *(Liquidambar styraciflua* L.) (Schlaegel 1984b), and green ash *(Fraxinus pennsylvanica* Marsh.) (Schlaegel 1984c).

METHODS

The data were collected from 15 natural bottomland hardwood stands in west-central Mississippi. Stands were either even- or uneven-aged with a mixed species composition. Each stand was measured for species composition and diameter distribution; 121 trees, ranging in dbh from 1 through 22 inches, were chosen for destructive sampling. Growing stock trees with healthy crowns and no visible signs of disease or decay were selected from both the overstory and understory. When available, three trees were selected from each 1-inch diameter class. Cutting was done throughout the year.

Stump height and total height were measured on each felled sample tree. Disks about 1-inch thick were cut from the bole at regular intervals from the stump to the top of the tree. These were then sealed in separate polyethylene bags for laboratory determination of moisture content and specific gravity. The first disk was at stump height and the remainder at 5-foot intervals measured from ground level for trees 5 inches dbh and larger and at 3-foot intervals for trees smaller than 5 inches dbh. All limbs, including leaves, were weighed on 115 of the trees.

In the laboratory, both wood and bark moisture content and specific gravity were determined as follows:

1. Wood and bark were separated with a hammer and chisel.
2. Each component was weighed green.
3. Both wood and bark were soaked in water for at least an hour to ensure complete swelling.
4. Volumes were obtained by immersion (Heinrichs and Lassen 1970).
5. Wood and bark were dried in a forced-air oven at 105°C for at least 48 hours.
6. Wood or bark moisture content = $\frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}}$.
7. Specific gravity = $\frac{\text{ovendry wood or bark weight (g)}}{\text{green wood or bark volume (cm}^3\text{)}}$.

Average tree moisture content and specific gravity were calculated from weighted averages of the disk moisture contents and specific gravities; each disk specific gravity or moisture content was weighted by its squared average diameter.

Taper functions (Schlaegel 1981, Schlaegel and Willson 1983) of the form

$$Y = b_1(X^1 - 1) + b_2(X^2 - 1) + \ldots + b_p(X^p - 1)$$

where

- $Y = d/D$,
- d = diameter at height h on the bole,
- D = dbh,
- $X = h/H$,
- h = height from ground to a specific measurement point,
- H = total height,
- b_i = coefficients estimated for each tree by linear regression; $i = 1, 2, \ldots p$; $4 \leq p \leq 7$,

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were calculated for each tree, both inside and outside bark. Cubic-foot volumes were obtained for each tree by integrating the taper function to heights of specific top diameters to obtain both total and merchantable bole volumes. Bole green and dry weights were calculated from estimated tree volume and weighted average tree density and moisture content.

Allometric regression equations were used to estimate volume, green weight, and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus limbs.

RESULTS

Characteristics of the trees used in this study are:

	Average	Range
Age *(years)*	38	8 – 156
Dbh *(in)*	8.1	0.8 – 21.9
Total height *(ft)*	54	11 – 92
Wood moisture content *(percent)*	80	56 – 97
Bark moisture content *(percent)*	74	44 – 201
Wood specific gravity	0.481	0.330 – 0.572
Bark specific gravity	0.579	0.283 – 0.782
Wood + bark green density *(lb/ft)*	54.63	34.88 – 64.53
Wood + bark dry density *(lb/ft)*	30.54	20.62 – 34.72
Wood + bark moisture content *(percent)*	79	57 – 101
Wood + bark specific gravity	0.489	0.330 – 0.556

Individual tree volumes and weights were fitted to the allometric model:

$$\text{Ln}(Y) = b_0 + b_1 \text{Ln}(D^2H) \quad (1)$$

where

Y = the volume or weight variable of interest,
Ln is a natural logarithm;
b_0 and b_1 are coefficients estimated from the data.

Estimates of the coefficients b_0 and b_1 are presented in table 1 for predicting cubic foot volume and green and dry weight of bole wood, bole bark, total bole, and total tree excluding leaves. Additional statistics presented are the component average, fit index, regression standard error of estimate ($\hat{S}_e$) based on residuals after converting to actual units, and coefficient of variation (C.V.) of predictions in arithmetic units. Fit index, which is similar to R^2, is used to judge equation efficiency when the dependent varia-

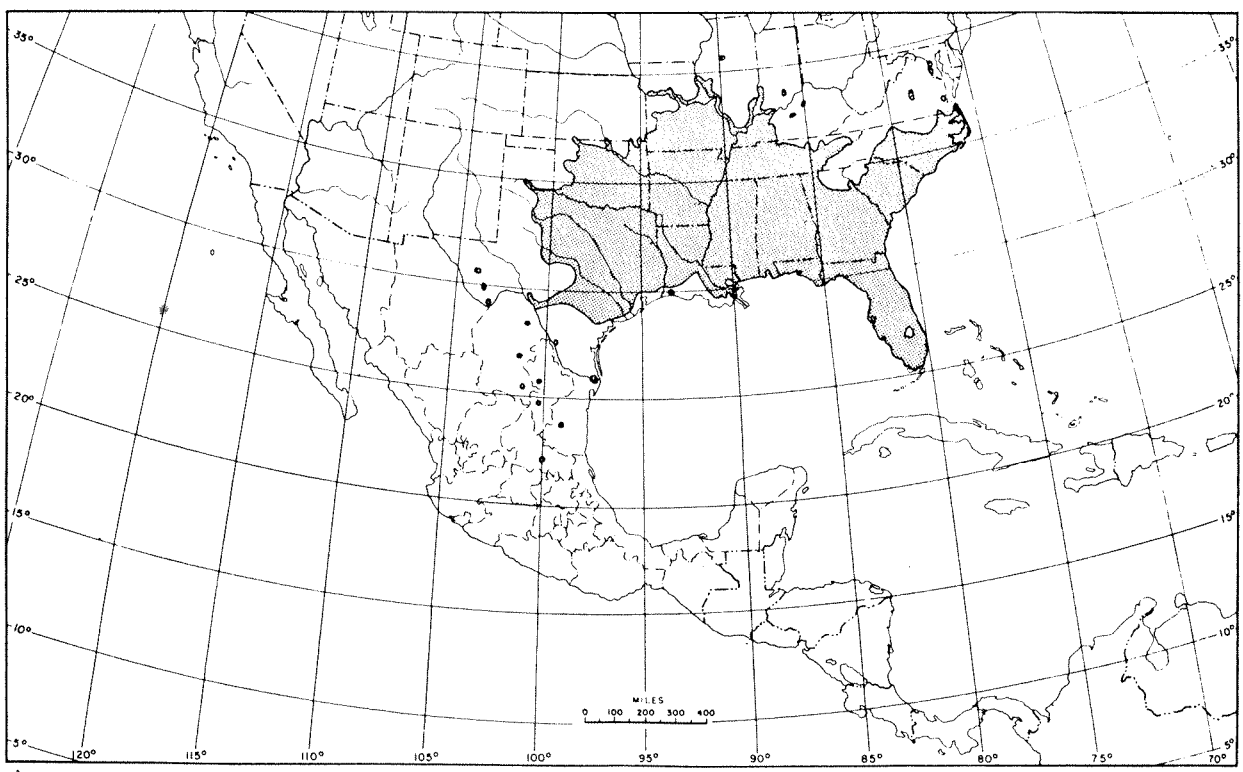

Figure 1.—*The range of sugarberry (Fowells 1965). (F-506584)*

ble has been transformed (Farrar 1978) and is calculated in untransformed units from the total and residual sums of squares.[1] The fit index and R^2 are equal when a simple linear regression analysis is performed on an untransformed dependent variable.

Fit indices range from 0.792 for dry bark weight to 0.988 for bole wood volume. A fit index of 1.0 indicates that predictions can be made without error with the data used to fit the model; a value close to 1 is desirable. Coefficients of variation, which are indices of relative precision of prediction, range from 66.1 percent for dry bark weight to 13.8 percent for bole wood volume.

Using measures of individual tree dbh and total height, estimates can be made using table 1 for tree volume (given in table 2), green weight (given in table 3), and dry weight (given in table 4) for bole wood, bole wood plus bark, and for bole wood plus bark plus limbs excluding leaves.

The equations were developed using trees from a limited geographic range compared to the total range. Therefore, predictions may be less precise when the equations are applied in other parts of the range. Using an upper bole diameter measurement in addition to dbh as described later should alleviate this problem.

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as the tree bole from a 1-foot stump to a specified top diameter, ignoring limbs. Merchantable bole volume or weight can be expressed as a proportion of the total bole by a generalized form of the logistic model

$$R_I = (1.0 + e^{f(X)})^{-1} \quad (2)$$

where

R_I = ratio of merchantable bole volume or weight to total bole volume or weight, where I = top outside bark diameter of merchantable bole,

$X = (D - d_I)/D$,

D = tree dbh outside bark, and

d_I = outside bark top diameter.

For a specific top diameter, the ratio of merchantable bole to total bole is the same for volume, green weight, dry weight, and inside and outside bark (Schlaegel and Willson 1983).

Model 2 was fitted to the overcup oak data for trees ≥4.6 inches dbh, with $f(X) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4$. Inverting (2) and taking the natural logarithm results in

$$\mathrm{Ln}\left(\frac{1-R_I}{R_I}\right) = b_0 + b_1X + b_2X^2 + b_3X^3 + b_4X^4;$$

this was solved using multiple linear regression techniques giving:

$$R_I = [1.0 + \mathrm{EXP}(1.58529 + 1.83111\,X - 51.10565\,X^2 + 91.90861\,X^3 - 54.30496\,X^4)]^{-1} \quad (3)$$

with fit index = 0.951 and $\hat{S}_e = 0.052$; EXP is the base of the natural logarithm and equals 2.71828.

Volume or weight to any top diameter (V_I) is found by multiplying the ratio estimate obtained from (3) by a total bole volume or weight estimate from either table 2, 3, or 4:

$$V_I = R_I \cdot V_T,$$

where V_T is the total bole volume or weight of interest.

IMPROVED TOTAL BOLE ESTIMATES

The precision of the merchantable bole estimate depends upon accuracy in measuring total bole. Total bole estimates can be significantly improved by measuring one or two additional diameters. Tables 5 and 6 give regression statistics for total bole volume and weight under two different model forms:

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}(D \cdot D_{1/3} \cdot H) \quad (4)$$

and

$$\mathrm{Ln}(Y) = b_0 + b_1\,\mathrm{Ln}[(D \cdot D_{1/2} + D^2_{1/4}) \cdot H] \quad (5)$$

where D, H, and Y are as defined previously, and $D_{1/3}$, $D_{1/2}$, and $D_{1/4}$ are diameters measured outside the bark at one-third, one-half, and one-fourth the total height.

Statistics from tables 5 and 6 show the significant ($\alpha = 0.05$) improvement over the previous D^2H equations of table 1. Measuring one additional diameter at one-third the tree height reduces $\hat{S}_e$ for bole wood volume, total bole volume, green wood and total bole weight, and total dry bole weight by 31, 45, 18, 32, and 30 percent, respectively. Other standard errors are reduced but not significantly.

Measuring two upper bole diameters at one-fourth and one-half total height will result in further significant increases in precision. Improvements over the D^2H model range from 17 to 53 percent for bole wood and total bole and from 6 to 9 percent for bark.

Taking additional bole measures means a higher inventory cost, since more time will be spent at each tree, but most of the inventory cost is in traveling to the candidate tree. Data presented in this paper allow total and merchantable bole estimates to be made with high reliability. Each user has to decide when increased precision is needed and whether the need offsets the higher cost.

LOCAL VOLUME TABLES

There are many occasions when the only tree variable available is dbh, or perhaps only a rough estimate of tree volume or weight is needed. In these cases a local volume table will suffice. Table 7 gives the sta-

[1] $FI = \{1 - [\Sigma(Y_i - \hat{Y}_i)^2] / [\Sigma(Y_i - \bar{Y})^2]\}$

tistics needed for estimating by the local volume table technique. However, it must be realized that estimation precision may be considerably lessened. The local volume or weight model is

$$\text{Ln}(Y) = b_0 + b_1 \text{Ln}(D^2). \quad (6)$$

Precision is significantly ($\alpha = 0.05$) reduced when only dbh is used to predict bole wood, total bole, and total tree. But bark estimates are more precise using the local equations.

CALCULATING CONFIDENCE LIMITS

Confidence limits ($(1-\alpha)$ percent confidence limits) of individual predictions can be calculated using statistics presented in table 8. Clark et al. (1980) used the technique of Land (1972) to estimate approximate confidence limits for lognormal means of scarlet oak:

$$Y_{U.L.} = \text{EXP}\left\{\text{Ln}(Y) \pm Z_{\alpha/2}\left[S^2_{y\cdot x}\left[\frac{1}{n} + \frac{(X-\bar{X})^2}{\Sigma(X-\bar{X})^2}\right] + \frac{S^4_{y\cdot x}}{2(n+1)}\right]^{1/2}\right\}$$

where:

$Y_{U.L.}$ = upper and lower limits for Y,
EXP = base of natural logarithm; EXP = e = 2.71828,
Y = predicted volume or weight of component,
$Z_{\alpha/2}$ = value for the upper $\alpha/2$ percentage point from the standard normal table,
$S_{y\cdot x}$ = standard error of estimate for prediction equation,
n = number of observations used to develop the equation,
$\bar{X}$ = sample mean of Ln(X),
$\Sigma(X-\bar{X})^2$ = corrected sum of squares for Ln(X),
X = $\text{Ln}(D^2H)$; D = dbh and H = total height of tree for which Y is predicted.

LITERATURE CITED

Clark, Alexander, III; Phillips, Douglas R.; Hitchcock, Harry C., III. Predicted weights and volumes of scarlet oak trees on the Tennessee Cumberland Plateau. Res. Pap. SE-214, Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1980. 23 p.

Farrar, R. M., Jr. Silvicultural implications of the growth response of naturally regenerated even-aged stands of longleaf pine *(Pinus palustris* Mill.) to varying stand age, site quality, and density and certain stand structure measures. Athens, GA: University of Georgia; 1978. 132 p. Ph.D. Dissertation.

Fowells, H. A., comp. Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture; 1965. 762 p.

Heinrichs, J. Frank; Lassen, L. E. Improved technique for determining the volume of irregularly shaped wood blocks. For. Prod. J. 20(4): 24; 1970.

Land, Charles E. An evaluation of approximate confidence interval estimation methods for lognormal means. Technometrics 14(1): 145 – 158; 1972.

Little, Elbert L., Jr. Checklist of United States Trees. Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture; 1979. 375 p.

Schlaegel, Bryce E. Willow oak volume and weight tables for the Mississippi Delta. Res. Pap. SO-173, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1981. 14 p.

Schlaegel, Bryce E. Overcup oak volume and weight tables. Res. Pap. SO-207, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984a. 14 p.

Schlaegel, Bryce E. Sweetgum volume and weight tables. Res. Pap. SO-204, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984b. 14 p.

Schlaegel, Bryce E. Green ash volume and weight tables. Res. Pap. SO-206, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984c. 14 p.

Schlaegel, Bryce E.; Willson, Regan B. Nuttall oak volume and weight tables. Res. Pap. SO-186, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1983. 14 p.

Table 1.—*Regression statistics for predicting sugarberry tree volumes and weights using dbh and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	13.1	−5.862	0.95323	0.988	1.81	13.8
Bole bark	1.2	−7.223	0.83390	0.825	0.67	56.9
Total bole	14.3	−5.649	0.93856	0.986	2.07	14.5
Total tree, excluding leaves	21.1	−5.484	0.95437	0.962	5.28	25.0
			Green weight *(pounds)*			
Bole wood	708	−1.892	0.95566	0.984	111	15.6
Bole bark	78	−3.332	0.86691	0.806	48	62.2
Total bole	786	−1.683	0.94340	0.983	126	16.1
Total tree, excluding leaves	1158	−1.515	0.95778	0.963	283	24.4
			Dry weight *(pounds)*			
Bole wood	393	−2.474	0.95535	0.982	64	16.4
Bole bark	48	−4.067	0.89204	0.792	32	66.1
Total bole	441	−2.287	0.94643	0.984	70	15.8
Total tree, excluding leaves	652	−2.118	0.96116	0.963	160	24.5

[1]Volumes and weights of trees from a 1-foot stump to the tree tip, using $Ln(Y) = b_0 + b_1 Ln(D^2H)$; D = dbh, H = total tree height.

[2]Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \overline{Y})^2]$, using untransformed values.

[3]$\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.

[4]Coefficient of variation = $100\ \hat{S}_e / \overline{Y}$.

Table 2.—*Cubic-foot volume for sugarberry bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*cubic feet*									
1	0.03[2]	0.05								
	0.03[3]	0.06								
	0.04	0.07								
2	0.10	0.19	0.27							
	0.11	0.22	0.31							
	0.14	0.27	0.40							
3		0.40	0.59	0.78						
		0.46	0.67	0.88						
		0.59	0.87	1.14						
4		0.70	1.02	1.35	1.67	1.98				
		0.79	1.16	1.52	1.87	2.22				
		1.02	1.50	1.98	2.45	2.91				
5			1.57	2.06	2.55	3.03				
			1.76	2.30	2.84	3.37				
			2.30	3.03	3.75	4.46				
6				2.92	3.61	4.29	4.97			
				3.24	4.00	4.75	5.48			
				4.29	5.31	6.32	7.32			
7				3.91	4.84	5.76	6.67	7.58		
				4.33	5.34	6.34	7.32	8.30		
				5.76	7.13	8.48	9.82	11.20		
8				5.05	6.24	7.43	8.60	9.77		
				5.57	6.86	8.14	9.41	10.70		
				7.43	9.19	10.90	12.70	14.40		
9					7.81	9.30	10.8	12.2		
					8.56	10.20	11.7	13.3		
					11.50	13.70	15.9	18.0		
10					9.55	11.4	13.2	14.9	16.7	
					10.40	12.4	14.3	16.2	18.1	
					14.10	16.7	19.4	22.0	24.7	
11					11.5	13.6	15.8	17.9	20.1	
					12.5	14.8	17.1	19.4	21.7	
					16.9	20.1	23.3	26.4	29.6	
12					13.5	16.1	18.6	21.2	23.7	
					14.7	17.4	20.1	22.8	25.5	
					19.9	23.7	27.5	31.2	34.9	
13					15.7	18.7	21.7	24.7	27.6	
					17.1	20.3	23.4	26.5	29.6	
					23.2	27.6	32.0	36.4	40.7	
14						21.6	25.0	28.4	31.8	
						23.3	26.9	30.5	34.1	
						31.8	36.9	41.9	46.9	
15						24.6	28.5	32.4	36.2	
						26.5	30.6	34.7	38.8	
						36.3	42.1	47.8	53.5	
16						27.8	32.2	36.6	41.0	45.3
						29.9	34.6	39.2	43.8	48.3
						41.1	47.6	54.1	60.5	66.9
17						31.3	36.2	41.1	46.0	50.9
						33.5	38.7	43.9	49.0	54.1
						46.1	53.4	60.7	67.9	75.1
18						34.9	40.4	45.8	51.3	56.7
						37.3	43.1	48.9	54.6	60.3
						51.4	59.6	67.7	75.7	83.8

Table 2.—*Cubic-foot volume for sugarberry bole wood, bole wood plus bark, and total tree—(Continued)*

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*cubic feet*									
19						38.6	44.8	50.8	**56.9**	62.9
						41.3	47.7	54.1	**60.4**	66.7
						57.0	66.1	75.1	**84.0**	92.8
20						42.6	49.4	56.0	**62.7**	69.3
						45.5	52.5	59.6	**66.5**	73.4
						62.9	72.9	82.8	**92.6**	102.0
21						**46.8**	54.2	61.5	68.8	76.1
						49.8	57.6	65.3	72.9	80.5
						69.0	80.0	90.9	102.0	112.0
22						51.1	59.2	67.2	**75.2**	83.2
						54.4	62.8	71.2	**79.6**	87.8
						75.4	87.4	99.3	**111.0**	123.0
23						55.6	64.4	73.2	81.9	90.5
						59.1	68.3	77.4	86.5	95.5
						82.1	95.2	108.0	121.0	134.0
24						60.3	69.9	79.3	88.8	98.2
						64.0	74.0	83.9	93.7	103.0
						89.1	103.0	117.0	131.0	145.0
25						65.2	75.5	85.8	96.0	106
						69.1	79.9	90.6	101.0	112
						96.3	112.0	127.0	142.0	157
26						70.3	81.4	92.4	103	114
						74.4	86.0	97.5	109	120
						104.0	120.0	137.0	153	169

[1]Tree volume from a 1-foot stump to the tree tip.
[2]The three vertical figures for each dbh give volumes of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.
[3]Boldface numbers span the range of the data.

Table 3.—*Green weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
1	**1.4**[2]	**2.6**								
	1.6[3]	**3.1**								
	2.0	**3.9**								
2	**5.1**	**9.9**	**15**							
	6.0	**11.6**	**17**							
	7.5	**14.6**	**22**							
3		**22**	**32**	**42**						
		25	**37**	**48**						
		32	**47**	**62**						
4		37	**55**	**72**	**90**	107				
		43	**63**	**82**	**102**	121				
		55	**81**	**107**	**133**	158				
5			84	**111**	**137**	164				
			96	**126**	**155**	184				
			125	**164**	**203**	242				
6				157	**195**	232	268			
				177	**219**	260	301			
				233	**288**	343	398			
7				211	**261**	**311**	**360**	410		
				237	**293**	**348**	**402**	456		
				313	**387**	**461**	**535**	608		
8				273	337	**402**	**465**	529		
				305	377	**447**	**517**	587		
				404	500	**596**	**691**	785		

Table 3.—*Green weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree—(Continued)*

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
9					422	**503**	**583**	662		
					470	**559**	**646**	733		
					627	**747**	**865**	983		
10					517	**615**	**713**	**810**	906	
					574	**681**	**788**	**894**	999	
					767	**913**	**1059**	**1203**	1347	
11					620	**738**	**855**	**972**	1087	
					687	**816**	**943**	**1070**	1196	
					921	**1096**	**1271**	**1444**	1617	
12					732	**872**	**1010**	**1147**	1284	
					809	**961**	**1112**	**1261**	1409	
					1088	**1295**	**1501**	**1706**	1910	
13					853	**1016**	**1177**	**1337**	1496	
					941	**1118**	**1293**	**1466**	1639	
					1268	**1510**	**1750**	**1989**	2226	
14						1170	**1356**	**1540**	1724	
						1286	**1487**	**1686**	1885	
						1740	**2017**	**2292**	2566	
15						1335	1547	**1758**	1967	
						1464	1694	**1921**	2147	
						1986	2302	**2616**	2929	
16						1510	1750	**1988**	2225	2461
						1654	1913	**2170**	2425	2678
						2247	2605	**2960**	3314	3666
17						1696	**1965**	**2233**	**2499**	2763
						1854	**2145**	**2433**	**2718**	3003
						2524	**2926**	**3325**	**3722**	4117
18						1892	**2192**	**2490**	**2787**	3082
						2066	**2389**	**2710**	**3028**	3344
						2816	**3264**	**3710**	**4153**	4594
19						2098	2431	2761	**3090**	3418
						2287	2645	3001	**3353**	3704
						3124	3621	4114	**4606**	5095
20						2314	2681	3046	**3409**	3770
						2520	2914	3306	**3694**	4080
						3446	3994	4539	**5081**	5621
21						**2540**	2943	3344	3742	4138
						2763	3195	3624	4050	4473
						3784	4386	4984	5579	6172
22						2776	3217	3654	**4090**	4523
						3016	3488	3957	**4422**	4884
						4136	4794	5448	**6099**	6747
23						3022	3502	3979	4452	4924
						3280	3794	4303	4809	5311
						4504	5221	5933	6641	7346
24						3278	3799	4316	4830	5341
						3554	4111	4663	5211	5755
						4887	5664	6437	7205	7970
25						3544	4107	4666	5222	5775
						3839	4440	5036	5628	6216
						5284	6125	6960	7791	8619
26						3820	4427	5029	5628	6224
						4134	4781	5423	6060	6694
						5696	6602	7503	8399	9291

[1]Tree weight from a 1-foot stump to the tree tip.

[2]The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.

[3]Boldface numbers span the range of the data.

Table 4.—*Dry weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree*[1]

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
1	**0.8**[2]	**1.5**								
	0.9[3]	**1.7**								
	1.1	**2.1**								
2	**2.9**	**5.5**	**8.2**							
	3.3	**6.4**	**9.4**							
	4.2	**8.1**	**12.0**							
3		**12**	**18**	**23**						
		14	**20**	**27**						
		18	**26**	**34**						
4		21	**31**	**40**	**50**	60				
		24	**35**	**46**	**57**	67				
		31	**45**	**60**	**74**	88				
5			47	**62**	**77**	91				
			53	**70**	**87**	103				
			70	**92**	**114**	136				
6				88	**109**	129	150			
				99	**122**	145	168			
				131	**162**	193	224			
7				118	**146**	**173**	**201**	228		
				133	**164**	**195**	**225**	256		
				176	**218**	**259**	**301**	342		
8				152	188	**224**	**259**	295		
				171	211	**251**	**290**	329		
				227	281	**335**	**389**	442		
9					235	**280**	**325**	369		
					264	**313**	**362**	411		
					353	**420**	**487**	554		
10					288	**343**	**397**	**451**	505	
					322	**382**	**442**	**502**	561	
					432	**515**	**597**	**679**	760	
11					346	**411**	**476**	**541**	606	
					385	**458**	**530**	**601**	672	
					519	**618**	**717**	815	913	
12					408	**486**	**563**	**639**	715	
					454	**540**	**625**	**709**	793	
					613	**731**	**847**	**964**	1079	
13					475	**576**	**656**	**745**	834	
					529	**628**	**727**	**825**	922	
					715	**852**	**988**	**1124**	1259	
14						652	**755**	**858**	960	
						723	**837**	**949**	1061	
						983	**1140**	**1296**	1451	
15						744	862	**979**	1096	
						824	953	**1082**	1209	
						1122	1301	**1480**	1657	
16						841	975	**1108**	1240	1371
						931	1077	**1222**	1366	1510
						1270	1473	**1675**	1876	2076
17						945	**1095**	1244	**1392**	1539
						1044	**1208**	**1371**	**1532**	1693
						1427	**1655**	**1882**	**2108**	2332
18						1054	**1221**	**1387**	1552	1717
						1163	**1346**	**1527**	1708	1887
						1593	**1848**	**2101**	2353	2603

Table 4.—*Dry weight in pounds for sugarberry bole wood, bole wood plus bark, and total tree—(Continued)*

Dbh	Total height in feet									
	10	20	30	40	50	60	70	80	90	100
inches	*pounds*									
19						1168	1354	1538	**1721**	1904
						1289	1491	1692	**1892**	2090
						1768	2050	2331	**2610**	2888
20						1289	1493	1696	**1899**	2100
						1420	1643	1865	**2084**	2303
						1951	2263	2572	**2881**	3188
21						**1415**	1639	1862	2084	2305
						1558	1802	2045	2286	2526
						2143	2485	2825	3164	3501
22						1546	1792	2035	**2278**	2519
						1701	1968	2233	**2497**	2758
						2343	2717	3090	**3460**	3829
23						1683	1950	2216	2480	2742
						1850	2141	2429	2716	3000
						2552	2960	3365	3769	4170
24						1826	2116	2403	2690	2975
						2005	2320	2633	2944	3252
						2770	3212	3652	4090	4526
25						1974	2287	2598	2908	3216
						2167	2507	2845	3180	3513
						2996	3474	3950	4424	4895
26						2128	2465	2801	3134	3466
						2334	2700	3064	3425	3784
						3231	3747	4260	4770	5279

[1]Tree weight from a 1-foot stump to the tree tip.
[2]The three vertical figures for each dbh give weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus limbs excluding leaves) last.
[3]Boldface numbers span the range of the data.

Table 5.—*Regression statistics for predicting sugarberry bole volumes and weights using two bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
	Volume *(cubic feet)*					
Bole wood	13.1	−5.802	0.98071	0.994	1.24*	9.5
Bole bark	1.2	−7.185	0.85923	0.847	0.62	53.2
Total bole	14.3	−5.591	0.96572	0.996	1.12*	7.9
	Green weight *(pounds)*					
Bole wood	708	−1.834	0.98331	0.989	91*	12.9
Bole bark	78	−3.295	0.89339	0.829	45	58.3
Total bole	786	−1.627	0.97083	0.992	86*	11.0
	Dry weight *(pounds)*					
Bole wood	393	−2.415	0.98301	0.986	58	14.7
Bole bark	48	−4.030	0.91937	0.816	30	62.2
Total bole	441	−2.231	0.97398	0.992	49*	11.2

[1]Volumes and weights of trees from a 1-foot stump to the tree tip, using $Ln(Y) = b_0 + b_1 Ln(D \cdot D_{1/3} \cdot H)$; D = dbh, H = total tree height, $D_{1/3}$ = bole diameter outside bark at 1/3H.
[2]Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.
[3]$\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.
[4]Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.
*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 6.—*Regression statistics for predicting sugarberry bole volumes and weights using three bole diameter measurements and total height*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	13.1	−6.513	1.00617	0.996	1.00*	7.7
Bole bark	1.2	−7.812	0.88195	0.852	0.61	52.3
Total bole	14.3	−6.292	0.99084	0.999	0.64*	4.5
			Green weight *(pounds)*			
Bole wood	708	−2.547	1.00883	0.991	83+	11.8
Bole bark	78	−3.946	0.91693	0.835	45	57.3
Total bole	786	−2.331	0.99606	0.995	71*	9.0
			Dry weight *(pounds)*			
Bole wood	393	−3.128	1.00857	0.988	53+	13.6
Bole bark	48	−4.701	0.94369	0.821	30	61.3
Total bole	441	−2.938	0.99936	0.995	40*	9.1

[1]Volumes and weights of trees from a 1-foot stump to the tree tip, using $Ln(Y) = b_0 + b_1 Ln[(D \cdot D_{1/2} + D^2_{1/4})H]$; D = dbh, H = total tree height, $D_{1/2}$ and $D_{1/4}$ = bole diameters outside bark at ½H and ¼H, respectively.
[2]Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.
[3]$\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.
[4]Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.
+Significantly more precise by the F test than $D \cdot D_{1/4} \cdot H$ model; $\alpha = 0.05$.
*Significantly more precise by the F test than D^2H model; $\alpha = 0.05$.

Table 7.—*Local volume and weight equations for sugarberry*[1]

Component	Average Y	b_0	b_1	Fit index[2]	$\hat{S}_e$[3]	C.V. percent[4]
			Volume *(cubic feet)*			
Bole wood	13.1	−3.179	1.23777	0.934	4.18*	31.9
Bole bark	1.2	−4.904	1.08668	0.880	0.56+	47.1
Total bole	14.3	−3.011	1.21917	0.950	3.95*	27.7
Total tree, excluding leaves	21.1	−2.819	1.24272	0.949	6.08	28.8
			Green weight *(pounds)*			
Bole wood	708	0.796	1.24113	0.919	249*	35.2
Bole bark	78	−0.916	1.12891	0.861	41+	52.6
Total bole	786	0.967	1.22559	0.939	241*	30.7
Total tree, excluding leaves	1158	1.159	1.24723	0.946	344*	29.7
			Dry weight *(pounds)*			
Bole wood	393	0.217	1.24031	0.909	146*	37.1
Bole bark	48	−1.591	1.16320	0.849	27+	56.2
Total bole	441	0.373	1.22941	0.934	140*	31.7
Total tree, excluding leaves	652	0.566	1.25157	0.941	202*	30.9

[1]Volumes and weights of trees from a 1-foot stump to the tree tip, using $Ln(Y) = b_0 + b_1 Ln(D^2)$; D = dbh.
[2]Fit index = $1.0 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$, using untransformed values.
[3]$\hat{S}_e = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$, using untransformed values.
[4]Coefficient of variation = $100\ \hat{S}_e / \bar{Y}$.
+Significantly more precise by the F test than D^2H model; $\alpha = 0.005$.
*Significantly less precise by the F test than D^2H model; $\alpha = 0.05$.

Table 8.—*Statistics for estimating confidence bounds for sugarberry predictions for the bole and total tree*

Independent variable – X	n	Mean of X	Corrected sum of squares for X[1]	$S_{y \cdot x}$ Standard error of estimate for tree components			
	Bole predictions				Wood	Bark	Total
$Ln(D^2)$	121	3.556	354.483	Volume	0.1915	0.3029	0.1775
				Green weight	0.2053	0.3616	0.1983
				Dry weight	0.2178	0.3408	0.2017
$Ln(D^2H)$	121	7.422	600.271	Volume	0.1306	0.3188	0.1255
				Green weight	0.1548	0.3690	0.1560
				Dry weight	0.1617	0.3644	0.1574
$Ln(D \cdot D_{1/3} \cdot H)$	121	7.148	568.328	Volume	0.0847	0.2889	0.0716
				Green weight	0.1143	0.3396	0.1119
				Dry weight	0.1227	0.3315	0.1116
$Ln[(D \cdot D_{1/4} + D^2_{1/4})H]$	121	7.672	540.282	Volume	0.0643	0.2791	0.0423
				Green weight	0.1004	0.3315	0.0964
				Dry weight	0.1079	0.3215	0.0929
	Total tree predictions					Total tree	
$Ln(D^2)$	115	3.491	344.521	Volume		0.1540	
				Green weight		0.1774	
				Dry weight		0.1786	
$Ln(D^2H)$	115	7.339	584.102	Volume		0.1555	
				Green weight		0.1800	
				Dry weight		0.1799	

[1] $\Sigma(X - \bar{X})^2$ in base e logarithmic units.

APPENDIX

Examples Using the Equations

In this section examples are presented to illustrate use of the equations. The following tabulation gives data used to illustrate equation use:

$D = 21.7$ in.
$H = 75.0$ ft.
$D_{1/4} = 15.5$ in.
$D_{1/3} = 14.8$ in.
$D_{1/2} = 11.5$ in.

Bole wood volume (V) is calculated using $X = D^2H$ and the parameter estimates from table 1 as follows:

$$\begin{aligned}
\text{Ln}(V) &= b_0 + b_1 \text{Ln}(D^2H) \\
&= -5.862 + 0.95323 \text{ Ln } (21.7 \times 21.7 \times 75.0) \\
&= -5.862 + 0.95323 \text{ Ln } (35316.75) \\
&= -5.862 + 0.95323 \ (10.472) \\
&= -5.862 + 9.982 \\
\text{Ln}(V) &= 4.120 \\
V &= e^{4.120}; \text{ bole wood volume} = 61.6 \text{ ft}^3.
\end{aligned}$$

To calculate total green bole weight (W) using $X = D \cdot D_{1/3} \cdot H$ and the parameter estimates from table 5:

$$\begin{aligned}
\text{Ln}(W) &= b_0 + b_1 \text{ Ln } (D \cdot D_{1/3} \cdot H) \\
&= -1.627 + 0.97083 \text{ Ln } (21.7 \times 14.8 \times 75.0) \\
&= -1.627 + 0.97083 \text{ Ln } (24087.00) \\
&= -1.627 + 0.97083 \ (10.089) \\
&= -1.627 + 9.795 \\
\text{Ln}(W) &= 8.168 \\
W &= e^{8.168}; \text{ total bole green weight} = 3526 \text{ lb.}
\end{aligned}$$

To calculate bole dry weight (W) using $X = [(D \cdot D_{1/2} + D^2_{1/4})H]$ and the parameter estimates from table 6:

$$\begin{aligned}
\text{Ln}(W) &= b_0 + b_1 \text{ Ln } [(D \cdot D_{1/2} + D^2_{1/4})H] \\
&= -2.938 + 0.99936 \text{ Ln } [(21.7 \times 11.5 + 15.5 \times 15.5) \times 75.0] \\
&= -2.938 + 0.99936 \text{ Ln } [(249.55 + 240.25) \times 75.0] \\
&= -2.938 + 0.99936 \text{ Ln } [489.80 \times 75.0] \\
&= -2.938 + 0.99936 \text{ Ln } [36735.00] \\
&= -2.938 + 0.99936 \ (10.511) \\
&= -2.938 + 10.504 \\
\text{Ln}(W) &= 7.566 \\
W &= e^{7.566}; \text{ total bole dry weight} = 1931 \text{ lb.}
\end{aligned}$$

Merchantable bole estimates to, say, an 8-inch top are calculated using equation 3 to estimate the merchantable portion of the bole and then multiplying that proportion (R8) by the predicted bole estimate of interest. Letting $DI = 8.0$, $X = [(21.7 - 8.0)/21.7]$, or $X = 0.631$, and from (3):

$$\begin{aligned}
R8 &= [1.0 + \text{EXP } (1.58529 + 1.83111 \ (0.631) - 51.10565 \ (0.631)^2 + 91.90861 \ (0.631)^3 - 54.30496 \ (0.631)^4)]^{-1} \\
&= [1.0 + \text{EXP } (1.58529 + 1.83111 \ (0.631) - 51.10565 \ (0.39816) + 91.90861 \ (0.25124) - 54.30496 \ (0.15853))]^{-1} \\
&= [1.0 + \text{EXP } (1.58529 + 1.15543 - 20.34823 + 23.09112 - 8.60897)]^{-1} \\
&= [1.0 + \text{EXP } (-3.12536)]^{-1} \\
&= [1.0 + 0.04392]^{-1} \\
&= [1.04392]^{-1} \\
R8 &= 0.958.
\end{aligned}$$

Then bole wood volume to an 8-inch top (V8) can be calculated:

$$\begin{aligned}
V8 &= (R8)(\text{predicted total bole wood volume}) \\
&= (0.958)(61.6) \\
&= 59.0 \text{ ft}^3.
\end{aligned}$$

Of course, total bole volumes or weights can be calculated using any one of the three sets of parameter estimates given in tables 1, 5, or 6. Then any of these total bole calculations can be used with the estimate of merchantable proportion to calculate merchantable bole values. The choice of which set of equations to use is left to the user, who must balance inventory precision against inventory cost.

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Schlaegel, Bryce E. Sugarberry volume and weight tables. Res. Pap. SO-205. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1984. 13 p.

A sample of 121 trees from the Mississippi Delta is used to construct volume and weight tables for sugarberry.

Additional keywords: *Celtis laevigata*, merchantable bole estimates, biomass.