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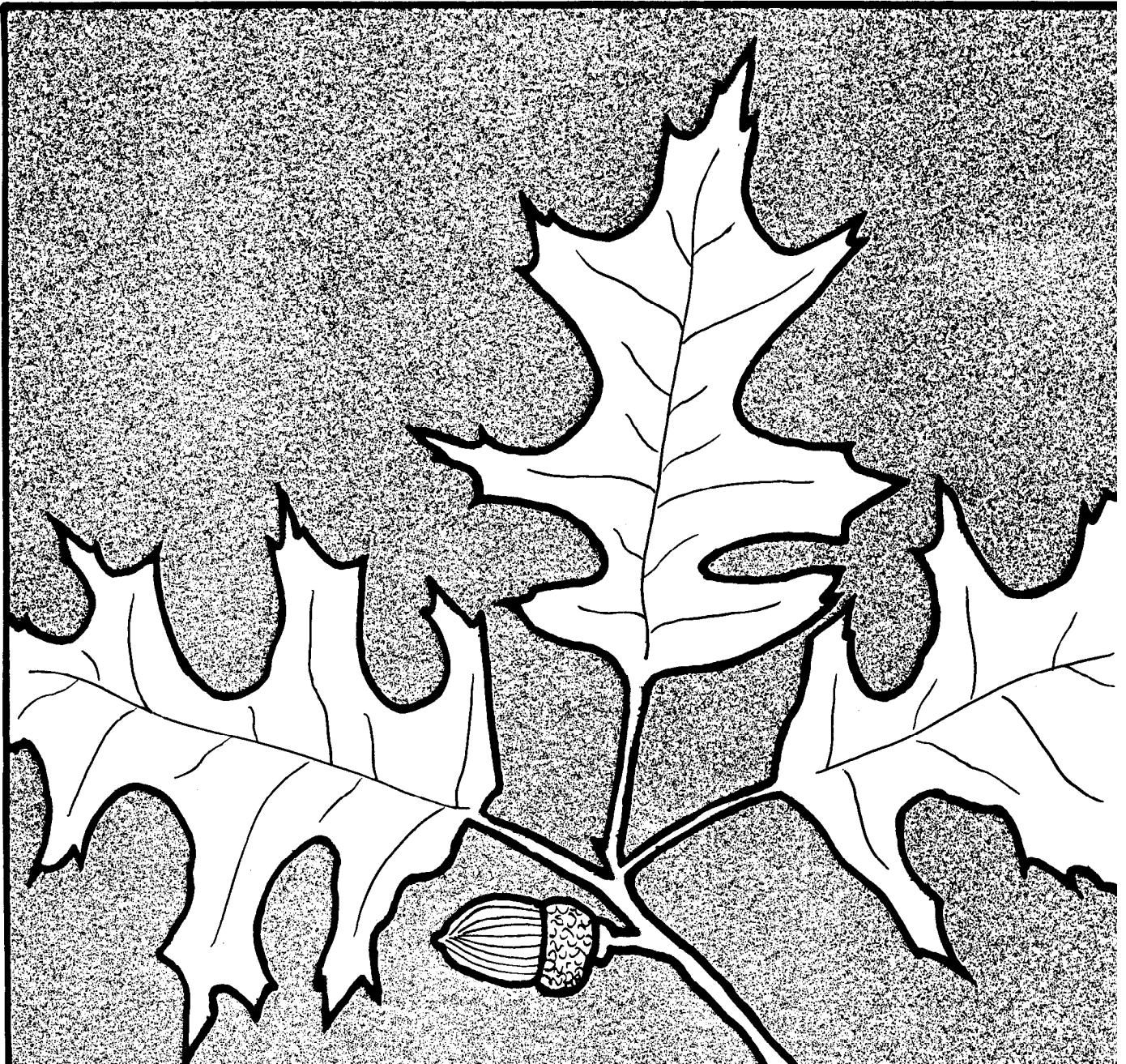
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Nuttall Oak Volume and Weight Tables

Bryce E. Schlaegel and Regan B. Willson



SUMMARY

Volume and weight tables were constructed from a **62-tree** sample of Nuttall oak (*Quercus nuttallii* Palmer) taken in the Mississippi Delta. The tables present volume, green weight, and dry weight of **bole** wood, bole wood plus bark, and total tree above a one-foot stump as predicted from the nonlinear model $Y = b_0 D^{b_1} H^{b_2}$. Merchantable bole volumes and weight estimates can be made to outside bark diameter limits of 2 to 12 inches in 2-inch increments. More precise bole estimates can be obtained from equations using upper bole diameters at relative heights of 25, 33, and 50 percent of total tree height.

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INTRODUCTION

Nuttall oak (*Quercus nuttallii* Palmer) grows on the bottomlands of the Coastal Plain of the southern United States from Alabama to southeastern Texas, north in the Mississippi Valley to Arkansas, southeastern Missouri and western Tennessee (fig. 1). It reaches its best development on the alluvial bottomlands of the Mississippi River and its tributaries. On good sites, it is a moderately rapid grower reaching heights of 120 feet and a dbh in excess of 36 inches.

In recent years there has been considerable demand for volume and weight tables for bottomland hardwood species. This paper is the second 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 (*Q. phellos* L.) (Schlaegel 1981), overcup oak (*Q. lyrata* Walt.), sugarberry (*Celtis laevigata* Willd.), sweetgum (*Liquidambar styraciflua* L.), and green ash (*Fraxinus pennsylvanica* Marsh.).

METHODS

The data were collected from 13 natural bottomland hardwood stands in Mississippi. All stands were uneven-aged of mixed species composition. Each stand was measured for species composition and diameter distribution. A total of 62 trees was chosen for destructive sampling and ranged in dbh from 2 through 38 inches. 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 diameter class.

Stump height, height to base of live crown, 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 polyene bags for laboratory determination of moisture content and specific gravity. The first disk was stump height and the remainder at 5-foot intervals from the ground for trees 5 inches dbh and larger and at 3-foot intervals for trees smaller than 5 inches dbh. All limbs were weighed on 60 of trees.

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

1. Wood and bark were separated with hammer and chisel.
2. Each component was weighed green.
3. Both wood and bark were soaked in water 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 =
$$\frac{\text{green weight} - \text{oven-dry weight}}{\text{oven-dry weight}}$$
7. Specific gravity =
$$\frac{\text{oven-dry wood or bark weight (g)}}{\text{green wood or bark volume (cm}^3\text{)}}$$

Average tree moisture content and specific gravity were calculated from weighted averages of the disk values; each disk specific gravity and moisture content was weighted by its square of average diameter.

Taper functions of the form

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

where

$$Y = d/D,$$

d = diameter at height h on the bole,

$$D = \text{dbh},$$

$$X = h/H,$$

h = height from ground to a specific measurement point,

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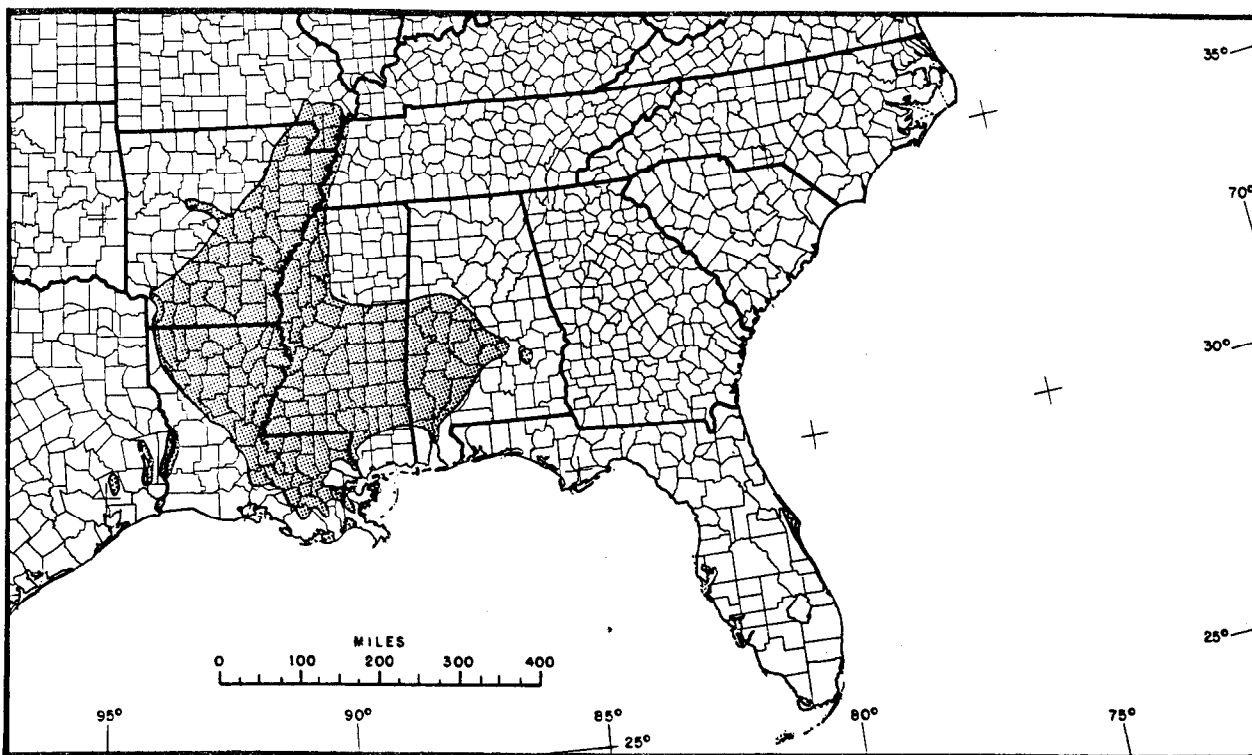


Figure 1.—The range of Nuttall oak. (F-506656)

H = total height,
 b_i = coefficients estimated for each tree by linear regression; i = 1, 2, . . . p; 4 ≤ p ≤ 7, 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. Bole green and dry weights were calculated from estimated tree volume and weighted average tree density and moisture content.

Nonlinear regression equations were used to predict volume, green weight, and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus branches.

RESULTS

Average characteristics for the trees in this study were:

	Average	Range
Age (years)	71	28-123
Dbh (in)	17.6	2.6-37.9
Total height (ft)	a2	25-118
Wood moisture content (percent)	90	57-112
Bark moisture content (percent)	64	53-93
Wood specific gravity	0.558	0.505-0.660

Bark specific gravity	0.619	0.389-0.702
Wood + bark green density (lbs/ft ³)	65.62	61.26-69.15
Wood + bark dry density (lbs/ft ³)	35.20	32.08-39.90
Wood + bark moisture content (percent)	87	60-107
Wood + bark specific gravity	0.564	0.514-0.635

The nonlinear model used to fit individual tree volume and weights is

$$Y = b_0 D^{b_1} H^{b_2} + e \quad (1)$$

where

Y = the volume or weight variable of interest,

D = tree dbh in inches,

H = total height in feet,

e = random error for Y, and

b₀, b₁, and b₂ are coefficients estimated from the data. An iterative least squares technique proposed by Hartley (1961) was used to estimate equation coefficients.

Estimates of the coefficients are presented in table 1 for predicting cubic-foot volume, green and dry weight of bole wood, bole wood plus bark, and bole wood plus bark plus branches. Additional statistics presented are the component means, fit index (FI), the regression standard error of estimate (S_{y.x}), and the coefficient of variation (C.V.) of predictions. Fit index, which is similar to the coeffi-

cient of determination (R^2) is used to judge equation efficiency when the dependent variable has been transformed (Farrar 1978) or has been estimated by other than linear least squares techniques. It is calculated from the total and residual sums of squares of untransformed units. 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 0.982 to 0.988 for all components. 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 1.0 is desirable. Coefficients of variation, which are indices of relative precision of prediction, range from 10.9 percent to 13.3 percent.

Using measures of individual tree dbh and total height, estimates can be made for tree volume (table 2), green weight (table 3), or dry weight (table 4) for bole wood, bole wood plus bark, and for bole wood plus bark plus branches.

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as that portion of the tree bole from a one-foot stump to a specific top diameter outside bark, excluding limbs. Merchantable bole volume or weight can be expressed as a proportion of the total bole by a simple asymptotic model proposed by Stevens (1951):

$$RI = \alpha + \beta\gamma^D \quad (2)$$

where

D = tree dbh outside bark,

RI = ratio of merchantable bole volume (weight) to total bole volume (weight), where I = top d.o.b. of merchantable bole, e.g. $R4 = V4/VT$, where

R4 = ratio to a 4-inch top

V4 = bole volume to a 4-inch top

VT = bole volume to top of tree

α, β, γ = parameters to be estimated from the data, where

α = the upper asymptote of the ratio, $\alpha < 1$,

β = the change in the ratio estimate as D extends from 0 toward infinity, and

γ = the factor by which the deviation of the ratio is reduced from its asymptotic value by each unit step of D.

For each top diameter, separate ratio equations were fitted for inside and outside bark volume, green weight, and dry weight. Placing confidence

bounds on the parameter estimates recommended by Gallant (1975) showed significant difference between the inside and outside bark equations for either the volume or weight ratio estimates. Thus, for a given outside bark top diameter, both the inside and outside bark merchantable bole ratio can be estimated using the same equation.

The data inside and outside bark were then combined to test the applicability of using a single ratio equation to predict, for a given top diameter either merchantable volume, green weight, or dry weight. As above, separate equations were derived for volume, green weight, and dry weight. The three sets of parameters were compared by using confidence interval estimation as above. No significant differences were found between parameter estimates for volume, green weight, or dry weight. Thus, for a specific top diameter, the ratio of merchantable bole to total bole is the same for either volume, green weight, or dry weight inside and outside bark. Thus, only one ratio equation per top diameter is needed.

Table 5 gives the parameter estimates for the second model by 2-inch top diameters outside bark using nonlinear least squares techniques proposed by Stevens (1951). The volume or weight to any top diameter is found by multiplying the ratio estimate from one of the equations in table 5 times the total bole volume or weight estimates from tables 2, 3, or 4.

IMPROVED TOTAL BOLE ESTIMATES

The precision of the merchantable bole estimate depends upon the precision of the total bole estimate. The more precisely the total bole is predicted, the more precise will be the merchantable bole prediction. But how can total bole estimates be improved?

Total bole estimates can be significantly improved by measuring one or two additional diameters on the bole. Tables 6 and 7 give regression statistics for total bole volume and weight under two different model forms:

$$Y = b_0(D^{b_1} + D_{1/3}^{b_2}) H^{b_3} + e$$

and

$$Y = b_0[(D^{b_1} + D_{1/2}^{b_2}) + D_{1/4}^{b_3}] H^{b_4} + e$$

where D, H, and Y are as defined previously, and $D_{1/3}$, $D_{1/2}$, and $D_{1/4}$ are diameters outside bark at 1/3, 1/2, and 1/4 the total height, respectively.

Statistics from tables 6 and 7 show the significant improvement, based on variance reduction, over the previous dbh and height equations of table 5. Measuring one additional diameter at 1/3 the total

$$F = [1 - \frac{\sum(Y - \hat{Y})^2}{\sum(Y - \bar{Y})^2}]$$

height, $D_{1/3}$, reduces the standard error of estimate 33 to 47 percent for both bole wood and the total bole.

Measuring two upper bole diameters at points 1/4 and 1/2 of the total height result in further significant increases in precision. Improvements in the standard error of estimate over the dbh and height model range from 60 to 80 percent for bole wood and total bole.

Taking additional bole measurements means a higher inventory cost, since more time will need to be spent at each tree. However, a large proportion of inventory cost is travel to the candidate tree. The data presented in this section allow total and merchantable bole estimates to be made with a high degree of reliability. Each user has to decide when increased precision is needed and whether the need will offset the increased 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 8 gives the statistics 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 $Y = b_0 D^{b_1} + e$.

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Table I.-Regression statistics for predicting *Nuttall oak tree volumes and weights*¹

Component	Average Y	b ₀	b ₁	b ₂	Fit index ²	$\hat{S}_{y,x}$ ³	C.V. percent ⁴
Volume (cubic feet)							
Bole wood	68.8	0.00160	1.7760	1.1794	0.987	7.87	11.4
Total bole	76.6	0.00211	1.7490	1.1609	0.987	8.68	11.3
Total tree	113.9	0.00844	2.2210	0.6112	0.988	13.23	11.6
Green weight (pounds)							
Bole wood	4576	0.05261	1.7910	1.3211	0.988	510	11.1
Total bole	5076	0.07352	1.7646	1.2893	0.988	551	10.9
Total tree	7540	0.30356	2.2438	0.7269	0.987	934	12.4
Dry weight (pounds)							
Bole wood	2324	0.05839	1.7362	1.1899	0.982	308	13.3
Total bole	2631	0.08238	1.7130	1.1582	0.982	342	13.0
Total tree	3909	0.31596	2.1854	0.6169	0.984	616	13.2

¹Volumes and weights of trees from a 1-foot stump to the tree tip, using $Y = b_0 D^{b_1} H^{b_2}$; D = dbh, H = total height.

²Fit index = $1 - [\sum(Y - \hat{Y})^2 / \sum(Y - \bar{Y})^2]$.

³ $\hat{S}_{y,x} = [\sum(Y - \hat{Y})^2 / (n - 3)]^{1/2}$.

⁴Coefficient of variation = $100 \hat{S}_{y,x} / \bar{Y}$.

Table 2.—Cubic-foot volume for Nuttall oak bole wood, bole wood plus bark, and total tree¹

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>cubic feet</i>											
2	0.192											
	0.23											
	0.25											
3	0.39 ³	0.62										
	0.47	0.75										
	0.60	0.77										
4		1.04	1.45									
		1.24	1.73									
		1.47	1.75									
5		1.54	2.16									
		1.83	2.55									
		2.41	2.87									
6		2.13	2.99	3.89								
		2.51	3.51	4.55								
		3.61	4.30	4.93								
7			3.93	5.11	6.34							
			4.59	5.95	7.36							
			6.06	6.94	7.76							
8			4.98	6.48	8.04	9.64						
			5.80	7.52	9.29	11.1						
			8.15	9.34	10.4	11.5						
9			6.14	7.99	9.91	11.9	13.9					
			7.13	9.24	11.4	13.7	15.9					
			10.6	12.1	13.6	14.9	16.2					
10				9.63	11.9	14.3	16.8					
				11.1	13.7	16.4	19.2					
				15.3	17.1	18.8	20.4					
11				11.4	14.1	17.0	19.9	22.8				
				13.1	16.2	19.4	22.6	26.0				
				19.0	21.2	23.3	25.3	27.1				
12				13.3	16.5	19.8	23.2	26.6	30.2			
				15.3	18.9	22.6	26.4	30.2	34.2			
				23.0	25.7	28.2	30.6	32.9	35.1			
13					19.0	22.8	26.7	30.7	34.8			
					21.7	26.0	30.3	34.8	39.3			
					30.7	33.7	36.6	39.3	42.0			
14					21.7	26.0	30.5	35.0	39.7			
					24.7	29.6	34.5	39.6	44.7			
					36.2	39.8	43.2	46.4	49.5			
15					24.5	29.4	34.5	39.6	44.8			
					27.9	33.4	39.0	44.7	50.5			
					42.2	46.4	50.3	54.1	57.6			
16						33.0	38.6	44.4	50.3	56.3		
						37.4	43.6	50.0	56.5	63.1		
						53.5	58.1	62.4	66.5	70.5		
17						36.8	43.0	49.5	56.0	62.7		
						41.5	48.5	55.6	62.8	70.2		
						61.2	66.4	71.4	76.1	80.7		
18						40.7	47.6	54.7	62.0	69.4		
						45.9	53.9	61.4	69.4	77.6		
						69.5	75.4	81.0	86.4	91.6		
19						44.8	52.4	60.3	68.2	76.3	84.6	
						50.4	58.9	67.5	76.3	85.3	94.3	
						78.4	85.0	91.4	97.5	103.0	109.0	

Table Z.-Cubic-foot volume for Nuttall oak bole wood, bole wood plus bark, and total tree'-Continued

Dbh	Total height, in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>cubic feet</i>											
20						49.1	57.4	66.0	74.7	83.6	92.7	
						55.2	64.4	73.9	83.5	93.3	103	
						87.8	95.3	102	109	116	122	
21						53.5	62.6	72.0	81.5	91.2	101	
						60.1	70.2	80.5	90.9	102	112	
						97.9	106	114	122	129	136	
22							68.0	78.2	88.5	99.0	110	
							76.1	87.3	98.6	110	122	
							118	127	135	143	151	
23							73.6	84.6	95.8	107	119	
							82.3	94.3	107	119	132	
							130	140	149	158	167	
24							79.4	91.2	103	116	128	
							88.6	102	115	128	142	
							143	154	164	174	183	
25							85.4	98.1	111	124	138	151
							95.2	109	123	138	152	167
							156	168	179	190	200	210
26							91.5	105	119	133	148	162
							102	117	132	148	163	179
							171	183	196	207	219	230
27							97.9	112	127	142	158	174
							109	125	141	158	174	191
							186	199	213	226	238	250
28							104	120	136	152	168	185
							116	133	150	168	186	204
							201	216	231	244	258	271
29							113	128	145	162	179	197
							123	141	160	179	198	217
							217	234	249	264	279	293
30							118	136	154	172	190	209
							131	150	170	190	210	230
							235	252	269	285	300	316
31							125	144	163	182	202	222
							139	159	180	201	222	244
							252	271	289	306	323	339
32								152	172	193	213	235
								168	190	212	235	258
								291	310	329	347	364
33								161	182	203	225	248
								177	200	224	248	272
								311	332	352	371	390
34								169	192	215	238	261
								187	211	236	261	286
								333	355	376	397	417
35								178	202	226	250	275
								197	222	248	275	301
								355	378	401	423	444
36								187	212	238	263	289
								207	233	261	288	316
								378	403	427	450	473

Table Z.—Cubic-foot volume for *Nuttall oak* bole wood, bole wood plus bark, and total tree¹—Continued

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>cubic feet</i>											
37								197	223	249	276	304
								217	245	274	303	332
								402	428	454	479	503
38								206	234	261	290	318
								227	257	287	317	348
								426	454	482	508	533
39								216	245	274	303	333
								238	268	300	332	364
								451	481	510	538	565
40								226	256	286	317	349
								248	281	313	347	381
								477	509	540	569	598

¹Tree volume above a 1-foot stump.

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 branches) last.

²Italicized numbers span the range of the data.

Table 3.—Green weight in pounds for *Nuttall oak* bole wood, bole wood plus bark, and total tree¹

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>pounds</i>											
2	10 ²											
	12											
	13											
3	203	34										
	24	41										
	32	42										
4		56	82									
		68	99									
		81	100									
5		84	123									
		101	146									
		133	164									
6		116	170	229								
		139	202	269								
		200	247	291								
7			224	301	383							
			265	353	447							
			349	411	469							
8			285	383	487	597						
			335	447	566	690						
			471	554	633	708						
9			352	473	601	737	879					
			413	551	696	850	1009					
			614	722	824	922	1016					
10				571	726	890	1062					
				663	839	1023	1215					
				914	1044	1167	1286					

Table 3.—Green weight in pounds for Nuttall oak bole wood, bole wood plus bark, and total tree—Continued

Dbh inches	Total height in feet.											
	20	30	40	50	60	70	80	90	100	110	120	130
11				677	861	1056	1260	1472				
				785	992	1211	1438	1674				
				1132	1293	1446	1593	1736				
12				791	1007	1234	1472	1720	1977			
				915	1157	1412	1677	1952	2236			
				1376	1571	1758	1937	2110	2278			
13					1162	1424	1699	1985	2281			
					1333	1626	1931	2248	2575			
					1880	2103	2318	2525	2726			
14					1327	1626	1940	2267	2605			
					1519	1853	2201	2562	2935			
					2221	2484	2737	2982	3219			
15					1501	1840	2195	2565	2948			
					1715	2093	2486	2894	3315			
					2592	2900	3195	3481	3758			
16						2066	2464	2879	3309	3753		
						2345	2786	3243	3714	4200		
						3351	3693	4023	4343	4655		
17						2303	2747	3209	3689	4183		
						2610	3100	3609	4134	4674		
						3840	4231	4609	4976	5333		
18						2551	3043	3555	4086	4634		
						2887	3429	3992	4572	5170		
						4365	4810	5240	5657	6063		
19						2810	3352	3917	4502	5106	5728	
						3176	3773	4391	5030	5680	6363	
						4928	5431	5916	6387	6845	7292	
20						3081	3675	4294	4935	5597	6279	
						3477	4130	4807	5507	6227	6966	
						5530	6093	6638	7166	7680	8182	
21						3362	4010	4686	5385	6108	6852	
						3739	4501	5240	6002	6787	7592	
						6169	6798	7406	7995	8569	9128	
22						4359	5093	5853	6639	7447		
						4886	5687	6515	7367	8242		
						7546	8221	8875	9511	10132		
23						4720	5515	6338	7189	a064		
						5235	6152	7047	7968	8914		
						8337	9083	9806	10509	11395		
24						5094	5951	6840	7758	8703		
						5697	6632	7597	8590	9610		
						9173	9993	10788	11562	12317		
25						5480	6403	7359	8347	9363	10408	
						6123	7127	8164	9232	10328	11450	
						10053	10951	11823	12671	13499	14307	
26						5879	6869	7895	8954	10045	11166	
						6562	7638	8749	9893	11068	12271	
						10978	11959	12911	13837	14740	15623	
27						6290	7349	8447	9580	10747	11946	
						7013	8164	9352	10574	11830	13116	
						11948	13016	14052	15060	16043	17004	
28						6713	7844	9015	10225	11470	12750	
						7478	8705	9971	11275	12614	13986	
						12964	14122	15246	16340	17407	18450	

Table 3.—Green weight in pounds for Nuttall oak bole hood, bole wood plus bark, and total tree¹—Continued

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>pounds</i>											
29						7149	8353	9600	10888	12214	13577	
						7956	9261	10608	11995	13420	14879	
						14026	15279	16495	17679	18833	19961	
30						7596	8875	10201	11570	12979	14426	
						8447	9832	11262	12735	14247	15796	
						15134	16487	17799	19076	20321	21539	
31						8056	9412	10818	12269	13764	15299	
						8950	10417	11933	13494	15096	16737	
						16290	17746	19158	20532	21873	23183	
32							9963	11451	12987	14569	16194	
							11018	12621	14271	15965	17701	
							19056	20573	22048	23488	24895	
33							10527	12099	13723	15395	17112	
							I 1633	13325	15067	16856	18689	
							20418	22043	23625	25167	26675	
34							11105	12764	14477	16240	18051	
							12262	14046	15882	17768	19700	
							21833	23570	25261	26911	28523	
35							11697	13444	15248	17105	19013	
							12905	14783	16716	18701	20734	
							23300	25154	26959	26719	30440	
36							12303	14140	16037	17991	19997	
							13563	15536	17568	19654	21790	
							24820	26796	28718	30593	32426	
37							12921	14851	16844	18895	21003	
							14235	16306	18438	20627	22870	
							26394	28495	30539	32533	34482	
38							13553	15577	17668	19820	22039	
							14921	17092	19327	21621	23972	
							28022	30252	32422	34539	36698	
39							14199	16319	18509	20764	23079	
							15621	17893	20233	22635	25096	
							29703	32068	34368	36612	38805	
40							14857	17076	19368	21727	24150	
							16334	18711	21158	23669	26243	
							31440	33942	36377	38752	41074	

¹Tree weight above a 1-foot stump.

²The three vertical figures for each dbh give green weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus branches) last.

³Italicized numbers span the range of the data.

Table 4.—Oven-dry weight in pounds for Nuttall oak bole wood, bole wood plus bark, and total tree¹

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>pounds</i> -----											
2	7 ²											
	8											
	9											
3	14 ³	23										
	17	27										
	22	28										
4		37	52									
		45	63									
		53	64									
5		55	77									
		67	93									
		87	104									
6		75	106	138								
		91	127	165								
		129	154	177								
7			138	180	224							
			166	214	265							
			216	248	278							
8			174	227	282	339						
			208	270	333	398						
			289	332	372	409						
9			213	278	346	415	487					
			255	330	407	487	568					
			374	430	481	529	574					
10				334	415	499	585					
				395	488	583	681					
				541	605	666	723					
11				394	490	589	690	794				
				465	574	687	802	919				
				666	745	820	890	957				
12				459	570	685	802	923	1047			
				540	667	797	930	1066	1205			
				806	901	991	1076	1158	1235			
13					655	787	922	1061	1203			
					765	914	1067	1223	1382			
					1074	1181	1282	1379	1471			
14					745	895	1049	1207	1368			
					868	1038	1212	1389	1569			
					1262	1388	1508	1621	1730			
15					840	1009	1182	1360	1542			
					977	1168	1363	1563	1766			
					1468	1614	1753	1885	2012			
16						1128	1322	1521	1724	1932		
						1305	1523	1745	1972	2202		
						1859	2018	2171	2316	2457		
17						1253	1469	1690	1916	2146		
						1447	1690	1936	2188	2443		
						2122	2304	2478	2644	2805		
18						1384	1622	1866	2116	2310		
						1596	1863	2136	2413	2694		
						2405	2611	2808	2996	3178		
19						1520	1782	2050	2324	2603	2887	
						1751	2044	2343	2647	2956	3269	
						2706	2939	3160	3372	3576	3774	

Table 4.—Oven-dry weight in pounds for Nuttall oak bole wood, bole wood plus bark, and total tree¹—Continued

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
<i>inches</i>	<i>pounds</i>											
20						1662	1948	2241	2540	2846	3156	
						1912	2232	2558	2890	3227	3570	
						3027	3287	3535	3772	4001	4221	
21						1809	2120	2439	2765	3097	3435	
						2079	2426	2781	3142	3509	3881	
						3368	3657	3933	4197	4451	4696	
22							2299	2644	2998	3358	3724	
							2628	3012	3403	3800	4203	
							4048	4353	4646	4927	5199	
23							2483	2857	3238	3627	4023	
							2836	3250	3672	4100	4535	
							4461	4797	5120	5430	5729	
24							2673	3076	3486	3905	4331	
							3050	3496	3950	4411	4878	
							4896	5265	5619	5959	6287	
25							2870	3302	3743	4192	4649	5114
							3271	3749	4236	4730	5232	5740
							5353	5756	6143	6515	6874	7222
26							3072	3534	4006	4487	4977	5474
							3498	4010	4530	5059	5595	6139
							5832	6272	6693	7098	7489	7868
27							3280	3774	4278	4791	5314	5845
							3732	4277	4832	5397	5969	6549
							6333	6811	7268	7708	8133	8545
28							3494	4020	4556	5104	5660	6226
							3972	4552	5143	5743	6352	6969
							6857	7374	7869	8346	8806	9252
29							3713	4272	4843	5424	6016	6617
							4218	4834	5462	6099	6746	7401
							7404	7962	8497	9011	9508	9989
30							3939	4531	5136	5753	6381	7018
							4470	5123	5788	6464	7149	7844
							7973	8574	9150	9704	10239	10757
31							4169	4796	5437	6090	6754	7429
							4728	5419	6123	6837	7562	8297
							8566	9211	9830	10425	11000	11556
32								5068	5745	6435	7137	7850
								5722	6465	7219	7985	8761
								9873	10536	11174	11790	12387
33								5346	6060	6788	7529	8281
								6032	6815	7610	8417	9235
								10560	11269	11951	12610	13248
34								5631	6383	7149	7929	8722
								6348	7172	8010	8859	9719
								11272	12028	12757	13460	14142
35								5921	6712	7518	8339	9172
								6672	7538	8417	9310	10214
								12009	12815	13591	14341	15066
36								6218	7049	7895	8757	9631
								7001	7910	8833	9770	10719
								12771	13629	14454	15251	16023
37								6521	7392	8280	9183	10101
								7338	8290	9258	10240	11234
								13559	14470	15346	16192	17012

Table 4.—Oven-dry weight in pounds for Nuttall oak bole wood, bole wood plus bark, and total tree'—Continued

Dbh	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	.130
<i>inches</i>	<i>pounds</i>											
38								6830	7743	8672	9618	10579
								7681	8678	9691	10718	11759
								14373	15338	16267	17164	18033
39								7145	8100	9072	10062	11067
								8030	9073	10132	11206	12294
								15213	16234	17217	18167	19086
40								7466	8464	9480	10514	11565
								8386	9474	10581	11702	12839
								16078	17158	18197	19200	20172

¹Tree weight above a 1-foot stump.

*The three vertical figures for each dbh give dry weights of bole wood first, bole wood plus bark second, and total tree (bole wood plus bark plus branches) last.

³Italicized numbers span the range of the data.

Table 5.—Nuttall oak ratio parameter estimates for estimating the proportion of merchantable bole to total bole*

Ratio	n	a	β	Y	$\hat{S}_{y,x}$
R2	56	0.999	- 0.270	0.691	0.00175
R4	56	0.989	• 9.461	0.566	0.01172
R6	54	0.979	-18.577	0.627	0.02203
R8	49	0.972	-24.961	0.690	0.03558
R10	43	0.964	-30.795	0.729	0.04854
R12	36	0.953	-57.489	0.740	0.04851

¹RI = $\alpha + \beta\gamma^D$; D = dbh; RI = ratio of merchantable bole at top diameter I to total bole.

Table 6.—Regression statistics for predicting Nuttall oak bole volumes and weights'

	Volume (ft ³)		Green weight (lbs)		Dry weight (lbs)	
	Bole wood	Total bole	Bole wood	Total bole	Bole wood	Total bole
Average Y	68.8	76.6	4575	5076	2324	2631
b ₀	0.00095	0.00126	0.02923	0.04096	0.03585	0.05108
b ₁	1.58765	1.55802	1.69554	1.66217	1.49837	1.45780
b ₂	2.01417	1.98440	2.00641	1.97965	1.97468	1.94976
b ₃	1.17072	1.15284	1.31468	1.28352	1.18306	1.15232
Fit index'	0.996	0.995	0.995	0.995	0.992	0.992
$\hat{S}_{y,x}$ ³	4.19*	5.30'	335*	351*	206'	222
C.V. percent ⁴	6.1	6.9	7.3	6.9	8.9	8.4

¹All predictions from a 1-foot stump to the tree tip using $Y = b_0(D^{b_1} t D_{1/3}^{b_2}) H^{b_3}$; D = dbh, H = total tree height, $D_{1/3}$ = diameter outside bark at 1/3 H.

²Fit index = $1 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$.

³ $\hat{S}_{y,x} = [\Sigma(Y - \hat{Y})^2 / (n - 4)]^{1/2}$.

⁴Coefficient of variation = $100 \hat{S}_{y,x} / \bar{Y}$.

*Significantly more precise than the two variable model $Y = b_0 D^{b_1} H^{b_2}$; $\alpha = 0.01$.

Table 7.—Regression statistics for predicting Nuttall oak bole volumes and weights'

	Volume (ft ³)		Green weight (lbs)		Dry weight (lbs)	
	Bole wood	Total bole	Bole wood	Total bole	Bole wood	Total bole
Average Y	68.8	76.6	4575	5076	2324	2631
b ₀	0.00127	0.00174	0.04421	0.06615	0.04617	0.06875
b ₁	0.87745	0.89690	1.12244	1.13885	0.52735	0.60499
b ₂	1.10015	1.06095	0.88478	0.85108	1.41691	1.32736
b ₃	1.92812	1.88605	1.87860	1.82274	1.91916	1.87988
b ₄	1.07231	1.04448	1.20056	1.15453	1.08714	1.04030
Fit index'	0.999	0.999	0.998	0.998	0.997	0.998
$\hat{S}_{y,x}^3$	1.65*	1.74*	204*	201'	121*	127*
C.V. percent ⁴	2.4	2.3	4.5	4.0	5.2	4.8

¹All predictions from a 1-foot stump to the tree tip using $Y = b_0[(D^{b_1} \cdot D_{1/2}^{b_2}) + D_{1/4}^{b_3}] H^{b_4}$; D = dbh, H = total tree height, $D_{1/2}$ and $D_{1/4}$ = diameters outside bark at $\frac{1}{2}H$ and $\frac{1}{4}H$, respectively.

²Fit index = $1 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$.

³ $\hat{S}_{y,x} = [\Sigma(Y - \hat{Y})^2 / (n - 5)]^{1/2}$.

⁴Coefficient of variation = $100 \hat{S}_{y,x} / \bar{Y}$.

⁵Significantly more precise than either the two variable model $Y = b_0 D^{b_1} H^{b_2}$ or the three variable model $Y = b_0(D^{b_1} + D_{1/3}^{b_2}) H^{b_3}$; $\alpha = 0.01$.

Table 8.—Local volume and weight equations for Nuttall oak'

Component	Average Y	b ₀	b ₁	Fit index'	$\hat{S}_{y,x}^3$	C.V. percent ⁴
	Volume (cubic feet)					
Bole wood	68.8	0.13184	2.09394	0.972	11.28	16.4
Total bole	76.6	0.16154	2.06406	0.972	12.36	16.1
Total tree	113.9	0.07353	2.41890	0.977	17.71	15.5
Green weight (pounds)						
Bole wood	4575	7.51917	2.14149	0.970	787	17.2
Total bole	5076	9.26000	2.10884	0.971	851	16.8
Total tree	7540	4.09080	2.47130	0.974	1261	16.7
Dry weight (pounds)						
Bole wood	2324	4.99446	2.05787	0.967	411	17.7
Total bole	2631	6.21402	2.02829	0.967	455	17.3
Total tree	3909	2.83658	2.38225	0.974	646	16.5

*From a 1-foot stump to the tree tip, using $Y = b_0 D^{b_1}$; D = dbh.

²Fit index = $1 - [\Sigma(Y - \hat{Y})^2 / \Sigma(Y - \bar{Y})^2]$.

³ $\hat{S}_{y,x} = [\Sigma(Y - \hat{Y})^2 / (n - 2)]^{1/2}$.

⁴Coefficient of variation = $100 \hat{S}_{y,x} / \bar{Y}$.

APPENDIX

Examples Using the Equations

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

$$\begin{aligned} D &= 23.2 \text{ in} \\ H &= 108 \text{ ft} \\ D_{1/4} &= 18.0 \text{ in} \\ D_{1/3} &= 16.8 \text{ in} \\ D_{1/2} &= 10.9 \text{ in.} \end{aligned}$$

Bole wood volume is calculated using D, H, and the parameter estimates from table 1 as follows:

$$\begin{aligned} V &= b_0 D^{b_1} H^{b_2} \\ &= 0.00160 (23.2)^{1.7760} (108)^{1.1794} \\ &= 0.00160 (266.14) (250.16) \\ V &= 107; \text{ bole wood volume} = 107 \text{ ft}^3. \end{aligned}$$

To calculate total green bole weight using D, H, and $D_{1/3}$ and the parameter estimates from table 6:

$$\begin{aligned} W &= b_0 [D^{b_1} + D_{1/3}^{b_2}] H^{b_3} \\ &= 0.04096 [(23.2)^{1.66217} + (16.8)^{1.97965}] (108)^{1.28352} \\ &= 0.04096 [186.07 + 266.49] (407.32) \end{aligned}$$

$W = 7550$; total green bole weight is 7550 lbs.

To calculate total bole dry weight using D, H, $D_{1/4}$, and $D_{1/2}$ and the parameter estimates from table 7:

$$\begin{aligned} W &= b_0 [(D)^{b_1} (D_{1/2})^{b_2} + (D_{1/4})^{b_3}] H^{b_4} \\ &= 0.06875 [(23.2)^{0.60499} (10.9)^{1.32736} \\ &\quad + (18.0)^{1.87988}] (108)^{1.04030} \\ &= 0.06875 [(6.70) (23.83) + (228.96)] (130.43) \\ &= 3485; \text{ total dry bole weight is 3485 pounds.} \end{aligned}$$

For purposes of comparison, the measured values for this tree are: bole wood volume, 88 cu. ft.; total green bole weight, 6671 lbs.; and total bole dry weight, 3314 lbs.

Merchantable bole estimates to, say, a 10-inch top are calculated using table 5 to estimate the merchantable proportion of the total bole and then multiplying that proportion by the predicted bole estimate of interest:

$$\begin{aligned} RI &= \alpha + \beta \gamma^D \\ R10 &= 0.964 + (-30.795)(0.729)^{23.2} \\ &= 0.964 + (-30.795)(0.000654) \\ &= 0.964 - 0.020 \\ R10 &= 0.944. \end{aligned}$$

Then bole wood volume to a 10-inch top can be calculated:

$$\begin{aligned} V10 &= (R10)(\text{predicted total bole wood volume}) \\ &= (0.944)(107) \\ V10 &= 101 \text{ cubic feet} \end{aligned}$$

Of course, total bole volumes or weights can be calculated using any one of the three sets of parameter estimates given in tables 1, 6, or 7. 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.

The relative precision of the four different model forms in estimating the three components in this example are compared in the following tabulation:

Model	Bole wood volume	Total green bole weight	Total dry bole weight
	<i>cubic feet</i>	<i>pounds</i>	<i>pounds</i>
$b_0 D^{b_1}$	95	7018	3656
$b_0 D^{b_1} H^{b_2}$	107	7900	4074
$b_0 (D^{b_1} + D_{1/3}^{b_2}) H^{b_3}$	101	7550	3859
$b_0 [(D^{b_1} \cdot D_{1/2}^{b_2}) + D_{1/4}^{b_3}] H^{b_4}$	93	6897	3485
Measured	88	6671	3314

This tabulation compares estimates for a single tree. The estimates based on diameter alone are close to the estimate from the four-variable model. This is a chance occurrence in this case which always must be considered in single estimates. But on the average, taking more tree measurements will increase the precision of the estimate.

SCHLAEGEL, BRYCE E., AND REGAN B. WJLLSON.
1983. Nuttall oak volume and weight tables. U.S. Dep.
Agric. For. Serv. Res. Pap. SO-186, 14 p. South. For. Exp.
Stn., New Orleans, La.

A sample of 62 trees from the Mississippi Delta is used to
construct volume and weight tables for Nuttall oak.

Additional keywords: *Quercus nuttallii*, merchantable
bole estimates, biomass, nonlinear regression.