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Willow Oak Volume and Weight Tables for the Mississippi Delta

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SUMMARY

A sample of 79 trees from the Mississippi Delta is used to construct volume and weight tables for willow oak *(Quercus phellos* L.*)*. By using the allometric model, D^2H (squared diameter at breast height multiplied by total tree height) can predict volumes and weights of bole wood, bole wood plus bark, and bole wood plus bark plus limbs. Equations are presented for estimating merchantable bole volumes and weights at 2-inch intervals to top diameters of 2 to 12 inches. Additional equations are given for estimates using upper bole diameters at relative heights of 0.25H, 0.33H, and 0.50H, which are significant improvements over the D^2H equations.

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INTRODUCTION

Willow oak *(Q. phellos* L.*)* is a common bottom land species ranging from Long Island to Georgia and from the Atlantic Coast to eastern Texas (fig. 1). On good sites, it is a moderately rapid grower reaching heights over 120 ft and with a dbh (diameter at breast height) in excess of 3 ft.

In recent years there has been considerable demand for volume and weight tables for bottom land hardwood species. This paper is the first of a series of six giving both volume and weight tables for some of the major bottom land hardwood species. Species analyzed in later series are Nuttall oak *(Q. nuttallii* Palmer*)*, overcup oak *(Q. lyrata* Walt.*)*, sugarberry *(Celtis laevigata* Willd.*)*, sweetgum *(Liquidambar styraciflua* L.*)*, and green ash *(Fraxinus pennsylvanica* Marsh.*)*.

METHODS

Data were collected from 10 natural bottom land hardwood stands in Mississippi. Nine of the stands were uneven-aged, mixed species, and one of the stands was even-aged and pure.

Each stand was measured for species composition and diameter distribution. Chosen for destructive sampling were 79 trees ranging from 2 to 37 inches dbh. Both understory and overstory trees were judged as growing stock with healthy crowns and no visible signs of disease or decay. When available, three trees were selected from each diameter class.

Stump height, height to crown, and total height were measured on each felled sample tree. One-inch thick disks were cut from the bole at regular intervals and sealed in separate polyethylene bags for laboratory determination of moisture content and specific gravity. The first disk was at stump height and the remaining disks were from ground to tree top at 5-ft intervals for trees 5 inches dbh and larger and at 3-ft intervals for trees smaller than 5 inches dbh. All limbs were weighed on 65 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 or until weight loss was completed.

$$\text{Wood or bark moisture content} = \frac{\text{green weight-ovendry weight}}{\text{ovendry weight}}$$

$$\text{Specific gravity} = \frac{\text{ovendry wood (bark) weight (g)}}{\text{green wood (bark) volume (cm}^3\text{)}}$$

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

Taper functions were calculated for each tree both inside and outside the bark. Cubic foot volumes were obtained by integrating the taper function to heights of specific top diameters. Moisture content and specific gravity were assumed to be uniform along the bole. Bole green and dry weights were calculated from estimated tree volume and average tree density and moisture.

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 branches.

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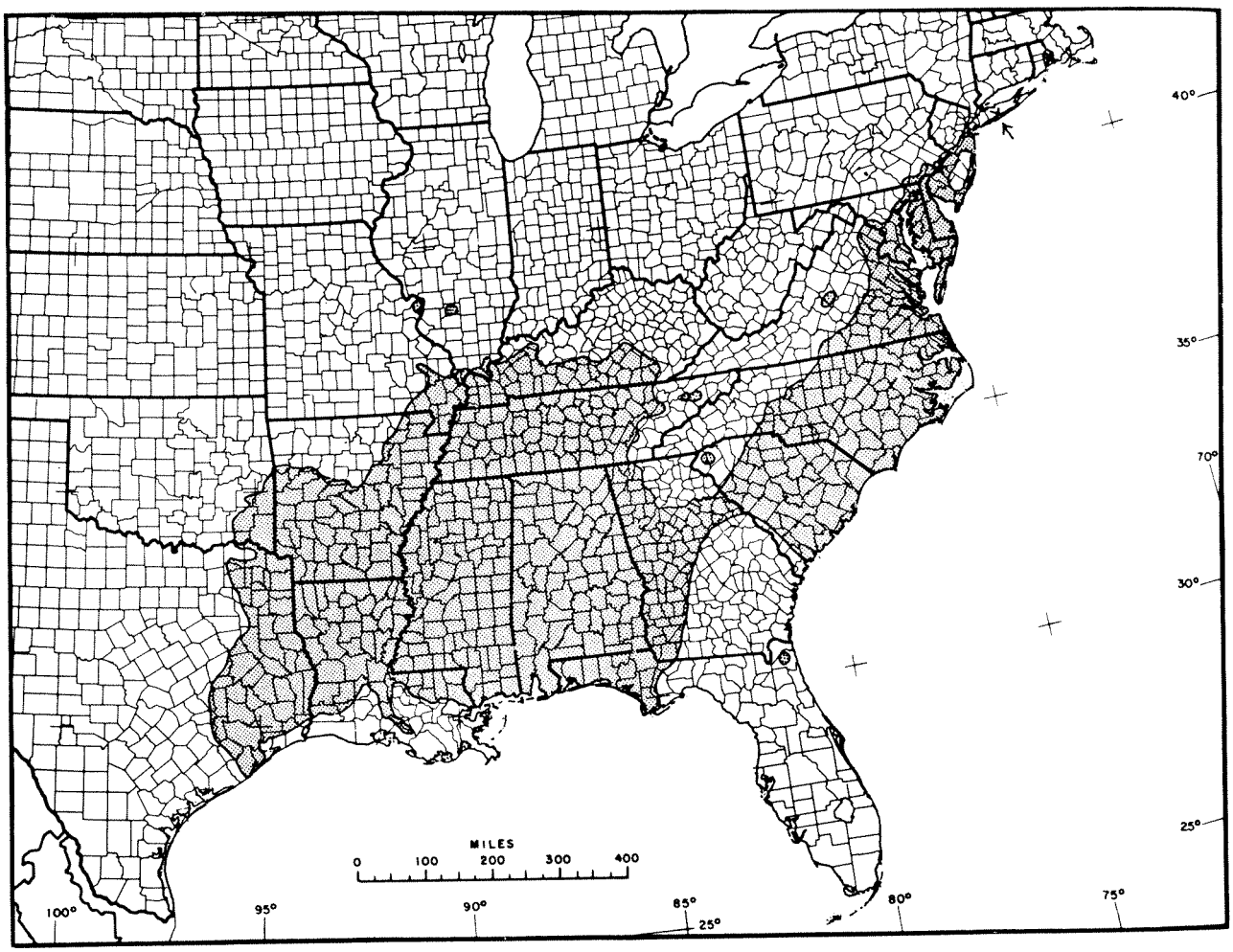

Figure 1—*The range of willow oak is from Long Island to Georgia and from the Atlantic Coast to eastern Texas.*

RESULTS

Characteristics of the trees used in this study are:

	Average	Range
Age *(years)*	59	19–111
Dbh *(in)*	15.7	1.7–37.0
Total height *(ft)*	76	20–124
Wood moisture content *(percent)*	80	68–99
Bark moisture content *(percent)*	67	45–171
Wood specific gravity	0.593	0.499–0.651
Bark specific gravity	0.625	0.396–0.989
Wood + bark green density *(lb/ft³)*	66.18	57.69–69.37
Wood + bark dry density *(lb/ft³)*	37.23	32.17–41.02
Wood + bark moisture content *(percent)*	78	66–93
Wood + bark specific gravity	0.596	0.515–0.657

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

$$LN(Y) = LN(a) + b\ LN(D^2H) \quad (1)$$

where

Y = the volume or weight variable of interest,
D = tree dbh in inches,
H = total height in feet, and
LN is a natural logarithm;
LN(a) and b are coefficients estimated from the data.

Estimates of the coefficients LN(a) and b are presented in table 1 for predicting cubic foot volume and green and dry weight of bole wood, total bole, and total tree. Additional statistics presented are the component average, fit index (FI), regression standard error of estimate ($\hat{S}_{y.x}$) 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 variable has been transformed (Farrar

1978) and is calculated in actual 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 0.884 for dry bole bark weight to 0.978 for bole wood volume. A fit index of 1.0 indicates that predictions can be made without error when the data are used to fit the model. Coefficients of variation, which are indices of relative precision of prediction, range from 33.0 percent for dry bark weight to 15.2 percent for bole wood volume.

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

MERCHANTABLE BOLE ESTIMATES

The merchantable bole is defined as the tree bole from a 1-ft stump to a specific top diameter, ignoring 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):

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

where

D = tree dbh outside bark,

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

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

α = the upper asymptote of the ratio,

β = the change in the ratio estimate as D goes from 0 to 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 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. Moisture and density trends within the bole are ignored.

Table 5 gives the parameter estimates for Model 2 using nonlinear techniques proposed by Stevens (1951). Intervals are measured by 2-inch top diameters outside the bark. Volume or weight to any top diameter I is found by multiplying the ratio estimate from one of the equations in table 5 with the total bole volume or weight estimate from tables 2, 3, or 4.

$$V4 = R4 \cdot VT,$$

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

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

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 6 and 7 give regression statistics for total bole volume and weight under two different model forms:

$$Ln(Y) = Ln(a) + b\ Ln(D \cdot D_{1/3} \cdot H)$$

and

$$Ln(Y) = Ln(a) + b\ Ln[(D \cdot D_{1/2} + D^2_{1/4}) \cdot H]$$

where D, H, and Y are 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 6 and 7 show the significant improvement over the previous D^2H equations of table 1. Measuring one additional diameter at one-third the tree height reduces standard error of estimate, $\hat{S}_{y \cdot x}$, by 32 to 40 percent for bole wood and total bole. Bark standard errors are reduced but not significantly.

Measuring two upper bole diameters at one-fourth and one-half total height result in greater precision with bark predictions being more precise than the D^2H model. Improvements over the D^2H model range from 53 to 71 percent for bole wood and total bole and from 28 to 31 percent for bark.

Taking additional bole measures means a higher inventory cost since more time will be spent at each tree. Much 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 will offset the higher cost.

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Table 1—*Regression statistics for predicting willow oak tree volumes and weights;*[1] $Ln(Y)=Ln(a) + b\ Ln(D^2H)$

Component	Average Y	Ln(a)	b	Fit index	$\hat{S}_{y \cdot x}$	C.V. percent
			Volume *(cubic feet)*			
Bole wood	54.7	−6.047	0.97301	0.978	8.32	15.2
Bole bark	7.3	−7.026	0.89551	0.913	2.04	27.9
Total bole	62.0	−5.798	0.96166	0.975	10.01	16.1
Total tree	101.0	−5.719	0.98243	0.961	19.01	18.8
			Green weight *(pounds)*			
Bole wood	3634	−1.856	0.97354	0.974	610	16.8
Bole bark	464	−2.903	0.88049	0.907	136	29.4
Total bole	4098	−1.590	0.96001	0.971	713	17.4
Total tree	6687	−1.546	0.98398	0.949	1460	21.8
			Dry weight *(pounds)*			
Bole wood	1991	−2.381	0.96703	0.969	359	18.1
Bole bark	299	−3.870	0.93109	0.884	99	33.0
Total bole	2290	−2.179	0.96142	0.965	435	19.0
Total tree	3728	−2.102	0.98175	0.947	812	21.8

[1]All predictions from a 1-ft stump to tree tip.

Table 2—*Cubic foot volume for willow oak bole wood, bole wood plus bark, and complete trees*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	cubic feet											
2	*0.17*[1]	*0.25*[4]	0.33									
	0.21[2]	*0.30*	0.40									
	0.24[3]	*0.36*	0.48									
3		*0.55*	*0.73*	0.90								
		0.66	*0.87*	1.08								
		0.80	*1.07*	1.33								
4		0.96	*1.27*	*1.58*	1.89							
		1.15	*1.52*	*1.88*	2.24							
		1.41	*1.88*	*2.34*	2.79							
5			1.96	2.44	2.91	3.38						
			2.33	2.88	3.44	3.99						
			2.91	3.62	4.33	5.04						
6			2.80	3.48	4.15	4.82	5.49					
			3.30	4.10	4.88	5.66	6.44					
			4.16	5.18	6.20	7.21	8.22					
7			3.78	*4.69*	*5.60*	*6.51*	7.41	8.31				
			4.45	*5.51*	*6.57*	*7.61*	8.66	9.70				
			5.63	*7.02*	*8.39*	*9.76*	11.1	12.5				
8			4.90	*6.08*	*7.27*	*8.44*	9.61	10.8				
			5.75	*7.12*	*8.49*	*9.84*	11.2	12.5				
			7.33	*9.12*	*10.9*	*12.7*	14.5	16.2				
9			6.16	7.65	*9.14*	*10.6*	*12.1*	*13.6*	15.0			
			7.21	8.93	*10.6*	*12.3*	*14.0*	*15.7*	17.4			
			9.23	11.5	*13.7*	*16.0*	*18.2*	*20.5*	22.7			

Table 2.—*Cubic foot volume for willow oak bole wood, bole wood plus bark, and complete trees—Continued*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	cubic feet											
10				9.39	*11.2*	*13.0*	*14.8*	*16.6*	18.4			
				10.9	*13.0*	*15.1*	*17.2*	*19.2*	21.3			
				14.1	*16.9*	*19.7*	*22.4*	*25.2*	27.9			
11				11.3	*13.5*	*15.7*	*17.9*	*20.0*	22.2	24.3		
				13.1	*15.7*	*18.2*	*20.6*	*23.1*	25.6	28.0		
				17.0	*20.4*	*23.7*	*27.1*	*30.4*	33.7	37.0		
12				13.4	*16.0*	*18.6*	*21.2*	*23.7*	26.3	28.8		
				15.5	*18.5*	*21.5*	*24.4*	*27.3*	30.3	33.2		
				20.2	*24.2*	*28.2*	*32.1*	*36.0*	40.0	43.9		
13				15.6	18.7	*21.7*	*24.7*	*27.7*	*30.7*	33.7		
				18.1	21.6	*25.0*	*28.5*	*31.9*	*35.3*	38.7		
				23.7	28.3	*32.9*	*37.6*	*42.2*	*46.8*	51.4		
14				18.1	21.6	*25.1*	*28.6*	*32.0*	*35.5*	38.9		
				20.9	24.9	*28.9*	*32.8*	*36.8*	*40.7*	44.6		
				27.4	32.8	*38.1*	*43.5*	*48.8*	*54.1*	59.4		
15				20.7	24.7	*28.7*	*32.7*	*36.6*	*40.6*	44.5		
				23.9	28.4	*33.0*	*37.5*	*42.0*	*46.5*	50.9		
				31.4	37.5	*43.6*	*49.8*	*55.9*	*62.0*	68.0		
16				23.4	28.0	*32.5*	*37.0*	*41.5*	*46.0*	50.5	55.0	
				27.0	32.2	*37.3*	*42.4*	*47.5*	*52.6*	57.7	62.7	
				35.6	42.6	*49.5*	*56.5*	*63.4*	*70.3*	77.3	84.2	
17					31.5	36.6	*41.7*	*46.7*	*51.8*	*56.8*	61.8	
					36.2	42.0	*47.7*	*53.4*	*59.1*	*64.8*	70.4	
					48.0	55.8	*63.6*	*71.5*	*79.2*	*87.0*	94.8	
18					35.2	40.9	*46.6*	*52.2*	*57.9*	*63.5*	69.1	
					40.4	46.8	*53.2*	*59.6*	*66.0*	*72.3*	78.6	
					53.7	62.5	*71.2*	*79.9*	*88.7*	*97.4*	106	
19					39.1	*45.4*	*51.7*	*58.0*	*64.3*	70.5	76.8	
					44.8	*52.0*	*59.1*	*66.2*	*73.2*	80.2	87.3	
					59.7	*69.5*	*79.2*	*88.9*	*98.6*	108	118	
20					43.2	*50.2*	*57.2*	*64.1*	*71.0*	77.9	84.8	
					49.4	*57.3*	*65.2*	*73.0*	*80.8*	88.6	96.3	
					66.0	*76.8*	*87.6*	*98.3*	*109*	120	130	
21					47.5	*55.2*	*62.9*	*70.5*	*78.1*	*85.7*	93.3	101
					54.3	*63.0*	*71.6*	*80.2*	*88.8*	*97.3*	106	114
					72.7	*84.5*	*96.4*	*108*	*120*	*132*	144	155
22					52.0	*60.4*	*68.8*	*77.2*	*85.5*	*93.8*	102	110
					59.4	*68.9*	*78.3*	*87.7*	*97.1*	*106*	116	125
					79.6	*92.6*	*106*	*119*	*132*	*144*	157	170
23					56.7	65.9	*75.0*	*84.2*	*93.2*	*102*	*111*	120
					64.7	75.0	*85.3*	*95.5*	*106*	*116*	*126*	136
					86.9	101	*115*	*129*	*144*	*158*	*172*	186
24					61.6	71.6	*81.5*	*91.4*	*101*	*111*	*121*	131
					70.2	81.4	*92.6*	*104*	*115*	*126*	*137*	148
					94.5	110	*125*	*141*	*156*	*171*	*187*	202
25						77.5	*88.3*	*99.0*	*110*	*120*	*131*	*142*
						88.1	*100*	*112*	*124*	*136*	*148*	*160*
						119	*136*	*152*	*169*	*186*	*202*	*219*
26						83.7	*95.3*	*107*	*118*	*130*	*141*	*153*
						95.0	*108*	*121*	*134*	*147*	*160*	*172*
						129	*147*	*165*	*183*	*201*	*218*	*236*

Table 2.—*Cubic foot volume for willow oak bole wood, bole wood plus bark, and complete trees—Continued*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	cubic feet											
27						90.0	103	*115*	*127*	*140*	152	164
						102	116	*130*	*144*	*158*	172	185
						139	158	*177*	*197*	*216*	235	255
28						96.6	110	*123*	*137*	*150*	163	176
						110	125	*139*	*154*	*169*	184	199
						149	170	*190*	*211*	*232*	253	273
29						103	*118*	*132*	*146*	161	175	189
						117	*133*	*149*	*165*	181	197	213
						159	*182*	*204*	*226*	249	271	293
30						111	*126*	*141*	*156*	172	187	202
						125	*142*	*159*	*176*	193	210	227
						170	*194*	*218*	*242*	266	289	313
31						118	*134*	*150*	*167*	*183*	199	215
						133	*151*	*170*	*188*	*206*	224	242
						182	*207*	*233*	*258*	*283*	309	334
32						125	*143*	*160*	*177*	*195*	212	229
						142	*161*	*180*	*200*	*219*	238	257
						193	*221*	*248*	*275*	*302*	328	355
33						133	152	170	188	*207*	*225*	243
						150	171	191	212	*232*	*252*	272
						206	234	263	292	*320*	*349*	378
34							161	180	199	*219*	*238*	258
							181	203	224	*246*	*267*	289
							248	279	309	*340*	*370*	400
35							170	191	211	232	252	272
							191	214	237	260	283	305
							263	295	327	360	392	424
36								201	223	245	266	288
								226	250	274	298	322
								312	346	380	414	448
37								212	235	258	*281*	*304*
								238	264	289	*314*	*340*
								329	365	401	*437*	*473*
38								224	248	272	296	320
								251	278	304	331	357
								347	385	423	460	498
39								235	261	286	311	336
								264	292	320	348	376
								365	405	445	485	524
40								247	274	300	327	353
								277	307	336	365	395
								384	426	468	509	551

[1]Bole wood volume only, from a 1-ft stump to tip of tree.
[2]Bole wood plus bark volume from a 1-ft stump to tip of tree.
[3]Complete tree volume, including branches, from a 1-ft stump to tip of tree.
[4]Italicized numbers denote limits of the data.

Table 3.—*Green weight in pounds for willow oak bole wood, bole wood plus bark, and complete trees*

Dbh in inches	Total height in feet										
	20	30	40	50	60	70	80	90	100	110	120
	pounds										
2	*11*[1]	*17*[4]	22								
	14[2]	*20*	27								
	16[3]	*24*	31								
3		*36*	*48*	60							
		44	*58*	72							
		53	*70*	87							
4		64	*84*	*105*	125						
		76	*101*	*125*	149						
		93	*123*	*153*	183						
5			130	162	193	224					
			155	192	228	265					
			191	238	284	331					
6			186	231	275	320	364				
			219	272	324	376	427				
			273	340	407	474	540				
7			251	*311*	*372*	*432*	492	552			
			295	*365*	*435*	*505*	574	643			
			370	*461*	*551*	*642*	732	822			
8			325	*404*	*482*	*560*	638	716			
			381	*472*	*563*	*652*	742	830			
			481	*599*	*717*	*834*	952	1069			
9			409	508	*606*	*705*	*803*	*900*	997		
			478	592	*705*	*818*	*930*	*1041*	1152		
			607	756	*904*	*1052*	*1200*	*1347*	1494		
10				623	*745*	*865*	*985*	*1105*	1224		
				725	*864*	*1001*	*1138*	*1275*	1410		
				930	*1112*	*1295*	*1476*	*1658*	1839		
11				751	*896*	*1042*	*1186*	*1330*	1474	1617	
				871	*1037*	*1202*	*1367*	*1531*	1693	1856	
				1121	*1342*	*1562*	*1781*	*2000*	2218	2436	
12				889	*1062*	*1234*	*1405*	*1576*	1746	1916	
				1029	*1226*	*1421*	*1615*	*1809*	2001	2193	
				1331	*1592*	*1853*	*2113*	*2373*	2632	2891	
13				1039	1241	*1442*	*1642*	*1842*	*2041*	2239	
				1200	1429	*1657*	*1884*	*2109*	*2334*	2557	
				1558	1864	*2169*	*2474*	*2778*	*3082*	3385	
14				1200	1434	*1666*	*1897*	*2127*	*2357*	2586	
				1383	1648	*1911*	*2172*	*2432*	*2691*	2948	
				1803	2157	*2510*	*2863*	*3214*	*3565*	3916	
15				1373	1640	*1905*	*2170*	*2433*	*2696*	2958	
				1579	1881	*2181*	*2479*	*2776*	*3072*	3366	
				2065	2470	*2875*	*3279*	*3682*	*4084*	4485	
16				1557	1859	*2160*	*2460*	*2759*	*3057*	3354	3651
				1787	2129	*2469*	*2807*	*3143*	*3477*	3810	4142
				2344	2805	*3264*	*3723*	*4180*	*4637*	5093	5548
17					2092	2431	*2768*	*3105*	*3440*	*3775*	4108
					2392	2774	*3153*	*3530*	*3906*	*4280*	4653
					3160	3678	*4195*	*4710*	*5225*	*5738*	6251
18					2339	2717	*3094*	*3470*	*3845*	*4219*	4592
					2670	3095	*3519*	*3940*	*4359*	*4777*	5193
					3537	4116	*4694*	*5271*	*5847*	*6421*	6995

Table 3.—*Green weight in pounds for willow oak bole wood, bole wood plus bark, and complete trees—Continued*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	pounds											
19					2598	*3019*	*3438*	*3856*	*4272*	4687	5102	
					2962	*3434*	*3904*	*4371*	*4836*	5300	5761	
					3934	*4578*	*5221*	*5863*	*6503*	7142	7781	
20					2871	*3336*	*3799*	*4261*	*4721*	5180	5638	
					3268	*3789*	*4308*	*4823*	*5337*	5848	6358	
					4352	*5064*	*5776*	*6485*	*7194*	7901	8607	
21					3157	*3668*	*4178*	*4685*	*5191*	*5696*	6200	6702
					3589	*4161*	*4731*	*5297*	*5861*	*6422*	6982	7540
					4790	*5575*	*6358*	*7139*	*7919*	*8697*	9475	10251
22					3456	*4016*	*4574*	*5129*	*5683*	*6236*	6787	7337
					3924	*4550*	*5173*	*5792*	*6408*	*7022*	7634	8244
					5249	*6109*	*6967*	*7823*	*8678*	*9531*	10383	11234
23					3769	4379	*4987*	*5593*	*6197*	*6800*	*7401*	8001
					4274	4956	*5634*	*6308*	*6979*	*7648*	*8314*	8978
					5729	6668	*7604*	*8538*	*9471*	*10402*	*11332*	12261
24					4095	4758	*5418*	*6076*	*6733*	*7387*	*8040*	8692
					4638	5378	*6113*	*6845*	*7574*	*8299*	*9022*	9743
					6230	7250	*8268*	*9284*	*10299*	*11311*	*12322*	13332
25						5151	*5866*	*6579*	*7290*	*7998*	*8706*	*9411*
						5816	*6612*	*7403*	*8191*	*8976*	*9758*	*10537*
						7857	*8960*	*10061*	*11160*	*12257*	*13353*	*14447*
26						5560	*6332*	*7101*	*7868*	*8633*	*9396*	*10158*
						6271	*7129*	*7982*	*8832*	*9678*	*10521*	*11361*
						8487	*9679*	*10868*	*12056*	*13241*	*14424*	*15607*
27						5984	6815	*7643*	*8468*	*9291*	10113	10932
						6742	7664	*8582*	*9495*	*10405*	11312	12215
						9142	10425	*11706*	*12985*	*14262*	15537	16810
28						6423	7315	*8203*	*9089*	*9973*	10855	11735
						7230	8219	*9203*	*10182*	*11158*	12130	13099
						9820	11199	*12575*	*13948*	*15320*	16689	18057
29						6877	*7832*	*8783*	*9732*	10678	11622	12564
						7734	*8792*	*9844*	*10892*	11935	12975	14012
						10522	*11999*	*13474*	*14946*	16415	17883	19348
30						7346	*8366*	*9383*	*10396*	11407	12416	13422
						8254	*9383*	*10506*	*11624*	12738	13848	14954
						11248	*12827*	*14404*	*15977*	17548	19116	20683
31						7831	*8918*	*10001*	*11082*	*12159*	13234	14307
						8790	*9993*	*11189*	*12380*	*13566*	14748	15926
						11998	*13682*	*15364*	*17042*	*18717*	20391	22062
32						8330	*9487*	*10639*	*11788*	*12935*	14078	15219
						9343	*10621*	*11892*	*13158*	*14419*	15675	16927
						12771	*14564*	*16354*	*18141*	*19924*	21705	23484
33						8844	10072	11296	12516	*13733*	*14947*	16159
						9911	11267	12616	13959	*15296*	*16629*	17957
						13568	15474	17375	19273	*21168*	*23060*	24950
34							10675	11972	13265	*14555*	*15842*	17126
							11932	13360	14782	*16198*	*17610*	19016
							16410	18426	20439	*22449*	*24456*	26460
35							11295	12667	14036	15400	16762	18120
							12615	14125	15628	17126	18618	20105
							17373	19508	21639	23767	25891	28013

Table 3.—*Green weight in pounds for willow oak bole wood, bole wood plus bark, and complete trees—Continued*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	pounds											
36								13382	14827	16269	17707	19142
								14910	16497	18077	19652	21222
								20620	22873	25122	27367	29610
37								14115	15639	17160	*18677*	*20191*
								15715	17388	19054	*20714*	*22368*
								21763	24140	26513	*28883*	*31250*
38								14867	16473	18075	19672	21267
								16541	18301	20055	21802	23543
								22935	25441	27942	30440	32934
39								15638	17328	19012	20693	22370
								17387	19237	21080	22917	24747
								24138	26775	29408	32036	34662
40								16429	18204	19973	21739	23500
								18253	20195	22130	24058	25980
								25371	28143	30910	33673	36432

[1]Bole wood weight only, from a 1-ft stump to tip of tree.
[2]Bole weight of wood plus bark from a 1-ft stump to tip of tree.
[3]Complete tree weight, including branches, from a 1-ft stump to tip of tree.
[4]Italicized numbers denote limits of the data.

Table 4.—*Ovendry weight in pounds for willow oak bole wood, bole wood plus bark, and complete trees*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	pounds											
2	*6*[1]	*9*[4]	13									
	8[2]	*11*	15									
	9[3]	*13*	18									
3		*21*	*27*	34								
		25	*32*	40								
		30	*40*	49								
4		36	*48*	*59*	71							
		43	*56*	*70*	83							
		52	*70*	*87*	103							
5			74	91	109	127						
			87	107	128	148						
			108	134	160	187						
6			105	130	155	180	205					
			123	153	182	211	240					
			154	192	229	267	304					
7			141	*175*	*209*	*243*	276	309				
			166	*205*	*245*	*284*	322	361				
			209	*260*	*311*	*361*	412	462				
8			183	*227*	*270*	*314*	357	400				
			214	*265*	*316*	*367*	417	467				
			271	*338*	*404*	*470*	535	601				

Table 4.—*Ovendry weight in pounds for willow oak bole wood, bole wood plus bark, and complete trees—Continued*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	pounds											
9			230	285	*340*	*394*	*449*	*503*	557			
			268	333	*396*	*460*	*523*	*585*	648			
			342	425	*509*	*592*	*675*	*757*	840			
10				349	*416*	*483*	*550*	*616*	683			
				407	*486*	*563*	*640*	*717*	793			
				523	*626*	*728*	*830*	*932*	1033			
11				420	*501*	*581*	*661*	*741*	821	900		
				489	*583*	*676*	*769*	*861*	953	1044		
				631	*754*	*878*	*1001*	*1123*	1246	1368		
12				497	*593*	*688*	*783*	*877*	971	1065		
				579	*689*	*799*	*909*	*1018*	1127	1235		
				748	*895*	*1041*	*1187*	*1332*	1478	1623		
13				580	692	*803*	*914*	*1024*	*1134*	1243		
				675	804	*933*	*1060*	*1187*	*1314*	1440		
				876	1047	*1218*	*1389*	*1559*	*1729*	1899		
14				669	798	*927*	*1054*	*1182*	*1308*	1435		
				778	927	*1075*	*1223*	*1369*	*1515*	1661		
				1013	1211	*1409*	*1607*	*1803*	*2000*	2196		
15				765	912	*1059*	*1205*	*1350*	*1495*	1640		
				889	1059	*1228*	*1396*	*1563*	*1730*	1896		
				1160	1387	*1614*	*1840*	*2065*	*2290*	2515		
16				867	1034	*1200*	*1365*	*1530*	*1694*	1858	2021	
				1006	1199	*1390*	*1581*	*1770*	*1959*	2147	2334	
				1316	1574	*1832*	*2088*	*2344*	*2600*	2855	3109	
17					1162	1349	*1535*	*1720*	*1905*	*2089*	2272	
					1347	1562	*1776*	*1989*	*2201*	*2412*	2623	
					1773	2063	*2352*	*2640*	*2928*	*3215*	3502	
18					1298	1507	*1714*	*1921*	*2127*	*2333*	2538	
					1503	1743	*1982*	*2220*	*2457*	*2692*	2927	
					1984	2308	*2631*	*2954*	*3276*	*3597*	3918	
19					1441	*1673*	*1903*	*2133*	*2362*	2590	2817	
					1668	*1934*	*2199*	*2463*	*2726*	2987	3248	
					2206	*2567*	*2926*	*3285*	*3643*	4000	4357	
20					1591	*1847*	*2102*	*2356*	*2608*	2860	3111	
					1841	*2135*	*2427*	*2718*	*3008*	3297	3585	
					2440	*2839*	*3236*	*3633*	*4029*	4424	4819	
21					1749	*2030*	*2310*	*2589*	*2866*	*3143*	3419	3694
					2022	*2345*	*2666*	*2986*	*3304*	*3621*	3937	4252
					2685	*3124*	*3562*	*3998*	*4434*	*4869*	5303	5737
22					1914	*2221*	*2527*	*2832*	*3136*	*3439*	3741	4042
					2211	*2564*	*2916*	*3265*	*3613*	*3960*	4306	4650
					2942	*3423*	*3902*	*4381*	*4858*	*5335*	5810	6285
23					2085	2421	*2754*	*3087*	*3418*	*3748*	*4077*	4405
					2408	2793	*3176*	*3557*	*3936*	*4313*	*4690*	5065
					3210	3735	*4258*	*4780*	*5301*	*5821*	*6340*	6859
24					2264	2628	*2991*	*3351*	*3711*	*4069*	*4426*	4783
					2614	3031	*3447*	*3860*	*4271*	*4681*	*5090*	5497
					3490	4061	*4629*	*5197*	*5763*	*6328*	*6893*	7456
25						2844	*3236*	*3627*	*4016*	*4403*	*4790*	*5176*
						3279	*3728*	*4175*	*4620*	*5064*	*5505*	*5946*
						4399	*5016*	*5630*	*6244*	*6857*	*7468*	*8079*

Table 4.—*Ovendry weight in pounds for willow oak bole wood, bole wood plus bark, and complete trees—Continued*

Dbh in inches	Total height in feet											
	20	30	40	50	60	70	80	90	100	110	120	130
	pounds											
26						3068	*3491*	*3913*	*4332*	*4750*	*5168*	*5583*
						3536	*4020*	*4502*	*4982*	*5460*	*5937*	*6411*
						4752	*5417*	*6081*	*6744*	*7405*	*8066*	*8725*
27						3301	3756	*4209*	*4660*	*5110*	5559	6006
						3802	4323	*4841*	*5357*	*5871*	6383	6894
						5117	5834	*6549*	*7263*	*7975*	8686	9396
28						3541	4029	*4516*	*5000*	*5483*	5964	6444
						4077	4636	*5192*	*5745*	*6296*	6846	7393
						5496	6266	*7034*	*7800*	*8565*	9329	10092
29						3790	*4312*	*4833*	*5351*	5868	6383	6896
						4362	*4959*	*5554*	*6146*	6736	7324	7910
						5888	*6713*	*7535*	*8357*	9176	9995	10812
30						4047	*4605*	*5160*	*5714*	6265	6815	7364
						4656	*5293*	*5928*	*6560*	7190	7817	8442
						6293	*7175*	*8054*	*8932*	9808	10683	11556
31						4312	*4906*	*5498*	*6088*	*6675*	7261	7846
						4959	*5638*	*6314*	*6987*	*7658*	8326	8992
						6712	*7652*	*8590*	*9526*	*10460*	11393	12324
32						4585	*5217*	*5846*	*6473*	*7098*	7721	8343
						5271	*5993*	*6711*	*7427*	*8140*	8850	9558
						7143	*8144*	*9142*	*10139*	*11133*	12126	13117
33						4866	5537	6205	6870	*7533*	*8195*	8854
						5592	6358	7121	7880	*8636*	*9389*	10140
						7588	8651	9712	10770	*11826*	*12881*	13934
34							5866	6573	7278	*7981*	*8682*	9381
							6734	7541	8345	*9146*	*9944*	10739
							9173	10298	11420	*12540*	*13659*	14775
35							6204	6952	7698	8441	9182	9921
							7120	7973	8823	9670	10514	11355
							9711	10901	12089	13275	14459	15641
36								7342	8129	8914	9697	10477
								8417	9315	10208	11099	11987
								11521	12777	14030	15281	16530
37								7741	8572	9399	10224	11047
								8873	9819	10761	11700	12636
								12158	13483	14805	16125	17444
38								8151	9025	9897	10765	11632
								9339	10335	11327	12315	13300
								12811	14208	15601	16992	18382
39								8571	9490	10407	11320	12231
								9818	10864	11907	12946	13982
								13482	14951	16417	17882	19343
40								9001	9967	10929	11888	12845
								10308	11406	12501	13592	14679
								14169	15713	17254	18793	20329

[1]Bole wood weight only, from a 1-ft stump to tip of tree.
[2]Bole weight of wood plus bark from a 1-ft stump to tip of tree.
[3]Complete tree weight, including branches, from a 1-ft stump to tip of tree.
[4]Italicized numbers denote limits of the data.

Table 5.—*Willow oak ratio parameter estimates for calculating the proportion of merchantable bole to total bole:* $RI = \alpha + \beta\gamma^{D*}$

Ratio	n†	α	β	γ	$S_{y \cdot x}$
R2	62	0.999	− 0.426	0.654	0.00140
R4	62	0.995	− 1.257	0.732	0.00847
R6	61	0.979	−32.613	0.607	0.03062
R8	58	0.970	−22.975	0.694	0.03285
R10	51	0.964	−43.915	0.718	0.04494
R12	44	0.944	−57.668	0.735	0.05016

*RI = (merchantable bole to outside bark diameter I)/total bole.
†n = number of observations used to estimate equation parameters.

Table 6.—*Regression statistics for predicting willow oak bole volumes and weights;*[1] $Ln(Y) = Ln(a) + b\,Ln(D \cdot D_{1/3} \cdot H)$

Component	Average	Ln(a)	b	FI	$\hat{S}_{y \cdot x}$	C.V. percent
			Volume *(cubic feet)*			
Bole wood	54.7	−5.901	0.98709	0.992	5.03*	9.2
Bole bark	7.3	−7.073	0.90868	0.938	1.73	23.6
Total bole	62.0	−5.654	0.97561	0.990	6.35*	10.2
			Green weight *(pounds)*			
Bole wood	3634	−1.710	0.98764	0.989	402*	11.1
Bole bark	464	−2.774	0.89352	0.931	117	25.2
Total bole	4098	−1.446	0.97395	0.987	478*	11.7
			Dry weight *(pounds)*			
Bole wood	1991	−2.235	0.98105	0.986	243*	12.2
Bole bark	299	−3.733	0.94483	0.915	84	28.2
Total bole	2290	−2.034	0.97539	0.984	297*	13.0

[1]All predictions from a 1-ft stump to tree tip.
*Significantly more precise than D^2H model; $\alpha = 0.05$.

Table 7.—*Regression statistics for predicting willow oak bole volumes and weights;*[1] $Ln(Y) = Ln(a) + b\,Ln[(D{\cdot}D_{1/2} + D^2_{1/4})H]$

Component	Average	Ln(a)	b	FI	$\hat{S}_{y \cdot x}$	C.V. percent
			Volume *(cubic feet)*			
Bole wood	54.7	−6.545	1.00359	0.998	2.38*	4.4
Bole bark	7.3	−7.672	0.92423	0.959	1.41*	19.3
Total bole	62.0	−6.291	0.99196	0.998	3.02*	4.9
			Green weight *(pounds)*			
Bole wood	3634	−2.354	1.00410	0.995	259*	7.1
Bole bark	464	−3.364	0.90895	0.953	97†	20.8
Total bole	4098	−2.083	0.99026	0.995	284*	6.9
			Dry weight *(pounds)*			
Bole wood	1991	−2.875	0.99738	0.993	168*	8.4
Bole bark	299	−4.356	0.96103	0.940	71†	23.7
Total bole	2290	−2.672	0.99169	0.993	191*	8.3

[1]All predictions from a 1-ft stump to tree tip.
*Significantly more precise than $D{\cdot}D_{1/3}{\cdot}H$ model; $\alpha = 0.05$.
†Significantly more precise than D^2H model; $\alpha = 0.05$.

APPENDIX
Examples of Equation and Table Use

In this section a few examples are given to illustrate use of the equations and tables presented. The following tabulation presents data for one of the trees used in constructing the equations; these data are used to illustrate equation use:

$$D = 18.0 \text{ in}$$
$$H = 107 \text{ ft}$$
$$D_{1/4} = 14.5 \text{ in}$$
$$D_{1/3} = 14.1 \text{ in}$$
$$D_{1/2} = 10.0 \text{ in}$$

To calculate bole wood volume from D^2H and the coefficients from table 1:

$$\begin{aligned} Ln(V) &= Ln(a) + b\,Ln(D^2H) \\ &= -6.047 + 0.97301\,Ln\,(18.0\times18.0\times107) \\ &= -6.047 + 0.97301\,Ln\,(34668) \\ &= -6.047 + 0.97301\,(10.454) \\ &= -6.047 + 10.171 \\ Ln(V) &= 4.124 \\ V &= e^{(4.124)} \end{aligned}$$

Bole wood volume = 61.8 ft^3.

To calculate total bole green weight from $X = D{\cdot}D_{1/3}{\cdot}H$ and the coefficients given in table 6:

$$\begin{aligned} Ln(W) &= Ln(a) + b\,Ln\,(D{\cdot}D_{1/3}{\cdot}H) \\ &= -1.446 + 0.97395\,Ln(18.0\times14.1\times107) \\ &= -1.446 + 0.97395\,Ln(27156.6) \\ &= -1.446 + 0.97395(10.209) \\ &= -1.446 + 9.943 \\ Ln(W) &= 8.497 \\ W &= e^{(8.497)} \end{aligned}$$

Total bole green weight = 4,902 lb.

To calculate bole bark dry weight using $X=(D{\cdot}D_{1/2} + D^2_{1/4})H$ and the coefficients of table 7:

$$\begin{aligned} Ln(W) &= Ln(a) + b\,Ln[(D\times D_{1/2}+D^2_{1/4})H] \\ &= -4.356 + 0.96103\,Ln[(18.0\times10.0 + 14.5 \\ &\quad \times14.5)\times107] \\ &= -4.356 + 0.96103\,Ln[(180 + 210.25) \\ &\quad \times107] \\ &= -4.356 + 0.96103\,Ln[41756.75] \\ &= -4.356 + 0.96103\,(10.640) \\ &= -4.356 + 10.225 \\ Ln(W) &= 5.869 \end{aligned}$$

$$W = e^{(5.869)}$$

Bole bark dry weight = 353.9 lb.

Merchantable bole values to a 6-inch top, for example, are calculated using table 5 to estimate the merchantable proportion of the total bole and then multiplying this proportion by the total bole estimate of interest:

$$RI = \alpha + \beta\gamma^{D}$$
$$R6 = 0.979 + (-32.613)\,(0.607)^{18.0}$$
$$= 0.979 + (-32.613)\,(0.00012514)$$
$$= 0.979 - 0.00408$$
$$R6 = 0.97492.$$

Then bole wood volume to a 6-inch top can be calculated:

$$V6 = (R6)\ (\text{total bole wood volume})$$
$$V6 = (0.97492)\ (61.8)$$
$$V6 = 60.3\text{ft}^3.$$

And dry bark weight to the 6-inch top is:

$$W6 = (R6)\ (\text{total bole dry bark weight})$$
$$W6 = (0.97492)\ (353.9)$$
$$W6 = 345\text{ lb.}$$

Total bole volumes or weights can be calculated by any one of the three sets of coefficients given in tables 1, 6, or 7. Then, any of these total bole calculations can be used with the ratio estimators to find merchantable bole values. The choice of equations is left to the user who must balance inventory precision against inventory cost.

SCHLAEGEL, BRYCE E.
1981. Willow oak volume and weight tables for the Mississippi Delta. U.S. Dep. Agric. For. Serv. Res. Pap. SO-173 14 p. South. For. Exp. Stn., New Orleans, La.

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

Additional keywords: Quercus phellos, merchantable bole estimates, biomass, allometric regression.

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