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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.

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

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

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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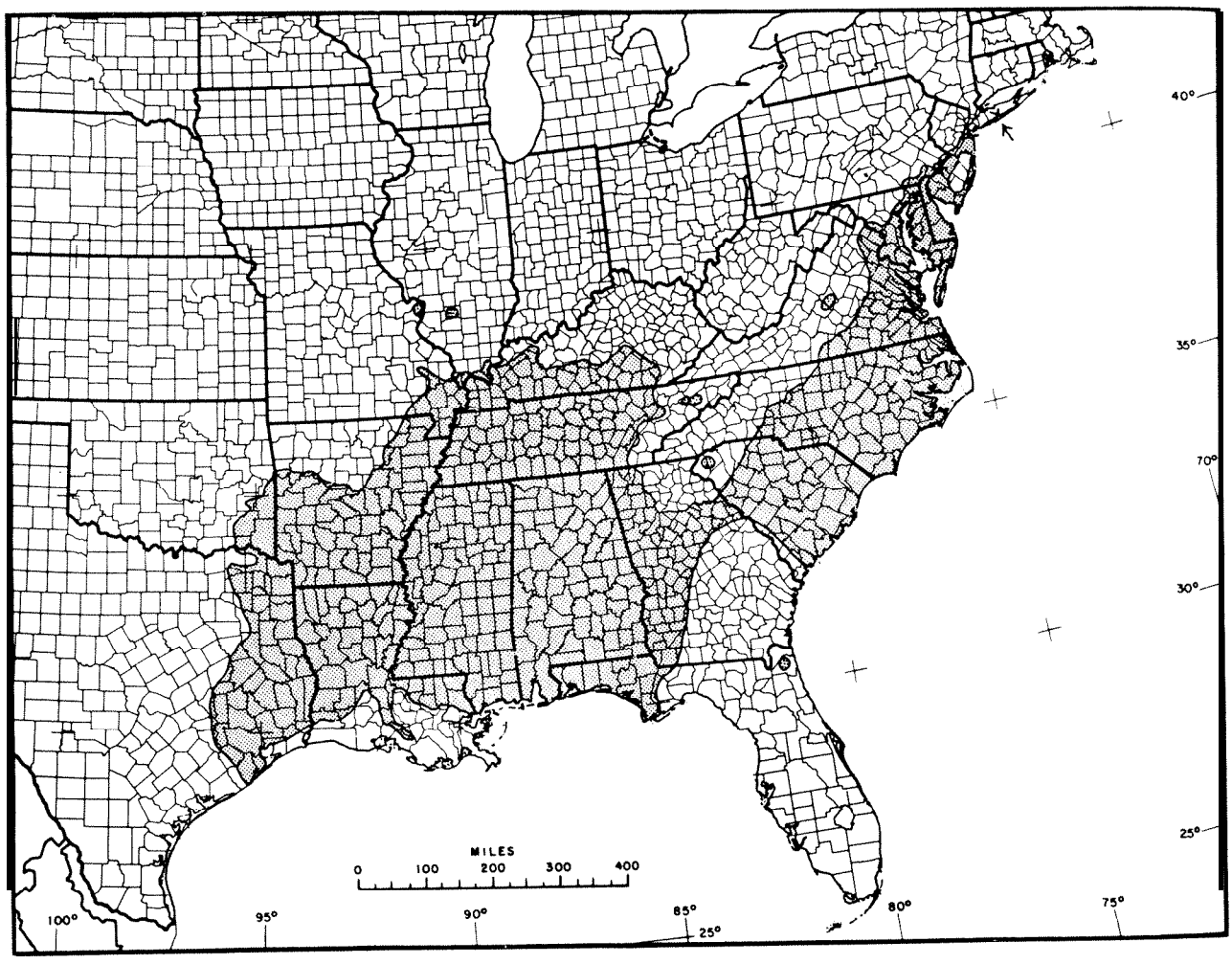

Figure *l-The range of willow oak is from Long Island to Georgia and from the Atlantic Coast to eastern Texas*

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/ft^3)*	66.18	57.69-69.37
Wood + bark dry density *(lb/ft^3)*	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 ($S_{y.x}$) 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

19781 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):

$$RI = a + \beta\gamma^{D} \qquad (2)$$

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 ofinterest.

[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 *l-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	0.57354	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 l-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 *Z.-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 hole 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 l-ft stump to tip of tree.
[3]Complete tree volume, including branches, from a 1-ft stump to tip of tree.
*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'	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	6,358	***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	***9,383***	***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 l-ft stump to tip of tree.
[3]Complete tree weight, including branches, from a 1-ft stump to tip of tree.
"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"	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	1.55	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 hole 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
*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	$S_{y.x}$
R2	62	0.999	0.426	0.654	0.00140
R4	62	0.995	-1.251	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 ofobservations used to estimate equation parameters.

Table *B.-Regression statistics forpredicting* willow *oak bole volumes and* weights;' $Ln(Y) = Ln(a) + b\ Ln(D^2D_{1/3}H)$

Component	Average	Ln(a)	b	FI	$\hat{S}_{y.x}$	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

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

Table 1.-*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	$\hat{S}_{y.x}$	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:

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

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

$$Ln(V) = Ln(a) + b\ Ln(D^2H)$$
$$= -6.047 + 0.97301\ Ln\ (18.0 \times 18.0 \times 107)$$
$$= -6.047 + 0.97301\ Ln\ (34668)$$
$$= -6.047 + 0.97301\ (10.454)$$
$$= -6.047 + 10.171$$
$$Ln(V) = 4.124$$
$$V = e^{(4.124)}$$

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:

$$Ln(W) = Ln(a) + b\ Ln\ (D \cdot D_{1/3} \cdot H)$$
$$= -1.446 + 0.97395\ Ln(18.0 \times 14.1 \times 107)$$
$$= -1.446 + 0.97395\ Ln(27156.6)$$
$$= -1.446 + 0.97395(10.209)$$
$$= -1.446 + 9.943$$
$$Ln(W) = 8.497$$
$$W = e^{(8.497)}$$

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:

$$Ln(W) = Ln(a) + b\ Ln[(D \times D_{1/2} + D^2_{1/4})H]$$
$$= -4.356 + 0.96103\ Ln[(18.0 \times 10.0 + 14.5 \times 14.5) \times 107]$$
$$= -4.356 + 0.96103\ Ln[(180 + 210.25) \times 107]$$
$$= -4.356 + 0.96103\ Ln[41756.75]$$
$$= -4.356 + 0.96103\ (10.640)$$
$$= -4.356 + 10.225$$
$$Ln(W) = 5.869$$

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

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:

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

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

V6 = (R6) (total bole wood volume)
V6 = (0.97492) (61.8)
V6 = 60.3ft^3.

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

W6 = (R6) (total bole dry bark weight)
W6 = (0.97492) (353.9)
W6 = 345 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.

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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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