Standing Tree Weight and Volume Tables for Natural Loblolly Pine at the First Delivery Point

by
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Robert C. Parker

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STANDING TREE WEIGHT AND VOLUME TABLES

FOR

NATURAL LOBLOLLY PINE

AT THE FIRST DELIVERY POINT

by

G. Shane Lee

and

Robert C. Parker

Forest and Wildlife Research Center

Mississippi State University

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INTRODUCTION

There has been much research on generating volume and weight equations for many southern tree species. Most research on weight equations was conducted in the 1970's and 1980's when weight scaling of trees and logs had become standard practice in the Southern pulp and paper industry (Saucier and Clark 1985). This practice created a need for weight tables, equations, and conversion factors.

Green wood is preferred by most mills because it can be stored longer at the wood yard without deteriorating, which is of great concern in warm and humid regions (Avery and Burkhart 2002). Green weight functions and tables for standing trees are available; however, most equations predict green weight immediately after felling rather than delivered weight at the wood yard or mill. It was the intent of this study to simulate green weight at the wood yard for use in field inventory procedures. However, time and costs limitations prevent such a study when dealing with multiple-product timberstands. Therefore, trees were weighed at the next best place, the loading deck, which is referred to as the first delivery point for the remainder of this paper. Loss of bark, wood, or moisture during felling, skidding, loading, and hauling, may result in an inventory to delivery deficit at the mill. There are no studies to quantify differences between delivered tree functions and standing tree green weight functions. Therefore, the intent of this research was to develop compatible weight and volume equations that predict delivered weight and volume at the first delivery point. The intent of this bulletin is to provide weight and volume tables for loblolly pine (*Pinus taeda* L.) growing in mature, fully-stocked, natural stands. Field foresters and foresters alike should find these tables useful for looking up volumes and weights to common merchantability limits.

METHODS

Site Description

The study area was located on the John W. Starr Memorial Forest in Oktibbeha County, Mississippi. During 2000, three stands were selected from the forest and consisted of predominantly mature, natural loblolly pine sawtimber ranging from 40 - 85 years of age, 80 - 120 trees per acre, and 90 - 110 ft^2 of basal area per acre. Stands were planned for harvest in the fall of 2000.

Measurements

Ninety-two trees were initially selected for sample trees. However, some were lost during harvesting resulting in 87 sample loblolly pine trees. Trees selected from each stand covered a wide diameter distribution. Criteria for selection of sample trees included:

- no forks or broken tops
- little or no fusifom rust (*Cronartium quercuum f. sp. fusiforme*)
- no "severe" crooks.

Sample trees ranged in size of 4 - 29 inches in diameter at breast height (DBH) and 39.2 - 115.8 ft in total height (TH).

Sample trees were measured standing and after felling. Standing trees were tagged and numbered above breast height with bright red paint so they could be easily detected before and after felling. A red line was sprayed around breast height for detection after felling. Diameter at breast height was measured with a diameter tape, and height with the Haglöf Forestor™ Vertex III Hypsometer.

After felling, profile measurements were taken. Tree segments were measured with a logger's tape, and diameter with a caliper, perpendicular to the felled stem. Bark thickness, obtained with a bark gauge, was used to estimate diameter inside bark (dib).

After being skidded to the loading deck, de-limbed, and topped, sample trees were

measured for length to the cutoff point, for diameter outside bark (dob) at the cutoff point, and weighed individually. The loader operator picked up each log or tree segment separately while weighing was completed. A Dillon (ED-2000 Electronic Dynamometer with HR-2000 Remote; http://www.dillon-force.com/) load cell was used to obtain stem weights to the nearest 5 lbs. The load cell had an accuracy of 0.10% of the 20,000 lb load capacity.

RESULTS

Equations of the combined variable form were constructed from volumes computed from profile equations. A nonlinear, combined variable equation with an exponential term was chosen to predict weight and volume of loblolly pine:

$$Y = \beta_0 \left(DBH^{\beta_1} MH^{\beta_2}\right) e^{\beta_3 \left(\frac{MTD}{DBH}\right)^{\beta_4}} \qquad (1)$$

where: Y = tree weight or volume,
MH = merchantable height,
MTD = merchantable top-diameter, and
β_i = regression parameters to be estimated.

The exponential term allows the user to predict volume or weight to practically any MTD, making it a more versatile model.

Sample tree weights and volumes were fitted to Equation 1. The resulting regression equation coefficients and fit statistics are given in Table 1. Weight data were obtained from individually weighed trees, whereas volume data were computed from profile equations. Hence, fit statistics for volume equations were exceptionally good.

The model fit the data reasonably well and was logical. However, coefficients, β_3 and β_4, for the exponential term in the weight equation were somewhat difficult to estimate. These parameter estimates were important to the rationality of the model, and they would not converge to logical estimates due to a lack of observations. Therefore, coefficients of the exponential term for the weight equation were fixed to have the same relationship as cubic foot volume equation coefficients. This gave satisfactory results when compared to other green weight equations. In conclusion, all equations performed well for the sampled dataset and should be adequate for similar stands.

User Weight and Volume Tables

Based on the equations and tables presented in this bulletin, users must specify DBH, MH, and MTD. Tables 2 - 10 give the weight in tons and volume in cubic feet (ob), cords, Doyle board feet, and Scribner board feet of loblolly pine to a 6- and 8-inch MTD.

Table 1. Regression equation coefficients and fit statistics for predicting weight and sample profile volumes for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

	Weight and Volume Equations*						
Coefficients	Pounds	Ft^3 ob	Ft^3 ib	Cords	Doyle BF	Scribner BF	Int-¼" BF
β_0	0.284043	0.004315	0.003207	0.000117	0.001102	0.004858	0.007174
β_1	1.993407	2.012104	2.028062	1.651819	2.684712	2.282177	2.170757
β_2	0.866926	0.896237	0.923953	0.928341	1.094743	1.074633	1.084732
β_3	0.500000	0.498399	0.508773	0.465495	1.002157	0.881074	0.862677
β_4	1.140000	1.149355	1.136078	1.06535	2.052055	1.897239	1.890456
n	103	568	568	568	394	394	394
S_{yx}	451.677	0.705	0.579	0.010	12.162	8.550	6.721
I^2	97.46%	99.99%	99.99%	99.97%	99.89%	99.95%	99.97%

$$*Y = \beta_0 \left(DBH^{\beta_1} MH^{\beta_2}\right) e^{\beta_3 \left(\frac{MTD}{DBH}\right)^{\beta_4}}$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, *MTD* is merchantable top-diameter, and β_i are parameter estimates.

Table 2. Predicted weight in tons to a 6-inch merchantable top for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

DBH (inches)	Merchantable Height to 6" top (16 ft logs and half logs)								
	1	1½	2	2½	3	3½	4	4½	5
	Tons*								
10	0.205	0.291	0.373	0.453	0.530	0.606	0.681	0.754	0.826
11	0.240	0.342	0.438	0.532	0.623	0.712	0.800	0.886	0.970
12	0.279	0.397	0.509	0.618	0.724	0.827	0.929	1.029	1.127
13	0.321	0.456	0.586	0.711	0.832	0.951	1.068	1.183	1.296
14	0.366	0.520	0.668	0.810	0.949	1.085	1.218	1.349	1.478
15	0.414	0.588	0.755	0.916	1.073	1.227	1.377	1.525	1.671
16	0.465	0.661	0.848	1.029	1.205	1.378	1.547	1.713	1.877
17	0.519	0.738	0.947	1.149	1.346	1.538	1.727	1.912	2.095
18	0.576	0.819	1.051	1.275	1.493	1.707	1.917	2.123	2.326
19	0.636	0.904	1.160	1.408	1.649	1.885	2.116	2.344	2.568
20	0.699	0.994	1.276	1.548	1.813	2.072	2.326	2.577	2.823
21	0.766	1.088	1.396	1.694	1.984	2.268	2.547	2.820	3.090
22	0.835	1.186	1.523	1.848	2.164	2.473	2.777	3.075	3.369
23	0.907	1.289	1.654	2.007	2.351	2.687	3.017	3.341	3.661
24	0.982	1.396	1.792	2.174	2.546	2.910	3.267	3.619	3.965
25	1.061	1.507	1.934	2.347	2.749	3.142	3.528	3.907	4.281
26	1.142	1.623	2.083	2.527	2.960	3.383	3.798	4.207	4.609
27	1.226	1.743	2.237	2.714	3.179	3.633	4.079	4.518	4.950
28	1.314	1.867	2.396	2.907	3.405	3.892	4.370	4.840	5.302
29	1.404	1.996	2.561	3.107	3.640	4.160	4.671	5.173	5.667
30	1.498	2.128	2.731	3.314	3.882	4.437	4.981	5.517	6.045

$$*Y = \left[0.284043 \left(DBH^{1.993407} \, MH^{0.866926} \right) e^{0.5\left(\frac{MTD}{DBH} \right)^{1.14}} \right] \Big/ 2000 \; lbs / ton$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, and *MTD* is merchantable top-diameter.

Table 3. Predicted weight in tons to an 8-inch merchantable top for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

DBH (inches)	Merchantable Height to 8" top (16 ft logs and half logs)								
	1	1½	2	2½	3	3½	4	4½	5
	Tons*								
10	0.228	0.324	0.416	0.505	0.591	0.676	0.759	0.840	0.920
11	0.265	0.377	0.483	0.586	0.687	0.785	0.881	0.976	1.069
12	0.305	0.433	0.556	0.675	0.790	0.903	1.014	1.123	1.231
13	0.348	0.495	0.635	0.770	0.902	1.031	1.158	1.282	1.405
14	0.394	0.560	0.719	0.872	1.022	1.168	1.311	1.452	1.591
15	0.443	0.630	0.809	0.981	1.149	1.313	1.475	1.633	1.789
16	0.496	0.704	0.904	1.097	1.284	1.468	1.648	1.825	2.000
17	0.551	0.783	1.004	1.219	1.428	1.632	1.832	2.029	2.223
18	0.609	0.866	1.111	1.348	1.579	1.804	2.026	2.244	2.458
19	0.670	0.953	1.223	1.484	1.738	1.986	2.230	2.469	2.706
20	0.735	1.044	1.340	1.626	1.904	2.177	2.444	2.706	2.965
21	0.802	1.140	1.463	1.775	2.079	2.376	2.668	2.955	3.237
22	0.873	1.240	1.591	1.931	2.261	2.585	2.902	3.214	3.521
23	0.946	1.344	1.725	2.093	2.452	2.802	3.146	3.485	3.818
24	1.022	1.453	1.865	2.263	2.650	3.029	3.401	3.766	4.126
25	1.102	1.566	2.010	2.439	2.856	3.264	3.665	4.059	4.447
26	1.184	1.683	2.160	2.621	3.070	3.509	3.940	4.363	4.780
27	1.270	1.805	2.316	2.810	3.292	3.762	4.224	4.678	5.126
28	1.359	1.931	2.478	3.006	3.521	4.025	4.519	5.004	5.483
29	1.450	2.061	2.645	3.209	3.759	4.296	4.823	5.342	5.853
30	1.545	2.195	2.817	3.419	4.004	4.576	5.138	5.691	6.235

$$*\bar{Y}=\left[0.284043\left(DBH^{1.993407}\,MH^{0.866926}\right)e^{0.5\left(\frac{MTD}{DBH}\right)^{1.14}}\right]\Big/2000\ lbs/ton$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, and *MTD* is merchantable top-diameter.

Table 4. Predicted volume in cubic feet (ob) to a 6-inch merchantable top for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

DBH (inches)	Merchantable Height to 6" top (16 ft logs and half logs)								
	1	1½	2	2½	3	3½	4	4½	5
	Cubic Feet (ob)*								
10	7	10	13	16	19	22	24	27	30
11	8	12	15	19	22	25	29	32	35
12	10	14	18	22	26	30	33	37	41
13	11	16	21	25	30	34	38	43	47
14	13	18	24	29	34	39	44	49	54
15	14	21	27	33	38	44	50	55	61
16	16	23	30	37	43	50	56	62	68
17	18	26	34	41	48	55	62	69	76
18	20	29	37	45	54	61	69	77	85
19	22	32	41	50	59	68	77	85	94
20	24	35	45	55	65	75	84	94	103
21	27	38	50	61	71	82	92	103	113
22	29	42	54	66	78	89	101	112	123
23	32	46	59	72	85	97	110	122	134
24	34	49	64	78	92	105	119	132	145
25	37	53	69	84	99	114	128	143	157
26	40	57	74	91	107	123	138	154	169
27	43	62	80	98	115	132	149	165	182
28	46	66	86	105	123	141	159	177	195
29	49	71	92	112	132	151	170	189	208
30	53	76	98	119	141	161	182	202	222

$$*Y = 0.004315\left(DBH^{2.012104}\, MH^{0.896237}\right) e^{0.498399\left(\frac{MTD}{DBH}\right)^{1.149355}}$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, and *MTD* is merchantable top-diameter.

Table 5. Predicted volume in cubic feet (ob) to an 8-inch merchantable top for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

DBH (inches)	Merchantable Height to 8" top (16 ft logs and half logs)								
	1	1½	2	2½	3	3½	4	4½	5
	Cubic Feet (ob)*								
10	8	11	15	18	21	24	27	30	33
11	9	13	17	21	24	28	32	35	39
12	11	15	20	24	28	32	36	40	44
13	12	17	22	27	32	37	42	46	51
14	14	20	25	31	36	42	47	52	58
15	15	22	29	35	41	47	53	59	65
16	17	25	32	39	46	53	59	66	73
17	19	27	36	43	51	59	66	74	81
18	21	30	39	48	57	65	73	81	89
19	23	34	43	53	62	72	81	90	99
20	26	37	48	58	68	79	89	98	108
21	28	40	52	63	75	86	97	108	118
22	30	44	57	69	81	93	105	117	129
23	33	47	61	75	88	101	114	127	140
24	36	51	66	81	96	110	124	137	151
25	38	55	72	88	103	118	133	148	163
26	41	60	77	94	111	127	143	159	175
27	44	64	83	101	119	137	154	171	188
28	48	68	89	108	127	146	165	183	201
29	51	73	95	115	136	156	176	196	215
30	54	78	101	123	145	166	188	208	229

$$*Y = 0.004315\left(DBH^{2.012104}\, MH^{0.896237}\right) e^{0.498399\left(\frac{MTD}{DBH}\right)^{1.149355}}$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, and *MTD* is merchantable top-diameter.

Table 6. Predicted volume in cords to a 6-inch merchantable top for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

DBH (inches)	Merchantable Height to 6" top (16 ft logs and half logs)								
	1	1½	2	2½	3	3½	4	4½	5
	Cords*								
10	0.090	0.131	0.172	0.211	0.250	0.289	0.327	0.365	0.402
11	0.103	0.150	0.196	0.241	0.285	0.329	0.373	0.416	0.458
12	0.116	0.169	0.221	0.272	0.322	0.372	0.421	0.470	0.518
13	0.130	0.190	0.248	0.305	0.361	0.417	0.472	0.526	0.581
14	0.145	0.211	0.276	0.339	0.402	0.464	0.525	0.586	0.646
15	0.160	0.234	0.305	0.375	0.445	0.513	0.581	0.648	0.714
16	0.176	0.257	0.336	0.413	0.489	0.564	0.639	0.712	0.786
17	0.193	0.281	0.367	0.452	0.535	0.617	0.699	0.779	0.859
18	0.210	0.306	0.400	0.492	0.583	0.672	0.761	0.849	0.936
19	0.228	0.332	0.434	0.533	0.632	0.729	0.825	0.921	1.015
20	0.246	0.359	0.469	0.576	0.683	0.788	0.892	0.995	1.097
21	0.265	0.386	0.505	0.621	0.735	0.848	0.960	1.071	1.181
22	0.285	0.415	0.542	0.666	0.789	0.911	1.031	1.150	1.268
23	0.305	0.444	0.580	0.713	0.845	0.975	1.103	1.231	1.357
24	0.325	0.474	0.619	0.761	0.902	1.041	1.178	1.314	1.449
25	0.346	0.505	0.659	0.811	0.960	1.108	1.254	1.399	1.543
26	0.368	0.536	0.700	0.861	1.020	1.177	1.333	1.487	1.639
27	0.390	0.568	0.742	0.913	1.082	1.248	1.413	1.576	1.738
28	0.413	0.602	0.786	0.966	1.145	1.321	1.495	1.668	1.839
29	0.436	0.635	0.830	1.021	1.209	1.395	1.579	1.762	1.943
30	0.460	0.670	0.875	1.076	1.275	1.471	1.665	1.857	2.048

$$*Y = 0.000117\left(DBH^{1.651819}\, MH^{0.923953}\right) e^{0.465495\left(\frac{MTD}{DBH}\right)^{1.063535}}$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, and *MTD* is merchantable top-diameter.

Table 7. Predicted volume in cords to an 8-inch merchantable top for loblolly pine on the John W. Starr Memorial Forest, Oktibbeha County, Mississippi.

DBH (inches)	Merchantable Height to 8" top (16 ft logs and half logs)								
	1	1½	2	2½	3	3½	4	4½	5
	Cords*								
10	0.099	0.145	0.189	0.233	0.276	0.318	0.360	0.402	0.443
11	0.112	0.164	0.214	0.263	0.311	0.359	0.407	0.454	0.500
12	0.126	0.183	0.240	0.295	0.349	0.403	0.456	0.509	0.561
13	0.140	0.204	0.267	0.328	0.389	0.449	0.508	0.566	0.625
14	0.155	0.226	0.295	0.363	0.430	0.496	0.562	0.627	0.691
15	0.171	0.249	0.325	0.400	0.473	0.546	0.618	0.690	0.761
16	0.187	0.272	0.356	0.438	0.518	0.598	0.677	0.755	0.833
17	0.204	0.297	0.388	0.477	0.565	0.652	0.738	0.823	0.908
18	0.221	0.322	0.421	0.518	0.613	0.708	0.801	0.894	0.986
19	0.239	0.349	0.455	0.560	0.663	0.766	0.867	0.967	1.066
20	0.258	0.376	0.491	0.604	0.715	0.825	0.934	1.042	1.149
21	0.277	0.404	0.527	0.649	0.768	0.886	1.003	1.119	1.234
22	0.297	0.432	0.565	0.695	0.823	0.950	1.075	1.199	1.322
23	0.317	0.462	0.603	0.742	0.879	1.014	1.148	1.281	1.413
24	0.338	0.492	0.643	0.791	0.937	1.081	1.224	1.365	1.505
25	0.359	0.523	0.684	0.841	0.996	1.149	1.301	1.451	1.600
26	0.381	0.555	0.725	0.892	1.057	1.219	1.380	1.540	1.698
27	0.404	0.588	0.768	0.945	1.119	1.291	1.461	1.630	1.798
28	0.426	0.621	0.812	0.998	1.182	1.364	1.544	1.723	1.900
29	0.450	0.655	0.856	1.053	1.247	1.439	1.629	1.817	2.004
30	0.474	0.690	0.902	1.109	1.314	1.516	1.716	1.914	2.111

$$*Y = 0.000117\left(DBH^{1.651819}\, MH^{0.923953}\right) e^{0.465495\left(\frac{MTD}{DBH}\right)^{1.063535}}$$

where: *DBH* is tree diameter in inches, *MH* is height in feet to specified top-diameter limit, outside bark, and *MTD* is merchantable top-diameter.

SUMMARY

The model chosen for predicting weights and volumes to any MTD was logical and reasonably accurate. However, users should take caution in predicting weights beyond the range of data. No weight data were collected above a 3-inch top for pulpwood size trees, and none were collected above a 6-inch top for sawtimber size trees. As the tree increased in diameter and roughness, so did the cutoff limit.

The main limitation for the weight equation, was a lack of data. This was an operational study where loggers felled trees and assisted researchers with the weighing process. Individual sample trees were not weighed to multiple top-diameters, which is time consuming and expensive. Only tree sections utilized by loggers were weighed. Nonetheless, these models should perform well for loblolly pine trees occurring in older, well stocked, natural stands in Mississippi. With the compatible weight and volume equations, users can compute useful ratios, such as lbs per cubic foot, board feet per cubic foot, and lbs or tons per thousand board feet. Users should apply these equations only to stands that are similar to those in which data were collected.

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