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Handbook for Predicting Slash Weight in the Northeast

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HANDBOOK FOR PREDICTING SLASH WEIGHT IN THE NORTHEAST

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Woody debris or "slash"—the foliage, branches, unmerchantable bole tips, and broken or defective boles of trees left on the ground after tree cutting (fig. 1)—often poses a serious fire threat to forest resources. When weather conditions are conducive, fires encountering heavy accumulations of slash burn with high intensity, are generally difficult to control, and can quickly spread into surrounding stands of valuable timber. Where the risk of fire damage is high, management action to treat or remove slash accumulations is often desirable.

Whether slash treatment is necessary and which type of treatment is most effective in a particular situation are complex decisions involving a variety of factors. Among them are the amount of slash involved, land management objectives, resource values, land ownership and use patterns, topography, climate, vegetation types, fire frequency, fire effects, local fire suppression capability, slash disposal laws, and timber sale contract requirements.

This handbook focuses on the first of these factors, the amount of slash involved. While field inventory methods can be used to estimate slash weight (Roussopoulos and Johnson 1973), they are expensive and must be applied after cutting rather than before. The primary objective of this guide is to provide methods for predicting slash weight prior to cutting using common and easily obtainable tree measurements as independent variables (i.e., d.b.h. or, in some cases, d.b.h. with tree height). Tables are included that allow the user to estimate weights of crowns and unmerchantable bole tips, both on a "per tree" and a "per unit of tree basal area" basis for 10 coniferous species and 9 hardwood species (or species groups) common to forests of the North Central and Northeastern United States. Methods of estimating the weight of slash by standard fuel size classes are also included.

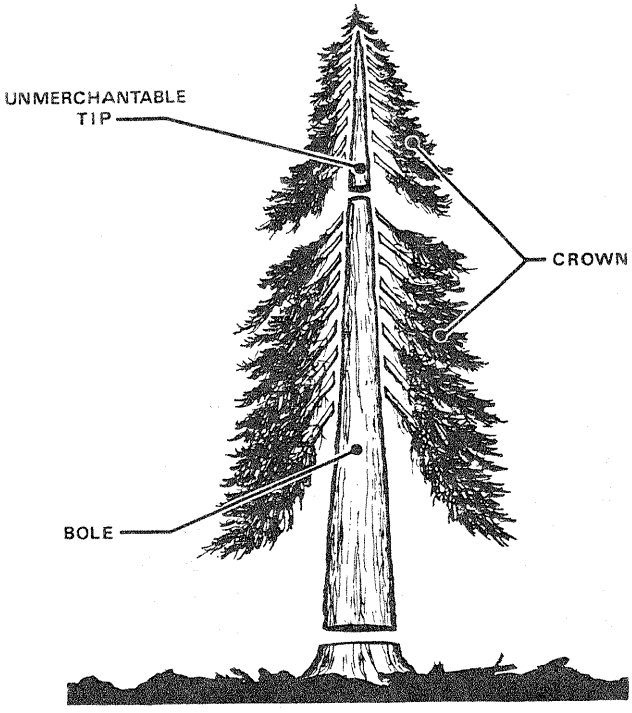

Figure 1.—*Slash is produced from three portions of the tree: (1) crown; (2) unmerchantable tip; and (3) defective or broken bole (adapted from Brown* et al. *1977).*

PREDICTING SLASH WEIGHT

In the slash weight prediction process, four sources of slash or debris are recognized: cutting, trampling, defect and breakage, and existing debris.

(a) Cutting debris consists of tree crowns and tops remaining on the site after cutting.
(b) Trampling debris is incidental material resulting from logging activities; it generally consists of small trees damaged during skidding or other logging operations.
(c) Breakage and defect is debris left on the site as cull material. The amount of debris can vary considerably by locality, site, age of the stand, timber sale operator, and timber sale requirements.
(d) Existing debris consists of material on the site prior to logging or precommercial thinning. A downed woody fuels inventory (Brown 1974) can be used to estimate the amount of existing debris.

Estimates of cutting and trampling debris can be made using the crown weight information presented in tables 1-7. These tables were generally patterned after those found in the *Handbook for Predicting Slash Weight of Western Conifers* (Brown *et al.* 1977) and in the *Handbook for Predicting Residue Weights of Pacific Northwest Conifers* (Snell and Brown 1980). In developing our tables we did not make allowances for differing stand conditions, although it is known, for example, that crown weight of red pine can vary with site quality and stand density (Brown 1963). The user should be aware that such differences exist, and that more precise slash weight estimates can be made by using additional variables such as site index and stand density (Brown 1965) or crown ratio (Loomis and Blank 1981).

The equations and sources of information used in constructing crown weight tables 1-7 are shown in Appendix I. Tables 1 and 2 list species requiring only d.b.h. as the independent variable for estimating crown weight. Tables 3-7 list species requiring both d.b.h. and tree height as the independent variables for estimating crown weight. If tree heights cannot be measured, estimated heights will suffice, although additional error may be introduced.

In tables 1-7, the "a" portions give weight per tree and the "b" portions give weight per square foot of basal area. Tables 2 and 7 list crown weights of hardwoods, but do not include foliage (fig. 2). Table 8 lists foliage weights of hardwoods, which can be added to the branchwood crown weights to predict total debris from summer harvest of hardwoods.

The equations and sources used in constructing table 8 are shown in Appendix II. Although the equations for hardwood crown weights and foliage weights were sometimes developed from different sources, the same species was used whenever possible. When this was not possible, species within the same genus were used.

The weights given in tables 1-8 include all crown branchwood, including the unmerchantable bole tip to a 4-inch top. Appendix III shows weight per tree and top diameter based on equations listed in Appendix I. Bole section weights as needed were added to weights shown in Appendix III to get the weights listed in tables 1 and 2.

Wood densities needed for calculating slash resulting from defect and breakage, are given in table 9.

The steps for using the tables to predict the weights of the various slash components are outlined below.

Step 1

Summarize tree harvest data by (a) number of trees to be cut per acre by species and d.b.h. or (b) basal area by species and d.b.h., whichever is most

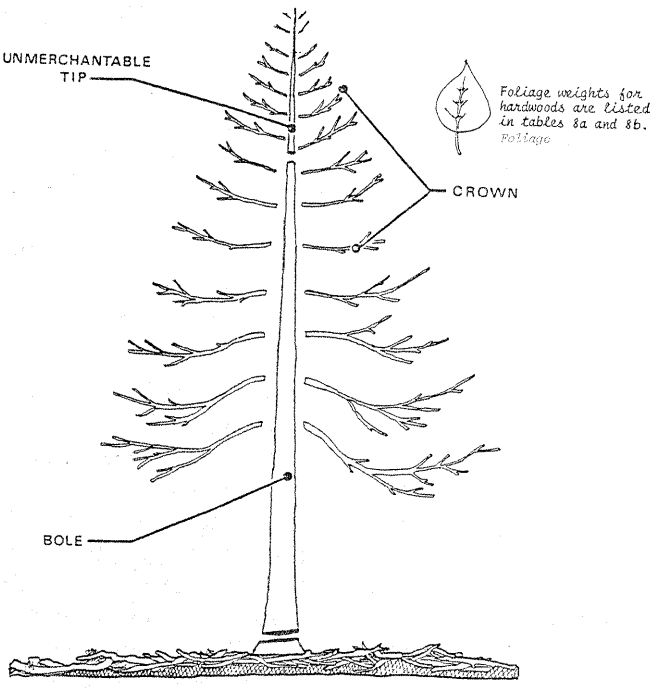

Figure 2.—*Crown weight tables for hardwoods do not include foliage (adapted from Stanek and State 1978).*

convenient. Trees per acre can be converted to basal area per acre using table 10. Always use a d.b.h. distribution rather than an average stand diameter to avoid bias resulting from curvilinear weight relations.

Step 2

From the appropriate crown-weight table, multiply the number of trees times the weight for each d.b.h. and species category. Total the cutting debris for each species. Do the same with small-diameter trees that have been trampled during logging.

For stands of intolerant coniferous species with significant numbers of intermediate or suppressed crowns (fig. 3), crown weight should be adjusted by using the following equations (Brown *et al.* 1977):

D.b.h.	Equation
Less than 7.5 inches	$AW = W \times [1 - (0.5 \times f_I)]$
7.5 inches and greater	$AW = W \times [1 - (0.4 \times f_I)]$

where AW = adjusted weight per acre for intermediate crowns,
W = weight of crowns per acre calculated from the crown weight tables, and
f_I = the fraction of trees per acre having intermediate and suppressed crowns.

Step 3

Estimate slash weight in tons per acre for breakage and defect using the following equation:

$$W = \frac{(v) \times (f) \times (d),}{2{,}000}$$

where W = the weight of debris from defect and breakage in tons per acre,
v = merchantable volume to be cut in cubic feet per acre (note: 180 cu ft per MBF, 90 cu ft per cord),
f = fraction of merchantable volume expected to be left on the ground as defect and breakage, and
d = density of wood in pounds per cubic foot (from table 9).

Step 4

Summarize the total debris by adding:
(a) Weight of crowns or cutting debris.
(b) Weight of trampling debris.
(c) Weight of defect (cull) and breakage debris left in the woods.
(d) Weight of downed woody material or existing debris.

This will yield the total predicted weight of slash or debris remaining on the ground after cutting.

EXAMPLES OF SLASH PREDICTION

Example 1.—Commercial Thinning in a Red Pine Plantation

To determine the weight of cutting debris: assume 50 trees per acre are to be cut from each of three d.b.h. classes (5-, 6-, and 7-inch trees), with utilization to a 4-inch top diameter.

D.b.h. (in.)	Trees/acre	Lbs/tree (from table 1a)	Lbs/acre	Tons/acre
5	50	58	2,900	1.45
6	50	60	3,000	1.50
7	50	68	3,400	1.70
TOTAL			9,300	4.65

To determine the weight of trampling debris: assume that boles of trees damaged by trampling have been removed to a 4-inch top and only the slash from the crowns and unmerchantable tips remains on the site.

D.b.h. (in.)	Trees/acre	Lbs/tree (from table 1a)	Lbs/acre	Tons/acre
4	5	56	280	0.14

To determine the weight of defect and breakage debris: assume volume to be removed to be 670 cubic feet per acre; breakage of about 2 percent and defect left on the site of 3 percent (based on experience with similar red pine stands); and red pine density of 28.7 pounds per cubic foot (from table 9). Then, in the equation for determining weight (W), the volume (v) is 670, the fraction (f) of merchantable volume expected to be left on the site is 0.02 + 0.03 or 0.05, and the density (d) is 28.7, or

$$W = \frac{(v) \times (f) \times (d)}{2{,}000} = \frac{670 \times 0.05 \times 28.7}{2{,}000}$$
$$= 0.48 \text{ tons/acre.}$$

Thus, the total predicted slash from cutting = 4.65 + 0.14 + 0.48 = 5.27 tons per acre.

To determine the weight of downed woody material: assume the volume of existing downed debris to be 3 tons per acre.

Figure 3.—*The crown weights of intermediate and suppressed trees of shade-intolerant coniferous species are less than those of dominant or codominant trees, and adjustments in crown weights may be needed.*

The total predicted slash weight, therefore, becomes 8.27 tons per acre (5.27 + 3.0).

Example 2.—Clearcutting in an 80-year-old, Second-growth Northern Red Oak Stand

To determine the weight of cutting debris: assume harvest of 70 9-inch trees per acre, 100 10-inch trees per acre, and 50 11-inch trees per acre, with utilization to a 4-inch top diameter.

D.b.h. (in.)	Trees/acre	Lbs/tree (from table 2a)	Lbs/acre	Tons/acre
9	70	138	9,660	4.83
10	100	177	17,700	8.85
11	50	222	11,100	5.55
TOTAL			38,460	19.23

To determine the weight of trampling debris: assume all trees of merchantable size to be harvested with no damage from trampling.

To determine the weight of defect and breakage debris: assume a volume to be removed of 1,930 cubic feet per acre; breakage of 5 percent and defect left on the site of 10 percent (based on experience with similar northern red oak stands); and northern red oak density of 39.3 pounds per cubic foot (from table 9). Then, in the equation for determining weight (W), the volume (v) is 1,930, the fraction (f) of merchantable volume to be left on the site is 0.05 + 0.10 or 0.15, and the density (d) is 39.3, or

$$W = \frac{(v) \times (f) \times (d)}{2{,}000} = \frac{1{,}930 \times 0.15 \times 39.3}{2{,}000}$$

$$= 5.7 \text{ tons/acre.}$$

Thus, the total predicted slash from cutting = 19.23 + 0 + 5.7 = 24.93 tons per acre.

To determine the weight of downed woody material: assume the volume of existing downed debris to be 5 tons per acre.

The total predicted slash weight, therefore, becomes 29.93 tons per acre (24.93 + 5.0).

Example 3.—Adjusting for Intolerant Coniferous Species

To determine the weight of cutting debris for stands of intolerant coniferous species with significant numbers of intermediate or suppressed crowns: assume the calculated crown weight for the stand to be 30,000 pounds per acre in trees 8 inches d.b.h. and greater, and the proportion of intermediate and suppressed crowns in the stand to be 25 percent.

Then, adjusted crown weight (AW) = W x [1–(0.4 x f_I)] = 30,000 x [1–(.4 x .25)] = 27,000 lbs/acre. Thus, the adjusted crown weight is about 14 tons per acre.

FUEL SIZE CLASSES

Fuel size class component fractions are given in tables 11 and 12. The weights of individual fuel size classes (foliage, branchwood 0 to 1/4-inch in diameter, 1/4 to 1 inch, 1 to 3 inches, and 3 inches and larger) (fig. 4) are needed if the fuel manager wishes to use debris prediction information to estimate fire behavior by computer (Radloff *et al.* 1982). These fuel size classes are used to predict fire behavior potential in the Rothermel (1972) fire behavior model. Also, the branchwood fuel size classes correspond to the 1-, 10-, 100-, 1,000-hour timelag fuels described in the National Fire Danger Rating System (Deeming *et al.* 1977). Some examples of predicting slash weights by fuel size classes are given below.

Example 1.—Conifers

The fuel loading in tons per acre for each size class is estimated using the crown component fractions from table 11 multiplied by the corresponding crown weight per acre for each species and d.b.h. class. In this example, we used the red pine stand described earlier. Since table 11 does not include component fractions for the 5- and 7-inch diameter classes, the fractions for the 6-inch category are used to represent the 5-, 6-, and 7-inch diameter classes. The total weight within each diameter class is multiplied by each crown component fraction to obtain weights within each fuel class size as shown below. For example, the 1.45 tons per acre in the 5-inch diameter class multiplied by the 0.28 fraction of foliage from table 11 equals 0.40 ton per acre of foliage.

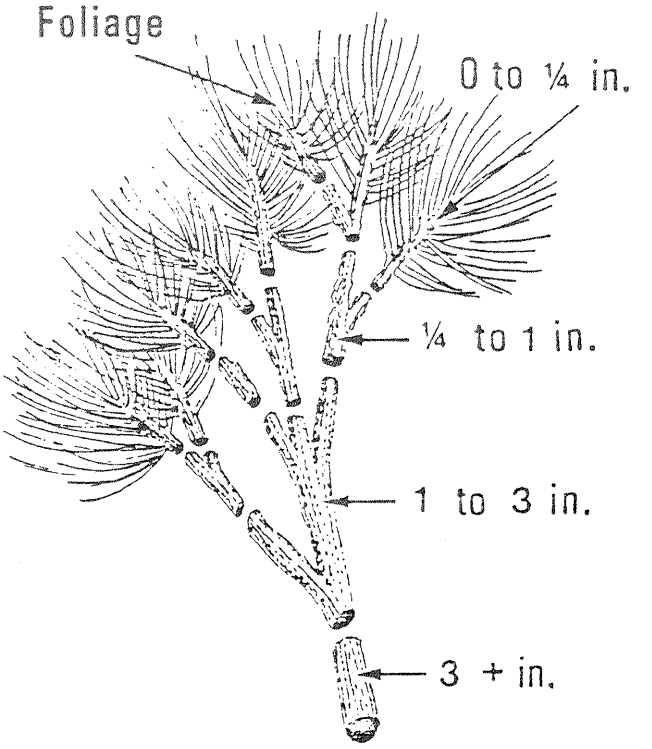

Figure 4.—*Component fractions of foliage and branchwood size classes are used for calculating tons per acre input for computer-based, fire-behavior predictions (adapted from Brown 1978).*

D.b.h. (inches)	Total	Foliage	Fuel class size (inches) 0-¼	¼-1	1-3	3+
		Tons/acre				
4	0.14	0.03	0.01	0.02	0.02	0.06
5	1.45	.40	.06	.39	.34	.26
6	1.50	.42	.05	.40	.36	.27
7	1.70	.47	.07	.46	.40	.30
Total	4.79	1.32	.19	1.27	1.12	.89

Example 2.—Hardwoods

The fuel loadings for hardwood species are estimated using the crown component fractions from table 12 multiplied by the corresponding crown weight estimate for each d.b.h. class. In this example, we used the second-growth hardwood (northern red oak) stand described earlier. The total weight within each diameter class is multiplied by each crown component fraction to obtain weights within each fuel class size as shown below. For example, the 4.83 tons per acre of 9-inch slash multiplied by the 0.05 fraction of 0- to 1/4-inch material from table 12 equals 0.24 ton per acre of 0- to 1/4-inch material.

D.b.h. (inches)	Total	Fuel class size (inches) 0-¼	¼-1	1-3	3+
		Tons/acre			
9	4.83	0.24	1.06	2.80	0.73
10	8.85	.35	1.86	4.78	1.86
11	5.55	.22	1.11	2.72	1.50
Total	19.23	.81	4.03	10.30	4.09

For summer-cut trees, hardwood foliage estimates are calculated using weights from table 8a, multiplied by the number of harvested stems per acre.

D.b.h. (inches)	Trees/acre	Foliage	Foliage	Foliage
		Lbs/tree	*Lbs/acre*	*Tons/acre*
9	70	12	840	0.42
10	100	15	1,500	.75
11	50	17	850	.43
Total				1.60

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Table 1a.—*Crown weight (per tree), including unmerchantable tip to a 4-inch top, for selected coniferous species (weights above the dotted line are total tree weights including the tree bole; weights above the dashed lines are within the limits of sampled data)*

(In pounds per tree)

D.b.h. (inches)	Jack pine	Red pine	Pitch pine	Balsam fir	Black spruce	White spruce
1	2	2	2	1	1	1
2	10	10	10	7	8	8
3	28	26	26	20	22	22
4	54	56	60	56	55	56
5	66	58	64	67	63	69
6	80	60	71	81	74	85
7	100	68	85	99	89	104
8	123	79	104	121	106	127
9	150	95	127	146	125	152
10	182	115	156	173	145	180
11	218	142	187	203	168	210
12	257	177	223	236	192	243
13	299	222	266	271	218	277
14	345	281	313	308	245	314
15	395	356	365	348	274	352
16	448	454	421	390	305	393
17			484			437
18			551			482
19						528
20						577
21						628
22						681

Table 1b.—*Crown weight (per square foot of basal area), including unmerchantable tips to a 4-inch top, for selected coniferous species (weights above the dotted line are total tree weights including the tree bole; weights above the dashed lines are within the limits of sampled data)*

(In pounds per square foot)

D.b.h. (inches)	Jack pine	Red pine	Pitch pine	Balsam fir	Black spruce	White spruce
1	367	367	367	183	183	183
2	455	455	455	318	364	364
3	571	531	531	408	449	449
4	621	644	690	643	632	644
5	485	426	471	493	463	507
6	408	306	362	413	378	434
7	375	255	318	371	333	390
8	352	226	298	347	304	364
9	339	215	287	330	283	344
10	334	211	286	317	266	330
11	330	215	283	308	255	318
12	327	225	284	301	245	310
13	324	241	288	294	236	300
14	323	263	293	288	229	294
15	322	290	297	284	223	287
16	321	325	302	279	218	282
17			307			277
18			312			273
19						268
20						264
21						261
22						258

Table 2a.—*Crown weight*[1] *(per tree), including unmerchantable tip to a 4-inch top, for selected hardwoods (weights above the dotted lines are total tree weights including the tree bole; weights above the dashed lines are within the limits of sampled data)*

(In pounds per tree)

D.b.h. (inches)	Yellow-poplar	Red oaks	White oaks	Aspen	American beech	Red maple	Black cherry	Hickory
1	2	2	2	1	3	2	3	2
2	9	12	10	8	17	11	14	12
3	25	34	30	25	44	30	37	34
4	52	71	63	29	29	63	75	73
5	33	57	44	38	83	49	39	50
6	26	66	47	50	113	64	49	54
7	23	83	58	65	151	82	62	69
8	25	107	75	84	199	101	76	95
9	33	138	98	107	258	122	93	131
10	45	177	128	135	326	145	112	178
11	62	222	165	167	408	170	133	236
12	85	274	208	205	502	197	156	304
13	112	334	258	248	608	225	181	383
14	144	401	315	295	728	256	209	473
15	182	474	378	349	862	288	238	574
16	224	555	448	410	1,012	323	270	685
17	271	643	525	475	1,177			
18	323	738	608	546	1,356			
19	381	841	698	625				
20	443	950	794	711				
21	510	1,066	897					
22	582	1,190	1,007					
23		1,320	1,123					
24		1,458	1,246					
25		1,603	1,375					

[1]Foliage weight not included.

Table 2b.—*Crown weight*[1] *(per square foot of basal area), including unmerchantable tips to a 4-inch top, for selected hardwoods (weights above the dotted lines are total tree weights including the tree bole; weights above the dashed lines are within the limits of sampled data)*

D.b.h. (inches)	Yellow-poplar	Red oaks	White oaks	Aspen	American beech	Red maple	Black cherry	Hickory
1	367	367	367	183	550	367	550	367
2	409	545	455	363	773	500	636	545
3	510	694	612	510	898	612	755	693
4	598	816	724	333	333	724	862	839
5	243	419	324	279	610	360	287	368
6	133	337	240	255	577	327	250	276
7	86	311	217	243	566	307	232	258
8	72	307	215	241	570	289	218	272
9	75	312	222	242	584	276	210	296
10	83	325	235	248	598	266	206	327
11	94	336	250	253	618	258	201	358
12	108	349	265	261	639	251	199	387
13	121	362	280	269	659	244	196	415
14	135	375	295	276	681	239	196	442
15	148	386	308	284	702	235	194	468
16	160	398	321	294	725	231	193	491
17	172	408	333	301	747			
18	183	418	344	309	767			
19	193	427	354	317				
20	203	435	364	326				
21	212	443	373					
22	220	451	381					
23		458	389					
24		464	397					
25		470	403					

[1]Foliage weight not included.

Table 3a.—*Crown weight (per tree), including unmerchantable tip to a 4-inch top, for* ***eastern hemlock*** *(weights above the dotted line are total tree weights)*

(In pounds per tree)

D.b.h. (inches)	Total height (feet)						
	5	10	20	30	40	50	60
<6	1	3	23	72			
6					22	15	
7					33	23	
8					46	33	
9					62	47	
10						63	43
11						81	56
12						102	73
13						126	93
14						153	115
15						183	140

Table 3b.—*Crown weight (per square foot of basal area), including unmerchantable tips to a 4-inch top, for* ***eastern hemlock*** *(weights above the dotted line are total tree weights)*

(In pounds per square foot)

D.b.h. (inches)	Total height (feet)						
	5	10	20	30	40	50	60
<6	183	136	469	529			
6					112	77	
7					124	86	
8					132	95	
9					140	106	
10						116	79
11						123	85
12						130	93
13						137	101
14						143	108
15						149	114

Table 4a.—*Crown weight (per tree), including unmerchantable tip to a 4-inch top, for* ***red spruce*** *(weights above the dotted line are total tree weights)*

(In pounds per tree)

D.b.h. (inches)	Total height (feet)							
	5	10	20	30	40	50	60	70
<6	1	5	21	54				
6					28	18		
7					41	29	15	
8					58	42	24	
9						58	36	
10						78	51	21
11						101	69	32
12						128	89	47
13							114	64
14							142	85
15							172	108

Table 4b.—*Crown weight (per square foot of basal area), including unmerchantable tips to a 4-inch top, for* ***red spruce*** *(weights above the dotted line are total tree weights)*

(In pounds per square foot)

D.b.h. (inches)	(In pounds per square foot)							
	5	10	20	30	40	50	60	70
<6	183	227	429	621				
6					142	92		
7					153	109	56	
8					166	120	69	
9						131	81	
10						143	94	39
11						153	104	48
12						163	113	60
13							124	69
14							133	80
15							140	88

Table 5a.—*Crown weight (per tree), including unmerchantable tip to a 4-inch top for* ***eastern white pine*** *(weights above the dotted line are total tree weights)*

(In pounds per tree)

D.b.h. (inches)	Total height (feet)								
	5	10	20	30	40	50	60	70	80
<6	1	2	11	32					
6					29	20			
7					42	32	19		
8						45	30		
9						62	43	22	
10						82	59	33	
11							78	47	14
12							100	64	25
13								84	38
14								106	54
15								132	73

Table 5b.—*Crown weight (per square foot of basal area), including unmerchantable tips to a 4-inch top for* ***eastern white pine*** *(weights above the dotted lines are total tree weights)*

(In pounds per square foot)

D.b.h. (inches)	Total height (feet)								
	5	10	20	30	40	50	60	70	80
<6	183	367	500	653					
6					148	102			
7					157	120	71		
8						129	86		
9						140	97	50	
10						150	108	61	
11							118	71	21
12							127	82	32
13								91	41
14								99	51
15								108	59

Table 6a.—*Crown weight (per tree), including unmerchantable tip to a 4-inch top for* ***northern white-cedar*** *(weights above the dotted line are total tree weights)*

(In pounds per tree)

D.b.h. (inches)	Total height (feet)					
	5	10	20	30	40	50
<6	1	4	26			
6				21	25	
7				16	31	
8					38	
9					45	
10					52	55
11					60	64
12					68	73

Table 6b.—*Crown weight (per square foot of basal area), including unmerchantable tips to a 4-inch top for* ***northern white-cedar*** *(weights above the dotted line are total tree weights)*

(In pounds per square foot)

D.b.h. (inches)	Total height (feet)					
	5	10	20	30	40	50
<6	183	182	299			
6				107	127	
7				60	116	
8					109	
9					102	
10					95	101
11					91	97
12					87	93

Table 7a.—*Crown weight*[1] *(per tree), including unmerchantable tip for* ***paper birch*** *(weights above the dotted line are total tree weights)*

(In pounds per tree)

D.b.h. (inches)	Total height (feet)							
	5	10	20	30	40	50	60	70
<6	0.5	1	5	22				
6					31	22		
7					49	36		
8					68	55	34	
9					91	72	49	25
10							69	38
11							92	55
12							120	77

[1]Foliage weight not included. Crown weights from the original sources (Young *et al.* 1964, Young and Carpenter 1967) included foliage. To estimate weights listed here, foliage weights (Storey and Pong 1957) from Table 8a were subtracted from the original crown weights.

Table 7b.—*Crown weight*[1] *(per square foot of basal area), including unmerchantable tips to a 4-inch top for* ***paper birch*** *(weights above the dotted line are total tree weights)*

(In pounds per square foot)

D.b.h. (inches)	Total height (feet)							
	5	10	20	30	40	50	60	70
<6	92	183	227	253				
6					158	112		
7					184	135		
8					195	158	97	
9					206	163	111	57
10							127	70
11							139	83
12							152	98

[1]Foliage weight not included.

Table 8a.—*Foliage weight (per tree) for selected hardwoods (weights above the dashed lines are within the limits of sampled data)*

(In pounds per tree)

D.b.h. (inches)	Yellow-poplar	Red oak	White oak	Aspen	American beech	Maple	Cherry	Hickory	Birch
1	0.2	0.5	0.4	0.1	0.3	0.1	0.3	0.1	0.2
2	.6	1	1	.5	1	.5	1	.5	1
3	1	2	3	1	3	1	2	1	2
4	2	4	4	2	5	2	4	3	4
5	3	5	7	4	8	4	7	5	5
6	5	7	9	5	12	6	10	7	8
7	6	9	12	7	17	9	13	10	10
8	8	10	15	10	22	13	17	14	13
9	9	12	19	12	28	18	21	19	17
10	11	15	22	16	35	23	26	24	21
11	13	17	27	19	42	29	32	30	25
12	15	19	31	23	50	37	38	37	29
13	18	22	36	27	59	45	44	44	34
14	20	24	41	32	69	54	51	53	39
15	23	27	46	37	80	65	59	62	45
16	26	30	51	42	91	76	66	73	
17	29	32	57	48	103			84	
18	32	35	63	54	116			96	
19	35	38	70	60				109	
20	38	41	76	67				123	
21	42	44						138	
22	45	48						154	
23	49	51						171	
24	53	54							
25	57	58							

Table 8b.—*Foliage weight (per square foot of basal area) for selected hardwoods (weights above the dashed lines are within the limits of sampled data)*

(In pounds per square foot of basal area)

D.b.h. (inches)	Yellow-poplar	Red oak	White oak	Aspen	American beech	Maple	Cherry	Hickory	Birch
1	37	91	73	18	55	18	55	18	37
2	27	45	45	23	45	23	45	23	45
3	20	41	61	20	61	20	41	20	41
4	23	46	46	23	57	23	46	34	46
5	22	37	51	29	59	29	51	37	37
6	26	36	46	26	61	31	51	36	41
7	22	34	45	26	64	34	49	37	37
8	23	29	43	29	63	37	49	40	37
9	20	27	43	27	63	41	48	43	38
10	20	28	40	29	64	42	48	44	39
11	20	26	41	29	64	44	48	45	38
12	19	24	39	29	64	47	48	47	37
13	20	24	39	29	64	49	48	48	37
14	19	22	38	30	65	51	48	50	37
15	19	22	37	30	65	53	48	51	37
16	19	21	37	30	65	54	47	52	
17	18	20	36	30	65			53	
18	18	20	36	31	66			54	
19	18	19	36	31				55	
20	17	19	35	31				56	
21	17	18						57	
22	17	18						58	
23	17	18						59	
24	17	17							
25	17	17							

Table 9.—*Specific gravities and densities of selected North Central and Northeastern tree species*

Species	Scientific name	Specific gravity[1]	Density
			[2]*Lbs/ft*^{3}
CONIFERS			
Northern white-cedar	*Thuja occidentalis* L.	0.31	19.3
Balsam fir	*Abies balsamea* (L.) Mill.	.36	22.5
Eastern hemlock	*Tsuga canadensis* (L.) Carr.	.40	25.0
Jack pine	*Pinus banksiana* Lamb.	.43	26.8
Pitch pine	*Pinus rigida* Mill.	.52	32.6
Red pine	*Pinus resinosa* Ait.	.46	28.7
Virginia pine	*Pinus virginiana* Mill.	.48	30.0
Eastern white pine	*Pinus strobus* L.	.35	21.8
Black spruce	*Picea mariana* (Mill.) B.S.P.	.40	25.0
Red spruce	*Picea rubens* Sarg.	.41	25.6
White spruce	*Picea glauca* (Moench) Voss	.40	25.0
Tamarack	*Larix laricina* (Du Roi) K. Koch	.53	33.1
HARDWOODS			
Quaking aspen	*Populus tremuloides* Michx.	.38	23.7
American beech	*Fagus grandifolia* Ehrh.	.64	39.9
Paper birch	*Betula papyrifera* Marsh.	.55	34.3
Yellow birch	*Betula alleghaniensis* Britton	.62	38.7
Black cherry	*Prunus serotina* Ehrh.	.50	31.2
Hickory	*Carya* spp. Nutt.	.72	44.9
Red maple	*Acer rubrum* L.	.54	33.7
Sugar maple	*Acer saccharum* Marsh.	.63	39.3
Northern red oak	*Quercus rubra* L.	.63	39.3
White oak	*Quercus alba* L.	.68	42.4
Yellow-poplar	*Liriodendron tulipifera* L.	.42	26.2

[1]Weight when ovendry and volume at 12 percent moisture content. Table A-4-2, U.S. Forest Products Laboratory, Wood Handbook, USDA Handbook 72 (Rev. 1974), p. 4-41 to 4-55. U.S. Government Printing Office, Washington, D.C.

[2]The average density for coniferous forest types in the Northeast is 26.2 pounds/cubic foot and 38.1 pounds/cubic foot for hardwood types. To obtain wood densities in pounds per cubic foot, multiply the specific gravity by 62.4.

Table 10.—*Basal area*[1] *table*[2]
(In square feet)

Diameter (inches)	Trees (number)									
	1	2	3	4	5	6	7	8	9	10
2	0.02	0.04	0.07	0.09	0.11	0.13	0.15	0.17	0.20	0.22
3	.05	.10	.15	.20	.25	.29	.34	.39	.44	.49
4	.09	.17	.26	.35	.44	.52	.61	.70	.79	.87
5	.14	.27	.41	.55	.68	.82	.95	1.09	1.23	1.36
6	.20	.39	.59	.79	.98	1.18	1.37	1.57	1.77	1.96
7	.27	.53	.80	1.07	1.34	1.60	1.87	2.14	2.41	2.67
8	.35	.70	1.05	1.40	1.75	2.09	2.44	2.79	3.14	3.49
9	.44	.88	1.33	1.77	2.21	2.65	3.09	3.53	3.98	4.42
10	.55	1.09	1.64	2.18	2.73	3.27	3.82	4.36	4.91	5.45
11	.67	1.32	1.98	2.64	3.30	3.96	4.62	5.28	5.94	6.60
12	.79	1.57	2.36	3.14	3.93	4.71	5.50	6.28	7.07	7.85
13	.92	1.84	2.77	3.69	4.61	5.53	6.45	7.37	8.30	9.22
14	1.07	2.14	3.21	4.28	5.35	6.41	7.48	8.55	9.62	10.69
15	1.23	2.45	3.68	4.91	6.14	7.36	8.59	9.82	11.04	12.27
16	1.40	2.79	4.19	5.59	6.98	8.38	9.77	11.17	12.57	13.96
17	1.58	3.15	4.73	6.31	7.88	9.46	11.03	12.61	14.19	15.76
18	1.77	3.53	5.30	7.07	8.84	10.60	12.37	14.14	15.90	17.67
19	1.97	3.94	5.91	7.88	9.84	11.81	13.78	15.75	17.72	19.69
20	2.18	4.36	6.54	8.73	10.91	13.09	15.37	17.45	19.63	21.82
21	2.41	4.81	7.22	9.62	12.03	14.43	16.84	19.24	21.65	24.05
22	2.64	5.28	7.92	10.56	13.20	15.84	18.48	21.12	23.76	26.40
23	2.89	5.77	8.66	11.54	14.43	17.31	20.20	23.08	25.97	28.85
24	3.14	6.28	9.42	12.57	15.71	18.85	21.99	25.13	28.27	31.42
25	3.41	6.82	10.23	13.65	17.04	20.45	23.86	27.27	30.68	34.09
26	3.69	7.37	11.06	14.75	18.44	22.12	25.81	29.50	33.18	36.87
27	3.98	7.95	11.93	15.90	19.88	23.86	27.83	31.81	35.78	39.76
28	4.28	8.55	12.83	17.10	21.38	25.66	29.93	34.21	38.48	42.76
29	4.59	9.17	13.76	18.35	22.93	27.52	32.11	36.70	41.28	45.87
30	4.91	9.82	14.73	19.63	24.54	29.45	34.36	29.27	44.18	49.09

[1]To find the basal area (B.A.) in square feet from a diameter (D) measurement in inches, use the equation:

$$B.A. = \frac{\pi D^2}{4 \times 144} = 0.00545415D^2.$$

[2]Forbes, R. D. 1961. Forestry handbook. Society of American Foresters, 1955. The Ronald Press, New York. Adapted by E. T. Hawes, U.S. Forest Service, from H. H. Chapman and D. B. Demeritt. Elements of forest mensuration. J. B. Lyon Co., 1936.

Table 11.—*Fraction of crown component weight*[1] *(per tree), including unmerchantable tip to a 4-inch top, for selected coniferous species by fuel size classes*

FOLIAGE

D.b.h. (inches)	Jack pine	Red pine Pitch pine	Balsam fir	Spruce	Hemlock	White pine	White cedar
2	0.19	0.26	0.41	0.33	0.26	0.27	0.32
4	.13	.18	.28	.26	.18	.16	.27
6	.22	.28	.37	.35	.27	.25	.37
8	.25	.28	.37	.36	.29	.27	.39
10	.27	.30	.40	.38	.32	.31	.41
12	.26	.26	.35	.34	.30	.27	.37
14	.26	.26	.35	.34	.31	.29	.38
16	.23	.20	.29	.30	.26	.25	.34
18		.21	.29	.30		.25	.34
20				.24		.22	

BRANCHWOOD 0 to 1/4 inch

2	0.12	0.04	0.16	0.16	0.13	0.14	0.08
4	.09	.02	.11	.13	.10	.09	.06
6	.17	.03	.15	.19	.15	.14	.09
8	.20	.03	.15	.20	.16	.17	.09
10	.22	.04	.16	.21	.17	.18	.10
12	.21	.03	.14	.21	.15	.19	.09
14	.22	.03	.14	.21	.16	.20	.09
16	.21	.02	.12	.19	.13	.19	.08
18		.02	.12	.19		.20	.08
20				.18		.20	

BRANCHWOOD 1/4 to 1 inch

2	0.12	0.21	0.14	0.13	0.13	0.13	0.17
4	.10	.17	.11	.12	.10	.10	.15
6	.20	.27	.17	.17	.16	.16	.22
8	.26	.32	.23	.21	.20	.21	.26
10	.29	.35	.24	.23	.22	.23	.27
12	.30	.34	.29	.25	.24	.26	.27
14	.27	.35	.30	.26	.25	.27	.28
16	.25	.33	.32	.27	.26	.28	.26
18		.33	.33	.27		.29	.26
20				.28		.29	

BRANCHWOOD 1 to 3 inches

2	0.48	0.43	0.25	0.33	0.41	0.40	0.37
4	.13	.17	.11	.10	.13	.13	.11
6	.17	.24	.15	.14	.20	.19	.16
8	.15	.25	.15	.14	.21	.18	.17
10	.13	.23	.14	.13	.19	.16	.16
12	.18	.28	.18	.16	.25	.19	.22
14	.21	.27	.18	.16	.24	.18	.22
16	.28	.31	.25	.22	.31	.23	.30
18		.31	.24	.21		.22	.30
20				.29		.26	

BRANCHWOOD 3 + inches

2	0.08	0.06	0.04	0.05	0.07	0.06	0.06
4	.54	.46	.39	.39	.48	.52	.41
6	.24	.18	.16	.15	.22	.26	.16
8	.13	.12	.09	.09	.14	.17	.09
10	.09	.08	.06	.05	.09	.12	.06
12	.05	.09	.04	.04	.06	.09	.04
14	.04	.09	.03	.03	.04	.06	.03
16	.03	.13	.02	.02	.03	.05	.02
18		.13	.02	.02		.04	.02
20				.01		.03	

[1]Fractions were developed from tables and equations for similar western species using information from Brown *et al.* (1977) and Brown (1978).

Table 12.—*Fraction of crown branchwood*[1] *(per tree), including unmerchantable tip to a 4-inch top, by fuel size classes*
(In inches)

D.b.h. (inches)	Aspen				Oak and other hardwoods			
	0-¼	¼-1	1-3	3+	0-¼	¼-1	1-3	3+
1	0.14	0.31	0.55	0.00	0.09	0.05	0.86	0.00
2	.16	.24	.60	.00	.05	.11	.84	.00
3	.16	.31	.53	.00	.03	.13	.32	.52
4	.12	.28	.22	.38	.04	.18	.36	.42
5	.14	.33	.24	.29	.05	.21	.40	.34
6	.14	.35	.29	.22	.05	.23	.46	.26
7	.15	.36	.34	.15	.05	.23	.52	.20
8	.14	.35	.39	.12	.05	.23	.57	.15
9	.14	.34	.43	.08	.05	.22	.58	.15
10	.13	.33	.46	.08	.04	.21	.54	.21
11	.13	.32	.47	.08	.04	.20	.49	.27
12	.12	.30	.50	.08	.04	.19	.46	.31
13	.12	.29	.50	.09	.04	.18	.42	.36
14	.11	.28	.52	.09	.03	.17	.40	.40
15	.11	.27	.52	.10	.03	.16	.37	.44
16	.10	.26	.53	.11	.03	.15	.35	.47
17	.10	.25	.53	.12	.03	.14	.33	.50
18	.09	.24	.54	.13	.03	.14	.30	.53
19	.09	.23	.55	.13	.03	.13	.29	.55
20	.09	.22	.55	.14	.02	.12	.28	.58
21					.02	.12	.26	.60
22					.02	.11	.25	.62
23					.02	.11	.24	.63
24					.02	.10	.23	.65
25					.02	.10	.22	.66

[1]Fractions for aspen are from Loomis and Roussopoulos (1978), while those for oak and other hardwoods are from Loomis and Blank (1981).

APPENDIX I.

Equations and sources for crown weight prediction tables.

Species	D.b.h.	Equation[1]	r^2[2]	Source	Location	Top diameter
	Inches					Inches
CONIFERS						
Northern white-cedar	<6	$W = 0.0108H^{2.07}+0.0040H^{2.37}+0.0016H^{3.07}$	0.89	Dyer 1967	Maine	tree
	≥6	$W = 0.01887D^{1.41}H^{1.59}-0.00243D^{1.39}H^{2.06}$	.91	Dyer 1967	Maine	4.0
Balsam fir	<4	$W = 1.2189D^{2.53}$	.96	Baskerville 1965	Eastern Canada	tree
	≥4	$W = 2.2728D^{1.845}$	.96	Roussopoulos[3] 1978	Minnesota	2.5
Eastern hemlock	<6	$W = 0.0078H^{2.192}+0.0048H^{2.320}+0.00536H^{3.343}$	.94	Young and Carpenter 1967	Maine	0.0
	≥6	$W = 0.03711D^{2.1679}{}_{H}{}^{0.4292}-0.0498D^{2.0215}{}_{H}{}^{0.9670}$	.98	Young et al. 1964	Maine	4.0
Jack pine	<4	$W = 1.2189D^{2.53}$	.99	Hegyi 1972	Eastern Canada	tree
	≥4	$W = 1.5914D^{2.0270}$	.91	Sando and Wick 1972	Great Lakes Region	2.5
Pitch pine	<4	$W = 2.0243D^{2.3373}$	.99	Whittaker and Woodwell 1968	New York	tree
	≥4	$W = 2.0243D^{2.3373}-1.4469D^{2.3261}$	.99	Whittaker and Woodwell 1968	New York	0.0
Red pine	<4	$W = 2.0243D^{2.3373}$ (pitch pine used)	--	---	---	---
	≥4	$W = 8.076(1.284)^{D}$	.91	Brown 1963	Michigan	1.5
White pine	<6	$W = 0.00495H^{1.750}+0.00333H^{2.064}+.00185H^{2.814}$	.89	Young and Carpenter 1967	Maine	tree
	≥6	$W = 0.4464D^{2.1679}{}_{H}{}^{0.4292}{}_{0}.0585D^{2.0215}{}_{H}{}^{0.9670}$	.98	Young et al. 1964	Maine	4.0
Black spruce	<4	$W = 1.413D^{2.48}$ (white spruce used)	--	---	---	---
	≥4	$W = 2.5986D^{1.7052}$	.90	Roussopoulos[3] 1978	Minnesota	2.5
Red spruce	<6	$W = 0.0397H^{1.626}+0.01378H^{1.847}+0.00999H^{2.705}$	.94	Young and Carpenter 1967	Maine	tree
	≥6	$W = 0.4848D^{2.1679}{}_{H}{}^{0.4292}-0.0659D^{2.0215}{}_{H}{}^{0.9670}$	.98	Young et al. 1964	Maine	4.0
White spruce	<4	$W = 1.413D^{2.48}$	.98	Baskerville 1965	Eastern Canada	tree
	≥4	$W = 5.5208xCf[4]xD^{1.753}$	.82	Keen 1963	Eastern Canada	3.0
HARDWOODS						
Aspen	<4	$W = 0.3640D^{1.8545}+1.0246D^{2.7859}$	.85	Ribe 1973	Maine	tree
	≥4	$W = 7.0+0.4162D^{2.5094}-0.1235D^{2.1012}$	.97	Loomis and Roussopoulos 1978	Minnesota	3.0

(Appendix I. continued on next page)

(Appendix I. continued)

Species	D.b.h.	Equation[1]	$^2/r^2$	Source	Location	Top diameter
	Inches					Inches
American beech	<4	$W = 0.8743D^{1.5402+2.5854D^{2.4868}}$	0.79	Ribe 1973	Maine	tree
	≥4	$W = 0.837D^{2.552}$	.987	Storey and Pong 1957	North Carolina	0.0
Paper birch	<6	$W = 0.00219H^{2.116}+0.00188H^{2.276}+0.00178H^{2.739}$	.97	Young and Carpenter 1967	Maine	tree
	≥6	$W = 0.5705D^{2.1679}{}_H{}^{0.4292-0.0721D^{2.0215}}{}_H{}^{0.9670}$	.97	Young et al. 1964	Maine	4.0
Black cherry	<5	$W = 2.5881D^{2.42530}$	.994	Wiant et al. 1977	West Virginia	tree
	≥5	$W = 20.48931+1.07958D^2-1.67602D$	.811	Wiant et al. 1977	West Virginia	4.0
Hickory	<5	$W = 1.93378D^{2.62090}$	.987	Wiant et al. 1977	West Virginia	tree
	≥5	$W = 191.16897+5.36555D^2-54.98699D$	.842	Wiant et al. 1977	West Virginia	4.0
Red maple	<5	$W = 1.81301D^{2.56226}$	.981	Wiant et al. 1977	West Virginia	tree
	≥5	$W = 0.93846D^2+5.18726D-0.55683$	.793	Wiant et al. 1977	West Virginia	4.0
Red oaks	<5	$W = 2.09014D^{2.54052}$	.989	Wiant et al. 1977	West Virginia	tree
	≥5	$W = 114.40758+3.55460D^2-29.31907D$	.891	Wiant et al. 1977	West Virginia	4.0
White oaks	<5	$W = 1.68565D^{2.60982}$	.985	Wiant et al. 1977	West Virginia	tree
	≥5	$W = 124.89440+3.31160D^2-32.77917D$	.910	Wiant et al. 1977	West Virginia	4.0
Yellow-poplar	<5	$W = 1.57792D^{2.51532}$	.995	Wiant et al. 1977	West Virignia	tree
	≥5	$W = 146.29742+2.49589D^2-35.08911D$	.732	Wiant et al. 1977	West Virginia	4.0

[1]/W = weight in lbs/tree; D = d.b.h. in inches; H = tree height in feet.

[2]/r^2 = coefficient of determination.

[3]/Unpublished secondary analysis of data from Sando and Wick (1972).

[4]/Assume fresh debris (including foliage, wood, and bark) had a moisture content of 85 percent. Original data were reported as fresh weights. Dry weight was computed using $Cf = \frac{1}{1+\frac{85}{100}} = 0.541$.

APPENDIX II.

Equations and sources for hardwood foliage weight tables.

Species and equation[1/]	[2/] r^2	Source
Aspen		
$W = 0.1235D^{2.1012}$	0.98	Loomis and Roussopoulos 1978
American beech		
$W = 0.311D^{2.048}$	.96	Storey and Pong 1957
Birch		
$W = 0.243D^{1.928}$	.93	Storey and Pong 1957
Cherry (*Prunus pensylvanica*)		
$W = 0.2759D^{1.9784}$	.87	Ribe 1973
Hickory		
$W = 0.101D^{2.372}$	.97	Storey and Pong 1957
Maple		
$W = 0.066D^{2.544}$	.87	Storey and Pong 1957
Red oak (*Quercus rubra*)		
$W = 0.4590D^{1.5018}$	.96	Loomis and Blank 1981
White oak (*Quercus alba*)		
$W = 0.3802D^{1.77}$	[3/]	Ralston and Prince 1965
Yellow-poplar		
$W = 0.188D^{1.775}$	.92	Storey and Pong 1957

[1/] W = weight in pounds; D = d.b.h. in inches.

[2/] r^2 = coefficient of determination.

[3/] Information not available.

APPENDIX III.

Crown weight[1] based on equations listed in Appendix I and used to construct tables to include unmerchantable bole tips to a 4-inch top (weights above the dashed lines are within the limits of sampled data)

(In pounds per tree)

	Species and unmerchantable tip diameter (in inches)							
D.b.h.	Jack pine[2]	Red pine[3]	Pitch pine[4]	Balsam fir[2]	Black spruce[2]	White spruce[5]	Aspen[6]	American beech[6]
(inches)	2½	1½	0	2½	2½	3	3	0
4	26	22	15	29	28	34	18	29
5	42	28	26	44	40	50	27	51
6	60	36	40	62	55	69	39	81
7	82	46	57	82	72	90	55	120
8	108	60	79	105	90	114	74	169
9	136	77	104	131	110	141	98	228
10	169	98	134	159	132	169	126	298
11	205	126	167	190	155	200	159	381
12	245	162	205	223	180	233	197	475
13	288	208	248	258	206	268	240	583
14	335	267	296	296	234	305	288	704
15	385	343	348	336	263	344	342	840
16	439	441	405	379	294	385	403	990
17			468			429	469	1,156
18			536			474	541	1,337
19						521	620	
20						570	706	
21						621		
22						674		

[1]Crown weight for conifers includes foliage; crown weight for hardwoods does not include foliage.

[2]For jack pine, balsam fir, and black spruce, Lagrange interpolation equations and weights of 3-, 4-, and 6-inch tips for lodgepole pine, grand fir, and Englemann spruce (Brown *et al.* 1977) were used to calculate the weight of a 2-inch tip for each d.b.h. class. The weights of tips were subtracted from the 4-inch tips to get weights of the 2-inch to 4-inch tips. Then, weights of the 2- to 4-inch bole sections were converted to volumes by dividing by the densities of lodgepole pine, grand fir, and Engleman spruce respectively; then the volumes were converted back to weights of jack pine, balsam fir, and black spruce by multiplying these volumes by densities of jack pine, balsam fir, and black spruce respectively.

[3]For red pine, calculations were made similar to the above, using ponderosa pine information and a Lagrange interpolation equation for a 1-inch top.

[4]Equation for branches only and does not include the tree bole. Weights by d.b.h. of unmerchantable bole tips to a 4-inch top for ponderosa pine (Brown *et al.* 1977) were used, then converted to volumes by dividing by the density of ponderosa pine; then the volumes were converted back to weights of pitch pine by multiplying by the density of pitch pine.

[5]Equation based on a 3-inch top. The difference between a 3-inch top and a 4-inch top of Englemann spruce (Brown *et al.* 1977) was used to get the weight of the 3- to 4-inch bole section. Then, using the method described above for pitch pine, weights of the 3- to 4-inch bole sections were converted to volumes and back to weights.

[6]For aspen and American beech, information on tip weights of northern red oak was used to calculate weights of tips for each d.b.h. class.

APPENDIX IV.
Conversion Factors

All units are presented in U.S. standard measurements regardless of the units given in the source reference. The units can be converted to metric (SI) measurements using the following conversion factors:

To convert:	to:	Multiply by:
inches	centimeters	2.540
feet	meters	0.3048
chains	meters	20.12
acres	hectares	0.4047
cubic feet	cubic meters	0.02832
pounds	grams	453.59
pounds	kilograms	0.45359
tons per acre	kilograms per square meter	0.2243

U.S. Standard Measurement Conversions:

To convert tons per acre to cords or cunits per acre, take the pounds per acre of usable wood and divide by the density of the species, or use an average density of 38.1 pounds per cubic foot for northeastern hardwood forest types or 26.2 pounds per acre for coniferous forest types. Divide this amount by 90 cubic feet per cord to get cords per acre, or by 100 cubic feet to get cunits per acre.

Example: There are 10 tons per acre of hardwood material 3 inches and larger that can be used as an energy source.

10 tons/acre = 20,000 pounds.

20,000 pounds ÷ 38.1 pounds/foot^3 ÷ 90 feet^3 = 5.8 cords/acre.

20,000 pounds ÷ 38.1 pounds/foot^3 ÷ 100 feet^3 = 5.2 cunits/acre.

APPENDIX V.
Similar Species

The tables presented can be used for species with similar crown characteristics:

For:	Use:
Virginia pine	Jack pine
Tamarack	Western larch (Brown *et al.* 1977)
Sugar maple	Red maple
Yellow birch	Paper birch
Balsam poplar	Quaking aspen

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Freeman, Duane R.; Loomis, Robert M.; Roussopoulos, Peter J.
Handbook for predicting slash weight in the Northeast. Gen. Tech. Rep. NC-75. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1982. 23 p.

Tables are provided for estimating tree crown weights based on species and diameters (d.b.h.) for 10 conifer and 9 hardwood species or species groups of the North Central and Northeastern United States. Procedures are given for predicting slash weights resulting from: cutting timber, trampling during logging activities, and defect and breakage left on the site after cutting.

KEY WORDS: Fuel management, slash, debris prediction, forest fuels, tree biomass.