



Tree Replacement Value Equivalence

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Many regulatory controls on tree removals and replacements involve an estimation of equivalent tree values. As one large tree is removed, a corresponding number of trees of a given size are planted in an attempt to replace tree values and functions (ecological, engineering, micro-site) lost from removal. In some cases, a few small trees are planted as a political replacement for one large tree. The immense scale of values, benefits, and functions from a large tree can require many trees in replacement to reach some semblance of equivalency and value return to the owner and/or society.

Diameter Inches

An older and more simplistic means of determining number of replacement trees has been based upon diameter inches of the removed tree at some height above the ground. In this case, the total number of replacement trees must have diameters which add up to the diameter inches of the removed tree measured at the same or different height above the ground. Diameter inch matching can help return the visual density of tree stems back to a site and is relatively easy to determine. Unfortunately, tree functional values are not equivalent by diameter inch based replacements, especially as removed tree diameters become larger. This type of replacement accelerates tree and site quality loss.

Table 1 provides diameters and cross-sectional areas for trees of various stem diameters. The remaining tables provide different tree number and size replacement values based upon both a diameter inch or cross-sectional area basis. Basal area (cross-sectional area) of a removed tree is usually measured at 4.5 feet above the ground. Smaller (replacement) tree basal areas may be measured at 4 inches above the ground (a 4" caliper) or 12 inches above the ground (a 12" caliper). It is critical to define the location on a tree of any measure taken.

Table 2 provides the number of replacement trees of a given size needed to replace a larger removed tree utilizing a diameter inch equivalence basis. For example, a 20 inch diameter tree is removed and can be replaced with 6 four-inch diameter trees. Note the replacement tree values are rounded up to the next full tree.

Table 3 uses a diameter inch matching process, but utilizes an enhanced value for the removed tree diameter in order to recognize and reward large tree associated values. In this case, removed tree diameter is multiplied by 1.05 to estimate replacement trees under the enhanced diameter inch basis. In this table, a 20 inch diameter tree would be replaced by 6 four-inch trees. This is the same number of trees as in the previous table, but as removed tree diameters become progressively larger, a greater number of replacements will be required. Note the enhanced calculations do not tend to have great impact until large tree sizes are removed. Using an enhanced tree value for large trees is highly recommended.

Basal Area

Another more ecologically accurate means of determining the number of replacement trees with a given size is based upon removal tree cross-sectional area (sometimes referred to as a "basal area"). Each square inch of removed tree cross-sectional area is replaced by a square inch of a replacement tree cross-sectional area. Because removed tree trunk size was proportional to its crown, and because a tree crown provides many values, crown replacement as estimated by basal area is appropriate to use in replacing tree values and functions lost.

Table 4 provides the number of replacement trees of a given size needed to replace a larger removed tree utilizing a cross-sectional area equivalence basis. For example, a 20 inch diameter tree is

removed and can be replaced with 26 four-inch diameter trees. This number of small replacement trees may at first seem as too many. Remember the replacement is for a crown volume and associated total benefits from the large tree. Note value area for replacement is rounded up to the next full tree.

Table 5 uses a cross-sectional area matching process but utilizes an enhanced value for the removed tree to recognize and reward large tree values. Removed tree diameter is elevated to the 2.05 power ($\text{DIAMETER}^{2.05}$) to estimate replacement trees under the enhanced basal area basis. For example, a 20 inch diameter tree is removed and can be replaced with 30 four-inch diameter trees. Using an enhanced tree basal area for large trees is highly recommended.

Conclusion

It is critical to continue tree and site quality management over time. Do not accept “pennies for dollars lost” when big trees are removed. Maintaining tree asset values and their appreciation over time is key to great communities.

Table 1: Basal area (cross-sectional area perpendicular to the longitudinal axis of a tree stem) in square feet and square inches for given tree diameter in inches.

diameter (in)	BA_{ft} (ft²)	BA_{in} (in²)	diameter (in)	BA_{ft} (ft²)	BA_{in} (in²)
1	0.006	0.75	26	3.7	531
2	0.02	3	27	4.0	573
3	0.05	7	28	4.3	616
4	0.09	12.5	29	4.6	661
5	0.14	19.5	30	4.9	707
6	0.20	28	31	5.2	755
7	0.27	38.5	32	5.6	804
8	0.35	50	33	5.9	855
9	0.44	63.5	34	6.3	908
10	0.55	78.5	35	6.7	962
11	0.66	95	36	7.1	1,018
12	0.79	113	37	7.5	1,075
13	0.92	133	38	7.9	1,134
14	1.1	154	39	8	1,195
15	1.3	177	40	8.5	1,257
16	1.4	201	41	9	1,320
17	1.6	227	42	9.5	1,385
18	1.8	255	43	10	1,452
19	2.0	284	44	10.5	1,521
20	2.2	314	45	11	1,590
21	2.4	346	46	11.5	1,662
22	2.6	380	47	12	1,735
23	2.9	416	48	12.5	1,810
24	3.1	452	49	13	1,886
25	3.4	491	50	13.5	1,964

Table 1 (continued): Basal area (cross-sectional area perpendicular to the longitudinal axis of a tree stem) in square feet and square inches for a given tree diameter in inches.

diameter (in)	BA_{ft} (ft²)	BA_{in} (in²)	diameter (in)	BA_{ft} (ft²)	BA_{in} (in²)
51	14	2,043	76	31.5	4,536
52	14.5	2,124	77	32	4,657
53	15	2,206	78	33	4,778
54	16	2,290	79	34	4,902
55	16.5	2,376	80	35	5,027
56	17	2,463	81	35.5	5,153
57	17.5	2,552	82	36.5	5,281
58	18	2,642	83	37.5	5,411
59	19	2,734	84	38.5	5,542
60	19.5	2,827	85	39	5,674
61	20	2,922	86	40	5,809
62	21	3,019	87	41	5,945
63	21.5	3,117	88	42	6,082
64	22	3,217	89	43	6,221
65	23	3,318	90	44	6,362
66	24	3,421	91	45	6,504
67	24.5	3,526	92	46	6,648
68	25	3,632	93	47	6,793
69	26	3,739	94	48	6,940
70	26.5	3,848	95	49	7,088
71	27.5	3,959	96	50	7,238
72	28	4,072	97	51	7,390
73	29	4,185	98	52	7,543
74	30	4,301	99	54	7,698
75	30.5	4,418	100	55	7,854

Table 2: DIAMETER INCH REPLACEMENT --

Number of replacement trees needed for each tree removed based upon a 1:1 ratio of diameter inches.

Each number is rounded up to next whole tree value.

removed tree diameter (inches)	diameter of replacement tree(s)											
	1(in)	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	1	1	1	1	1	1	1	1
2	3	1	1	1	1	1	1	1	1	1	1	1
3	4	2	1	1	1	1	1	1	1	1	1	1
4	5	3	2	1	1	1	1	1	1	1	1	1
5	6	3	2	2	1	1	1	1	1	1	1	1
6	7	4	3	2	2	1	1	1	1	1	1	1
7	8	4	3	2	2	2	1	1	1	1	1	1
8	9	5	3	3	2	2	2	1	1	1	1	1
9	10	5	4	3	2	2	2	2	1	1	1	1
10	11	6	4	3	3	2	2	2	2	1	1	1
11	12	6	4	3	3	2	2	2	2	2	1	1
12	13	7	5	4	3	3	2	2	2	2	2	1
13	14	7	5	4	3	3	2	2	2	2	2	2
14	15	8	5	4	3	3	3	2	2	2	2	2
15	16	8	6	4	4	3	3	2	2	2	2	2
16	17	9	6	5	4	3	3	3	2	2	2	2
17	18	9	6	5	4	3	3	3	2	2	2	2
18	19	10	7	5	4	4	3	3	3	2	2	2
19	20	10	7	5	4	4	3	3	3	2	2	2
20	21	11	7	6	5	4	3	3	3	3	2	2
21	22	11	8	6	5	4	4	3	3	3	2	2
22	23	12	8	6	5	4	4	3	3	3	3	2
23	24	12	8	6	5	4	4	3	3	3	3	2
24	25	13	9	7	5	5	4	4	3	3	3	3
25	26	13	9	7	6	5	4	4	3	3	3	3

Table 2 (continued): **DIAMETER INCH REPLACEMENT --**
 Number of replacement trees needed for each tree removed based upon a 1:1 ratio of diameter inches.
 Each number is rounded up to next whole tree value.

removed tree diameter (inches)	diameter of replacement tree(s)											
	1(in)	2	3	4	5	6	7	8	9	10	11	12
26	27	14	9	7	6	5	4	4	3	3	3	3
27	28	14	10	7	6	5	4	4	4	3	3	3
28	29	15	10	8	6	5	5	4	4	3	3	3
29	30	15	10	8	6	5	5	4	4	3	3	3
30	31	16	11	8	7	6	5	4	4	4	3	3
32	33	17	11	9	7	6	5	5	4	4	3	3
34	35	18	12	9	7	6	5	5	4	4	4	3
36	37	19	13	10	8	7	6	5	5	4	4	4
38	39	20	13	10	8	7	6	5	5	4	4	4
40	41	21	14	11	9	7	6	6	5	5	4	4
42	43	22	15	11	9	8	7	6	5	5	4	4
44	45	23	15	12	9	8	7	6	5	5	5	4
46	47	24	16	12	10	8	7	6	6	5	5	4
48	49	25	17	13	10	9	7	7	6	5	5	5
50	51	26	17	13	11	9	8	7	6	6	5	5
52	53	27	18	14	11	9	8	7	6	6	5	5
54	55	28	19	14	11	10	8	7	7	6	5	5
56	57	29	19	15	12	10	9	8	7	6	6	5
58	59	30	20	15	12	10	9	8	7	6	6	5
60	61	31	21	16	13	11	9	8	7	7	6	6
65	66	33	22	17	14	11	10	9	8	7	6	6
70	71	36	24	18	15	12	11	9	8	8	7	6
75	76	38	26	19	16	13	11	10	9	8	7	7
80	81	41	27	21	17	14	12	11	9	9	8	7
85	86	43	29	22	18	15	13	11	10	9	8	8

Table 3: ENHANCED DIAMETER INCH BASIS --
 Number of replacement trees needed for each tree removed based upon an enhanced diameter inch basis. The enhanced calculations provide additional value for larger tree removal. Diameter inch value of removed tree changed to: (DIAMETER X 1.05).

removed tree diameter (inches)	diameter of replacement tree(s)											
	1(in)	2	3	4	5	6	7	8	9	10	11	12
1	2	1	1	1	1	1	1	1	1	1	1	1
2	3	2	1	1	1	1	1	1	1	1	1	1
3	4	2	2	1	1	1	1	1	1	1	1	1
4	5	3	2	2	1	1	1	1	1	1	1	1
5	6	3	2	2	2	1	1	1	1	1	1	1
6	7	4	3	2	2	2	1	1	1	1	1	1
7	8	4	3	2	2	2	2	1	1	1	1	1
8	9	5	3	3	2	2	2	2	1	1	1	1
9	11	6	4	3	3	2	2	2	2	2	1	1
10	12	6	4	3	3	2	2	2	2	2	2	1
11	13	7	5	4	3	3	2	2	2	2	2	2
12	14	7	5	4	3	3	2	2	2	2	2	2
13	15	8	5	4	3	3	3	2	2	2	2	2
14	16	8	6	4	4	3	3	2	2	2	2	2
15	18	9	6	5	4	3	3	3	2	2	2	2
16	19	10	7	5	4	4	3	3	3	2	2	2
17	20	10	7	5	4	4	3	3	3	2	2	2
18	21	11	7	6	5	4	3	3	3	3	2	2
19	23	12	8	6	5	4	4	3	3	3	3	2
20	24	12	8	6	5	4	4	3	3	3	3	2
21	25	13	9	7	5	5	4	4	3	3	3	3
22	26	13	9	7	6	5	4	4	3	3	3	3
23	27	14	9	7	6	5	4	4	3	3	3	3
24	29	15	10	8	6	5	5	4	4	3	3	3
25	30	15	10	8	6	5	5	4	4	3	3	3

Table 3 (continued): **ENHANCED DIAMETER INCH BASIS --**
 Number of replacement trees needed for each tree removed based upon an enhanced diameter inch basis. The enhanced calculations provide additional value for larger tree removal. Diameter inch value of removed tree changed to: (DIAMETER X 1.05).

removed tree diameter (inches)	diameter of replacement tree(s)											
	1(in)	2	3	4	5	6	7	8	9	10	11	12
26	31	16	11	8	7	6	5	4	4	4	3	3
27	32	16	11	8	7	6	5	4	4	4	3	3
28	34	17	12	9	7	6	5	5	4	4	4	3
29	35	18	12	9	7	6	5	5	4	4	4	3
30	36	18	12	9	8	6	6	5	4	4	4	3
32	39	20	13	10	8	7	6	5	5	4	4	4
34	41	21	14	11	9	7	6	6	5	5	4	4
36	44	22	15	11	9	8	7	6	5	5	4	4
38	46	23	16	12	10	8	7	6	6	5	5	4
40	49	25	17	13	10	9	7	7	6	5	5	5
42	51	26	17	13	11	9	8	7	6	6	5	5
44	54	27	18	14	11	9	8	7	6	6	5	5
46	56	28	19	14	12	10	8	7	7	6	6	5
48	59	30	20	15	12	10	9	8	7	6	6	5
50	61	31	21	16	13	11	9	8	7	7	6	6
52	64	32	22	16	13	11	10	8	8	7	6	6
54	66	33	22	17	14	11	10	9	8	7	6	6
56	69	35	23	18	14	12	10	9	8	7	7	6
58	72	36	24	18	15	12	11	9	8	8	7	6
60	74	37	25	19	15	13	11	10	9	8	7	7
65	81	41	27	21	17	14	12	11	9	9	8	7
70	87	44	29	22	18	15	13	11	10	9	8	8
75	94	47	32	24	19	16	14	12	11	10	9	8
80	100	50	34	25	20	17	15	13	12	10	10	9
85	107	54	36	27	22	18	16	14	12	11	10	9

Table 4: BASAL AREA BASIS -- Number of replacement trees needed for each tree removed based upon a 1:1 ratio of basal areas (cross-sectional areas). Each number is rounded up to next whole tree value.

removed tree diameter (inches)	diameter of replacement tree(s)									
	1(in)	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	1
2	5	1	1	1	1	1	1	1	1	1
3	10	3	1	1	1	1	1	1	1	1
4	17	5	2	1	1	1	1	1	1	1
5	26	7	3	2	1	1	1	1	1	1
6	37	10	5	3	2	1	1	1	1	1
7	50	13	6	4	2	2	1	1	1	1
8	65	17	8	5	3	2	2	1	1	1
9	82	21	10	6	4	3	2	2	1	1
10	101	26	12	7	5	3	3	2	2	1
11	122	31	14	8	5	4	3	2	2	2
12	145	37	17	10	6	5	3	3	2	2
13	170	43	19	11	7	5	4	3	3	2
14	197	50	22	13	8	6	5	4	3	2
15	226	57	26	15	10	7	5	4	3	3
16	257	65	29	17	11	8	6	5	4	3
17	290	73	33	19	12	9	6	5	4	3
18	325	82	37	21	13	10	7	6	5	4
19	362	91	41	23	15	11	8	6	5	4
20	401	101	45	26	17	12	9	7	5	5
21	442	111	50	28	18	13	10	7	6	5
22	485	122	54	31	20	14	10	8	6	5
23	530	133	59	34	22	15	11	9	7	6
24	577	145	65	37	24	17	12	10	8	6
25	626	157	70	40	26	18	13	10	8	7

Table 4 (CONTINUED): BASAL AREA BASIS -- Number of replacement trees needed for each tree removed based upon a 1:1 ratio of basal areas (cross-sectional areas). Each number rounded up to next whole value.

removed tree diameter (inches)	diameter of replacement tree(s)									
	1(in)	2	3	4	5	6	7	8	9	10
26	677	170	76	43	28	19	14	11	9	7
27	730	183	82	46	30	21	15	12	10	8
28	785	197	88	50	32	22	17	13	10	8
29	842	211	94	53	34	24	18	14	11	9
30	901	226	101	57	37	26	19	15	12	10
32	1,025	257	114	65	41	29	21	17	13	11
34	1,157	290	129	73	47	33	24	19	15	12
36	1,297	325	145	82	52	37	27	21	17	13
38	1,445	362	161	91	58	41	30	23	18	15
40	1,601	401	178	101	65	45	33	26	20	17
42	1,765	442	197	111	71	50	37	28	22	18
44	1,937	485	216	122	78	54	40	31	24	20
46	2,117	530	236	133	85	59	44	34	27	22
48	2,305	577	257	145	93	65	48	37	29	24
50	2,501	626	278	157	101	70	52	40	31	26
52	2,705	677	301	170	109	76	56	43	34	28
54	2,917	730	325	183	117	82	60	46	37	30
56	3,137	785	349	197	126	88	65	50	39	32
58	3,365	842	374	211	135	94	69	53	42	34
60	3,601	901	401	226	145	101	74	57	45	37
65	4,226	1,057	470	265	170	118	87	67	53	43
70	4,901	1,226	545	307	197	137	101	77	61	50
75	5,626	1,407	626	352	226	157	115	88	70	57
80	6,401	1,601	712	401	257	178	131	101	80	65
85	7,226	1,807	803	452	290	201	148	113	90	73

Table 5: ENHANCED BASAL AREA BASIS -- Number of replacement trees needed for each tree removed based upon a small enhanced value for cross-sectional area. This enhanced value attempts to conserve added values of larger trees. Enhanced basal area equation replaced $(\text{DIAMETER})^2$ with $(\text{DIAMETER})^{2.05}$.

removed tree diameter (inches)	diameter of replacement tree(s)									
	1(in)	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	1
2	5	1	1	1	1	1	1	1	1	1
3	10	3	1	1	1	1	1	1	1	1
4	18	5	2	1	1	1	1	1	1	1
5	28	7	4	2	1	1	1	1	1	1
6	40	10	5	3	2	1	1	1	1	1
7	55	14	7	4	3	2	1	1	1	1
8	72	18	8	5	3	2	2	1	1	1
9	91	23	11	6	4	3	2	2	1	1
10	113	29	13	8	5	4	3	2	2	1
11	137	35	16	9	6	4	3	3	2	2
12	164	41	19	11	7	5	4	3	3	2
13	193	49	22	13	8	6	4	4	3	2
14	224	56	25	14	9	7	5	4	3	3
15	258	65	29	17	11	8	6	5	4	3
16	295	74	33	19	12	9	7	5	4	3
17	333	84	37	21	14	10	7	6	5	4
18	375	94	42	24	15	11	8	6	5	4
19	419	105	47	27	17	12	9	7	6	5
20	465	117	52	30	19	13	10	8	6	5
21	514	129	58	33	21	15	11	9	7	6
22	565	142	63	36	23	16	12	9	7	6
23	619	155	69	39	25	18	13	10	8	7
24	676	169	76	43	28	19	14	11	9	7
25	735	184	82	46	30	21	15	12	10	8

Table 5 (CONTINUED): ENHANCED BASAL AREA BASIS --

Number of replacement trees needed for each tree removed based upon a small enhanced value for cross-sectional area. This enhanced value attempts to conserve added values of larger trees. Enhanced basal area equation replaced $(\text{DIAMETER})^2$ with $(\text{DIAMETER})^{2.05}$.

removed tree diameter (inches)	diameter of replacement tree(s)									
	1(in)	2	3	4	5	6	7	8	9	10
26	796	199	89	50	32	23	17	13	10	8
27	860	215	96	54	35	24	18	14	11	9
28	927	232	103	58	38	26	19	15	12	10
29	996	249	111	63	40	28	21	16	13	10
30	1,067	267	119	67	43	30	22	17	14	11
32	1,218	305	136	77	49	34	25	20	16	13
34	1,379	345	154	87	56	39	29	22	18	14
36	1,551	388	173	97	63	44	32	25	20	16
38	1,733	434	193	109	70	49	36	28	22	18
40	1,925	482	214	121	77	54	40	31	24	20
42	2,127	532	237	133	86	60	44	34	27	22
44	2,340	585	260	147	94	65	48	37	29	24
46	2,563	641	285	161	103	72	53	41	32	26
48	2,797	700	311	175	112	78	58	44	35	28
50	3,041	761	338	191	122	85	63	48	38	31
52	3,295	824	367	206	132	92	68	52	41	33
54	3,560	890	396	223	143	99	73	56	44	36
56	3,836	959	427	240	154	107	79	60	48	39
58	4,122	1,031	458	258	165	115	85	65	51	42
60	4,418	1,105	491	277	177	123	91	70	55	45
65	5,206	1,302	579	326	209	145	107	82	65	53
70	6,060	1,515	674	379	243	169	124	95	75	61
75	6,981	1,746	776	437	280	194	143	110	87	70
80	7,968	1,992	886	498	319	222	163	125	99	80
85	9,023	2,256	1,003	564	361	251	185	141	112	91



Outreach

Warnell School of Forestry & Natural Resources

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