

## Upper Canopy module – Fixed Area Plot Summary – and beyond!

Eight steps to process standard upper canopy inventory data:

1. Calculate mean DBH and Height: DBH ratio, R, for each plot
2. Calculate basal area for every tree on each plot.
3. Estimate basal area (BA) and trees per acre that each plot represents
4. Estimate stand mean DBH, stand height, BA, and trees per acre (TPA)
5. Estimate 70% Confidence Intervals for TPA and BA
6. Estimate tree species composition using basal area as basis
7. Estimate Site Index (measure of site quality)
8. Estimate Sample Size for a survey with specified reliability

Example:

We would like to summarize data collected from a recent upper canopy survey in a 30-acre, second-growth, Douglas-fir stand growing in the Pacific Northwest to obtain stand attributes, such as mean DBH and mean basal area per acre (in sq. ft.) including confidence interval. Plot size used was  $1/20 = 0.05$  acre.

Partial listing of the data (n = 3 plots):

<u>Plot 1</u>		<u>Plot 2</u>		<u>Plot 3</u>	
<u>DBH</u>	<u>Ht</u>	<u>DBH</u>	<u>Ht</u>	<u>DBH</u>	<u>Ht</u>
15.1		15.0	77.7	18.9	94.8
14.5		13.7	79.3	15.3	83.8
12.8		12.7		15.2	
12.7	70.4	12.6	82.4	15.2	
12.6	75.8	11.1		13.8	
12.3		11.4		13.5	
11.3	72.2			10.4	
9.6				8.8	64.0
9.1					
<u>(9 trees)</u>		<u>(6 trees)</u>		<u>(8 trees)</u>	

**Step 1.** Compute mean DBH for each plot.

Plot 1:  $\overline{DBH} = (15.1 + 14.5 + 12.8 + \dots + 9.1) / 9 = 12.2 \text{ in.}$

Plot 2: 12.8 in.

Plot 3: 13.9 in.

Compute Mean Height:DBH Ratio for each plot. Since we did not measure height on every tree, we need to use a **ratio estimator** for mean height.

First, add up all the heights, then add up all the DBHs corresponding to those heights, then form the ratio of summed heights to summed DBHs, calling it R. (In Step 4 mean stand height will be calculated from the mean of the R's.)

Sum of plot 1 Heights:  $(70.4 + 75.8 + 72.2) = 218.4 \text{ ft.}$

Sum of plot 1 DBHs:  $(12.7 + 12.6 + 11.3) = 37.1 \text{ in.}$

Ratio of summed Heights to DBHs,  $R = 218.4 / 37.1 = 5.887 \text{ ft. / in.}$

(Extra Credit) Compute mean Crown Ratio for each plot. Compute crown length for height trees as  $CL = H_{Tot} - H_c$ . Mean Crown Ratio is just the ratio of summed Crown Lengths to summed total Heights;  $\overline{CR} = \frac{\sum CL}{\sum H_{Tot}}$ .

**Step 2.** Calculate basal area for trees on the plot. Begin by calculating basal area (ba) for each tree, given by  $ba = 0.005454 \cdot DBH^2$

For the first tree on plot 1,

$$ba = 0.005454 \cdot 15.1^2 = 1.24 \text{ sq.ft.}$$

... repeat for all other trees on plot ...

Repeat for all plots.

**Step 3.** Estimate Basal area / ac. and Trees / ac. for ea. plot.

First, compute a Tree Factor (TF) for each tree, which is the number per acre each tree represents. For fixed area plots,

$TF = \frac{1}{a}$ , where  $a$  = plot size in decimal fraction of an acre. For the example,

$TF = \frac{1}{a} = \frac{1}{0.05} = 20$ , which is the same for every tree.

Next, Compute number of trees per acre for each plot. On plot 1 in this example, there are 9 trees total, and each tree represents 20 per acre, so  $9 \times 20 = 180$  trees per acre (TPA).

For Basal Area, multiply the sum of tree basal areas on the plot by TF to expand the plot to an acre basis.

Plot	BA (sq. ft. / ac.)	TPA
1:	150.1	180
2:	107.5	120
3:	175.8	160

**Step 4.** Estimate mean DBH, stand height, basal area / ac. and trees / ac.

For mean DBH:

$$\overline{DBH} = (12.2 + 12.8 + 13.9) / 3 = 13.0$$

For mean Height:

$$\bar{R} = (5.877 + 5.797 + 5.630) / 3 = 5.768$$

$$\bar{H} = \bar{R} (\overline{DBH}) = 5.768 (13.0) = 75.0 \text{ ft.}$$

Avg. BA per acre =  $(150.1 + 107.5 + 175.8) / 3 = 144.5$  sq. ft. / acre

Mean TPA calculated same way as mean DBH and BA.

**Step 5.** Estimate 70% C.I. for TPA and BA / ac.

For basal area:

Avg. BA per acre = 144.5 sq. ft. / acre

Variance ( $s^2$ ) = 1,190.0 (ft<sup>2</sup> / acre)<sup>2</sup>

Std. Dev. = 34.50 ft<sup>2</sup> / acre

Std. Err. = 19.92 ft<sup>2</sup> / acre

Desiring an 70% CI, let's say,  $t_{0.30, 2} = 1.3862$  (see Table 2, APPENDIX), then an 70%CI is given by

$$144.5 \pm 1.3862 (19.92);$$

The “plus” is for the upper confidence limit (UCL), “minus” for the lower confidence limit (LCL).

The population mean BA per acre for the sampled forest stand lies somewhere in the interval (116.9, 172.1) ft<sup>2</sup> / acre, unless a 30% chance occurred.

**Step 6.** Estimate tree species composition. Using the basal area calculations from Step 3, compute the proportion of plot basal area that each species represents. Let's say that on plot 1, the first tree was a hemlock, and the rest were Douglas-fir. The sum of tree basal areas for plot 1 is 7.50 sq. ft.

Proportion of hemlock =  $1.24 / 7.50 = 0.205$ ; therefore,

Plot 1 is ~ 21% hemlock, and ~ 79% Douglas-fir.

Perform similar calculations for each plot then average the resulting proportions for each species.

**Step 7.** Estimate Site Index. (See Figure 1 below.) Calculate a Site Index for each “site” tree, then average.

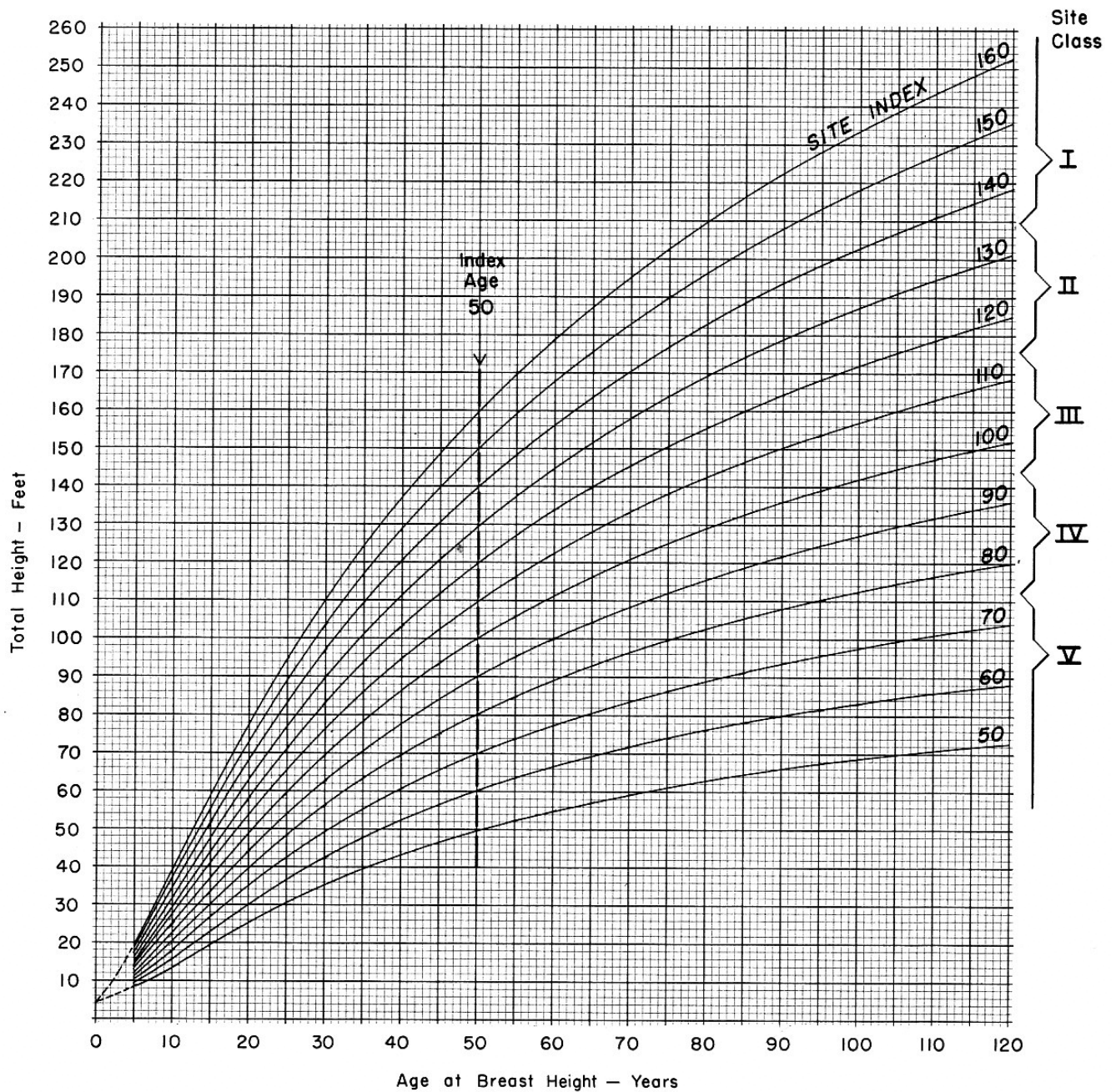


Figure 1. Site Index Curves for Douglas-fir. From King, J.E. 1966. Site Index Curves for Douglas-fir in the Pacific Northwest. Weyerhaeuser Forestry Paper No. 8.

$$S_{50} = 4.5 + \frac{274.3925 + 19.8059(A) + 0.494233(A^2)}{0.954038 - 0.0558178(A) + 0.000733819(A^2) + \frac{A^2}{H_D - 4.5}}$$

**Step 8.** Estimate Sample Size for a survey with specified reliability

Use of statistical formulas preferred

- For SRS infinite populations (or sampling with replacement)

$$n = k + \frac{z^2 (CV)^2}{E^2}, \quad \text{where}$$

n = number of sample units required for desired precision E, with confidence level implied by z, k

k = correction term to avoid iterating between *t*-values

Confidence level	z-value	k
80%	1.282	1.31
90%	1.645	1.87
95%	1.960	2.44
99%	2.576	3.79

z = standard normal deviate

CV = coefficient of variation, standard deviation divided by mean (in percent), for forest to be sampled

E = allowable error or desired precision (in percent) for average volume (or basal area, etc.).

- For SRS finite populations (or sampling without replacement)

$$n = k + \frac{Nz^2 (CV)^2}{NE^2 + z^2 (CV)^2}, \quad \text{where}$$

N = Total number of sampling units in population, and all other symbols are as before

Rules of thumb:

For ~ 1/10 acre plots in highly variable (i.e., CV > 45% populations:

Area (in acres)	number of samples
Up to 10	10
11 – 40	1 per acre
41 – 80	20 + 0.5 (area in acres)
81 – 200	40 + 0.25(area in acres)
200 +	Use sample size formulas

# APPENDIX.

Table 2. Student's *t* table (two-sided).

Degrees of Freedom	Two-Tailed Probability of Obtaining a Larger Value								
	0.5	0.4	0.3	0.2	0.1	0.05	0.02	0.01	0.001
1	1.0000	1.3764	1.9626	3.0777	6.3137	12.7062	31.8210	63.6559	636.5776
2	0.8165	1.0607	1.3862	1.8856	2.9200	4.3027	6.9645	9.9250	31.5998
3	0.7649	0.9785	1.2498	1.6377	2.3534	3.1824	4.5407	5.8408	12.9244
4	0.7407	0.9410	1.1896	1.5332	2.1318	2.7765	3.7469	4.6041	8.6101
5	0.7267	0.9195	1.1558	1.4759	2.0150	2.5706	3.3649	4.0321	6.8685
6	0.7176	0.9057	1.1342	1.4398	1.9432	2.4469	3.1427	3.7074	5.9587
7	0.7111	0.8960	1.1192	1.4149	1.8946	2.3646	2.9979	3.4995	5.4081
8	0.7064	0.8889	1.1081	1.3968	1.8595	2.3060	2.8965	3.3554	5.0414
9	0.7027	0.8834	1.0997	1.3830	1.8331	2.2622	2.8214	3.2498	4.7809
10	0.6998	0.8791	1.0931	1.3722	1.8125	2.2281	2.7638	3.1693	4.5868
11	0.6974	0.8755	1.0877	1.3634	1.7959	2.2010	2.7181	3.1058	4.4369
12	0.6955	0.8726	1.0832	1.3562	1.7823	2.1788	2.6810	3.0545	4.3178
13	0.6938	0.8702	1.0795	1.3502	1.7709	2.1604	2.6503	3.0123	4.2209
14	0.6924	0.8681	1.0763	1.3450	1.7613	2.1448	2.6245	2.9768	4.1403
15	0.6912	0.8662	1.0735	1.3406	1.7531	2.1315	2.6025	2.9467	4.0728
16	0.6901	0.8647	1.0711	1.3368	1.7459	2.1199	2.5835	2.9208	4.0149
17	0.6892	0.8633	1.0690	1.3334	1.7396	2.1098	2.5669	2.8982	3.9651
18	0.6884	0.8620	1.0672	1.3304	1.7341	2.1009	2.5524	2.8784	3.9217
19	0.6876	0.8610	1.0655	1.3277	1.7291	2.0930	2.5395	2.8609	3.8833
20	0.6870	0.8600	1.0640	1.3253	1.7247	2.0860	2.5280	2.8453	3.8496
25	0.6844	0.8562	1.0584	1.3163	1.7081	2.0595	2.4851	2.7874	3.7251
30	0.6828	0.8538	1.0547	1.3104	1.6973	2.0423	2.4573	2.7500	3.6460
35	0.6816	0.8520	1.0520	1.3062	1.6896	2.0301	2.4377	2.7238	3.5911
40	0.6807	0.8507	1.0500	1.3031	1.6839	2.0211	2.4233	2.7045	3.5510
45	0.6800	0.8497	1.0485	1.3007	1.6794	2.0141	2.4121	2.6896	3.5203
50	0.6794	0.8489	1.0473	1.2987	1.6759	2.0086	2.4033	2.6778	3.4960
55	0.6790	0.8482	1.0463	1.2971	1.6730	2.0040	2.3961	2.6682	3.4765
60	0.6786	0.8477	1.0455	1.2958	1.6706	2.0003	2.3901	2.6603	3.4602
70	0.6780	0.8468	1.0442	1.2938	1.6669	1.9944	2.3808	2.6479	3.4350
80	0.6776	0.8461	1.0432	1.2922	1.6641	1.9901	2.3739	2.6387	3.4164
90	0.6772	0.8456	1.0424	1.2910	1.6620	1.9867	2.3685	2.6316	3.4019
100	0.6770	0.8452	1.0418	1.2901	1.6602	1.9840	2.3642	2.6259	3.3905
150	0.6761	0.8440	1.0400	1.2872	1.6551	1.9759	2.3515	2.6090	3.3565
200	0.6757	0.8434	1.0391	1.2858	1.6525	1.9719	2.3451	2.6006	3.3398
∞	0.6745	0.8416	1.0364	1.2816	1.6449	1.9600	2.3263	2.5758	3.2905

Source: Table was generated using the Splus Statistical Software Package (Insightful Corp., Seattle, WA).