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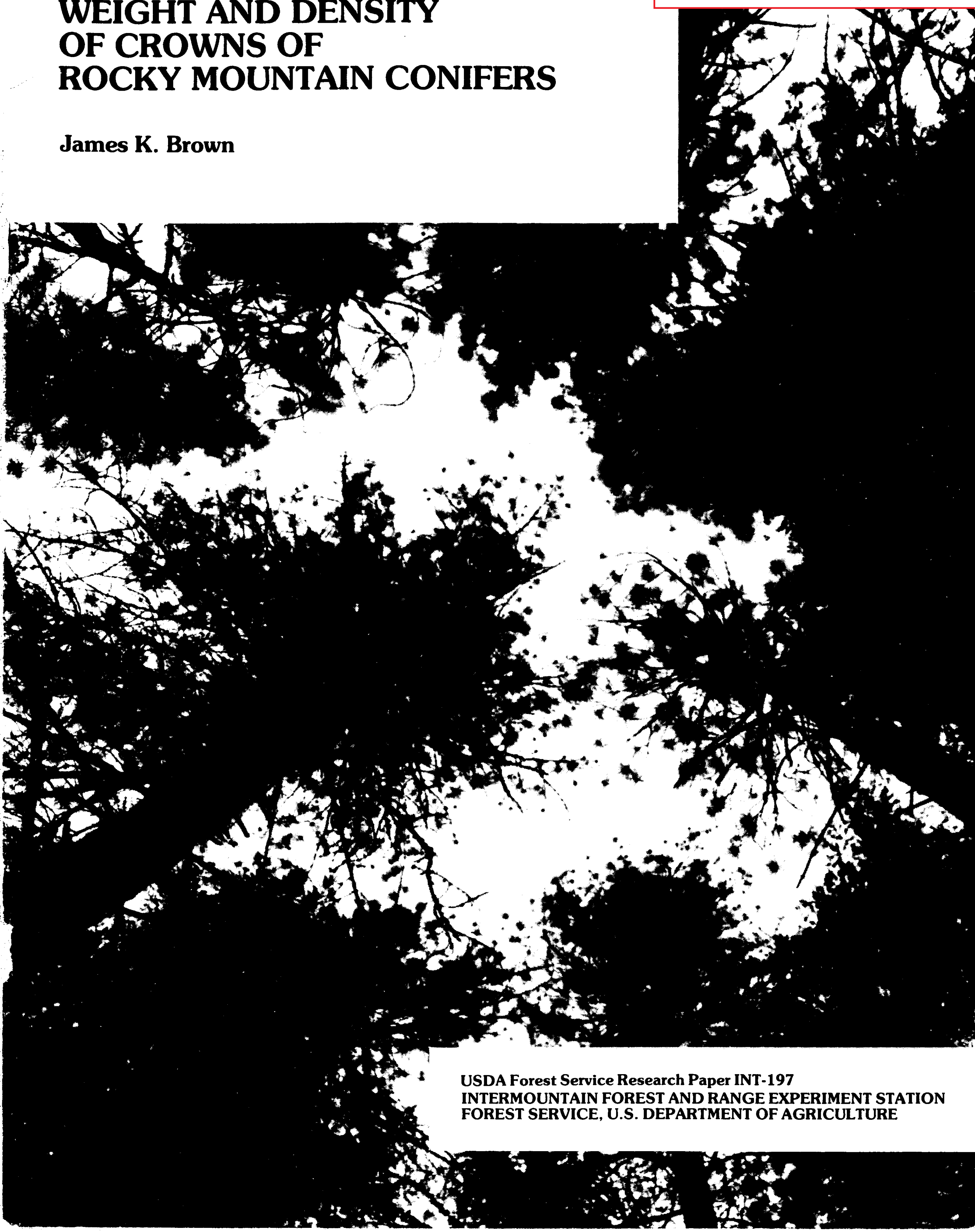

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JAMES K. BROWN received his bachelor's degree from the University of Minnesota in 1960, his master's from Yale University in 1961, and his Ph.D. from the University of Michigan in 1968, all in forestry. From 1961 to 1965 he did research on field measurement of fuel properties and fire-danger rating systems while with the Lake States Forest Experiment Station. in 1965, he transferred to the Northern Forest Fire Laboratory, Missoula, Montana, where he is responsible for research on the physical properties, inventory, and prediction of fuels.

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RESEARCH SUMMARY

Relationships between live and dead crown weight and d.b.h. (ranging from 0 to 40 inches), crown length, tree height, and crown ratio are presented for 11 conifer species in the Rocky Mountains. D.b.h. was highly correlated with crown weight; however, for most species, addition of height, crown length, and especially crown ratio improved precision. Site index and stand density improved precision of estimates slightly for about one-half of the species. Crown ratio accounted for most of the differences in crown weight between dominant and intermediate crown classes. Relationships between bole weights and d.b.h. and height are presented for trees up to 4 inches d.b.h.

For partitioning estimates of crown weight into foliage, and branchwood diameter classes (0- to 0.24-inch, 0.25- to 0.99-inch, 1.00- to 2.99-inch and 3.00-inch and larger), accumulative fractions of foliage and branchwood and their relationship to d.b.h. are presented. Relationships between weights of foliage and branchwood by diameter classes, highly correlated with branch basal diameter, are included.

Bulk densities for foliage and branchwood of live crowns ranged from 0.04 to 0.14 lb/ft^3 and were approximately twice that for foliage alone. Bulk densities and crown moisture contents were greater in the upper crowns.

INTRODUCTION

Tree crowns are a vital component of forest biomass and the functioning of forest ecosystems. The capability to estimate tree crown biomass is needed for evaluating fire behavior potential of forest fuels, productivity, nutrient cycling, fiber utilization, and interception of rainfall and radiation. The study reported here, initiated out of the need to appraise forest fuels, deals with estimation of weights and sizes of crowns for commercial conifer species in the Rocky Mountains.

Objectives of the study were to:

1. Determine relationships for predicting weight of both dead and live tree crowns, from d.b.h., crown length, tree height, and crown ratio.

2. Determine the fractions of crown weight for foliage and branchwood by diameter size classes of 0 to 0.24 inch (0 to 0.63 cm), 0.25 to 0.99 inch (0.64 to 2.53 cm), 1.00 to 2.99 inches (2.54 to 7.61 cm), and 3.00 inches (7.62 cm) and larger (fig. 1). Determine the relationships among the fractions, species, and d.b.h.

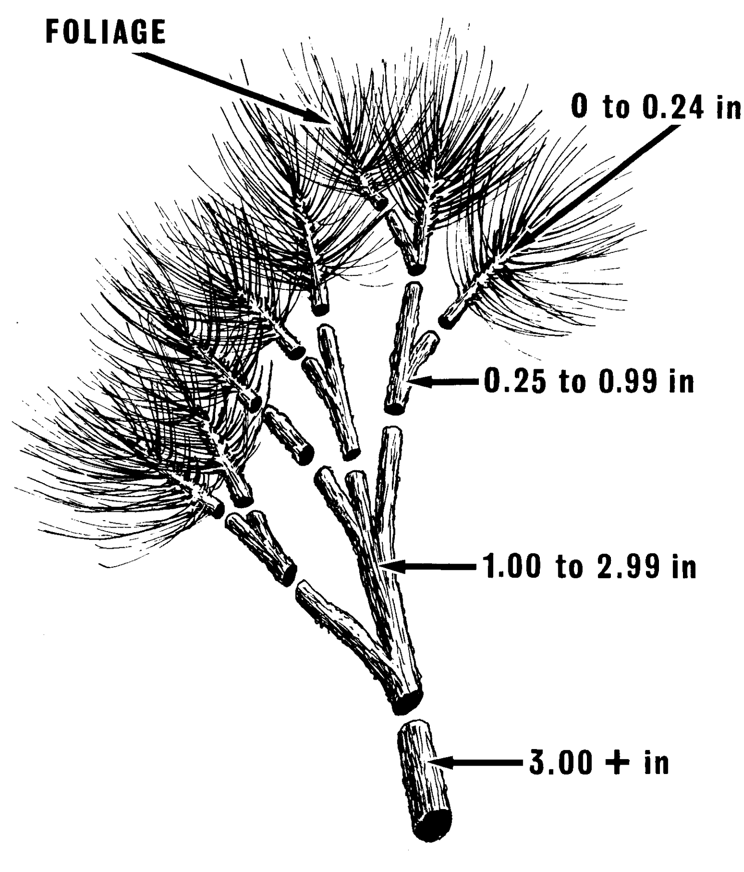

Figure 1.--Foliage and branchwood size classes, for determining moisture content and size fractions of crown material.

3. Determine the bulk density of live tree crowns.

To appraise fire behavior potential of fuels one must know the weight of vegetative material and its surface area. Surface area can be estimated from the size distribution of biomass. Fuels of critical importance to land managers include downed woody residues left after harvesting and thinning of trees, or residues created by factors such as windstorms and snow breakage. To help land managers in the Rocky Mountain area appraise the fuel and fire hazard of slash, a system for predicting slash weights and fire behavior potential has been developed (Puckett and others 1977). Slash weights are obtained from either a computer program for debris prediction[1] or a handbook that details computational procedures for predicting slash fuels using tables of crown weight per tree (Brown and others 1977). The computer program requires tree inventory data as input and computes weights of foliage and branchwood, unmerchantable bole tips, and cull material. It is the most accurate method for predicting slash because it sums weights predicted for individual trees read into the program.

Rate of fire spread, area growth, intensity, flame length, and scorch height (Van Wagner 1973) are estimated in the system primarily using Rothermel's (1972) mathematical model of fire spread. Nomographs developed by Albini (1976) also provide a means for predicting fire behavior in slash.

Many studies have shown that crown weights of conifers and hardwoods can be predicted from bole diameter. However, except for lodgepole pine in Canada (Muraro 1966; Kiil 1967; Johnstone 1970) and Engelmann spruce in Colorado (Landis and Mogren 1975), only limited information exists for Rocky Mountain species (Storey and others 1955; Fahnestock 1960). Also, limited information, especially size distribution of branchwood, has been published on West Coast species (Kittredge 1944; Chandler 1960; Cole and Dice 1969; Storey 1969).

Storey and Fahnestock studied trees having dominant and codominant crowns ranging in d.b.h. from about 2 to 40 inches. Influence of stand density on crown weight was not studied; however, site was shown to influence crown weight relationships (Storey and others 1955). Estimates of amount of foliage and branchwood were based on only a few observations. The study in this paper combines data by Fahnestock and Storey with considerable additional data, especially describing dead crown weights, size distribution of crown components, and live crown weights of trees less than 2 inches and greater than 20 inches.

The branchwood size classes under 3 inches correspond in increasing size to 1-, 10-, and 100-hour average moisture timelag classes for many woody materials (Fosberg 1970). These size classes are used as moisture timelag standards in the U.S. National Fire-Danger Rating System (Deeming and others 1972). A moisture timelag is the amount of time for a substance to lose or gain approximately two-thirds of the moisture above or below its equilibrium moisture content. Appraisal of forest fuels is greatly facilitated when data on biomass are assimilated by these size classes. Once weight of foliage and branchwood by diameter classes is determined, surface area can be estimated using surface area-to-volume ratios for foliage (Brown 1970) and branchwood (Brown and Roussopoulos 1974). Weights must be converted to volumes using known or assumed values of density (Brown 1974) for calculating surface area from volume and ratios of surface area-to-volume.

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[1]Brown, J. K., and C. M. Johnston. 1976. Debris prediction system. Unpublished report on file at the Northern Forest Fire Laboratory, Missoula, Montana.

METHODS

Trees of dominant and codominant crown classes (Society of American Foresters 1944) were studied for the following 11 species (abbreviations are used in tables and figures):

DF	Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
S	Engelmann spruce	*Picea engelmannii* Parry
GF	Grand fir	*Abies grandis* (Dougl.) Lindl.
LP	Lodgepole pine	*Pinus contorta* Dougl.
PP	Ponderosa pine	*Pinus ponderosa* Laws.
AF	Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
WH	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
L	Western larch	*Larix occidentalis* Nutt.
C	Western redcedar	*Thuja plicata* Donn
WP	Western white pine	*Pinus monticola* Dougl.
WBP	Whitebark pine	*Pinus albicaulis* Engelm.

Sample trees were selected to complement data on dominant and codominant crown classes gathered by Storey and others (1955) and Fahnestock (1960). Combining data economized effort to develop prediction equations for a wide range of tree sizes.

Trees of intermediate and suppressed crown classes were studied for ponderosa pine, Douglas-fir, grand fir, and western redcedar. These four species range from shade intolerant to tolerant. By studying them, the influence of shade tolerance and crown class and their interaction on crown weight per tree could be examined. Throughout the remainder of this paper, "dominants" refer to both dominant and codominant crown classes and "intermediates" to both intermediate and suppressed crown classes. Most of the intermediates sampled were from the intermediate rather than the suppressed crown class.

Fieldwork

Selection of Trees

Trees were selected, ranging from seedling size to 34 inches d.b.h. The sampling was designed to include the natural variation in crown weight by selecting trees from stands on poor-to-good sites and from low-to-high stand density conditions throughout western Montana and northern Idaho (fig. 2). The geographic distribution of trees is shown in appendix I. Trees were randomly picked; however, they were not accepted if they were (1) open-grown or "wolf" trees; (2) extremely lopsided in the crown; (3) deformed excessively by disease; (4) heavily defoliated; and (5) broken topped. These rules applied to data by Storey and Fahnestock except that our sites and stand densities were more restricted.

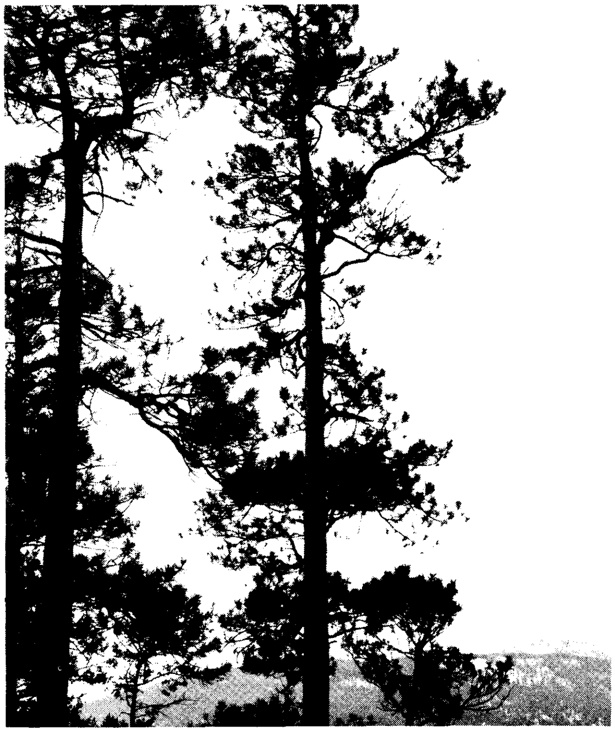
 

Figure 2.--These ponderosa pine show the variety of crown structure encountered in the sampling.

Measurements

On sample trees, crowns were visually divided into two or three horizontally partitioned live sections and one dead section that contained all dead branches within as well as below the live crown. Boundaries between live crown sections were located where diameters and lengths of branches changed distinctly. If changes in crown structure were not apparent, two crown sections were identified, with the boundary between them located near the middle of the crown. Weights, moisture contents, and crown volumes were determined by crown sections in order to characterize crown properties as accurately as possible.

Trees less than 6 inches d.b.h. were felled, then limbed; larger trees were climbed and limbed by workers using climbing spurs and safety belt (fig. 3). All branches were cut flush with the bole and separated by crown section. Basal diameters of all live branches were measured beyond the butt swell, 1 to 2 inches from the cut end.

Weights of each crown section and bole tips to 1-, 2-, 3-, 4-, and 6-inch diameter outside bark, were measured using spring scales of varying capacity, depending on amount of material. Canvas and nylon slings held the crown material for weighing. From each live section, a sample branch was randomly picked and from each dead section, a sample branch was picked that appeared average in size among the dead branches. The sample branches were divided into foliage and branchwood by size classes. The foliage and branchwood in each size class were weighed separately and moisture contents determined from duplicate samples ovendried at 100° C for 24 hours. In all, 22 to 34 moisture samples were taken for each tree. For small trees, most or all of the entire crown was often ovendried.

Figure 3.--Limbs were severed by the climber and allowed to free-fall except for large sample branches that were lowered by rope to prevent breakage. Tops were rigged with a safety rope to help control and direct the fall.

Trees were sampled from April to October during three successive field seasons. New growth was included in all weight and moisture measurements. Once foliage and branchwood of the current year's growth could be separated, they were thoroughly mixed with old foliage and branchwood before moisture samples were taken. Thus, moisture contents were averages of old and new growth.

Most trees were sampled after new foliage had been produced. Variation in foliage biomass due to sampling before and after growth of new foliage should be inconsequential except perhaps for ponderosa pine. For this species, which retains only 3 to 4 years' growth of foliage, trees with and without new foliage were sampled. Thus, this variation in foliage biomass was incorporated into the data.

Other measurements included:

--D.b.h. (outside bark);
--diameter outside bark at the base of live crown;
--total tree height (includes stump);
--length of bole tips to 1-, 2-, 3-, 4-, and 6-inch bole diameters;
--live crown length (base of the live crown was identified as the position on the bole where a full crown could exist if lower branches were moved up to fill in open spaces);
--length of the lower one or two live crown sections;
--crown widths (average of two perpendicular measurements taken at the bottom of each crown section);
--length of needle-free cavity (measured from the base of live crown to a point along the bole where live foliage was encountered);
--width of needle-free cavity (average of two perpendicular measurements taken at the base of the live crown);

- --age at ground level (on trees greater than about 6 inches d.b.h., age was measured at d.b.h. and increased by a constant 10 years to approximate age at ground level);
- --site index (determined from site index curves and a 50-year base, USDA Forest Service Northern Region Compartment Prescription Handbook, October 1965); and
- --basal area and trees per acre (for surrounding trees greater than 5 inches d.b.h., basal area and trees per acre were measured using one prism plot (20 basal area factor) having the sample tree at the center. For trees 5 inches and less in d.b.h., a 1/300-acre plot was used).

Many sample trees exceeded the d.b.h. range of Storey's and Fahnestock's data. A large number of trees within the d.b.h. range of their data were also sampled to help determine whether our data should be combined for analysis. Because Storey's and Fahnestock's data lacked weights of dead branches occurring below the live crown and lacked adequate information on size distribution of branchwood, some trees within the range of their data were sampled only for dead crown weights and counts of branch basal diameters for determining size distribution of crown material. For these trees, live crown weights were not recorded. A listing of data is in appendix II.

Analysis

Crown Weight and Bole Weight Per Tree

For each crown section, fresh crown weights were reduced to an ovendry basis, using an average moisture content that was determined by weighting sample moisture contents of foliage and the branchwood size classes by their respective weights. The foliage and branchwood weights were determined by means of step 2 in the section on foliage and branchwood fractions.

Live crown weights gathered in this study are probably slightly different from those of Storey and Fahnestock. In the studies by Storey and Fahnestock, which consist almost entirely of the same shared data, live crowns include dead branches found within the live crown sections. In this study, live crowns contain only live branches. Most of the dead branch weight occurred below the live crown; thus, the inconsistency, if it exists, should be of minor consequence. Plots of crown weight over d.b.h. indicated that data from Storey, Fahnestock, and this study fit together smoothly and could be pooled.

For d.b.h. greater than 1.0 inch, the relationships between ovendry crown weights and tree characteristics were determined by first screening logical combinations of the following variables using a multiple regression computer program called REX (Grosenbaugh 1967):

$$w = f(d, d^2, d^3, h, dh, d^2h, c, dc, d^2c, R, dR, d^2R)$$
$$\ln w = f(\ln d, \ln h, \ln dh, \ln c, \ln dc, \ln R, \ln dR)$$

where

d = d.b.h., inch
h = tree height, ft
c = crown length, ft
R = crown ratio, (live crown length/tree height)10
w = weight of crowns, lb.

Unless otherwise stated, the definition of these terms applies throughout the paper. Variables such as crown width and diameter at the base of live crown were omitted from the analysis; however, all data are available for others to analyze if desirable.

Height data were missing for some of Fahnestock's trees. To complete the data set, height was estimated from height-d.b.h. relationships of trees from the same area. Crown ratio was withheld from the screening process for dead crown weights. For screening, program REX provides a printout that lists ratios of residual mean square to total mean square for all possible combinations of variables. From the screening, several variable combinations having small residual mean squares were selected and details of multiple regression analysis examined using the following criteria to determine the best-fitting equations. The equations should:

1. Give unbiased predictions for the data collected;
2. fit trees greater than approximately 4 inches d.b.h. reasonably well;
3. give positive predictions throughout the range of independent variables;
4. have as low a residual mean square as possible; and
5. give reasonable extrapolations beyond the range of sample data.

To determine whether site quality and stand density could improve prediction of live crown weight beyond d.b.h., height, crown length, and crown ratio, variables from the "best-fitting equations" were screened together with site index, trees per acre, and basal area per acre. When regression coefficients for site and stand density variables (from equations selected in screening) were significant at the 0.90 probability level, they were considered influential.

Trees having a d.b.h. less than 2 inches underwent a separate regression analysis, with height as the only independent variable. For trees 4 inches and less, functions for estimating total bole weight were determined in the same manner as for crown weights, except only d.b.h. and height were involved in the screening process.

Foliage, Branchwood, and Bole Fractions

For each tree, the fractions of dead branchwood by size class were computed assuming that the proportion of weight in each size class for the dead sample branch represented the size distribution for all dead branches. However, for live crowns, fractions of foliage and branchwood by size classes were determined in four steps involving all branches on a tree:

1. Simple linear regressions between weights of each crown component and branch basal diameter were determined using sample branch data. Besides branches randomly picked from each crown section, additional branches were collected to assure having branches of large basal diameters. Natural log transforms of dependent and independent variables were used and weights estimated from:

$$y = e^{\left(a + b(\ln X) + \frac{s^2}{2}\right)} \tag{1}$$

where

y = ovendry weight of foliage or branchwood by size classes, lb
X = basal diameter of branch, inch
s^2 = sample variance of the logarithmic equation used to correct for an approximate bias in converting logarithmic estimates to arithmetic units (Baskerville 1972).

2. Solving equation (1) for tallies of branches by basal diameters, weights of foliage and branchwood by the 0- to 0.24-inch, 0.25- to 0.99-inch, 1.00- to 2.99-inch, and 3.00-inch-and-over classes were computed for the live crown sections of sample trees.

3. Calculated weights of foliage and branchwood components were then adjusted so that the sum of all component weights equaled the weight of each crown section actually measured in the field, as shown in equation (2).

$$y'_{ij} = \sum_{k=1}^{n} y_{ijk} R_j \tag{2}$$

where

y' = adjusted weights
y = calculated weight from equation (1)
R = ratio of measured weight for entire crown section to sum of estimated weights for all crown components
i = index for foliage and branchwood size classes
j = index for crown sections
k = index for individual branches
n = number of branches in a crown section.

Lastly, the adjusted weights of each crown component were summed for the entire tree.

4. For each sample tree, the following accumulative fractions of total live crown weight were calculated:

P_1 = foliage

P_2 = P_1 + 0- to 0.24-inch branchwood

P_3 = P_2 + 0.25- to 0.99-inch branchwood

P_4 = P_3 + 1.00- to 2.99-inch branchwood.

A similar set of fractions was calculated for dead branchwood but without foliage. These fractions were subjected to a least squares curve fitting analysis with d.b.h. as the independent variable. The fraction of any branchwood component can be obtained as the difference between two accumulative fractions. Fitting fractions of branchwood by individual size classes to d.b.h. was attempted, but for some sets of data it was difficult to find precise-fitting equations. Thus, accumulative fractions were used because they provided well-behaved data sets for curve fitting.

Fractions for dividing small tree boles and unmerchantable bole tips into diameter-size classes of 0 to 0.99 inch, 1.00 to 2.99 inches, and 3.00 inches and greater were computed from volume estimates of each size class. Volume of each size class was determined using length and diameter measurements of tip pieces. Tip pieces were considered as cones and other pieces as frustums of cones.

Bulk Density of Crowns

Bulk density of live crowns was computed using ovendry weights of foliage alone, and foliage and all branchwood together. Bulk density of foliage was computed two ways, using crown volume determined with and without the needle-free cavity. Crown volumes were computed from measurements of length and width of the top crown section and the two lower crown sections combined. Top sections were considered as either cones or paraboloids, depending on a shape designation assigned in the field. Lower sections were treated as frustums of right cones. The needle-free cavity was treated as a paraboloid.

RESULTS AND DISCUSSION

Crown Weights

Dominants Greater Than 1 Inch D.B.H.

Equations for live crown weight are presented in table 1 and for dead crown weight in table 2. In the tables, EXP is the base of natural logarithms. For all species, an equation containing d.b.h. as the only independent variable is presented because often d.b.h. may be the only information available for estimating weight. For some species, d.b.h. alone provided the best-fitting equation; however, where addition of tree height, crown length, or crown ratio to the equation improved fit, these equations are also presented. Although the equations in tables 1 and 2 were judged as "best fitting," other equation forms and combinations of independent variables gave good fits of the data. I found, as Crow (1971) reported, that the best-fitting equation varies by data sets. Several curve forms can fit about equally well.

Intercept regression parameters that were statistically nonsignificant were sometimes retained in the equations when the fit for trees of small d.b.h. was improved. Although the regression constants in tables 1 and 2 are significant at a confidence level of at least 0.95, unreasonable predictions beyond the range of sample data are possible. Extrapolation of equations beyond about 40 inches d.b.h. risks substantial error.

The data for Douglas-fir were particularly difficult to fit; hence, two equations covering different ranges in d.b.h. are presented. Data gathered by Fahnestock (1960) and myself are probably from different populations. Live crown weight populations within the Pacific Northwest are known to be different (Woodard 1974).

This study showed that to achieve a good fit for prediction, actual deviation between observed and predicted observations should be examined. It can be difficult to find a function that fits the data well throughout a large range of d.b.h. High R^2 values, as an indicator of good fit, can be deceiving. An examination of the literature on crown weight prediction suggests that some studies would profit from a reevaluation of prediction functions to improve accuracy, especially at the outer ends of their data range.

In equations for 8 of the 11 species, crown ratio or crown length accounted for a significant reduction (at the 0.95 percent probability level) in residuals beyond that accounted for by d.b.h. Crown ratio was more effective at reducing residual variation than either height or crown length alone or in combination, as similarly found by Loomis and others (1966). Site index reduced residual variation beyond d.b.h., height, crown length, and crown ratio for only western larch. Although site is known to influence live crown weight per tree (Tadaki 1966; Brown 1965), this study and work by Storey and others (1955) indicates that d.b.h. together with crown ratio or crown length can largely account for site effects. Trees per acre reduced residual variation for four species and basal area for two species. These measures of stand density were ineffective variables for the other five species. Even though stand density was significant for about one-half of the species, the actual reduction in residual variation beyond that accounted for by the tree dimension variables was very small.

Table 1.--*Live crown weight equations for dominant and codominant trees greater than 1-inch d.b.h.*

Species	R^2	MSR[1/]	$\left(\frac{\sqrt{MSR}}{\bar{Y}}\right)100$	n	Range in d.b.h.[2/]	Equations
		Lb^2	*Percent*		*Inches*	
GF	0.95	26,100	57	35	1-40	[3/] $w = EXP[1.3094 + 1.6076(\ln d)]$
L	.96	3,684	38	45	1-35	[3/] $w = EXP[0.4373 + 1.6786(\ln d)]$
S	.96	11,470	36	29	1-29	[3/] $w = EXP[1.0404 + 1.7096(\ln d)]$
AF	.95	276	25	16	1-13	$w = 1.066 + 0.1862(d^2R)$
	.84	947	46			$w = 7.345 + 1.255(d^2)$
LP	.88	600	22	45	1-16	$w = 0.02238(d^3) + 0.1233(d^2R) - 2.00$
	.88	1,065	30			[3/] $w = EXP[0.1224 + 1.8820(\ln d)]$
WP	.97	956	24	44	1-43	$w = 0.09470(d^2R)$
	.95	1,567	31			$w = 3.65 - 0.04534(d^3) + 0.01233(d^2h)$
	.95	3,279	45			[3/] $w = EXP[0.7276 + 1.5497(\ln d)]$
WBP	.99	0.889	5	10	1-8	$w = 0.65 + 0.06056(d^3) + 0.05477(d^2R)$
	.98	3.89	14			$w = 0.8371(d^2) - 1.00$
C	.97	7,965	46	34	1-37	$w = EXP[1.7273(\ln dR) - 2.8086]$
	.96	10,070	52			$w = EXP[0.8815 + 1.6389(\ln d)]$
PP	.97	37,560	36	40	1-34	[3/] $w = EXP[2.2812(\ln d) + 1.5098(\ln R) - 3.0957]$
	.95	82,570	53			[3/] $w = EXP[0.2680 + 2.0740(\ln d)]$
DF	.95	4,712	28	41	1-34	$w = 27.94 - 0.008695(d^2h) + 0.02839(d^2c)$, for $d \geq 15$ inches, and $R \geq 5$
	.93	21,620	64			[3/] $w = EXP[1.1368 + 1.5819(\ln d)]$, for $d < 17$ inches
	.85	13,460	48			$w = 1.0237d^2 - 20.74$, for $d \geq 17$ inches
WH	.98	809	15	27	1-32	$w = 0.3729(d^2) + 0.2840(dc) - 0.005525(d^2c) - 4.50$
	.98	1,076	17			$w = 3.60 - 1.5450(d^2) + 0.01734(d^3) + 0.3880(dh)$
	.98	4,605	36			$w = EXP[0.7218 + 1.7502(\ln d)]$

1/ MSR indicates mean square residuals. For logarithmic functions, MSR was calculated as $\Sigma(P-O)^2/df$, where P and O are predicted and observed values transformed to arithmetic units and df is the residual degrees of freedom.

2/ Range in d.b.h. for sample trees.

3/ These equations are of the form $\ln y = a + b\ln X$ + (mean square error/2). The latter term corrects for bias in transforming logs and is included in the intercept term in the equations. The intercept term was adjusted by (mean square/2) when the summation of predicted minus observed values in arithmetic units showed less bias with the correction term than without it.

Table 2.--*Dead crown weight equations for dominant and codominant trees greater than 1-inch d.b.h.*

Species	R^2	MSR[1/]	$\left(\frac{\sqrt{MSR}}{\bar{Y}}\right)100$	n	Range in d.b.h.[2/]	Equations[3/]
		Lb²	*Percent*		*Inches*	
GF	0.93	204	42	22	1-20	$w = 1.36 + 0.04371(d^3) - 0.003564(d^2h)$
	.93	487	62			$w = EXP[3.5638(lnd) - 5.3154]$, for $d \leq 18$ inches
						$w = 0.38$(live crown wt), for $d > 18$ inches
L[4/]						
S	.89	531	128	14	1-23	$w = EXP[3.2719(lndh) - 3.2603(lnc) - 6.8771]$
	.87	992	165			$w = EXP[3.6172(lnd) - 6.6860]$
AF	.95	11.2	36	16	1-13	$w = 1.65 + 0.5426(h) - 0.7808(c) + 0.04382(dc)$
	.93	116	104			$w = EXP[2.0757(lndh) - 10.4711]$
	.91	67	102			$w = EXP[4.0365(lnd) - 6.5431]$, for $d \leq 16$ inches
						$w = 0.31$(live crown wt), for $d > 16$ inches
LP[5/]					1-16	$w = (0.026(d) - 0.025)$(live crown wt), for $d \leq 10$ inches
						$w = 0.235$(live crown wt), for $d > 10$ inches
WP	.80	184	135	18	1-25	$w = EXP[2.6076(lnd) - 4.3970]$
WBP	.86	.93	48	13	1-11	$w = 0.001713(d^2c) + 0.33$
	.85	.98	51			$w = 0.001397(d^2h) + 0.28$
	.82	1.16	60			$w = 0.06117(d^2)$
C	.98	91.2	23	20	1-27	$w = 0.01063(d^3)$
PP	.87	4,590	79	26	1-34	$w = EXP[2.8376(lnd) - 3.7398]$
DF	.98	459	28	21	1-34	$w = 7.29 + 0.02768(d^3) - 0.006978(d^2c)$
	.91	1,431	50			$w = 0.01094(d^3)$
WH	.92	237	140	20	1-21	$w = EXP[6.0111(lnh) - 2.0496(lnd) - 19.340]$
	.84	297	227			$w = EXP[3.3664(lnd) - 6.6768]$

1/ MSR indicates mean square residuals. For logarithmic functions, MSR was calculated as $\Sigma(P-O)^2/df$, where P and O are predicted and observed values transformed to arithmetic units and df is the residual degrees of freedom.

2/ Range in d.b.h. for sample trees.

3/ Corrections for logarithmic transformation bias were omitted because they contributed more bias than they eliminated. Distributions apparently deviate considerably from log normal.

4/ This species retains little dead branchwood. For sample trees >4 inches d.b.h., dead weights ranged from 0.1 to 5.1 lb and averaged 1.1 lb.

5/ The equation for LP was from a free-hand curve through data that were insufficient for regression analysis.

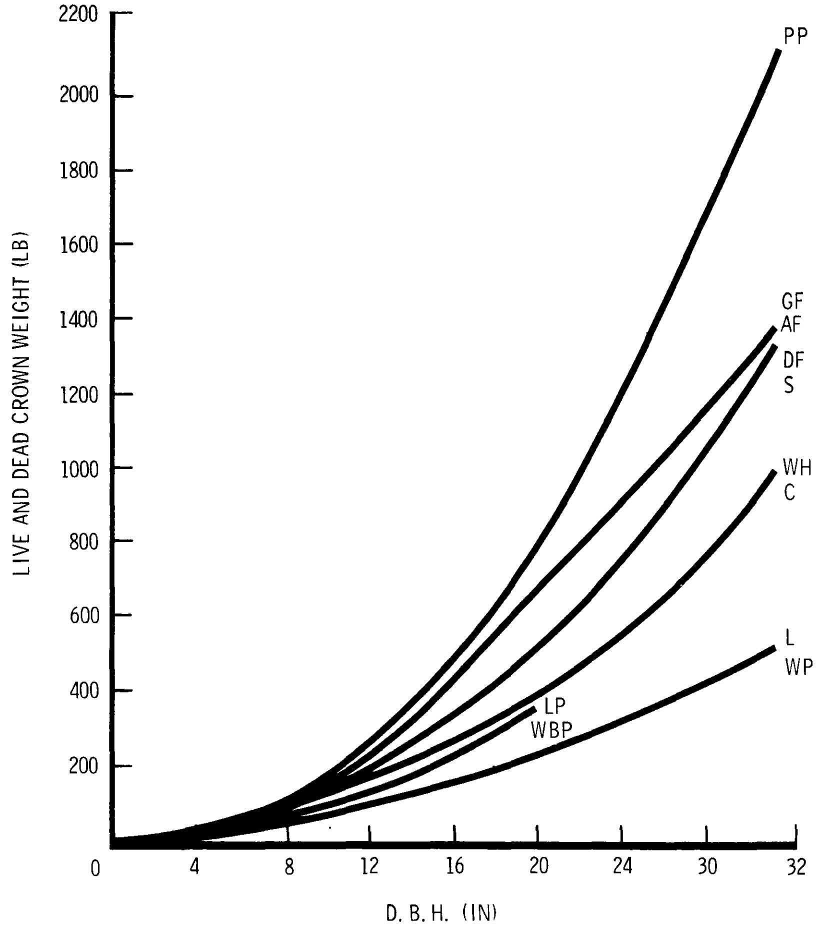


Figure 4.--Live and dead crown weight related to d.b.h. for groups of species having similar relationships.

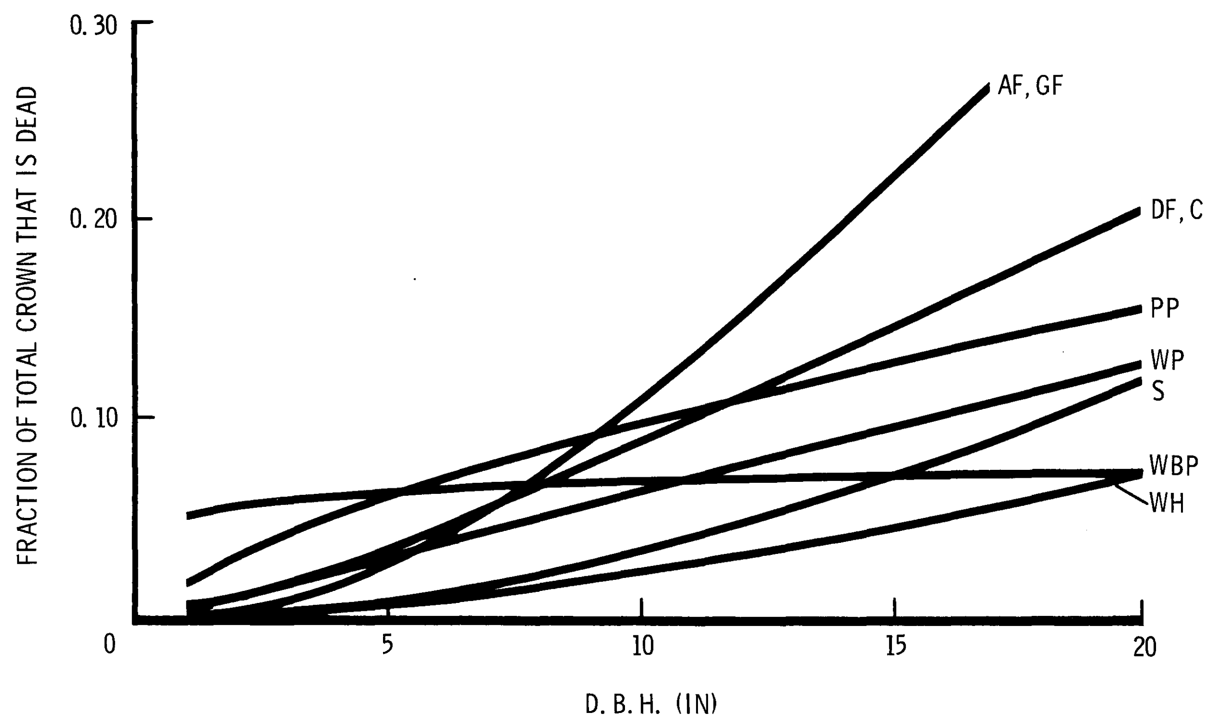


Figure 5.--The fraction of total crown that is dead (live plus dead branches) for dominants. The curves were plotted from equations in tables 1 and 2. Two species represented by one curve were averaged.

Relationships between total crown weight (live plus dead) and d.b.h. are shown in figure 4. Crown weight estimates for individual species of each group are within 10 percent of the average for the combined species curve. Figure 4 indicates that species tolerance is unrelated to crown weight per tree. The heaviest crowns are developed by ponderosa pine, a relatively intolerant species, probably because its branches grow to large diameters. The lightest crowns are also developed by an intolerant species--western larch.

For most species, the fraction of total crown weight that is dead increases with increasing d.b.h. and thus generally with increasing age (as shown in figure 5). This is expected because as trees age, branches die and can accumulate. Branch retention varies significantly among species. However, the pattern of differences in figure 5 does not appear readily explainable. The curve for grand fir and subalpine fir should level off for trees larger than about 15 inches d.b.h. Larch and lodgepole pine are omitted from figure 5 because of negligible branchwood for larch and insufficient data for lodgepole pine.

Dominants 1 Inch and Less in D.B.H.

Separation of data into two groups, one for trees greater than 1 inch d.b.h. and one for smaller trees, permitted derivation of more accurate relationships than handling all data together. To obtain adequate data for the small tree group, trees less than 2 inches d.b.h. were treated as a data set with tree height as an independent variable. As expected, live crown weight was strongly related to tree height (table 3). Generally, crowns of shade-tolerant species weighed more than crowns of less tolerant species. An exception is the shade-tolerant western hemlock, which was only heavier than western larch. The tolerant trees were also older than the intolerant trees; thus, age may help explain the major differences in weight. Dead crown weight was essentially negligible. For all species, it averaged 1 percent of total crown weight. The largest dead percentage was 2.4 for western larch, which is interesting because larch greater than 2 inches d.b.h. supported the least quantity of dead branches among all species.

Intermediates

Trees greater than 1 inch d.b.h.--Best-fitting equations for estimating live and dead crown weights are shown in table 4.

As species increased in shade tolerance, the difference between total crown weights of dominants and intermediates decreased (fig. 6). This was also true for live crown weights. For western redcedar, the most tolerant of the four species studied, crown class essentially had no effect on total weight and live crown weight per tree. For ponderosa pine, the most intolerant species, total crown weight of intermediates was about one-half of that for dominants.

For ponderosa pine and Douglas-fir, differences in crown weights between crown classes can be explained by crown ratio and crown length. For these species (trees 1 to 12 inches d.b.h.), crown ratio averaged 7.2 for dominants and 5.3 for intermediates. A test of differences between pooled residuals of dominants and intermediates and residuals from a composite regression showed that weight predictions based on d.b.h. were significantly different (95 percent confidence level). However, weight predictions based on d.b.h. and crown ratio were from a common population. Although crown ratio and crown length accounted for differences in weight between crown classes, the proportions of foliage and certain branchwood size classes varied considerably by crown class.

The importance of crown ratio in predicting weights of grand fir and western redcedar was unclear. The test of differences in live and total crown weight between crown classes was nonsignificant for grand fir and significant for western redcedar.

Table 3.--*Equations for live crown weight of trees less than 2 inches d.b.h.*

Species	R^2	MSR[1/]	n	Range in ht	Equations	Weight at 5 ft	Weight at 10 ft
		Lb^2		- -*Ft*- -		- - *Lb* - -	
					DOMINANTS		
DF	0.83	1.156	11	3.7-11.4	w = EXP[-4.212 + 2.7168(lnh)]	1.2	7.7
S	.94	7.290	12	1.9-10.4	w = EXP[-3.932 + 2.571(lnh)][2/]	1.2	7.3
AF	.90	1.343	13	2.5- 9.9	w = EXP[-3.335 + 2.303(lnh)][2/]	1.4	7.2
C	.90	1.908	12	1.8-10.1	w = 0.04833(h^2)	1.2	4.8
GF	.79	3.138	12	3.1-14.0	w = 0.4284(h)	2.1	4.3
PP	.81	1.235	12	2.3-10.0	w = 0.3451(h)	1.7	3.4
WP	.97	0.190	13	2.8-11.5	w = 0.3292(h)	1.7	3.3
LP	.96	.220	12	1.6-13.1	w = 0.03111(h^2)	0.8	3.1
WBP	.93	.085	10	2.5-10.0	w = 0.070 + 0.02446(h^2)	.7	2.5
WH	.91	2.221	12	3.6-13.6	w = EXP[-5.126 + 2.563(lnh)][2/]	.4	2.2
L	.80	1.230	12	2.8-18.0	w = 0.1128(h) + 0.00813(h^2)	.8	1.9
					INTERMEDIATES		
GF	.85	.374	9	3.7- 9.5	w = 0.0538(h^2)	1.3	5.4
C	.96	.142	11	3.7-10.4	w = 0.0307(h^2)	.8	3.1
DF	.66	.985	10	3.6-15.6	w = EXP[-2.8065 + 1.4802(lnh)][2/]	.6	1.8
PP	.35	.268	10	3.9-14.6	w = EXP[-2.7297 + 1.1707(lnh)][2/]	.4	1.0

[1/] MSR indicates mean square residuals. For logarithmic functions, MSR was calculated as $\Sigma(P-O)^2/df$, where P and O are predicted and observed values transformed to arithmetic units and df is the residual degrees of freedom.

[2/] These equations are of the form lny = a + blnX + (mean square error/2). The latter term corrects for bias in transforming logs and is included in the intercept term in the equations. The intercept term was adjusted by (mean square/2) when the summation of predicted minus observed values in arithmetic units showed less bias with the correction term than without it.

Table 4.--*Equations for live and dead crown weights of intermediate and suppressed trees*

Species	Crown section	R^2	MSR[1]	$\left(\frac{\sqrt{MSR}}{\bar{Y}}\right)100$	n	Range in d.b.h.	Equations
			Lb^2	*Percent*		*Inches*	
PP	Live	0.90	358.0	66	15	1-12	[2] $w = EXP[-0.7572 + 2.2160(lnd)]$
	Dead	.81	9.6	33	15	1-12	[2] $w = EXP[-2.5176 + 2.5100(lnd)]$
	Combined	.95	513.5	60	15	1-12	[2] $w = EXP[-0.4282 + 2.1772(lnd)]$
DF	Live	.96	170.0	30	15	1-11	$w = 10.9 - 11.34(d) + 4.059(d^2) - 0.03283(d^2h)$
	Live	.90	1,758	121	15	1-11	[2] $w = EXP[0.1508 + 1.862(lnd)]$
	Dead	.89	206.0	110	15	1-11	[2] $w = EXP[-1.9280 + 2.3530(lnd)]$
	Combined	.94	1,083	59	15	1-11	[2] $w = EXP[0.1242 + 2.0083(lnd)]$
GF	Live	.92	731.0	53	15	1-12	[2] $w = EXP[1.0144 + 1.6156(lnd)]$
	Dead	.83	80.4	112	15	1-12	[2] $w = EXP[-2.6214 + 2.5492(lnd)]$
	Combined	.94	651.8	43	15	1-12	[2] $w = EXP[1.0152 + 1.6839(lnd)]$
C	Live	.94	1,041	55	13	1-11	[2] $w = EXP[0.5743 + 1.7960(lnd)]$
	Dead	.90	24.4	74	13	1-11	[2] $w = EXP[-2.7990 + 2.4942(lnd)]$
	Combined	.95	1,077	50	13	1-11	[2] $w = EXP[0.6224 + 1.8289(lnd)]$

[1] MSR indicates mean square residuals. For logarithmic functions, MSR was calculated as $\Sigma(P-O)^2/df$, where P and O are predicted and observed values transformed to arithmetic units and df is the residual degrees of freedom.

[2] These equations are of the form $\ln y = a + b \ln X$ + (mean square error/2). The latter term corrects for bias in transforming logs and is included in the intercept term in the equations. The intercept term was adjusted by (mean square/2) when the summation of predicted minus observed values in arithmetic units showed less bias with the correction term than without it.

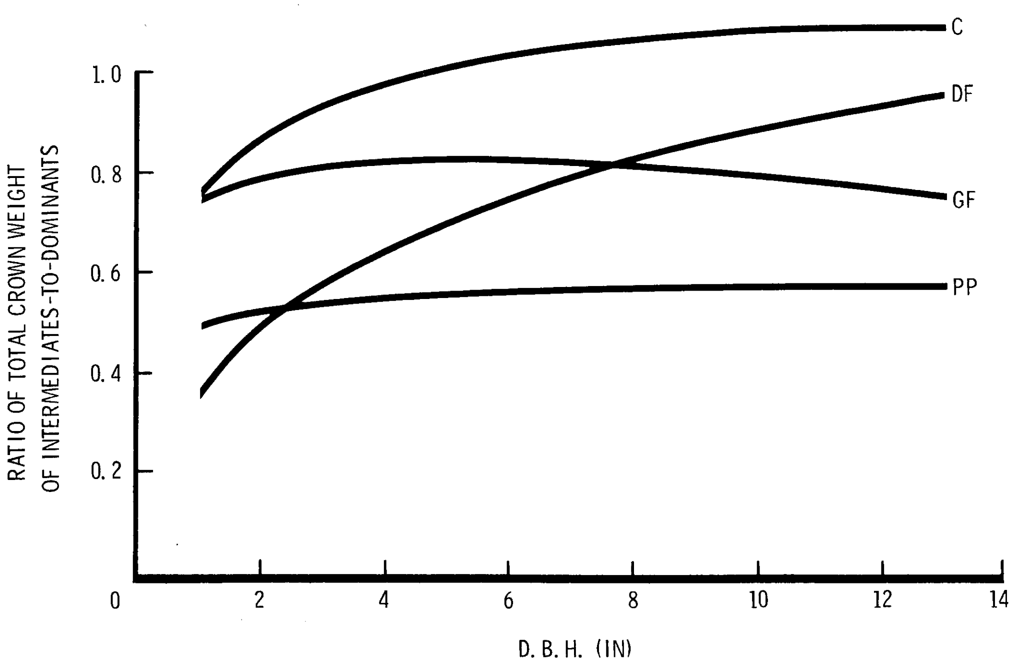


Figure 6.--Ratio of total crown weight for intermediates-to-dominants as a function of d.b.h. The ratios are calculated from equations in tables 1, 2, and 4.

For cedar, the differences in weight estimates seem small enough to ignore from a practical point of view. For both species, crown ratio was sampled over a narrow range; thus, evaluation of the relationship between crown weight and crown ratio was restrained.

Over the range of d.b.h. studied, intermediates supported approximately 2 to 6 times as much dead branch weight as dominants. Douglas-fir intermediates had 4 to 6 times as much dead branchwood as dominants, the highest ratio of any species. Ponderosa pine showed the lowest ratio, the intermediates supporting nearly 2 times as much deadwood as the dominants. The ratios increased substantially for trees less than 3 inches d.b.h. because little dead branchwood was found on small dominants. Although the percent of total crown that is dead increased with increasing d.b.h. for dominants, it appeared nearly constant for intermediates. For intermediates 2 inches and greater in d.b.h., the dead percentage for ponderosa pine and Douglas-fir averaged about 25 percent and for grand fir and western redcedar about 12 percent.

The influence of crown class on crown weight per tree suggests that for activities such as fuel appraisal, crown class can be disregarded for estimating crown weights of tolerant species. However, for intolerant species, weight estimates should be partly based on either crown class or crown ratio. Likewise, for estimation of total stand biomass involving intolerant or moderately tolerant species, crown class or crown ratio should be accounted for in estimating crown weight.

Trees 1 inch and less in d.b.h..--Except for grand fir, live crowns of intermediates under 2 inches d.b.h. weighed less than crowns of dominants (table 3). For trees greater than 8 feet in height, the equation for grand fir intermediates predicts greater crown weights than the equation for dominants. This holds true even after eliminating intermediate No. 835 from the regression analysis because it appeared unusually heavy. Apparently, several intermediates, at least 35 to 45 years of age and 8 to 10 feet tall, were responsible for the large weight predictions of intermediates. Although short in height, they had bushy crowns containing lots of foliage and branchwood. At comparable heights, the faster grown dominant trees contained less branchwood and foliage.

Similar to the trees greater than 1 inch d.b.h., crown weights for intolerant species were considerably greater for dominants than for intermediates. For tolerant species, crown weight predictions differ only a small amount between crown classes (table 3). Crown ratios averaged less for intermediates of all species and probably account for some of the weight differences between crown classes.

The percent of total crown that is dead varied considerably among individual trees. The percent dead for the intermediates averaged:

Species	*Percent dead*
Ponderosa pine	18.3
Douglas-fir	11.8
Western redcedar	6.0
Grand fir	2.6

The percent dead of intermediates is substantially greater than for the dominants, probably due to effects of shading. Among the intermediates, the tolerant species exhibited a smaller fraction of dead branchwood.

Bole Weights

The same procedure used in selecting equations for crown weights was applied to bole weights (including bark) for trees 4 inches and less in d.b.h. (table 5). Up to 2 inches d.b.h., estimated bole weights for all species are almost the same; however, beyond 2 inches d.b.h., large differences among some species appear (fig. 7). For

Table 5.--*Equations for estimating bole weights (w) of trees 4 inches and less in d.b.h.*

Species	R^2	MSR[1/]	$\left(\frac{\sqrt{MSR}}{\bar{Y}}\right)100$	n	Equations
		Lb^2	*Percent*		
					DOMINANTS
S	0.96	0.7472	17	10	$w = EXP[0.8381 + 1.3803(\ln d)]$ [2/]
DF	.99	.4056	11	12	$w = 0.74 + 1.591(d^2)$
PP	.96	1.378	20	11	$w = 1.08 + 0.9361(d^2)$
LP	.97	.07645	14	8	$w = 1.49 - 2.388(d) + 2.297(d^2)$
WP	.98	.2868	13	13	$w = 1.15 + 0.530(d^3)$
C	.99	.1849	6	13	$w = 1.436(d) + 0.3326(d^3)$
GF	.99	.0926	7	12	$w = 0.62 + 0.8024(d^2) + 0.1724(d^3)$
WH	.98	.6754	15	12	$w = 0.31 + 0.8334(d) + 0.06819(d^2h)$
	.97	.9778	18	12	$w = 0.11 + 1.665(d^2)$
L	.99	.4169	9	12	$w = 0.65 + 0.1004(d^2h)$
	.99	1.113	14	12	$w = 0.96 + 0.6532(d^3)$
AF	.99	.3078	8	12	$w = 0.28 + 0.02692(d^2h) + 0.1912(dh)$
	.99	.7491	12	12	$w = 1.55 + 0.4140(d^3)$
WBP	.95	2.718	26	8	$w = 1.33 + 0.08614(d^2h)$
	.91	4.866	34	8	$w = 0.52 + 1.441(d^2)$
					INTERMEDIATES
DF	.97	.8832	21	8	$w = -0.88 + 2.234(d^2)$
PP	.92	5.271	49	11	$w = 0.20 + 0.07058(d^2h)$
	.79	13.27	77	11	$w = 0.74 + 0.4006(d^3)$
C	.97	2.497	23	10	$w = 0.52 + 1.350(d^2)$
GF	.97	1.467	24	8	$w = 0.34 + 0.09182(d^2h)$
	.87	7.110	52	8	$w = -1.63 + 2.172(d^2)$

1/ MSR indicates mean square residuals. For logarithmic functions, MSR was calculated as $\Sigma(P-O)^2/df$, where P and O are predicted and observed values transformed to arithmetic units and df is the residual degrees of freedom.

2/ This equation is of the form $\ln y = a + b\ln X$ + (mean square error/2). The latter term corrects for bias in transforming logs and is included in the intercept term in the equation. The intercept term was adjusted by (mean square/2) when the summation of predicted minus observed values in arithmetic units showed less bias with the correction term than without it.

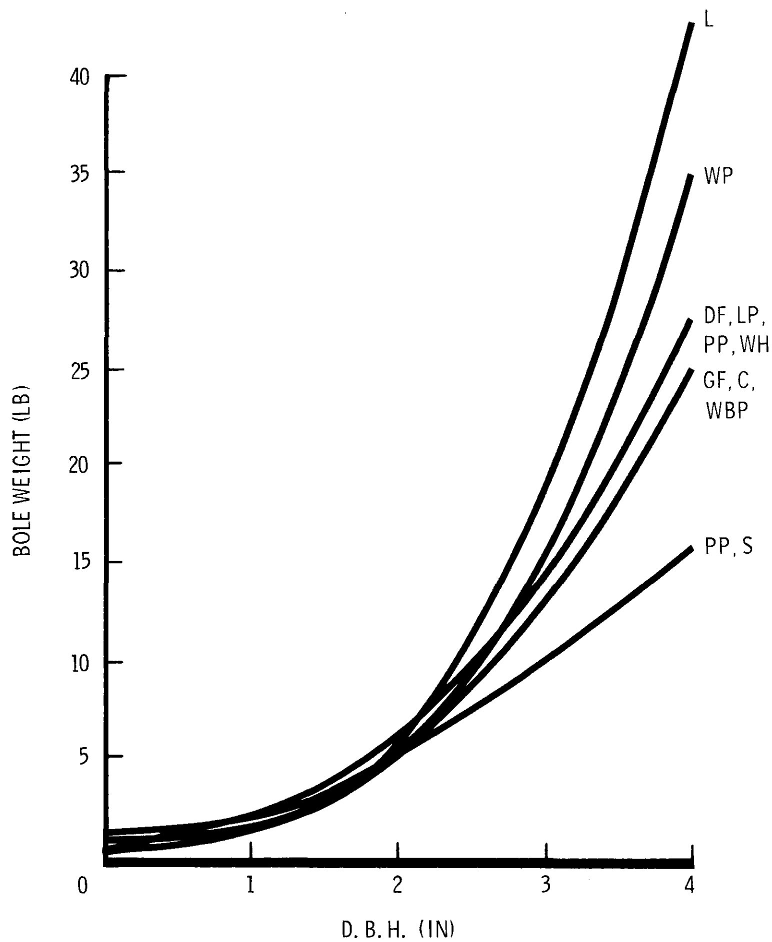


Figure 7.--Weights of boles for dominants 4 inches and less in d.b.h. Almost all estimates for individual species differ from the group average by less than 20 percent of the group average.

dominants, the extremes in estimated weights at 4 inches d.b.h. are 43 lb for western larch and 16 lb for Engelmann spruce. Differences in wood density and tree height account for the difference in weight.

Limited data from this study suggest that bole weights of intermediates tend to weigh more than dominants. Except for western redcedar, equations in table 5 yield greater bole weights for intermediates than dominants. For western redcedar and ponderosa pine, differences in bole weights between dominants and intermediates were statistically nonsignificant according to a test of differences between pooled residuals of dominants and intermediates and a composite regression (90 percent confidence level). For grand fir and Douglas-fir, bole weights were significantly different between dominants and intermediates (99 percent confidence level).

Whole Tree Weights

For seedlings and small saplings, separation of crown weights from bole weights may be undesirable for some purposes. Thus, the equations in table 6 were derived to estimate whole tree weights. Weight estimates for individual species are within about 15 percent of the average for the group of species. Weights of intermediate grand fir can be predicted using the equation for dominant grand fir.

Ponderosa pine, Douglas-fir, Engelmann spruce, and subalpine fir weighed noticeably more than the other species (fig. 8). For trees over 5 ft tall, average d.b.h. and age of the heaviest species group were greater than the other species. Although rate of height growth for the heaviest species group was less, more dry matter in crowns and boles had been produced. Proportions of foliage and branchwood are summarized in appendix III.

Table 6.--*Equations for predicting whole tree weights (w) of trees less than 15 feet in height*

Species	R^2	MSR[1/]	$\left(\frac{\sqrt{MSR}}{\bar{Y}}\right)100$	n	Equations[2/]
		Lb^2	*Percent*		
			DOMINANTS		
DF, PP, S, AF	0.93	7.475	34	58	w = EXP(-3.385 + 2.560 lnh)
WP, GF, WBP	.90	9.925	52	42	w = EXP(-2.876 + 2.175 lnh)
C, L, LP	.87	3.109	43	37	w = EXP(-3.720 + 2.411 lnh)
WH	.71	4.745	77	11	w = EXP(-4.824 + 2.722 lnh)
			INTERMEDIATES		
C, DF, PP	.79	1.698	58	31	w = EXP(-2.915 + 1.925 lnh)

1/ MSR indicates mean square residuals. For logarithmic functions, MSR was calculated as $\Sigma(P-O)^2/df$, where P and O are predicted and observed values transformed to arithmetic units and df is the residual degrees of freedom.

2/ These equations are of the form lny = a + blnX + (mean square error/2). The latter term corrects for bias in transforming logs and is included in the intercept term in the equations. The intercept term was adjusted by (mean square/2) when the summation of predicted minus observed values in arithmetic units showed less bias with the correction term than without it.

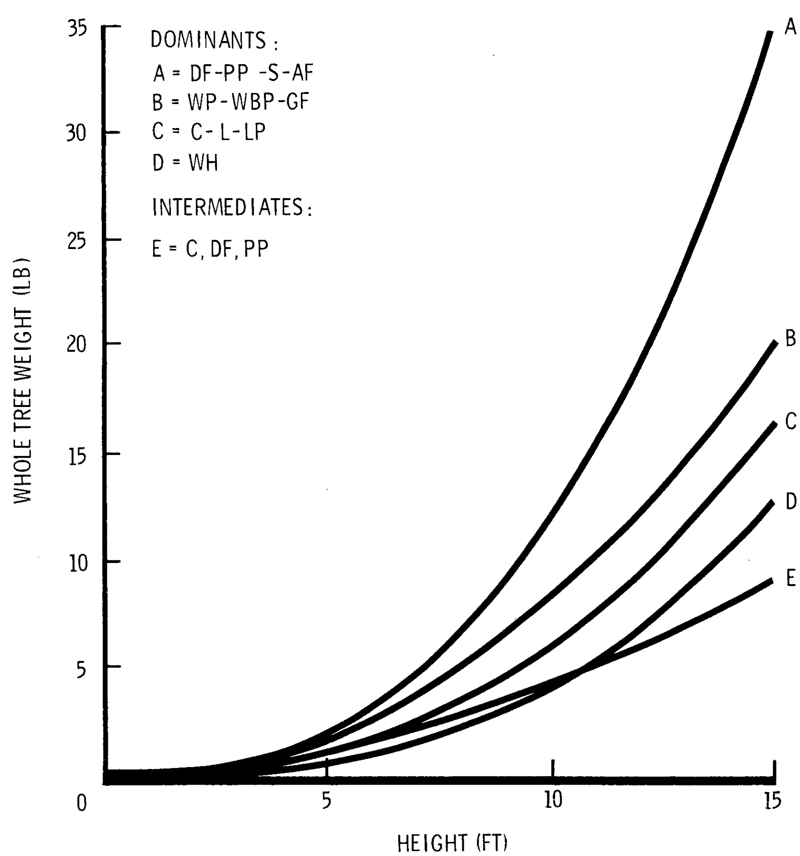


Figure 8.--Whole tree weights for trees less than 15 feet tall.

Table 7.--*Simple linear regressions for estimating weight of foliage and branchwood components of individual branches from dominant and codominant trees. Regressions are of the form lnw = a + b(lnd) where w = weight, lb; d = branch basal diameter, inches. Bias was corrected as shown in equation (1)*

Statistic	DF	GF	AF	WH	C	S	L	PP	LP	WP	WBP
					FOLIAGE						
a	-0.6747	-0.4568	-0.6519	-0.5089	-0.6891	-0.5180	-1.545	-0.9641	-0.9175	-1.128	-0.9265
b	2.121	2.204	2.076	2.117	2.114	2.169	2.023	2.035	2.260	2.018	2.292
n	64	65	56	61	69	44	51	48	47	64	40
r^2	.95	.92	.90	.96	.95	.95	.94	.92	.87	.94	.88
					0 TO 0.24 INCH						
a	-1.465	-1.506	-1.233	-1.192	-2.253	-1.082	-1.228	-3.424	-1.224	-1.626	-1.844
b	2.000	2.083	2.268	2.083	2.021	2.336	2.158	1.180	2.490	2.202	1.915
n	56	60	52	57	63	38	53	39	45	61	37
r^2	.96	.93	.91	.96	.93	.96	.95	.74	.95	.91	.70
					0.25 TO 0.99 INCH						
a	-.9315	-1.120	-.5650	-.8144	-1.311	-.9377	-.9763	-1.070	-1.077	-1.378	-1.008
b	2.126	2.690	3.268	2.390	2.192	2.694	2.426	2.399	2.607	2.638	2.664
n	40	37	35	30	44	30	23	41	28	45	24
r^2	.91	.91	.91	.86	.89	.92	.87	.94	.92	.91	.79
					1.00 TO 2.99 INCHES						
a	-1.000	-1.485	-1.675	-1.168	-1.318	-.9333	-.7957	-1.125	-1.159	-2.894	-2.180
b	3.002	3.960	7.047	3.912	3.536	3.184	1.861	2.490	3.199	5.106	3.351
n	20	13	9	12	15	12	10	18	11	14	4
r^2	.83	.83	.79	.85	.96	.78	.63	.89	.80	.91	.76
					3.00 INCHES AND GREATER 1/						
a								-3.687			
b								4.363			
n								11			
r^2								81			

1/ For species other than PP, material 3 inches and larger either did not exist or was approximated by means other than regression analysis.

Branch Weights

Using logarithmic transformations, weights of foliage and branch components for individual branches were highly correlated with branch basal diameters, as shown in table 7 for dominants and table 8 for intermediates. The pattern of weight curves for individual branch components shown in figure 9 for grand fir is typical of most species. Except for western larch, the 1- to 3-inch branchwood class has the steepest regression slopes showing a rapid increase in the weight of the largest diameter material as branch basal diameter increases.

Foliage weight per branch related closely to species tolerance with the most tolerant species supporting the most foliage (fig. 10). For the species groups in figure 10, deviations in foliage weight between individual species and the group average were mostly less than 10 percent of the group average. The maximum deviation was a negative 25 percent for western white pine.

Foliage and Branchwood Fractions

For each species, five or six equations were required to describe the accumulative fractions of live and dead crown components. Most equations were exponential, and for live crown weight they provided close-fitting relationships between accumulative crown fractions and d.b.h. (fig. 11). Because of variation in retention of dead branchwood, accumulative fractions of dead crown components were less closely correlated with d.b.h. than accumulative fractions of live crown components. Equations for accumulative crown fractions and conditions for maintaining reasonable solutions at limits of the data are in appendix III.

Table 8.--*Simple linear regressions for estimating weight of foliage and branchwood components of individual branches from intermediate and suppressed trees. Regressions are of the form lnw = a + b (lnd) where w = weight, lb; d = branch basal diameter, inch. Bias corrections for log transformations were omitted because they over compensated*

Statistic	PP	DF	GF	C
		FOLIAGE		
a	-1.412	-1.077	-0.6685	-0.8837
b	1.902	2.023	2.092	2.010
n	42	48	51	48
r^2	.86	.78	.92	.94
		0 TO 0.24 INCH		
a	-3.103	-1.551	-1.514	-2.325
b	1.549	1.934	1.842	1.863
n	34	47	50	48
r^2	.77	.89	.92	.91
		0.25 TO 0.99 INCH		
a	-3.103	-0.7598	-0.3637	-1.103
b	1.549	2.800	3.514	2.857
n	34	26	28	33
r^2	.77	.88	.88	.86
		1.00 TO 2.99 INCHES		
a	-2.457	1/	-2.551	-2.456
b	3.735		6.269	6.695
n	9		5	10
r^2	.42		.79	.70

1/ Regression was nonsignificant.

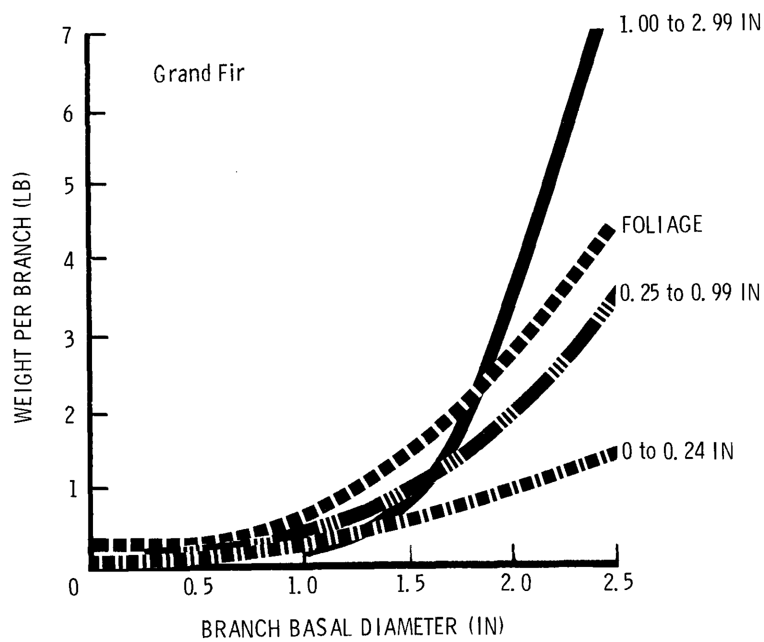


Figure 9.--Weight per branch of foliage and branchwood by size class as a function of branch basal diameter for grand fir.

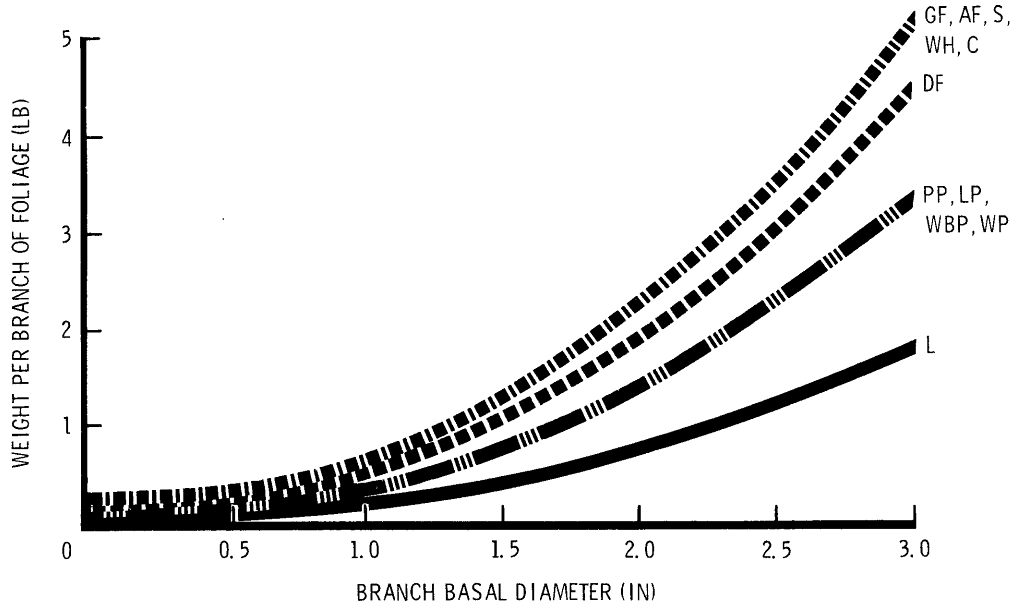


Figure 10.--Foliage weight per branch for groups of species that reflect general levels of species tolerance. Group 1 is the most tolerant and group 4 the least tolerant.

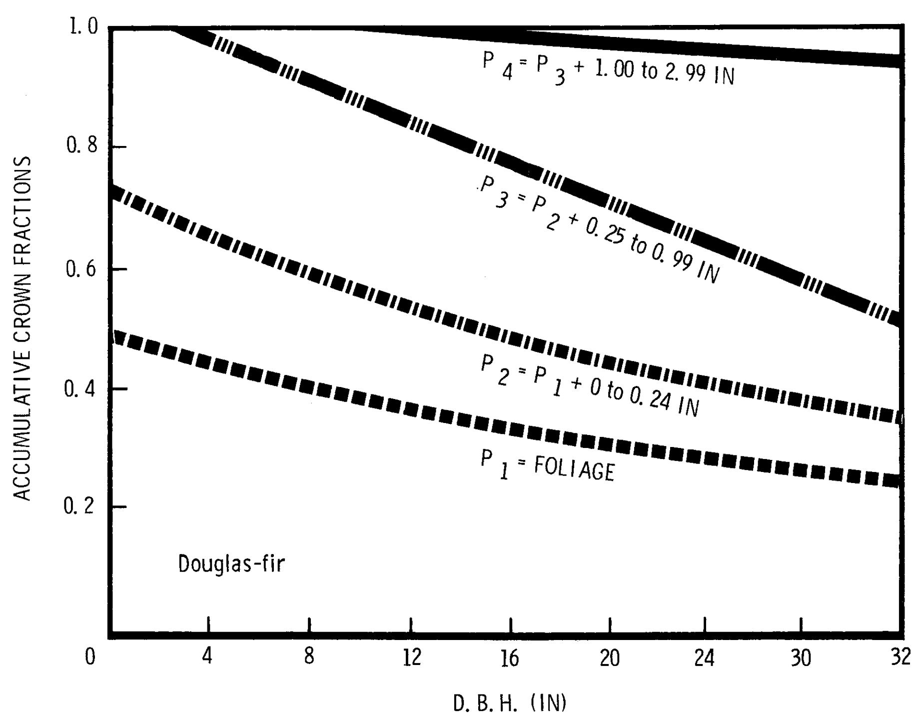


Figure 11.--Accumulative fractions of crown components for live crowns of Douglas-fir. For P_1, P_2, and P_3, $r^2 = 0.95$ and for P_4, $r^2 = 0.43$.

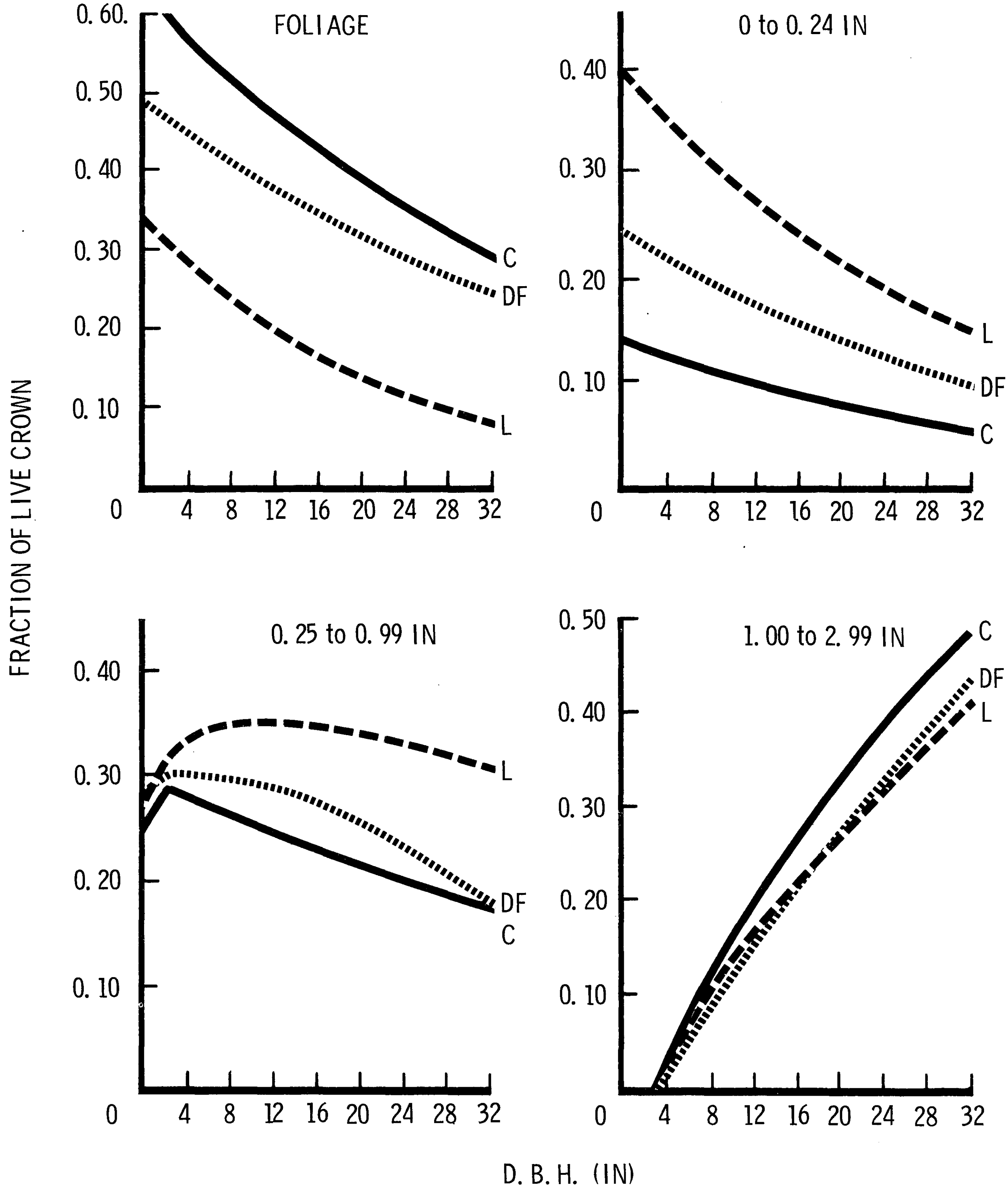


Figure 12.--Foliage and branchwood fractions of live crown weight related to d.b.h. for dominants of western larch, Douglas-fir, and western redcedar. The curves for foliage and 0- to 0.24-inch branchwood encompass the fractions of all 11 species studied.

Relationships between d.b.h. and actual fractions of foliage and branchwood components follow similar trends among species, probably largely influenced by the mechanical requirements for supporting suspended loads (McMahon 1975) (fig. 12). Foliage and 0- to 0.24-inch branchwood fractions decrease markedly with increasing d.b.h. The 0.25- to 0.99-inch branchwood fractions display the greatest variation; however, they generally increase up to 4 to 12 inches then decrease. The 1.00- to 2.99-inch branchwood fractions increase steeply throughout the range of sample tree data except for ponderosa pine. Its fraction levels off above a d.b.h. of 20 inches because increasing amounts of branchwood exceed 3 inches in diameter.

Large fractions of foliage and branchwood components are not necessarily associated with large weights per tree of foliage and branchwood components. The crown weights and component fractions must be viewed together to determine component weights. Generally, the tolerant species support the greatest weights of foliage, an exception being ponderosa pine which produces nearly as much foliage as Engelmann spruce at comparable tree diameters. Weights of 0- to 0.24-inch branchwood are greatest for the firs and hemlock. Weights of branchwood exceeding 1 inch are considerably greater for ponderosa pine than for other species.

For the species where dominants and intermediates were both sampled, the fraction of foliage for the dominants was consistently greater than for the intermediates, averaging 3 percentage points more at 2 inches d.b.h. and 16 percentage points more at 12 inches d.b.h. Differences in branchwood fractions between dominants and intermediates varied by species and d.b.h.; thus, any pattern of differences common to all species was not evident.

Bolewood Fractions

Weights of unmerchantable tips and boles of trees 4 inches and less in d.b.h. can be partitioned into 0- to 1-inch, 1- to 3-inch, and 3+-inch diameter size classes using fractions in table 9. Because unmerchantable tip and small tree bole material 0 to 0.25 inch in diameter was insignificant, this size class was lumped into the 0- to 1-inch class. The size class fractions are averages of data for all species. They were averaged after finding that variation of the fractions among species and dominants and intermediates was small.

Table 9.--*Fractions for partitioning weights of unmerchantable tips (for trees 5 inches and greater d.b.h.) and small tree boles (4 inches and less d.b.h.) into 0- to 1-inch, 1- to 3-inch, and 3+-inch size classes*

Size class (inch)	Tips: Merchantable top diameter, inches			Small tree boles: D.b.h., inches			
	3	4	6	1	2	3	4
0 - 1	0.03	0.01	0.003	0.08	0.03	0.01	0.01
1 - 3	.97	.39	.10	.91	.83	.31	.19
3+	0	.60	.90	.01	.14	.68	.80

Validation of Predictions

Verification of prediction equations is an arduous task because many sources of variation in inventorying standing trees and weights of downed material after cutting are difficult to control. Nonetheless, predictions were compared against inventoried weights in three stands dominated by a single species--ponderosa pine, Douglas-fir, and lodgepole pine. Crown and bole weights were predicted before cutting from complete stand inventories on areas approximately 0.15 acre in size. D.b.h., crown ratio, and crown class were used in the predictions. After cutting, the fresh slash was intensively inventoried using the planar intersect method (Brown and Roussopoulos 1974).

For slash less than 3 inches in diameter, predicted weights were less than inventoried weights by 15, 22, and 37 percent of inventoried values. For all slash, predicted weights varied from 4 percent more to 15 percent less than inventoried weights. Some of the discrepancies were traced to biases in the test; thus, differences between predicted weights and actual weights would be less than indicated by our test. The work in conducting a field verification test and the inconclusiveness of comparing two estimates based on sources of variation that are difficult to control makes this type of verification unappealing. The most productive verification would be additional crown weight sampling.

Considering the standard errors of estimate for the crown and bole weight equations and the verification test, most estimates of slash weight from crowns and unmerchantable bole tips for a stand of trees should be within 20 percent of the true mean. Occasionally estimates can be expected to deviate from the true mean by as much as 50 percent.

Crown Bulk Density

Bulk density of live crowns influences crown fire potential, interception of rainfall, interception of forest fire retardants, infrared detection of forest fires, and other phenomena. Quantifying bulk densities should help understand how tree species affect these phenomena and assist in analytical modeling of tree crown influences.

For dominants, bulk densities for foliage and all branches of live crowns ranged from 0.04 to 0.14 lb per cubic foot (fig. 13). The lowest bulk densities were displayed by western redcedar and western larch, probably largely because of the open crown nature of these species (Harlow and Harrar 1950). Crowns of whitebark pine had the greatest bulk densities, probably because the sample trees were relatively old and slow grown, and possessed short thick branches. Subalpine fir and Engelmann spruce also had high bulk densities, probably because branches were densely distributed within narrow crowns.

Bulk densities for foliage of live crowns averaged one-half of the bulk densities for entire crowns (foliage and branchwood). The ratios of foliage bulk density to entire crown bulk densities ranged from 0.36 for ponderosa pine to 0.61 for Engelmann spruce. Species having high crown bulk densities also had high foliage bulk densities. Conversely, species having low crown bulk densities also had low foliage bulk densities.

Bulk densities for foliage computed using crown volumes, excluding foliage-free cavities, differed only slightly from bulk densities based on crown volumes including foliage-free cavities. Because foliage-free cavities were a small part of crown volumes, only bulk densities based on the entire live crown volume are presented here. Foliage-free cavities of the pines and larch, which are generally more intolerant and retain foliage for only 1 to 3 years, were larger than cavities of the other species.

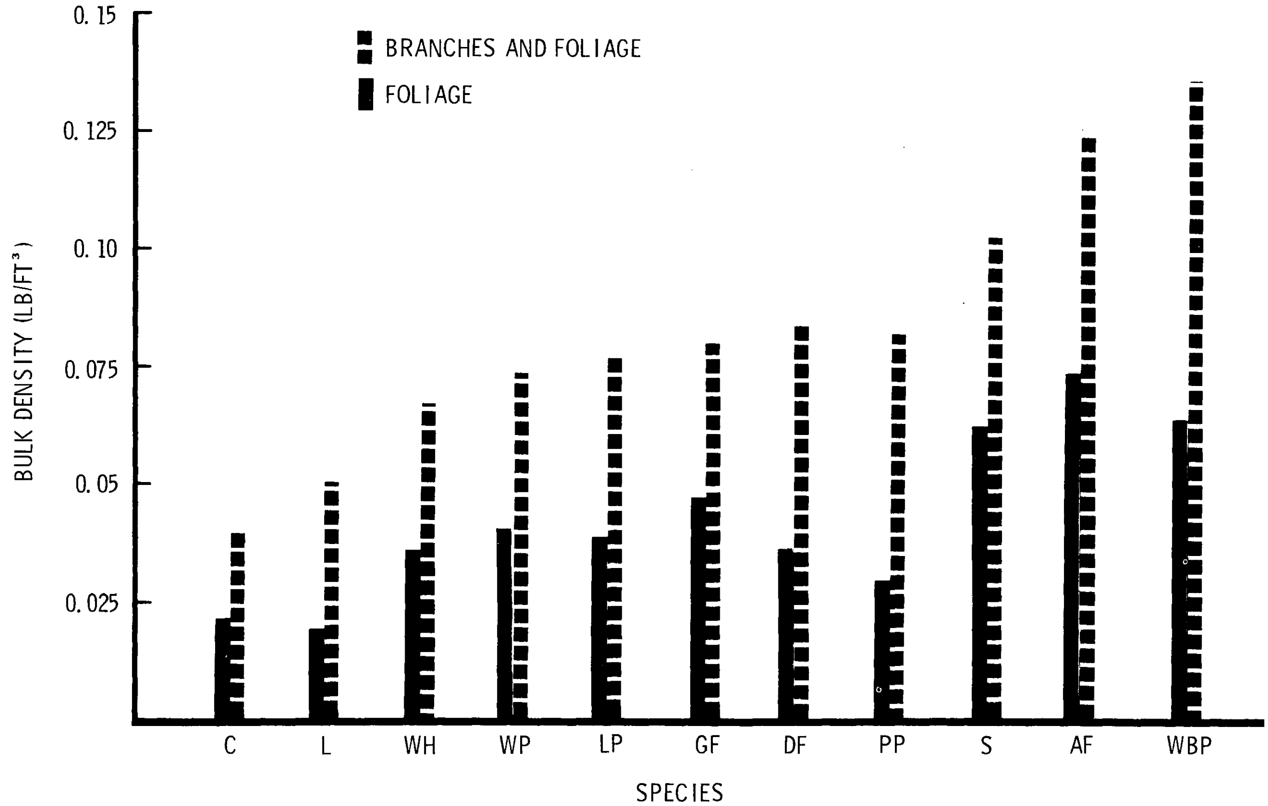


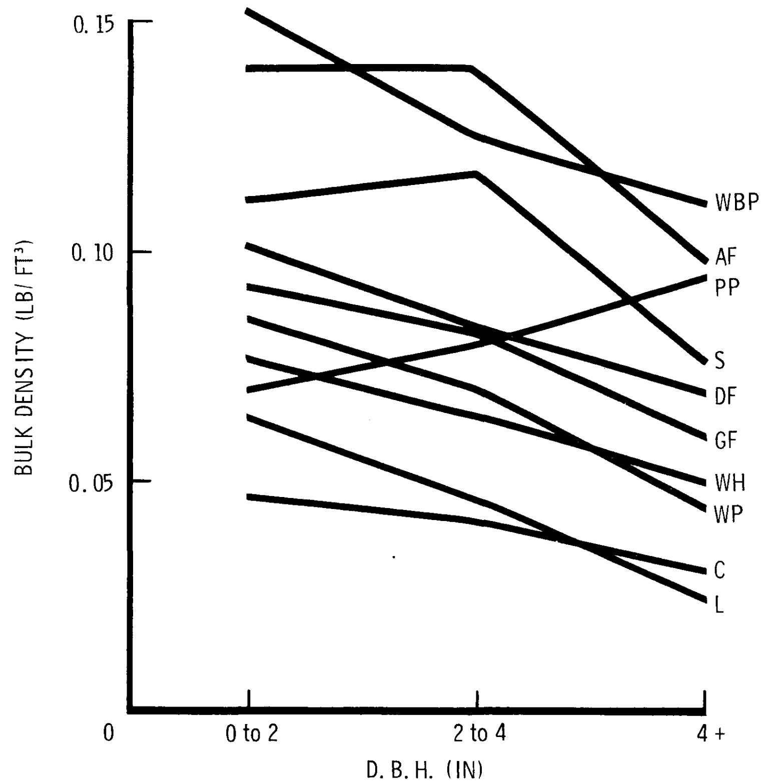
Figure 13.--Live crown bulk densities of dominants for foliage and for foliage and branchwood together. For all species, coefficients of variation for bulk densities of foliage and branchwood ranged from 32 to 65 percent, and averaged 47 percent.

Hence, bulk densities were altered more by omission of foliage-free cavities, as shown by the average ratios of bulk densities including foliage-free cavities to those without foliage-free cavities:

Species	*Ratios*
L, WP, PP, LP, WBP	1.16
AF, GF, DF, WH, C, S	1.03

To investigate the relationship between bulk density and d.b.h., regression analysis using polynomial, exponential, and linear models was employed. Relationships for only three species were significant and of these, the highest r^2 was 0.33. Although regression analyses failed to confirm relationships between bulk density and d.b.h., a plot of bulk density over averages of d.b.h. groups indicates that bulk density decreases as d.b.h. increases, at least up to 4 inches d.b.h. (fig. 14). One exception was ponderosa pine where bulk density increased with increasing d.b.h. Sample ponderosa pines of large d.b.h. were primarily from poor-to-medium sites. They supported many heavy branches, 3 to 6 inches in diameter, that probably accounted for the increased bulk density at large d.b.h.

Figure 14.--Live crown bulk densities for foliage and branchwood of dominants related to d.b.h. Lodgepole pine was omitted because all of its sample trees were less than 2 inches d.b.h.



Bulk densities increased vertically through the crowns, as shown in the following tabulation of live crown bulk densities:

Species group	Crown section: Top	Crown section: Middle and bottom	Ratio of top-to-middle and bottom
	(Pounds per cubic foot)		
DF, GF, WP, PP, LP	0.123	0.075	1.6
AF, WBP	.225	.110	2.0
C, L	.060	.042	1.4
S	.114	.102	1.1
WH	.072	.068	1.1

Bulk densities of each species in a group were within 10 percent of the group average. Engelmann spruce and western hemlock showed little variation in bulk densities between the upper and lower portions of the crown. Most of these sample trees had small d.b.h. The data for the other tolerant species indicate that variation in bulk density between upper and lower crown sections is greater for large trees. Thus, larger spruce and hemlock than studied here may show greater vertical variation in bulk density.

Bulk density of intermediates was less than for dominants but only decidedly so for grand fir, as shown in the following tabulation of intermediate-to-dominant bulk density ratios:

Species	Intermediates-to-dominants ratios: Foliage and branches	Intermediates-to-dominants ratios: Foliage
DF	0.80 (0.20)	0.81 (NS)
PP	.87 (NS)	.92 (NS)
C	.93 (NS)	.92 (NS)
GF	.66 (0.02)	.56 (0.01)

The parentheses contain levels of significance from a two-tailed t-test of differences between the bulk densities for intermediates and dominants. Branches of the sample grand fir intermediates appeared normal in length but were more spindly and sparsely distributed than for dominants. Hence, crown volume of intermediates was large relative to weight, resulting in low bulk densities. Surprisingly, bulk densities of intermediates and dominants for ponderosa pine were not significantly different. Apparently, both crown weight and volume are reduced for intermediate ponderosa pine, resulting in little change in bulk densities. This seems likely to hold true for other species as well.

Moisture Content

Moisture contents were intensively sampled to determine ovendry crown weights. Thus, reliable moisture estimates of foliage and branchwood at top, middle, and bottom live crown positions were obtained. Coefficients of variation computed for each species using individual tree moistures averaged 16 percent for foliage and 18 percent for branchwood. Evaluation of differences in moisture content among species and of seasonal variation in moisture content was confounded by uncontrolled sources of variation and thus was not attempted.

At the same crown positions, foliage moisture was consistently greater than branchwood moisture by an average of 24 percentage points (table 10). Moisture contents of both foliage and branchwood were highest in the top sections and decreased downward through the crown. Perhaps the upper sections of tree crowns contain a larger proportion of young growth that is characterized by low dry matter content and high percentage moisture content than the lower sections of crowns. Or perhaps growing tips, distributed more densely in the upper sections, exercise priority in the distribution of water in response to internal water deficits (Kramer and Kozlowski 1960). In either case, higher moisture contents are maintained in the upper crown. The moisture content of entire live crowns averaged 102 percent for dominants and 86 percent for intermediates. Thus, simply doubling ovendry weights of crown material should result in reasonable estimates of fresh green weights.

Although the data clearly indicate that the moisture content of dominants is greater than intermediates, conclusions are tenuous because influences such as date and site confound the data for this comparison. Differences in moistures between crown sections of intermediates are much less than for dominants. In fact, foliage moistures of intermediates appear uniform throughout the crown.

The variation in moistures between foliage and branchwood and by crown position points out the need to select samples wisely when studying tree crown moisture contents in order to avoid bias.

This study has provided equations based on about 500 sample trees for predicting weights of foliage, live and dead branchwood, and small tree boles. Relationships between tree crown biomass and d.b.h., tree height, crown length, crown ratio, and crown class were evaluated in selecting the most precise and useful equations. Tree crown bulk densities were also determined. This information provides a basis for appraising fire behavior potential of tree cutting activities in advance of cutting. Numerous other applications from predicting tree crown biomass are also possible.

Table 10.--*Moisture content (percent) by top, middle, and bottom crown sections for foliage, branchwood, and foliage and branchwood combined. The moisture contents were averaged for all species using individual tree moistures. Average moistures for all components are weighted by biomass of each component*

Crown component	Moisture content: Dominants: Top	Middle	Bottom	Intermediates: Top	Middle	Bottom
Foliage	116	111	102	102	99	104
Branchwood:						
0 to 0.25 inch	100	84	72	83	76	73
0.25 to 1 inch	95	84	75	85	74	68
1 to 3 inches	84	77	74	75	71	63
All components	111	100	86	92	84	82

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APPENDIX I

Geographic Distribution of Sample Trees

Location of sample trees is presented primarily to help others who may wish to combine data of their own with data from this study (fig. 15 and table 11).

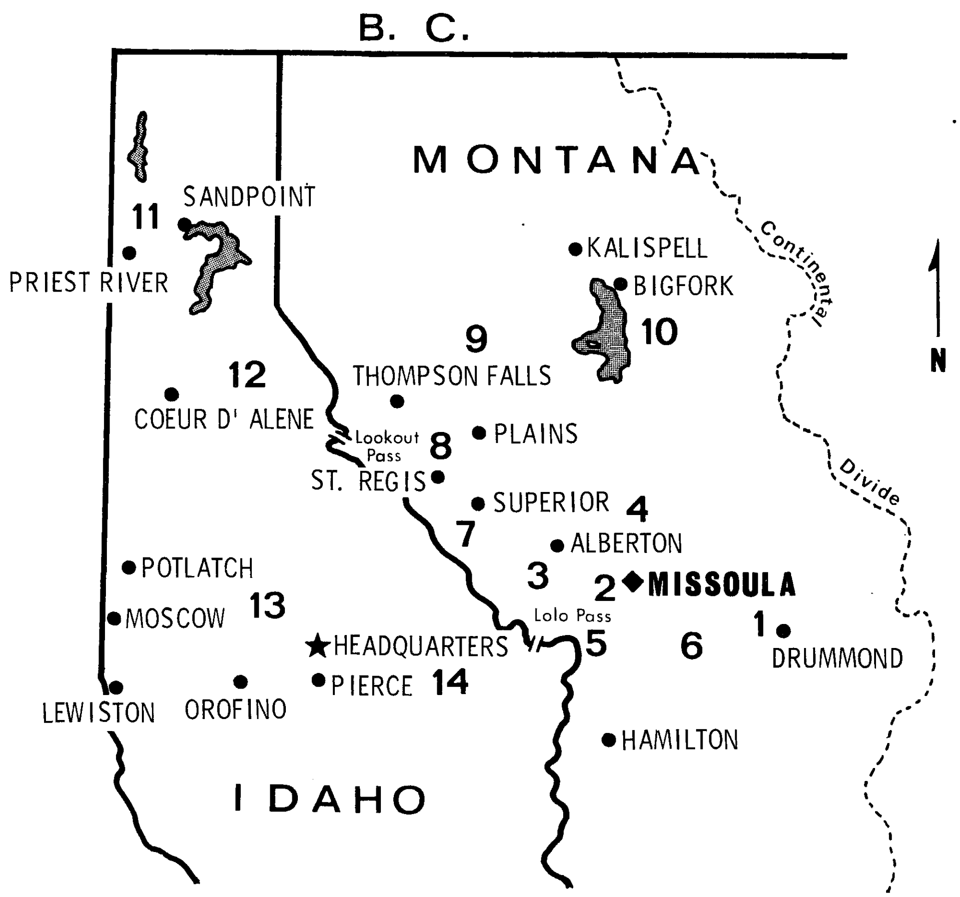

Figure 15.--Geographic distribution of sample trees. Numbers on the map are identified in table 11.

Table 11.--*Location of individual sample trees by species. The 800 series designates intermediates; others are dominants*

No.	Area	Identifying tree numbers										
		PP	WP	LP	WBP	AF	DF	GF	C	L	WH	S
1	Bearmouth	1-7										
2	Missoula	8-15, 19			192-197, 225-233, 237,C40-C42	236	801, 802					
3	Fish Creek	16-18,124, 126, 821		21,22,24, 25		147,149, 151,152, 200,201, 203	20,23,26, 27,125,184, 822,853, 858,860, 873	834,835, 838,866, 872	817-820, 836,837			148,150, 202
4	Ninemile	129,154, 155,211, 212,811, 813,814, 816,843, 854,855	C30	84,87,88, 90,91		86,188, 189,223	95-98,123, 130,166, 210,C32, 803,812, 815,856, 857	153,222, 224,832, 833,844, 863	156,157, 187,C28, C29,830, 831,862, 864,865, 874,875	82,83,89, 92-94		85,165, C25,C26, C27,C31
5	Lolo Creek					127				99,100,128		101,102
6	Swartz Creek					217	804-806, 828,829					219
7	Superior	45,115,122, 199,845-852, 868	28,29,158	38		31,34,47, 159,161	36,41,48, 208,209, 861,881	42,43,825, 827,867	37,39,40, 44,46,823, 824,826, 879,880			30,32,33, 35,160
8	St. Regis	876-878, 884	52,79,163, C33			51,78,164, 215	53,54,840, 869,871	162,186, 218,807, 810,841, 842,870, 882,883, 887	49,50,77, 185,191, 214,808, 809,839	80,81		190,213
9	Plains	121,198	216,C34-C36,C37	C18-C24		234,235	118, 204-206	116,117, 207,C16, C17,885, 886		119,120		C38,C39
10	Big Fork		144					141,142, 146	131,132, 136,138-140,859	133-135, 137,143, C01-C07		145
11	Priest River Exp. Forest						C43,C49	238, C44-C47	C48			
12	Deception Creek		177				183				167-176, 178-182, C08-C15	
13	Moscow	57,58,70	55,59,60, 72,73,221	75,76				56,61,62, 64,67,71	74,220		63,65,66, 68,69	
14	Pierce		104,105, 109,112, 113					108,114	106,107, 110,111			103

APPENDIX II

Listing of Data

Raw data for dominants are in table 12 and for intermediates in table 13. In both tables, tree numbers with a prefix C designate sample trees for which live crown weight was not measured. A dash in a column of data means no data taken.

Data from Fahnestock (1960) and Storey and others (1955) that were used in formulating live crown weight equations are not listed. However, the d.b.h. distribution of their sample trees is shown in table 14.

Table 12.--*Raw data for dominants*

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	- - - - -	- - - - -	*Lb*	- - - - -	- - - - -	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
										DOUGLAS-FIR									
27	0	4.2	17	4.2	2.9	--	0.0088	0.6812	0.3616	0.3307	0	0	0.48	4.2	2	11.93	1	81	646
96	0	4.5	8	4.5	2.2	1.3	0	.5181	.2822	.1455	0	0	.37	4.5	2	7.86	1	17	900
98	0	4.5	8	3.9	2.5	.9	.0022	.2028	.1124	.0419	0	0	.28	4.5	1	7.12	1	11	7,200
183	0	3.7	6	3.7	2.5	.9	0	.2800	.1587	0	0	0	.16	3.7	1	7.95	3	3	2,400
54	0.4	6.8	10	6.8	4.2	2.2	.0176	2.011	1.045	1.230	0	0	1.12	6.8	3	27.57	2	23	1,812
23	.5	5.8	25	4.7	4.0	--	.0309	1.340	.6967	.8113	0	0	1.31	5.8	2	19.17	1	2	1,200
36	.5	6.2	10	6.2	3.6	1.8	.0022	.8466	.4034	.4145	0	0	.75	6.2	2	27.26	4	15	5,100
20	.7	7.1	18	5.5	4.3	--	.0044	1.645	.8532	.9304	0	0	1.94	7.1	3	34.8	2	41	357
95	1.0	9.4	12	9.1	4.8	2.6	0	2.511	1.270	1.660	0	0	2.69	9.4	3	57.57	3	3	900
125	1.2	9.1	10	8.6	4.2	2.4	.0220	2.079	1.085	1.111	0	0	2.42	9.1	3	36.3	3	6	3,600
130	1.9	11.4	15	11.4	6.7	4.0	.0022	5.752	2.870	3.743	0	0	6.36	11.3	4	157.2	3	3	900
26	2.2	14.4	30	11.1	6.0	--	.2557	3.827	1.938	2.456	0	0	8.92	14.4	4	151.0	2	31	900
97	2.2	11.4	12	10.6	4.9	3.2	0	4.374	2.216	2.932	0	0	7.02	11.4	4	87.4	4	47	1,800
53	2.4	14.1	22	13.1	7.5	3.5	.0904	7.196	3.572	5.324	0	0	10.2	14.1	4	281.1	1	42	900
123	2.5	14.1	14	14.1	6.2	4.8	.0044	10.44	5.095	7.639	0	0	11.6	14.1	6	130.3	3	15	300
184	3.2	20.1	25	15.9	6.2	3.2	.6438	1.799	.9193	1.160	0	0	16.8	20.1	6	251.7	3	103	3,031
166	5.7	34.1	88	25.1	8.2	5.3	4.090	16.71	8.175	12.42	0	0	67.2	30.8	6	538.8	1	101	664
118	7.5	44.6	71	24.2	9.8	5.6	9.469	25.67	12.09	19.38	1.523	0	62.9	28.6	6	1,311	2	115	514
206	9.8	58.9	85	29.9	19.3	6.7	37.33	46.18	21.49	34.78	11.19	0	51.8	25.7	6	2,722	3	75	355
41	10.7	67.9	75	30.3	10.1	6.8	22.33	35.43	16.34	26.79	13.24	0	50.5	24.9	6	1,021	4	220	535
C49	12.1	74.3	63	56.0	16.9	10.2	34.94	--	--	--	--	--	--	--	6	5,328	6	100	306
C43	13.1	70.2	114	52.8	17.2	10.5	31.44	--	--	--	--	--	--	--	6	6,921	4	180	522
C32	17.9	111.1	111	52.3	11.7	10.8	14.69	--	--	--	--	--	--	--	6	3,047	7	221	742
204	21.6	92.0	203	53.4	19.2	15.5	119.8	162.6	68.71	126.6	198.2	0	30.8	15.3	6	9,042	5	160	150
48	25.0	106.3	181	61.8	28.0	17.2	173.6	210.3	87.69	164.5	287.6	9.006	34.0	17.7	6	11,948	6	204	3,060
205	26.4	92.3	210	63.8	20.2	18.8	181.6	170.6	69.99	133.8	263.9	30.10	26.9	13.4	6	11,709	5	55	313
208	28.3	142.7	219	81.7	20.1	18.3	220.6	255.2	108.2	199.0	304.6	0	43.0	20.9	6	6,860	7	238	997
210	30.5	112.9	210	85.9	21.4	23.9	196.5	336.3	135.4	264.6	595.8	114.0	29.6	15.2	6	15,263	6	60	21
209	33.9	136.0	262	70.8	29.9	20.3	531.1	238.9	99.01	187.0	346.8	27.28	38.8	19.8	6	29,031	7	140	46

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Live crown weight: Branchwood (inches): 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft³*		*Ft²*	
									ENGELMANN SPRUCE										
32	0	2.6	7	2.6	1.3	--	0	0.1389	0.0551	0	0	0	0.08	2.6	1	1.54	1	5	3,300
33	0	1.9	8	1.9	.8	--	0	.0750	.0309	0	0	0	.04	1.9	1	.51	1	5	3,300
150	0	3.5	13	3.0	2.2	1.0	0.0022	.4960	.2006	0	0	0	.24	3.5	2	4.35	1	1	900
190	0	3.6	12	3.6	2.7	.7	.0022	.3285	.1389	0	0	0	.16	3.6	1	9.58	1	6	3,900
30	0.3	5.0	12	5.0	2.5	--	0	1.074	.4387	0.0397	0	0	.53	5.0	2	13.67	1	24	3,365
101	.6	5.8	17	4.8	3.6	1.5	.0287	1.036	.4321	.0772	0	0	1.19	5.8	2	18.86	1	6	2,700
145	.6	6.6	11	6.6	3.0	1.8	.0176	1.193	.5137	.1587	0	0	.97	6.6	2	21.26	1	1	600
103	.8	7.7	9	7.7	3.3	1.6	.0022	1.440	.6548	.3616	0	0	1.08	7.7	2	30.28	3	7	2,700
102	1.1	8.3	12	8.3	4.3	2.7	.0088	3.188	1.506	1.085	0	0	2.78	8.3	3	46.68	1	8	3,900
85	1.9	9.8	14	9.3	6.0	3.5	.0066	7.438	3.752	3.296	0	0	7.19	9.8	4	110.7	3	5	1,200
160	1.9	10.4	36	8.3	4.5	1.7	.0683	2.452	1.142	.7650	0	0	5.58	10.4	3	68.72	1	5	1,500
148	2.0	9.6	30	8.1	5.2	2.9	.0022	4.330	2.061	1.497	0	0	5.66	9.6	4	59.37	1	52	2,111
202	2.3	12.9	14	12.9	5.0	3.9	0	6.607	3.098	2.141	0	0	7.94	12.9	4	134.1	3	21	3,900
35	3.2	14.2	20	12.7	5.2	3.8	.2579	7.383	3.655	3.062	0	0	9.94	14.2	6	135.7	2	45	4,204
219	6.8	34.2	33	24.3	12.5	6.2	3.294	40.07	21.71	22.80	8.618	0	45.4	24.2	6	1,108	3	182	902
213	8.8	57.5	126	31.4	11.3	6.8	7.324	67.26	37.13	40.46	11.62	0	50.6	26.8	6	1,515	1	125	12,730
165	9.0	56.5	153	44.3	11.3	7.7	4.374	36.19	19.56	20.33	1.448	0	54.2	28.6	6	1,966	1	82	1,670
C27	14.1	84.5	91	76.2	17.4	13.0	33.29	--	--	--	--	--	--	--	6	4,532	4	100	125
C26	16.3	95.4	117	56.2	12.7	12.0	118.6	--	--	--	--	--	--	--	6	4,364	4	240	294
C39	17.1	94.8	193	71.8	8.7	15.3	--	--	--	--	--	--	--	--	6	3,046	3	180	2,258
C25	18.7	104.0	117	68.5	16.9	12.8	34.59	--	--	--	--	--	--	--	6	10,068	4	224	2,900
C37	19.0	127.8	178	104.9	9.9	17.4	9.753	--	--	--	--	--	--	--	6	3,565	5	182	534
C31	23.2	103.2	112	78.2	22.5	18.4	66.45	--	--	--	--	--	--	--	6	15,036	5	162	4,226

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	Live crown weight: Branchwood (inches) 0.25 to 1	Live crown weight: Branchwood (inches) 1 to 3	Live crown weight: Branchwood (inches) 3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft³*		*Ft²*	
GRAND FIR																			
43	0	4.6	8	4.6	2.0	1.0	0.0022	0.4762	0.2138	0	0	0	0.25	4.5	1	10.37	1	2	1,200
61	0	4.4	7	4.4	3.5	1.4	0	1.157	.4740	0.2668	0	0	.67	4.4	2	24.46	1	1	300
62	0	3.7	6	3.7	1.9	1.0	0	.4519	.2050	0	0	0	.19	3.7	1	4.43	1	1	300
114	0	3.1	4	3.1	2.1	.9	0	.3461	.1565	0	0	0	.19	3.1	1	5.33	3	1	300
67	0.4	5.7	9	5.7	3.2	1.7	.0022	.9149	.3924	.1213	0	0	.64	5.7	2	13.08	1	1	300
71	.4	5.5	8	5.0	3.3	1.6	0	1.199	.4806	.3329	0	0	.89	5.5	2	20.92	2	1	900
141	.7	7.0	10	7.0	3.9	1.5	0	1.071	.4431	.2359	0	0	.88	7.0	2	25.49	1	10	6,900
162	1.0	9.5	17	8.1	5.7	1.6	.0617	1.347	.5534	.2998	0	0	1.40	9.5	2	33.64	3	6	3,000
42	1.1	7.6	42	6.6	4.4	2.2	.0022	4.228	1.682	1.272	0	0	1.68	7.6	3	42.83	1	3	900
153	1.1	8.9	8	7.9	5.1	2.2	0	4.023	1.609	1.131	0	0	2.57	8.9	3	67.17	3	2	300
142	1.3	9.5	10	9.0	5.9	2.0	.0331	2.672	1.096	.6217	0	0	2.22	9.5	3	71.47	3	11	5,700
64	1.8	14.0	12	11.6	5.2	2.2	.1698	2.985	1.186	.8885	0	0	4.11	14.0	3	88.88	4	19	5,400
146	2.1	12.3	12	12.3	5.3	4.1	.0088	9.449	3.620	3.393	0	0	6.03	12.3	6	128.8	3	15	600
108	2.3	14.3	18	12.3	5.2	2.6	.0882	5.479	1.261	1.515	0	0	6.84	14.3	3	111.7	3	112	3,687
186	2.7	16.0	35	11.2	9.0	2.5	.2491	5.075	1.927	1.900	0.3483	0	9.72	16.0	4	214.2	1	220	2,427
56	3.2	18.5	23	17.0	6.5	3.9	.2271	10.20	3.867	3.810	0	0	14.6	18.5	6	227.8	5	24	2,100
220	4.2	22.1	30	20.9	10.5	5.1	1.360	21.62	8.054	8.719	0	0	31.0	22.1	6	617.0	4	94	2,700
222	4.5	22.4	22	20.4	7.2	5.1	.3549	25.70	9.643	10.12	0	0	29.6	22.4	6	292.8	6	41	300
238	6.5	40.6	32	38.6	14.3	6.7	2.262	41.73	15.13	19.14	5.972	0	54.1	34.1	6	2,014	6	120	306
218	7.5	47.5	124	41.6	10.3	7.4	9.614	33.09	12.23	14.03	3.503	0	57.0	29.7	6	1,882	1	180	7,079
207	10.5	78.8	93	69.6	13.3	10.4	35.57	101.6	35.32	54.97	40.99	0	58.5	25.5	6	4,465	1	115	432
224	11.9	79.0	121	67.0	13.8	11.5	46.40	77.09	27.05	40.42	29.36	0	33.2	20.7	6	4,195	1	201	574
C17	12.3	71.5	85	55.0	16.8	10.7	53.54	--	--	--	--	--	--	--	6	2,246	1	180	304
116	12.4	69.0	91	40.7	15.5	10.0	46.13	73.03	25.42	39.38	29.48	0	29.8	17.5	6	3,548	1	176	866
C16	13.6	69.1	85	53.1	17.5	11.8	69.38	--	--	--	--	--	--	--	6	2,253	1	100	96
117	15.6	72.7	92	47.7	21.9	13.5	104.3	181.8	61.52	108.9	115.3	0	20.4	12.2	6	9,385	1	432	4,664
C44	16.0	103.8	81	55.1	19.5	11.3	90.13	--	--	--	--	--	--	--	6	4,644	4	300	340
C47	18.8	131.4	91	68.5	12.5	12.7	10.16	--	--	--	--	--	--	--	6	6,217	6	440	676
C46	19.0	126.3	96	94.3	22.8	16.6	89.49	--	--	--	--	--	--	--	6	10,028	5	189	901
C45	20.4	136.8	106	108.1	17.3	17.0	200.1	--	--	--	--	--	--	--	6	13,859	5	124	737

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft³*		*Ft²*	
LODGEPOLE PINE																			
24	0	1.6	5	1.3	1.3	--	0	0.0309	0.0132	0	0	0	0.04	1.6	1	1.01	1	1	600
25	0	2.7	8	2.7	1.9	--	0	.1543	.0705	0	0	0	.08	2.7	1	3.42	1	2	1,500
90	0	4.3	5	4.3	2.2	1.0	0.0044	.2690	.1433	0.0992	0	0	.20	4.3	2	6.22	2	5	3,300
91	0	3.9	5	3.9	2.1	1.0	0	.2337	.1301	.1102	0	0	.26	3.9	2	5.34	2	2	1,500
88	0.3	5.4	6	5.4	3.0	1.8	0	.6790	.3902	.3726	0	0	.77	5.4	2	8.96	1	7	4,800
21	.6	6.3	7	5.5	2.8	--	.0066	.5842	.3153	.2205	0	0	.91	6.3	2	14.30	1	22	1,224
75	.7	7.1	5	7.1	2.5	1.7	0	.7143	.4365	.4519	0	0	1.07	7.1	2	20.58	3	1	300
76	.8	7.5	5	7.0	3.4	2.0	0	.7540	.4343	.4145	0	0	1.44	7.5	2	26.41	3	43	2,128
84	1.3	8.6	8	7.6	3.7	1.9	.0022	1.186	.6878	.6768	0	0	1.97	8.6	2	27.75	3	25	2,105
87	1.3	8.1	7	7.1	4.0	2.0	.0176	1.067	.6327	.6415	0	0	2.07	8.1	2	36.31	3	113	3,920
38	1.5	11.3	12	10.3	3.7	2.0	.0044	1.343	.7540	.6548	0	0	3.02	11.3	2	62.59	3	20	6,000
22	1.8	13.1	11	11.9	5.8	--	.0882	2.703	1.629	1.676	0	0	4.83	13.1	2	73.59	3	65	2,463
C24	6.5	50.7	72	31.7	7.3	5.6	2.743	--	--	--	--	--	--	--	-	563.2	1	100	265
C18	9.5	76.1	96	40.3	5.8	6.5	25.39	--	--	--	--	--	--	--	-	665.5	3	140	222
C20	9.8	65.6	85	23.4	8.6	5.2	46.48	--	--	--	--	--	--	--	-	585.2	3	271	7,980
C21	11.6	78.9	75	46.5	8.7	8.0	46.64	--	--	--	--	--	--	--	-	1,205	4	188	6,378
C22	12.8	73.9	77	44.1	13.5	9.3	66.75	--	--	--	--	--	--	--	-	2,464	4	138	1,478
C19	14.0	76.6	85	50.2	16.5	10.0	147.2	--	--	--	--	--	--	--	-	3,903	3	100	399
C23	15.6	84.1	97	60.2	23.7	12.1	177.3	--	--	--	--	--	--	--	-	10,999	3	60	70

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
								PONDEROSA PINE											
13	0	4.5	11	4.5	2.5	--	0	0.5313	0.1146	0.3131	0	0	0.53	4.5	2	16.56	1	1	300
14	0	4.3	7	4.3	3.3	--	0	.5445	.1036	.3505	0	0	.48	4.3	2	15.34	1	20	328
18	0	2.3	7	2.3	1.6	--	0.0067	.1852	.0529	.0838	0	0	.18	2.3	1	3.72	1	20	307
19	0	4.6	6	3.3	2.1	--	.0132	.2624	.0705	.1279	0	0	.38	4.6	2	7.27	2	22	1,267
155	0.6	5.5	7	5.0	4.1	1.9	.0088	1.038	.1808	.6945	0	0	1.22	5.5	2	28.92	3	1	300
70	.7	6.0	6	6.0	3.8	1.8	0	.7231	.1477	.4431	0	0	1.32	6.0	2	24.22	3	13	7,200
154	.7	5.7	6	4.3	3.3	1.4	.0573	.3792	.0794	.2271	0	0	.91	5.7	2	18.47	5	1	300
126	.8	6.1	11	4.8	4.1	2.1	.0595	1.380	.2844	.8378	0	0	1.84	6.1	3	26.65	1	43	1,831
10	1.0	5.9	20	5.9	3.9	--	.0287	2.831	1.109	0	0	0	3.23	5.9	3	40.20	1	2	300
57	1.5	9.7	6	9.2	4.0	2.2	.0154	1.034	.1543	.7408	0	0	2.93	9.7	3	49.82	4	45	4,215
129	1.6	7.8	11	6.8	3.4	2.4	.0110	2.244	.3329	1.612	0	0	2.79	7.8	3	35.08	1	4	1,800
15	1.9	10.0	20	7.0	5.4	--	.2579	2.410	.3020	1.861	0	0	4.28	10.0	3	58.88	2	37	611
16	2.6	11.0	18	8.5	6.4	--	.2579	6.378	.7341	5.121	0	0	8.78	10.6	4	131.6	1	15	300
17	3.2	15.3	25	10.2	6.2	--	.5930	3.605	.4938	2.701	0	0	10.56	15.3	4	128.2	1	17	900
58	3.2	13.9	7	13.9	7.1	4.8	0	5.472	.4916	4.885	2.196	0	14.48	13.9	6	237.6	4	20	2,100
124	3.7	13.9	16	11.6	6.0	4.0	.3638	8.944	.9458	7.454	1.268	0	14.78	13.9	6	164.0	2	40	1,810
12	4.4	28.3	45	19.8	5.4	--	3.682	6.435	.7893	5.077	.6856	0	20.78	21.2	4	307.5	1	142	895
11	6.4	37.6	59	22.2	7.5	--	6.964	11.45	1.019	10.25	4.129	0	12.52	14.7	4	456.1	1	325	2,026
45	7.6	38.8	36	28.9	19.1	7.0	8.792	25.69	1.925	24.82	19.34	0	40.45	23.8	6	1,065	3	20	65
8	7.8	40.9	45	28.4	11.3	--	20.41	25.47	1.808	25.24	21.95	0	9.73	12.4	4	1,472	2	140	338
9	10.5	50.6	57	39.1	12.9	--	36.63	39.82	2.070	45.23	44.07	0	8.50	11.2	4	1,627	2	80	155
122	11.2	74.3	78	40.3	11.0	8.7	35.85	47.96	3.034	50.10	46.47	0	40.88	22.7	6	2,322	4	180	264
211	11.3	66.6	85	32.3	8.3	7.3	47.42	28.18	2.150	27.28	21.89	0	43.37	22.3	6	1,153	2	160	174
115	13.8	72.1	81	38.9	17.9	9.8	118.4	84.56	4.780	92.68	88.24	0	44.52	22.4	6	4,111	3	20	20
212	14.2	72.4	87	56.1	18.0	12.4	7.227	132.0	13.73	146.8	142.1	0	41.50	22.1	6	6,771	3	64	3,046
7	18.2	76.9	155	46.5	17.0	--	80.78	124.9	0	185.1	237.6	39.56	4.68	9.0	4	5,080	1	140	121
2	19.2	82.5	100	65.6	26.5	--	77.06	196.2	0	359.2	457.0	0	9.53	12.5	4	9,698	3	140	144
199	20.6	85.5	72	66.5	26.7	17.0	260.9	266.6	9.749	352.8	366.1	161.8	35.06	19.1	6	13,192	5	140	114
5	21.1	76.7	210	30.7	16.8	--	71.12	102.3	1.832	161.5	183.8	131.4	3.92	5.7	4	1,613	1	120	81
6	24.3	78.2	210	39.8	19.5	--	67.35	146.4	8.201	269.1	138.6	245.5	3.22	7.0	3	4,958	1	101	315
4	25.5	87.3	210	37.7	22.4	--	123.3	150.8	1.667	314.4	274.2	357.0	4.88	7.5	4	11,317	1	80	32
3	28.3	78.4	210	52.7	31.1	--	373.0	163.7	1.737	295.1	267.5	813.2	6.01	8.9	4	20,307	1	80	19
1	31.3	112.8	217	78.5	40.1	--	294.4	211.2	0	506.8	554.6	122.4	6.58	9.1	4	42,028	2	82	313
121	31.5	121.0	181	89.2	34.7	26.4	259.6	407.4	11.97	588.8	626.5	583.0	27.70	16.5	6	32,773	4	80	44
198	34.0	144.4	192	85.9	29.6	24.8	52.57	501.0	14.69	735.4	783.4	875.1	9.72	16.5	6	30,500	5	40	5

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Live crown weight: Branchwood (inches): 0 to 0.25	Branchwood (inches): 0.25 to 1	Branchwood (inches): 1 to 3	Branchwood (inches): 3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
									SUBALPINE FIR										
127	0	4.1	4	4.1	2.5	1.0	0	0.6878	0.2910	0.1235	0	0	0.21	4.1	2	8.23	5	4	2,700
149	0	3.0	14	3.0	1.3	.8	0	.1984	.0728	0	0	0	.11	3.0	1	1.98	1	1	900
161	0	4.4	18	4.4	2.8	1.8	0.0176	.8135	.3373	.1235	0	0	.50	4.4	2	10.81	1	3	1,800
200	0	2.5	14	2.0	2.6	.9	0	.3594	.1345	0	0	0	.20	2.5	1	4.46	1	85	3,101
201	0	4.3	12	3.5	2.2	1.2	.0331	.5445	.2116	.0309	0	0	.39	4.3	2	4.20	1	1	300
31	0.3	5.4	12	5.4	2.4	--	0	.8267	.3461	.1345	0	0	.58	5.4	2	8.80	1	2	1,200
151	.6	6.1	21	5.6	3.2	2.2	.0044	2.088	.9436	.6151	0	0	1.54	6.1	3	20.64	1	1	900
188	.6	6.1	37	5.1	2.7	1.5	.0088	1.323	.5115	.0551	0	0	1.02	6.1	2	11.30	1	1	900
189	.8	6.9	37	6.1	3.3	1.5	.0022	1.164	.4784	.1587	0	0	1.12	6.9	2	18.00	1	21	617
152	1.0	7.8	17	7.8	4.4	2.3	.0066	2.560	1.124	.6217	0	0	2.24	7.8	3	37.85	1	3	900
51	1.2	8.8	20	8.8	3.9	2.3	0	4.202	1.872	1.127	0	0	2.06	8.8	3	37.27	1	3	900
164	1.3	9.9	13	9.4	4.9	2.5	.0176	3.276	1.466	.9061	0	0	2.84	9.9	3	63.70	3	2	600
86	2.0	11.6	13	11.6	5.6	3.7	.0044	6.651	3.210	3.091	0	0	6.64	11.6	4	124.8	5	24	1,812
78	2.1	10.5	35	9.5	4.8	3.0	.0066	6.993	3.283	2.685	0	0	5.81	10.5	4	84.39	1	4	1,500
159	3.1	16.2	16	15.3	5.8	4.3	.3483	7.304	3.389	2.681	0	0	14.6	16.2	6	117.7	5	30	900
147	3.5	18.8	50	17.0	5.4	4.0	.2668	12.90	6.332	6.742	0	0	18.1	18.8	6	136.3	1	41	1,507
203	4.0	23.1	51	21.4	6.8	4.7	.4079	13.49	6.296	5.066	0	0	28.3	23.1	6	173.2	1	64	1,265
34	4.9	24.9	37	24.9	7.5	--	.3285	17.71	8.774	9.707	0	0	40.1	24.9	6	380.6	1	43	600
217	6.8	32.8	91	30.6	9.8	6.9	.8047	37.05	19.08	27.03	5.410	0	44.5	27.2	6	726.5	1	20	87
215	7.3	60.3	150	35.4	8.0	5.8	17.25	44.87	22.17	24.06	0	0	62.0	36.8	6	694.9	1	101	15,121
234	8.2	54.6	201	29.1	10.0	6.5	27.61	13.34	7.205	12.90	8.433	0	45.8	24.1	6	1,614	1	70	3,982
236	9.1	48.3	152	48.3	9.7	12.7	11.75	61.19	32.40	51.27	11.03	0	57.5	26.9	6	1,459	1	120	172
47	11.1	93.0	105	69.6	10.0	9.2	31.71	56.49	30.25	52.28	20.25	0	74.2	37.6	6	2,065	5	204	3,083
223	12.3	92.6	118	51.4	8.3	8.9	34.07	55.08	28.21	38.59	5.203	0	51.7	30.8	6	1,231	3	260	262
235	12.7	54.5	73	42.5	12.7	10.6	24.51	91.03	49.53	90.20	33.26	0	52.4	30.4	6	3,083	3	95	404

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
									WESTERN HEMLOCK										
68	0	4.4	10	3.9	2.2	1.0	0	0.3373	0.1808	0.0485	0	0	0.27	4.4	2	8.57	1	1	900
178	0	4.5	5	4.5	2.0	.6	0	.1080	.0595	0	0	0	.12	4.5	1	3.84	4	7	4,800
180	0	3.8	5	3.0	1.9	.5	0.0022	.0992	.0529	.0132	0	0	.09	3.8	1	3.79	2	7	5,100
181	0	3.6	4	3.6	1.4	.6	0	.0838	.0441	0	0	0	.09	3.6	1	2.54	5	2	1,500
175	0.1	6.5	7	5.5	2.2	1.0	0	.3175	.1698	.0309	0	0	.38	6.5	2	5.68	5	2	1,200
66	.2	5.9	8	5.9	2.7	1.3	0	.4321	.2315	.0728	0	0	.39	5.9	2	10.24	2	4	3,000
167	.5	8.0	7	7.2	3.2	1.1	0	.6945	.3748	.0750	0	0	.77	8.0	2	15.74	4	21	4,800
174	.6	8.3	6	7.7	4.1	1.7	0	.9700	.5159	.2998	0	0	.89	8.3	2	24.20	5	83	2,729
168	1.3	12.7	19	9.8	4.2	1.8	.0198	1.506	.7959	.5534	0	0	3.31	12.7	3	20.70	2	39	1,287
179	1.3	13.6	8	12.5	4.5	2.2	.0110	1.660	.8819	.5159	0	0	3.06	13.6	3	51.00	5	3	1,200
173	1.8	12.7	24	11.9	4.8	3.0	0	4.132	2.176	1.839	0	0	5.84	12.7	4	67.62	1	90	5,117
63	2.0	15.4	19	15.4	5.0	2.9	.0044	3.113	1.620	1.728	0	0	5.87	15.4	3	133.7	5	59	5,100
65	2.1	16.2	13	14.2	5.2	2.4	.0860	3.869	2.030	1.784	0	0	6.23	16.2	3	87.71	4	72	7,200
69	2.3	18.2	17	15.2	5.7	2.5	.0838	2.679	1.409	1.217	0	0	7.89	18.2	4	143.8	4	20	4,200
169	3.0	21.4	25	17.5	9.3	3.2	.0860	7.046	3.662	3.829	0	0	17.4	21.4	6	269.9	3	62	3,000
171	3.1	20.3	21	19.0	6.9	3.5	.0044	6.934	3.605	3.640	0	0	15.3	20.3	4	155.7	5	62	3,000
172	5.0	29.0	25	27.0	10.1	5.2	.0838	15.11	7.681	9.162	0.8488	0	42.5	29.0	6	748.9	5	128	1,926
170	5.7	27.4	23	25.6	10.7	6.2	.0838	20.95	10.76	13.17	0	0	42.8	24.3	6	784.4	5	83	1,986
176	6.3	35.2	23	35.2	12.3	7.0	1.157	32.09	16.44	20.81	4.799	0	43.1	27.5	6	1,261	5	148	6,009
182	7.0	38.4	32	38.4	12.8	7.2	.0882	31.46	16.12	20.21	2.967	0	47.5	29.4	6	1,610	5	129	848
C15	9.6	72.8	95	61.6	19.7	9.0	--	--	--	--	--	--	--	--	6	--	2	123	1,332
C13	10.3	78.2	108	62.7	15.8	9.5	--	--	--	--	--	--	--	--	6	--	1	320	436
C10	15.8	116.4	116	69.9	21.3	12.0	--	--	--	--	--	--	--	--	6	--	3	100	71
C 9	16.9	115.2	176	69.2	20.3	13.2	--	--	--	--	--	--	--	--	6	--	1	140	106
C 8	17.3	125.5	156	66.1	24.5	13.0	--	--	--	--	--	--	--	--	6	--	2	120	88
C12	18.9	115.3	121	76.8	31.5	16.4	--	--	--	--	--	--	--	--	6	--	3	100	83
C11	20.2	125.4	122	72.0	24.0	15.6	--	--	--	--	--	--	--	--	6	--	3	160	106
C14	21.4	126.2	161	111.5	31.6	21.1	--	--	--	--	--	--	--	--	6	--	3	180	88

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches): 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
								WESTERN LARCH											
92	0	4.5	6	4.5	1.9	1.3	0	0.2116	0.2447	0.1698	0	0	0.39	4.5	2	5.87	3	7	3,600
100	0	4.5	10	4.5	2.0	1.0	0	.2183	.2293	.0309	0	0	.19	4.5	1	6.30	1	1	600
120	0	3.6	3	3.6	1.0	0.4	0	.0198	.0198	0	0	0	.05	3.6	1	1.14	4	3	1,800
133	0	2.8	12	2.8	1.5	.3	0.0044	.0220	.0220	0	0	0	.04	2.8	1	1.18	1	11	7,800
119	0.2	6.9	5	6.9	2.6	1.2	.0022	.1565	.1631	0	0	0	.47	6.9	2	15.20	4	4	3,000
89	.3	6.3	6	6.3	2.5	1.3	0	.3241	.3505	.1058	0	0	.55	6.3	2	7.37	4	2	600
128	.5	5.0	9	5.0	3.4	1.6	.0220	.4167	.4696	.2601	0	0	1.00	5.0	2	16.69	1	7	5,100
81	.8	7.3	8	6.8	3.2	1.5	.0044	.4453	.5137	.3836	0	0	0.99	7.3	2	17.62	3	5	3,000
134	.9	11.3	13	7.7	3.5	1.1	.0926	.2822	.2932	0	0	0	1.23	11.3	2	45.21	1	7	4,800
80	1.6	12.0	8	10.2	5.2	2.1	.0353	1.292	1.510	1.221	0	0	3.76	12.0	3	89.46	4	3	900
137	1.7	18.0	12	16.4	5.6	2.2	.0220	1.257	1.431	.9171	0	0	5.86	18.0	3	169.4	4	48	4,841
99	1.9	13.6	16	11.8	4.0	2.8	.1058	1.574	1.883	1.728	0	0	6.48	13.6	4	59.94	3	17	1,200
94	2.1	13.7	15	12.7	3.5	2.8	0	1.894	2.238	1.916	0	0	6.25	13.7	4	138.3	4	18	2,100
135	2.2	14.5	8	12.8	6.2	2.8	.0022	2.335	2.754	2.370	0	0	8.84	14.5	4	154.6	4	18	2,400
93	2.9	18.1	14	18.1	4.8	4.2	0	2.577	3.071	2.654	0	0	14.7	18.1	5	188.9	5	15	900
143	3.8	25.2	17	23.5	7.5	4.8	.1808	3.616	4.378	4.202	0	0	37.4	25.2	6	287.8	2	31	1,800
83	4.7	45.6	52	23.8	6.8	3.3	5.135	3.325	3.973	3.629	0	0	70.1	44.6	6	510.6	2	78	2,221
82	6.6	50.1	55	28.8	9.3	5.2	4.235	6.524	8.151	8.541	0	0	99.9	42.6	6	824.1	4	89	765
C 7	10.3	96.2	160	38.2	--	--	.1940	--	--	--	--	--	--	--	6	--	3	182	475
C 1	17.2	113.7	185	44.7	12.9	10.3	0	--	--	--	--	--	--	--	6	--	3	100	77
C 4	17.5	115.9	235	48.4	16.8	10.5	.6085	--	--	--	--	--	--	--	6	--	3	203	1,450
C 5	17.5	118.0	235	53.7	15.7	9.8	.2381	--	--	--	--	--	--	--	6	--	3	271	1,163
C 2	19.0	124.4	250	74.8	18.0	13.5	.2072	--	--	--	--	--	--	--	6	--	3	77	661
C 6	19.6	128.9	250	69.0	16.0	13.4	.1036	--	--	--	--	--	--	--	6	--	3	175	422
C 3	21.8	125.3	250	61.3	20.2	13.2	.2844	--	--	--	--	--	--	--	6	--	3	241	554

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
									WESTERN REDCEDAR										
37	0	1.8	6	1.8	1.4	1.1	0	0.0661	0.0661	0	0	0	0.02	1.8	2	1.53	1	3	2,100
111	0	3.6	3	3.6	2.9	0.9	0	.3505	.0882	0	0	0	.20	3.6	1	9.58	3	1	300
132	0	3.7	6	3.7	3.0	1.1	0	.3880	.0948	.0728	0	0	.18	3.7	2	8.78	1	7	5,100
131	0.1	5.4	7	5.4	3.3	1.4	0.0044	.6614	.1587	.1676	0	0	.31	5.4	2	19.30	2	2	1,200
138	.4	6.0	6	5.7	3.5	1.1	0	.3219	.0794	.0595	0	0	.36	6.0	2	18.18	6	11	7,800
44	.8	7.7	15	7.7	4.8	2.0	0	1.336	.3109	.5071	0	0	1.45	7.7	3	75.27	1	7	4,200
157	.8	8.2	10	8.2	3.9	2.0	.0463	1.041	.2403	.4586	0	0	1.39	8.2	3	45.80	3	4	3,000
187	.8	7.9	11	7.9	5.1	2.4	.0485	.8951	.2072	.3836	0	0	.91	7.9	3	68.02	1	3	1,800
40	1.3	9.9	20	9.9	6.7	3.7	.1631	3.591	.8267	1.735	0	0	3.29	9.9	4	148.8	1	3	900
140	1.5	10.1	52	5.9	5.5	1.6	.1499	1.854	.4299	.8532	0	0	3.13	10.1	3	55.54	1	8	3,600
156	1.8	12.6	19	12.6	7.2	3.0	0	4.264	.9524	2.061	0	0	5.10	12.6	3	120.3	3	4	600
39	2.0	11.8	13	11.8	8.4	3.4	0	5.609	1.237	2.820	0	0	4.81	11.8	4	238.7	3	15	300
74	2.1	16.2	16	15.2	5.1	2.4	.0816	3.609	.8201	1.768	0	0	6.13	16.2	4	144.3	5	51	1,811
110	3.4	19.9	17	19.9	10.9	6.6	0	12.97	2.822	6.713	0	0	18.1	19.9	6	817.9	3	71	1,500
139	3.6	21.1	51	15.1	8.3	3.3	.0904	7.778	1.706	3.968	0	0	20.3	21.1	6	233.4	1	34	2,400
46	3.7	20.1	27	20.1	8.5	5.5	.0838	14.39	3.150	7.368	0	0	22.5	20.0	6	614.1	2	36	3,900
49	4.2	24.3	48	18.9	8.0	4.0	.1742	13.27	2.908	6.801	0	0	34.5	24.3	6	517.3	1	81	4,620
136	6.1	50.0	150	23.9	11.2	3.8	4.861	11.09	2.381	5.807	1.142	0	81.0	38.7	6	1,144	1	120	307
214	8.0	44.2	80	38.0	17.8	7.9	2.996	41.11	8.719	21.59	10.35	0	35.2	28.6	6	3,148	1	148	6,227
77	10.6	67.6	84	51.5	15.8	8.9	16.62	52.99	11.30	27.85	12.51	0	55.0	30.0	6	4,249	3	241	1,417
C28	12.6	66.2	99	45.3	16.0	9.7	16.01	--	--	--	--	--	--	--	6	4,094	3	140	154
C48	15.5	77.0	76	68.1	20.3	13.9	29.58	--	--	--	--	--	--	--	6	6,339	5	300	354
C29	17.6	77.9	106	56.4	22.6	13.2	40.43	--	--	--	--	--	--	--	6	9,235	3	200	186
50	18.6	101.1	171	80.8	19.3	15.2	78.19	137.8	28.27	75.15	97.43	0	40.4	22.2	6	8,037	3	220	110
185	21.0	105.2	237	76.0	26.0	16.4	108.0	154.6	31.40	85.07	138.5	0	45.2	24.3	6	17,831	1	236	728
107	22.9	117.2	210	98.2	30.4	18.8	156.6	249.4	50.16	147.2	264.2	0	33.2	18.3	6	33,742	4	246	4,603
191	26.3	107.3	210	84.3	24.1	21.4	178.5	212.9	42.58	118.8	284.6	9.275	33.5	21.6	6	17,068	1	202	646
106	26.6	126.5	210	80.2	23.0	19.3	195.1	226.2	45.53	125.5	237.1	0	29.5	16.2	6	14,383	4	240	401

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Branchwood (inches): 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft³*		*Ft²*	
								WESTERN WHITE PINE											
28	0	2.8	9	2.8	2.3	--	0	0.4343	0.2072	0.1301	0	0	0.17	2.8	2	4.97	1	1	900
29	0	3.5	10	3.5	3.1	--	0	.3990	.1653	0	0	0	.22	3.5	1	12.14	1	12	7,800
52	0	2.8	6	2.6	2.0	0.8	0	.2756	.1191	.0331	0	0	.11	2.8	1	3.99	1	12	7,800
112	0	2.8	4	2.8	2.3	.8	0	.1720	.0794	.0353	0	0	.12	2.8	1	3.06	3	2	1,200
144	0.3	5.3	9	5.3	3.0	1.3	0.0002	.6834	.3307	.2138	0	0	.73	5.3	2	18.53	1	22	995
60	.4	5.2	6	5.2	2.7	1.4	.0287	.8069	.4012	.3109	0	0	.62	5.2	2	16.96	3	1	300
113	.5	5.4	7	3.9	3.5	1.8	.0004	.8774	.4343	.3197	0	0	1.22	5.4	2	21.38	3	1	300
104	.9	7.5	9	7.0	4.0	2.2	0	1.495	.7694	.6614	0	0	2.22	7.5	3	26.94	2	6	3,000
59	1.0	7.5	7	7.5	3.5	2.3	.0375	1.612	.8554	.8025	0	0	1.97	7.5	3	17.51	5	2	300
163	1.1	9.0	11	9.0	4.5	2.2	.0683	1.642	.8091	.7165	0	0	2.43	9.0	3	61.14	4	23	3,300
177	1.4	7.8	11	7.8	4.4	2.0	.0002	1.369	.6834	.5247	0	0	1.97	7.8	2	54.84	3	9	1,500
158	1.5	9.7	15	8.7	5.2	2.1	.0463	1.585	.7871	.5997	0	0	3.14	9.7	3	78.36	2	3	900
73	1.6	11.5	9	10.5	5.0	2.4	.0794	2.090	1.049	.8356	0	0	3.92	11.5	3	95.85	4	17	600
72	2.1	12.5	10	12.5	5.9	3.1	.1609	2.568	1.376	1.316	0	0	5.22	12.5	4	131.6	4	60	973
79	2.3	11.1	31	10.0	5.6	3.2	.0002	4.535	2.502	2.584	0	0	7.20	11.1	4	85.79	1	26	3,005
109	2.5	14.8	19	12.0	5.4	2.8	.0926	3.155	1.609	1.347	0	0	9.62	14.8	4	144.9	2	15	300
105	2.8	14.1	17	14.1	6.0	4.7	.1808	6.616	3.684	3.885	0	0	13.1	14.1	6	168.1	2	58	4,500
216	4.7	26.3	55	15.1	10.8	4.0	4.991	10.72	5.781	5.650	0	0	44.2	26.3	6	511.2	1	101	414
221	5.8	35.8	24	32.5	9.3	6.0	1.931	20.67	11.83	13.26	0	0	55.2	32.3	6	855.3	5	--	--
55	7.4	66.1	43	45.5	6.0	6.3	3.790	13.90	7.789	8.320	0.1786	0	80.8	39.8	6	838.0	5	141	1,381
C30	13.8	110.2	98	79.4	9.1	11.4	47.76	--	--	--	--	--	--	--	6	3,527	3	157	2,337
C34	15.6	85.0	160	68.8	10.3	14.4	33.59	--	--	--	--	--	--	--	6	4,394	1	195	574
C35	17.1	106.8	186	82.9	7.6	15.3	12.29	--	--	--	--	--	--	--	6	2,229	1	103	1,096
C36	21.5	104.9	177	74.6	13.4	18.1	44.49	--	--	--	--	--	--	--	6	8,096	1	104	1,370
C33	22.1	136.9	144	88.3	9.5	17.1	5.348	--	--	--	--	--	--	--	6	3,966	2	82	4,226
C38	24.7	126.4	169	87.1	15.7	19.2	49.11	--	--	--	--	--	--	--	6	10,346	2	299	3,703

(con.)

Table 12.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
									WHITEBARK PINE										
192	0	2.5	15	1.5	1.3	0.8	0	0.1587	0.1124	0.0551	0	0	0.18	2.5	1	0.83	1	2	1,500
226	0	4.4	14	4.0	1.6	1.2	0.0066	.2976	.2359	.0529	0	0	.41	4.4	2	5.24	1	6	3,600
230	0	3.5	6	2.4	2.1	.5	0	.0816	.0529	.0397	0	0	.17	3.5	1	2.91	1	23	1,565
197	0.2	4.8	26	4.2	1.6	1.3	0	.3241	.2491	.0728	0	0	.70	4.8	2	3.71	1	1	900
195	.4	5.3	25	4.6	1.0	1.0	.0198	.1411	.1235	0	0	0	.42	5.3	2	2.36	1	63	1,597
228	.8	6.5	67	6.1	2.5	1.6	.0463	.6460	.4233	.3064	0	0	1.32	6.5	2	12.36	1	9	4,200
196	1.3	8.0	45	5.5	2.7	1.8	.0529	.9061	.5666	.4850	0	0	2.3	8.0	3	18.03	1	30	6,324
229	1.5	9.8	39	9.0	2.7	2.3	.1411	1.246	.7804	.6680	0	0	3.73	9.8	3	26.71	1	65	2,395
193	1.8	10.0	50	8.2	2.0	2.3	.0088	1.179	.7452	.6195	0	0	5.52	10.0	3	14.00	1	92	1,561
194	2.0	11.3	60	9.7	2.3	2.4	.0220	1.299	.8003	.7253	0	0	6.13	11.3	3	18.80	1	53	3,014
232	3.3	17.9	102	10.5	3.4	3.0	.8466	2.394	1.407	1.477	0	0	20.1	17.9	6	45.83	1	130	5,451
231	3.4	15.0	63	11.1	3.5	4.2	2.668	3.062	1.744	1.975	0	0	13.5	15.0	6	63.33	1	84	1,074
225	4.9	25.1	152	15.8	4.5	4.0	1.543	7.483	3.968	5.247	0	0	65.6	24.6	6	135.3	1	181	3,678
227	5.0	16.9	150	16.1	4.3	6.0	.8973	9.610	4.683	7.359	0	0	28.3	16.1	6	123.9	1	42	3,421
237	6.4	38.4	175	27.4	7.0	5.9	2.156	13.72	6.371	11.17	1.023	0	66.3	27.4	6	587.3	1	81	461
C40	6.7	34.7	200	28.7	7.8	6.5	.7408	--	--	--	--	--	--	--	6	903.9	1	115	2,877
233	7.4	29.7	182	21.2	6.5	6.3	1.795	19.21	8.931	15.92	2.564	--	48.8	19.7	6	538.2	1	99	2,252
C41	9.9	42.2	200	35.4	8.0	9.6	7.421	--	--	--	--	--	--	--	6	1,128	1	110	1,327
C42	10.6	44.0	200	35.5	11.0	10.3	6.815	--	--	--	--	--	--	--	6	1,597	1	92	2,493

Table 13.--*Raw data for intermediates*

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
									DOUGLAS-FIR										
802	0	3.8	28	1.1	3.3	0.3	0.0419	0.1168	0.0860	0	0	0	0.22	3.8	1	1.99	1	39	3,600
804	0	3.7	15	2.2	2.9	.9	.0441	.2668	.1918	0.0794	0	0	.38	3.7	1	5.66	1	36	2,400
822	0	4.0	12	3.7	3.0	1.0	.0198	.3858	.2888	0	0	0	.24	4.0	1	8.78	1	60	374
853	0	3.6	12	2.6	2.0	.6	.0088	.1477	.1102	0	0	0	.15	3.6	1	3.04	2	40	4,500
812	0.6	7.7	14	5.1	2.8	.8	.0220	.3020	.2271	0	0	0	.69	7.7	2	17.93	1	104	3,600
805	.9	6.6	35	2.5	3.5	1.1	.4343	.6283	.4409	.2800	0	0	1.48	6.6	2	8.88	1	82	3,600
829	.9	8.3	26	3.4	3.3	.8	.2293	.4012	.2954	.0485	0	0	1.21	8.3	2	9.94	1	38	3,900
840	1.0	9.5	24	5.5	3.6	.9	.0794	.5644	.4079	.1433	0	0	1.07	9.5	2	29.52	1	119	3,408
801	1.6	15.6	46	6.0	4.7	1.8	.2293	.7584	.5027	.7319	0.3770	0	4.49	15.6	3	35.92	1	92	2,942
806	1.7	11.1	40	8.1	5.5	2.0	1.094	2.134	1.471	1.164	0	0	3.81	11.1	3	142.3	1	63	1,287
803	2.1	15.6	51	6.0	4.5	1.6	.3483	1.552	1.027	1.314	0	0	8.80	15.6	4	54.86	1	131	2,400
828	2.5	17.8	43	7.5	3.4	1.8	.6393	1.726	1.191	.9259	0	0	14.1	17.8	3	31.51	1	60	2,400
815	4.1	30.2	38	8.7	6.5	2.7	1.455	3.962	2.604	3.567	0	0	42.4	30.2	6	83.21	3	121	694
856	4.2	43.9	59	21.3	5.9	3.0	4.508	4.279	2.862	3.236	0	0	58.4	43.9	6	299.6	3	262	1,072
857	6.7	57.4	85	41.4	5.5	5.6	7.897	7.791	5.132	6.997	1.263	0	112.8	45.9	6	719.1	3	160	281
871	6.9	48.1	74	30.9	11.2	5.7	5.983	25.34	16.33	26.67	2.648	0	82.5	35.2	6	1,486	2	180	261
858	7.5	69.9	76	46.7	5.1	6.0	9.855	8.309	5.390	8.609	2.258	0	80.9	37.9	6	294.2	4	160	326
869	8.2	52.7	89	37.2	11.0	7.2	4.286	33.78	21.75	36.01	4.096	0	59.1	31.1	6	2,506	3	180	415
881	8.6	47.7	145	28.5	13.9	6.6	10.25	20.03	12.61	26.35	11.45	0	55.7	25.6	6	2,092	1	360	516
860	10.2	77.0	74	26.8	11.1	6.0	59.17	14.97	9.504	17.97	4.676	0	54.0	26.8	6	1,288	5	220	274
873	10.7	36.1	75	27.3	17.7	9.9	16.54	52.95	32.62	81.62	54.21	0	21.6	12.7	6	3,770	1	134	517
861	11.2	82.6	77	38.6	8.2	6.3	74.24	19.44	12.41	22.32	3.797	0	84.5	36.9	6	996.4	5	160	516

(con.)

Table 13.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Live crown weight: Foliage	Live crown weight: Branchwood (inches): 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft³*		*Ft²*	
								GRAND FIR											
825	0	4.5	39	3.4	3.2	0.9	0.0463	0.5335	0.3020	0.1742	0	0	0.62	4.5	2	11.10	1	141	1,241
827	0	4.5	24	2.4	3.0	.6	.0287	.2271	.1631	0	0	0	.37	4.5	1	9.18	1	85	1,260
833	0	3.7	15	2.9	2.8	1.1	.0044	.3880	.2800	0	0	0	.28	3.7	1	10.67	2	64	1,322
834	0	3.7	16	2.7	1.5	.6	.0066	.1808	.1301	0	0	0	.11	3.7	1	2.83	2	39	2,720
841	0	4.0	33	2.6	4.0	.9	.0265	.4453	.2756	.0860	0	0	.44	4.0	2	13.49	1	228	2,710
832	0.3	5.3	28	2.8	4.5	.8	.0066	.2998	.1896	.0529	0	0	.61	5.3	2	14.95	1	66	2,244
842	.7	6.4	16	4.8	4.5	1.0	.0265	.4608	.3064	.0507	0	0	.59	6.4	2	31.51	4	145	4,607
838	1.0	9.5	34	9.2	6.0	1.9	.0838	2.191	1.250	.6393	0	0	2.07	9.5	2	66.11	1	102	441
810	1.5	8.3	45	6.4	4.7	2.2	.1080	2.361	1.389	.6085	0	0	3.62	8.3	3	42.48	1	91	5,804
835	1.5	9.1	48	8.2	5.0	2.6	.0198	4.015	2.130	1.865	0	0	3.54	9.1	3	101.6	1	144	2,088
807	2.1	12.4	36	9.0	6.8	2.1	.2403	2.710	1.534	.8157	0	0	4.14	12.4	3	96.8	1	110	2,487
863	2.3	15.9	51	9.6	7.0	2.1	1.290	3.139	1.682	1.426	0	0	8.51	15.9	3	189.1	1	205	1,474
844	3.0	24.8	80	12.3	5.6	2.5	2.372	4.634	2.438	2.275	0	0	21.0	24.8	4	142.3	1	164	1,524
867	4.1	19.7	48	16.0	10.0	4.2	1.466	12.31	5.842	10.76	0.2976	0	24.1	19.7	6	509.3	1	122	1,748
866	4.3	30.8	37	21.9	7.9	4.1	1.583	10.31	5.168	6.618	0	0	33.3	30.8	6	375.9	3	222	3,367
870	6.1	31.2	74	23.6	12.0	5.5	4.969	27.53	12.73	26.30	0	0	54.9	26.1	6	932.8	1	120	359
882	7.7	54.0	100	39.0	9.8	7.4	19.91	20.72	10.14	15.25	0	0	47.2	28.0	6	3,564	1	280	389
872	8.3	43.1	117	30.1	17.0	7.5	5.602	44.08	19.78	53.94	5.807	0	32.7	22.6	6	1,757	1	207	4,436
886	8.4	55.7	98	37.2	10.2	6.9	1.691	28.73	13.47	28.04	11.65	0	55.8	28.3	6	3,098	1	195	655
885	9.2	59.7	105	52.2	15.1	9.0	13.67	54.00	23.95	75.56	15.16	0	40.1	26.4	6	7,638	1	200	4,037
887	10.0	64.8	115	54.6	14.0	9.5	44.21	32.31	14.59	39.77	4.899	0	44.7	24.8	6	6,679	1	260	382
883	11.8	72.4	90	60.4	16.1	10.6	22.84	31.47	13.42	54.15	14.10	0	44.2	23.1	6	7,798	1	296	858

(con.)

Table 13.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight, Branchwood (inches): 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Ft*	*Inches*	*Ft^3*		*Ft^2*	
									PONDEROSA PINE										
849	0	3.9	14	2.9	1.8	0.5	0.0044	0.0970	0.0375	0	0	0	0.68	3.9	1	2.21	1	22	1,565
884	0	4.2	23	2.1	2.3	.5	.0088	.0992	.0375	0	0	0	.18	4.2	1	4.36	1	59	1,874
851	0.2	4.7	33	3.3	2.5	1.2	.0397	.4321	.1146	0.2624	0	0	.72	4.7	2	7.31	1	46	1,500
852	.3	4.6	24	1.4	1.9	.6	.0088	.1477	.0441	.0617	0	0	.38	4.6	1	1.98	1	83	2,187
850	.4	5.3	33	3.1	3.0	.9	.1874	.1653	.0507	.0661	0	0	.63	5.3	2	6.00	1	64	1,015
814	.9	6.8	17	4.2	2.8	1.4	.0198	.8157	.2161	.4762	0	0	1.36	6.8	2	15.92	1	96	3,344
843	1.0	9.8	43	6.1	3.5	1.2	.1235	.4674	.1213	.2800	0	0	1.84	9.8	2	20.61	1	105	1,639
848	1.2	9.4	48	2.2	3.0	.6	.3417	.1565	.0463	.0661	0	0	1.68	9.4	2	7.78	1	198	1,445
813	1.5	9.3	11	7.5	2.4	1.9	.0110	.6217	.1631	.3638	0	0	2.22	9.3	2	21.87	3	54	1,810
846	1.8	14.6	51	3.2	3.3	.9	.8973	.3902	.0992	.2557	0	0	4.80	14.6	3	13.68	1	198	1,410
845	2.7	28.3	65	11.4	5.4	1.6	2.469	1.543	.3836	1.083	0	0	13.7	28.3	4	122.2	1	231	1,581
821	2.8	11.1	31	7.4	10.0	2.7	.5313	1.969	.3858	2.729	2.582	0	9.10	11.1	6	99.90	1	129	772
816	3.8	21.7	48	14.8	8.7	3.3	5.902	3.805	.6945	6.305	7.727	0	24.4	21.7	6	462.4	1	115	468
811	4.4	37.4	57	18.8	4.0	3.0	3.752	4.987	1.113	4.572	0	0	46.3	37.4	6	158.6	1	141	406
847	4.5	38.7	65	18.1	7.0	3.0	3.640	2.546	.5710	1.001	0	0	49.5	38.7	6	260.6	1	236	1,018
868	6.2	53.9	75	19.7	5.5	3.5	5.013	5.395	1.111	6.358	2.348	0	83.9	48.2	6	163.9	1	120	264
854	6.9	70.5	73	34.5	5.0	3.7	8.190	4.601	.8113	8.420	12.32	0	73.2	34.5	6	387.5	3	200	400
877	8.1	40.3	140	18.0	9.7	5.4	12.52	6.625	1.129	12.76	19.12	0	48.5	27.7	6	698.9	1	220	268
855	8.8	53.8	76	15.1	3.2	3.3	20.61	3.545	.5953	7.088	11.21	0	44.3	18.9	6	72.66	2	120	142
878	10.8	50.3	105	26.8	13.3	8.0	39.97	11.17	1.579	35.57	95.62	0	38.6	17.6	6	1,655	1	280	198
876	12.1	67.1	113	43.8	15.3	8.6	38.09	18.88	3.146	39.81	69.88	0	51.6	27.8	6	4,172	1	260	168

(con.)

Table 13.--(con.)

Tree No.	D.b.h.	Tree height	Age	Live crown length	Crown width	Dia. crown base	Dead branch weight	Foliage	Live crown weight: Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+	Bole tip weight	Bole tip length	Dia. tip base	Crown volume	Site index	Basal area/acre	Trees/acre
	Inches	*Ft*	*Yr*	*Ft*	*Ft*	*Inches*	*Lb*	- - - - - -	- - - - - -	*Lb*	- - - - - -	- - - - - -	*Lb*	*Ft*	*Inches*	*Ft*^{3}		*Ft*^{2}	
										WESTERN REDCEDAR									
820	0	4.0	26	2.1	2.7	0.7	0.0353	0.2822	0.0794	0.0838	0	0	0.36	4.0	1	6.38	1	70	3,065
831	0	3.7	24	3.0	3.7	.8	.0088	.3086	.0904	.0639	0	0	.21	3.7	1	13.09	1	45	1,898
836	0	4.2	16	3.7	5.4	.8	.0022	.2954	.0860	.0617	0	0	.20	4.2	1	17.63	2	201	1,176
839	0	4.3	24	2.9	6.3	.8	.0309	.3946	.1124	.1124	0	0	.36	4.3	1	27.24	1	124	1,535
809	0.1	5.2	55	3.0	4.8	1.0	.0617	.5467	.1609	.1036	0	0	.78	5.2	2	18.61	1	68	3,110
824	.3	4.7	26	2.5	4.3	.7	.1631	.3461	.1014	.0705	0	0	.56	4.7	2	10.50	1	98	1,723
826	.5	5.8	50	3.3	4.5	.8	.0331	.3329	.0926	.1058	0	0	.57	5.8	2	17.82	1	156	3,611
837	.6	8.0	21	6.1	4.0	1.1	.0419	.6658	.1874	.1984	0	0	.84	8.0	2	21.77	2	140	2,569
818	.7	6.2	37	3.4	4.3	1.0	.0617	.7716	.2183	.2138	0	0	1.09	6.2	2	25.24	1	118	2,187
819	1.3	10.4	40	7.4	5.1	1.8	.0287	2.313	.6327	.8378	0	0	3.00	10.4	3	83.30	1	61	1,962
808	1.4	10.3	43	8.4	5.3	2.0	.2116	2.136	.5776	.8223	0	0	3.02	10.3	3	83.05	1	144	3,516
817	3.5	20.1	64	11.7	8.0	3.0	1.424	5.959	1.552	2.822	0	0	17.3	20.1	6	309.7	1	157	2,418
823	3.7	23.3	70	13.1	11.1	3.0	2.260	6.592	1.676	3.644	0	0	22.3	23.3	6	483.1	1	179	3,526
862	4.0	22.0	57	16.6	13.0	4.0	1.369	11.45	2.961	5.681	0	0	19.1	22.0	6	1,220	1	225	1,569
830	4.8	29.0	58	13.0	5.8	3.3	3.360	11.03	2.703	7.553	1.210	0	44.4	29.0	6	225.7	1	166	2,968
874	6.0	43.7	71	27.2	13.7	5.1	5.827	22.15	5.417	15.43	2.511	0	69.0	38.5	6	2,495	1	335	2,441
859	6.6	43.5	72	20.9	14.5	4.9	9.387	20.71	4.967	16.03	5.465	0	34.9	32.8	6	1,321	2	215	719
864	8.3	55.0	77	24.6	14.7	6.5	20.20	38.83	9.198	32.19	13.15	0	28.8	21.7	6	2,233	1	260	289
880	8.6	51.7	162	27.5	18.3	6.2	5.816	25.75	6.069	22.13	12.91	0	47.0	25.7	6	3,704	1	221	768
875	10.3	51.8	74	37.8	19.8	8.9	9.330	56.50	13.13	53.04	74.62	0	26.9	19.9	6	4,708	1	180	594
879	10.4	52.9	110	41.5	12.3	8.4	9.456	27.26	6.444	22.93	13.53	0	49.8	22.0	6	5,958	1	300	169
865	10.6	64.3	70	39.9	22.4	8.2	17.82	61.29	14.28	55.69	36.07	0	28.8	22.7	6	7,764	2	240	332

Table 14.--*Distribution of sample trees by d.b.h. from data by Fahnestock (1960) and Storey and others (1955)*

D.b.h. (inches)	Species								
	GF	L	S	LP	WP	C	PP	DF	WH
2- 5.9	1	2	3	2	1	1	1	1	1
6- 9.9	1	1	2	6	2	2	1	3	1
10-13.9		6	2	29	10	6		3	5
14-17.9	5	11	2	4	11	5	3	11	1
18-21.9	6	11	3		5	1	7	5	3
22-25.9	3	2	6		1		1		2
26-29.9		1	2						1
30-33.9						1			1
34-37.9	1	2				1			
38-43.9	1				2				
Total	18	36	20	41	32	17	13	23	15

APPENDIX III

Foliage and Branchwood Proportions

Table 15.--*Foliage and branchwood proportions for crowns of trees 1 inch and less in d.b.h.*

Crown	Species	Foliage	Branchwood 0 to 0.25	Branchwood 0.25 to 1
Live Dominants	S, AF, C, GF, WH	0.62	0.26	0.12
	DF, WP, LP, WBP	.52	.27	.21
	PP	.57	.14	.29
	L	.40	.42	.18
Live Intermediates	DF, GF	.55	.39	.06
	PP, C	.63	.20	.17
Dead Intermediates	DF, GF, PP, C		.94	.06

Table 16.--*Accumulative proportions of foliage and branchwood by size classes for live crowns of dominants greater than 1 inch d.b.h.*

Species	Function	R^2	Conditions
GF	P1 = 1/(1.592 + 0.0529d)	0.94	If d >36.0 in, P1 = 0.286, P2 = 0.378, P3 = 0.488
	P2 = 1/(1.150 + 0.0416d)	.96	
	P3 = 1.027 - 0.0150d)	.94	If d ≤2.9 in, P3 = 1.0
L	P1 = 0.347 EXP(-0.0434d)	.93	
	P2 = 0.745 EXP(-0.0362d)	.93	
	P3 = 1.054 EXP(-0.0213d)	.91	If d ≤2.9 in, P3 = 1.0
	P4 = 0.922 + 0.720/d	.07	If d ≤11.0 in, P4 = 1.0
S	P1 = 0.578 EXP(-0.0325d)	.97	If d >40.0 in, P1 = 0.158, P2 = 0.277, P3 = 0.423
	P2 = 0.852 EXP(-0.0281d)	.97	
	P3 = 1.038 - 0.0154d	.95	If d ≤2.9 in, P3 = 1.0
AF	P1 = 0.597 EXP(-0.0425d)	.74	
	P2 = 0.864 EXP(-0.0373d)	.72	
	P3 = 1.022 - 0.0108d	.50	If d ≤2.9 in, P3 = 1.0
LP	P1 = 0.493 - 0.0117d	.76	
	P2 = 0.777 - 0.0146d	.70	
	P3 = 1.049 - 0.0140d	.55	If d ≤3.9 in, P3 = 1.0
WP	P1 = 0.550 EXP(-0.0345d)	.95	
	P2 = 0.914 - 0.0978$\sqrt{d}$	.91	
	P3 = 1.056 EXP(-0.0181d)	.87	If d ≤3.9 in, P3 = 1.0
WBP	P1 = 0.512 EXP(-0.0374d)	.62	If d >20 in, P1 = 0.242, P2 = 0.268, P3 = 0.669
	P2 = 0.864 EXP(-0.0585d)	.75	
	P3 = 1.077 EXP(-0.0238d)	.53	If d ≤3.9 in, P3 = 1.0
C	P1 = 0.617 EXP(-0.0233d)	.98	
	P2 = 0.756 EXP(-0.0241d)	.98	
	P3 = 1.060 EXP(-0.0223d)	.98	If d ≤2.9 in, P3 = 1.0
PP	P1 = 0.558 EXP(-0.0475d)	.89	If d ≤31 in, P2 = P1 + 0.01
	P2 = 0.625 EXP(-0.0511d)	.89	
	P3 = 0.985 EXP(-0.0310d)	.85	If d ≤1.0 in, P3 = 1.0
	P4 = 1.083 - 0.0131d	.70	If d ≤6.5 in, P4 = 1.0
DF	P1 = 0.484 EXP(-0.0210d)	.95	If d >36.0 in, P1 = 0.227, P2 = 0.315, P3 = 0.465
	P2 = 0.729 EXP(-0.0233d)	.95	
	P3 = 1.034 - 0.0158d	.95	If d ≤2.9 in, P3 = 1.0
	P4 = 1.022 - 0.00182d	.43	If d ≤14.0 in, P4 = 1.0
WH	P1 = 0.547 EXP(-0.0370d)	.96	If d >40.0 in, P1 = 0.125, P2 = 0.183, P3 = 0.361
	P2 = 0.835 EXP(-0.0380d)	.97	
	P3 = 1.0781 EXP(-0.0274d)	.94	If d ≤2.9 in, P3 = 1.0

Table 17.--*Accumulative proportions of foliage and branchwood by size classes for live crowns of intermediates greater than 1 inch d.b.h.*

Species	Function	R^2	Conditions
C	P1 = 0.667 EXP(-0.0608d)	0.93	
	P2 = 0.857 EXP(-0.0653d)	.94	
	P3 = 1.031 EXP(-0.0270d)	.73	If d $\leq$1.0, P3 = 1.0
GF	P1 = 0.571 EXP(-0.0544d)	.93	
	P2 = 0.929 EXP(-0.0678d)	.93	
	P3 = 1.016 EXP(-0.0098d)	.59	If d $\leq$1.0, P3 = 1.0
DF	P1 = 0.514 EXP(-0.0552d)	.74	
	P2 = 0.886 EXP(-0.0610d)	.75	
	P3 = 1.0067 EXP(-0.0131d)	.38	If d $\leq$1.0, P3 = 1.0
PP	P1 = 0.650 EXP(-0.154d)	.79	
	P2 = 0.844 EXP(-0.166d)	.80	
	P3 = 1.086 EXP(-0.0833d)	.75	If d $\leq$1.0, P3 = 1.0

Table 18.--*Accumulative proportions of branchwood by size classes for dead crowns of dominants and intermediates greater than 1 inch d.b.h.*

Species	Function	R^2	Conditions
		DOMINANTS	
GF	P1 = 1.434 EXP(-0.182d)	0.77	If d <3.0 in, P1 = 1.0
	P2 = 1.262 EXP(-0.0347d)	.17	If d >27.0 in, P1 = 0.01
			If d <8.0 in, P2 = 1.0
DF	P1 = 0.0836 + (1.589/d)	.81	If d <1.8 in, P1 = 1.0
	P2 = 1.567 EXP(-0.0523d)	.56	If d <9.0 in, P2 = 1.0
S	P1 = $1.466d^{(-0.645)}$	.77	If d <1.8 in, P1 = 1.0
	P2 = 1/(0.847 + 0.0168d)	.34	If d <10.0 in, P2 = 1.0
AF	P1 = $1.210d^{(-0.565)}$	.62	If d <1.5 in, P1 = 1.0
LP	P1 = $1.353d^{(-0.758)}$	.95	If d >20.0 in, P1 = 0.139
	P2 = 2.798 EXP(-0.126d)	.77	If d >20.0 in, P2 = 0.226
			If d <9.0 in, P2 = 1.0
			If d <1.5 in, P1 = 1.0
WP	P1 = $1.0077d^{(-0.456)}$	.49	
	P2 = 1.029 - 0.00496d	.12	If d <7.0 in, P2 = 1.0
C	P1 = -0.0158 + (1.467/d)	.87	If d <1.5 in, P1 = 1.0
	P2 = 1.453 EXP(-0.0540d)	.66	If d <8.0 in, P2 = 1.0
PP	P1 = 1.411/d - 0.0434	.60	If d >30.0 in, P1 = 0.004
	P2 = 1.062 - 0.0334d	.69	If d >30.0 in, P2 = 0.06
WH	P1 = 1.961 EXP(-0.206d)	.79	If d <4.0 in, P1 = 1.0
	P2 = 1.0/(0.277 + 0.0614d)	.24	If d >28.0 in, P1 = 0.005
			If d <12.0 in, P2 = 1.0
		INTERMEDIATES	
C	P1 = $0.361d^{(-0.835)}$	.60	
GF	P1 = $1.549d^{(-1.089)}$	.81	If d $\le$1.5, P1 = 1.0
			If d $\ge$10.5, P2 = 0.88, P3 = 1.0
DF	P1 = 0.0790 + 1.248/d	.46	If d $\le$1.4, P1 = 1.0
			If d $\ge$1.4, P2 = 1.0
PP	P1 = $0.513d^{(-1.079)}$	.46	If d $\le$3.4, P2 = 1.0
	P2 = 1/0.379 + 0.180d	.65	If d $\ge$3.4, P3 = 1.0

Table 19.--*Accumulative proportions of foliage and branchwood by size class for entire trees less than 15 feet in height*[1/]

Species[2/]	Height (feet)	No. sample trees	Foliage	Branchwood (inches) 0 to 0.25	0.25 to 1	1 to 3	3+
			DOMINANTS				
C, GF, S, AF	0- 4.9	17	0.51	0.72	0.95	1.00	
	5- 9.9	26	.40	.56	.73	.99	1.00
	10-14.9	11	.33	.45	.63	.92	1.00
WP	0- 4.9	4	.48	.69	.99	1.00	
	5- 9.9	8	.31	.47	.65	1.00	
	10-14.9	5	.25	.37	.52	.89	1.00
DF, PP, LP, H	0- 4.9	16	.38	.56	.94	1.00	
	5- 9.9	23	.31	.45	.68	1.00	
	10-14.9	14	.27	.38	.57	.87	1.00
L, WBP	0- 4.9	9	.26	.49	.87	1.00	
	5- 9.9	7	.21	.40	.66	1.00	
	10-14.9	8	.15	.29	.45	.89	1.00
			INTERMEDIATES				
C, GF	0- 4.9	10	.38	.56	.96	1.00	
	5- 9.9	9	.32	.47	.76	1.00	
	10-14.9	3	.41	.55	.71	1.00	
DF	0- 4.9	4	.34	.59	1.00		
	5- 9.9	4	.23	.40	.67	1.00	
	10-14.9	1	.25	.42	.58	1.00	
PP	0- 4.9	4	.24	.32	.91	1.00	
	5- 9.9	5	.18	.23	.51	1.00	
	10-14.9	2	.16	.19	.43	.99	1.00

[1/] Coefficients of variation averaged over the foliage and branchwood categories of all species groups were 16, 17, and 25 percent for the 0- to 4.9-foot, 5- to 9.9-foot, and 10- to 14.9-foot height classes, respectively.

[2/] Fractions for individual species are within 20 percent of the group average.

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