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Diameter and Height Growth of Suppressed Grand Fir Saplings After Overstory Removal

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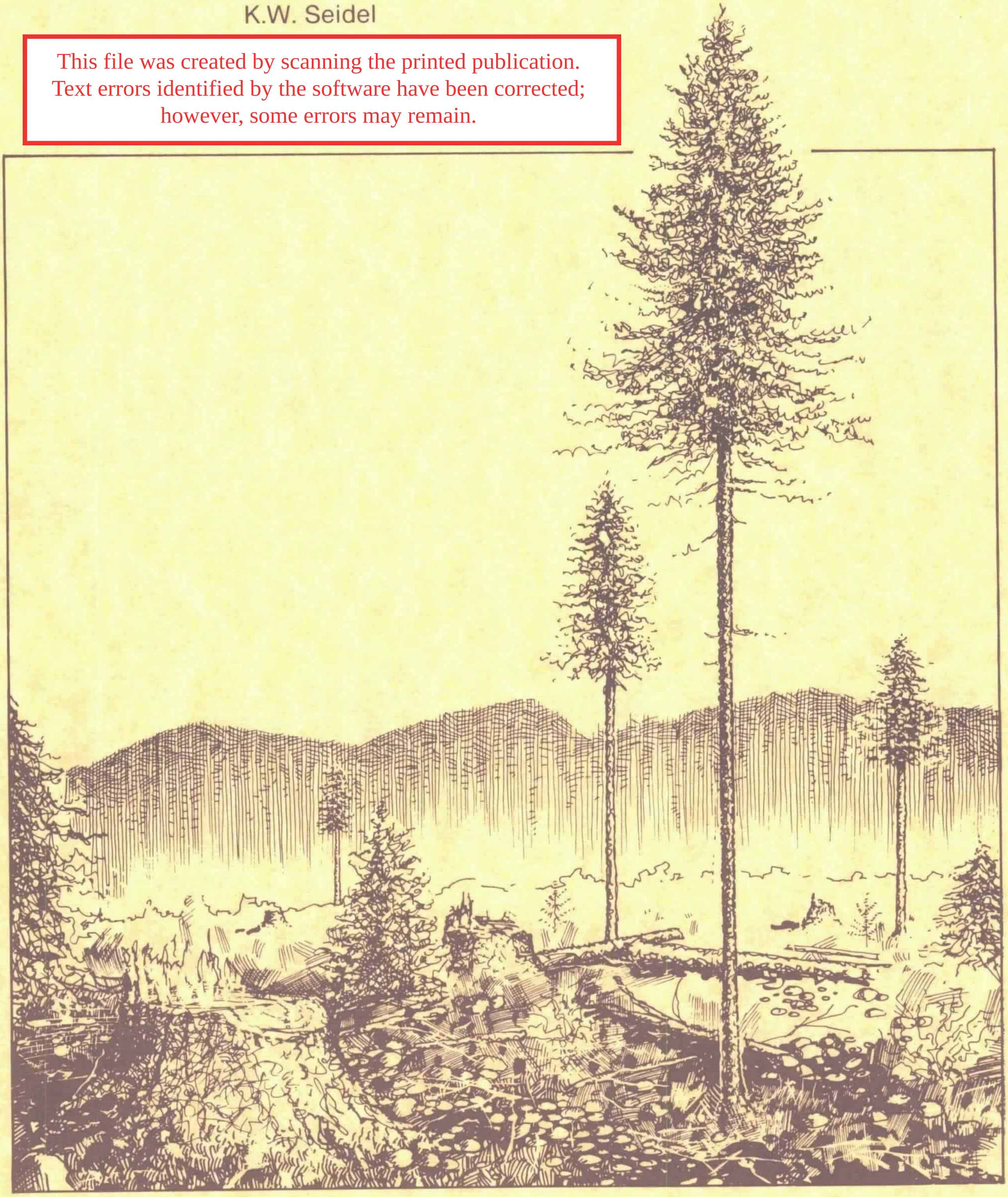

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Diameter and Height Growth of Suppressed Grand Fir Saplings After Overstory Removal

Reference Abstract

Seidel, K. W.
1980. Diameter and height growth of suppressed grand fir saplings after overstory removal. USDA For. Serv. Res. Pap. PNW-275, 9 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

The 2- and 5-year diameter and height growth of suppressed grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.) advance reproduction was measured in central Oregon after the overstory was removed. Multiple regression analyses were used to predict growth response as a function of individual tree variables. The resulting equations, although highly significant, explained only 17 to 44 percent of the variation in growth. Live crown ratio gave the best single variable correlation for both diameter and height growth. Height growth after release was similar to growth before release. Only vigorous advance reproduction having live crown ratios of 50 percent or more should be considered as potential crop trees.

KEYWORDS: Increment (height), increment (diameter), advance growth, release, grand fir, *Abies grandis*.

Research Summary

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In 1974, a study was begun to obtain information about the growth response of suppressed grand fir (Abies grandis (Dougl. ex D. Don) Lindl.) saplings after release by removal of the overstory. The purpose was to compare height growth before and after release, to compare diameter and height growth for several periods after release, and to develop an equation to predict diameter and height growth after release as a function of variables, such as live crown ratio, and initial height.

The study area is in an Abies grandis/ Linnaea borealis plant community in the Ochoco National Forest, central Oregon. Before logging, there was a three-storied stand structure consisting of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), grand fir, western larch (Larix occidentalis Nutt.), ponderosa pine (Pinus ponderosa Dougl. ex Laws.), and lodgepole pine (Pinus contorta var. latifolia Engelm.), averaging about 200 square feet of basal area per acre. After the overstory was removed, 115 grand fir saplings were selected for the study to include a wide range of vigor classes based on live crown.

Both diameter and height growth increased significantly during the last 3-year period after release compared with the first 2-year period. Height growth did not respond to release compared with growth before release. Live crown ratio gave the best single variable correlation for both diameter and height growth; height growth before release also was a significant variable. The prediction equations accounted for only 17 to 44 percent of the variation in growth.

The best potential crop trees are vigorous advance reproduction having live crown ratios greater than 50 percent and those with the greatest height growth before release.

Introduction

Many mixed conifer stands in the forests of eastern Oregon are two layered, consisting of a mature or overmature overstory and a well-stocked understory of true fir saplings and poles. If sufficient trees of the desired species remain after the overstory is removed and if they will respond to release, the use of advance reproduction for the new stand is better than relying on the uncertainties of obtaining new regeneration.

Suppressed advance reproduction of true firs will respond to release by increased diameter and height growth if the trees have relatively full crowns (Gordon 1973, Crossley 1976, Seidel 1977). In 1974, a study was begun to learn more about the growth response that can be expected from various classes of suppressed fir saplings. The purpose of this study was to: (1) compare height growth before and after release, (2) compare rate of diameter and height growth for several periods after release, (3) screen specific variables for potential inclusion in a model for predicting diameter and height growth, and (4) estimate the coefficients for these prediction equations and provide some index of their reliability.

Study Area

The study area is in the Big Summit District of the Ochoco National Forest about 40 miles[1] northeast of Prineville, Oregon, at an elevation of about 5,600 feet. The soil is a well-drained Regosol developed in dacite pumicite originating from the eruption of Mount Mazama (Crater Lake) 6,500 years ago. The ash layer has a fine sandy loam texture and is about 3 feet deep over the residual silty clay loam soil.

Before the overstory was logged, the timber stand consisted of a mixture of grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western larch (*Larix occidentalis* Nutt.), and a few scattered ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.). A three-storied stand structure existed before logging; it consisted of overmature old growth, smaller sawtimber, and advance reproduction averaging about 30,000 gross board feet (Scribner rule) per acre and 200 square feet of basal area per acre. After the overstory was removed only advance reproduction consisting of seedlings, saplings, and poles no larger than 6 inches in diameter at breast height (d.b.h.) remained.

The study area is located in an *Abies grandis*/*Linnaea borealis* plant community (Hall 1973). Ground vegetation is composed of genera, such as *Bromus*, *Rosa*, *Arnica*, *Mitella*, *Anenome*, and *Ribes*. Site index of grand fir in the area based on Schumacher's (1926) curves indicates a height of 50 feet at age 50, whereas Cochran's (1979) curves show 45 feet on a 50-year base.

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[1]Metric equivalents are given in the appendix.

Methods

The overstory was logged in 1974, and 115 grand fir saplings were selected in the 40-acre cutting unit. These study trees included a wide range of vigor classes from fully crowned trees to those with a relatively small crown; the trees were free from logging damage and infections of dwarf mistletoe. Trees were selected in an unordered sequence until specific crown classes were adequately sampled. Study trees were located on level ground and on slopes up to 33 percent. All aspects except south were sampled; only one tree was located on a southeast aspect, and three trees were on a slope facing southwest. Most sample trees were on the north, northwest, and west aspects. Height of the sample trees ranged from 2.9 to 12.2 feet (mean 6.8 feet), and diameter measured at 1 foot above the ground ranged from 0.55 inch to 2.9 inches (mean 1.4 inches). All trees within a 10-foot radius of each sample tree were cut to minimize the effect of competition from adjacent trees.

In the fall of 1974, 1976, and 1979 measurements taken on each sample tree were:

1. Stem diameter at ground level, 1 foot above the ground and one-half way up the bole to nearest 0.05 inch.
2. Double bark thickness at each diameter measurement point to nearest 0.05 inch.
3. Total height to nearest 0.1 foot.
4. Height growth during the past year, past 2 years, and past 5 years to nearest 0.1 foot.
5. Height to base of live crown to nearest 0.1 foot.
6. Average crown diameter at base of live crown to nearest 0.1 foot.

From these measurements, the variables--live crown ratio, crown volume, crown surface area, and bole area--of each tree were computed. In addition, several other ratios derived from the measured variables were calculated for use in the analyses.[2] Aspect and slope percentage were also measured for each tree.[3] Stepwise multiple regression procedures were then used to fit linear equations of the form $Y = b_0 + b_1 X_1 + b_2 X_2 + \ldots b_n X_n$ to the data and to determine the equations of best fit. Four separate analyses were performed using Y_1 = 2-year and 5-year diameter growth in inches and Y_2 = 2-year and 5-year height growth in feet. Values of Y_1 and Y_2 were subjected to a $\sqrt{Y + 1/2}$ transformation to reduce the heterogeneity of variance. Paired _t_ tests were used to test differences between 2- and 5-year postrelease and prerelease growth rates and differences between annual growth rates for the first 2 years and final 3 years of the 5-year period after release.

[2]See the appendix for independent variables and formulas used to calculate crown volume, crown surface area, and bole area.

[3]Aspect was coded by the method proposed by Day and Monk (1974), in which the following values were assigned to compass directions: N, 14; NE, 15; E, 11; SE, 7; S, 3; SW, 2; W, 6; NW, 10.

Results

Diameter Growth

During the 5 years after the overstory was removed, annual growth (1 foot above the ground) averaged 0.13 inch (table 1). Diameter growth rate increased significantly ($P < 0.01$)--more than threefold--from 0.05 inch per year the first 2 years of the period to 0.18 inch per year the last 3 years. Growth of individual trees ranged from 0 to 2.1 inches during the 5-year period.

Reliable equations for predicting diameter growth could not be developed because of the small amount of variation accounted for by the independent variables (table 2), although all variables were significant ($P < 0.01$). The best single variable equation involved live crown ratio and explained 30 percent of the variation in diameter growth during the first 2 years and 23 percent for the entire 5-year period. The addition of height growth for the 1st and 2d years before logging raised the explained variation to 44.1 percent (2-year growth), but the addition of crown diameter and 1-year height growth before release only increased the explained variation to 30 percent (5-year growth).

Although none of the variables can be used to reliably predict diameter growth, vigorous trees (as indicated by live crown ratio) are more likely to grow faster than trees of poor vigor. For example, average annual diameter growth rate on trees with live crown ratios greater than 50 percent was about twice that of trees having live crown ratios less than 50 percent for both 2- and 5-year periods (table 1). These differences were significant ($P < 0.01$).

Table 1--Periodic annual height growth before release and annual diameter and height growth of suppressed grand fir saplings after release

Tree vigor class	Number of trees	Before release		After release					
		1973-74	1970-74	1975-76		1977-79		1975-79	
		Height growth	Height growth	Diameter growth	Height growth	Diameter growth	Height growth	Diameter growth	Height growth
		Feet[2/]	Feet[2/]	Inches[2/]	Feet[2/]	Inches[2/]	Feet[2/]	Inches	Feet[2/]
All trees	107	0.14 ± 0.01	0.21 ± 0.01	0.05 ± 0.005	0.15 ± 0.01	0.18 ± 0.01	0.20 ± 0.02	0.13 ± 0.01	0.18 ± 0.01
Trees with live crown ratio less than 50 percent	36	.09 ± .01	.12 ± .01	.03 ± .01	.09 ± .01	.12 ± .01	.17 ± .03	.08 ± .01	.14 ± .02
Trees with live crown ratio more than 50 percent	71	.17 ± .01	.24 ± .02	.06 ± .01	.18 ± .01	.20 ± .01	.21 ± .02	.15 ± .01	.20 ± .02

1/Measured at 1 foot above the ground.

2/Mean ± standard error.

Table 2--Relationship of independent variables to 2-year and 5-year diameter growth of suppressed grand fir saplings

Independent variables[1]	Equation	Percent of variation explained,[3] R^2	Standard error of estimate,[3] $Sy \cdot x$
			Feet
	2-YEAR DIAMETER GROWTH		
LCR	y[2] = 0.6681 + 0.0019 (LCR)	30.0**	0.05
LCR, HG2	y = 0.6775 + 0.0014 (LCR) + 0.0692 (HG2)	35.1**	.05
LCR, HG2, HG1	y = 0.6759 + 0.0015 (LCR) + 0.1580 (HG2) - 0.3084 (HG1)	44.1**	.05
	5-YEAR DIAMETER GROWTH		
LCR	y = 0.7851 + 0.0048 (LCR)	23.0**	.15
LCR, CD	y = 0.6869 + 0.0044 (LCR) + 0.0300 (CD)	27.4**	.15
LCR, CD, HGI	y = 0.6753 + 0.0052 (LCR) + 0.0300 (CD) - 0.3087 (HG1)	29.6**	.15

1/ LCR = live crown ratio (percent); HG2 = height growth 2 years before release (feet); HG1 = height growth 1 year before release (feet); CD = crown diameter (feet).

2/ $y = \sqrt{\text{Diameter growth in inches} + 0.5}$.

3/ Of transformed data.

**Significant at the 1-percent level.

Height Growth

The average annual height growth was 0.18 foot during the 5 years after release (table 1), and total growth of individual trees ranged from 0.2 foot to 3.9 feet. The rate of height growth increased significantly ($P < 0.01$) from 0.15 foot per year the first 2 years after release to 0.20 foot per year the last 3 years.

Height growth did not respond to release compared with equal periods before release. The average annual growth during the first 2-year period before release increased by a nonsignificant 7.1 percent after release--from 0.14 to 0.15 foot. For the entire 5 years after release, height growth decreased significantly ($P < 0.05$) by 14.3 percent (from 0.21 to 0.18 foot), compared with growth 5 years before logging (table 1).

The amount of variation in height growth explained by the regression equations and the independent variables involved are similar to the diameter growth relations; all variables were significant. Live crown ratio again was the best single variable during the first 2-year period, explaining 30 percent of the variation in height growth (table 3). Adding height growth for the 1st and 2d years before release increased the R^2 to 44.2 percent. Only 23 percent of the variation in 5-year height growth after release was explained by the three variables--height growth 5 years before logging, live crown ratio, and crown volume/diameter ratio.

The average height growth rate of more vigorous trees (live crown ratio greater than 50 percent) was twice that of trees with live crown ratios less than 50 percent in the first 2-year period and about 43 percent greater for the entire 5 years (table 1). These differences were significant ($P < 0.01$).

Damage and Mortality

Of the 115 study trees, 0.9 percent died the first 2 years after the overstory was removed, and 6 percent died in the following 3 years. Five trees had yellowish-brown, chlorotic-appearing needles on a portion of the crown, and the terminal bud of three trees had aborted. There was also evidence of damage to some trees from porcupines and pocket gophers.

Table 3--Relationship of independent variables to 2-year and 5-year height growth of suppressed grand fir saplings

Independent variables[1]	Equation	Percent of variation explained,[3] R^2	Standard error of estimate,[3] $Sy{\cdot}x$
			Feet
	2-YEAR HEIGHT GROWTH		
LCR	y[2] = 0.7089 + 0.0033 (LCR)	30.0**	0.09
LCR, HG2	y = 0.7332 + 0.0019 (LCR) + 0.1793 (HG2)	41.4**	.08
LCR, HG2, HG1	y = 0.7317 + 0.0021 (LCR) + 0.2652 (HG2) - 0.2983 (HG1)	44.2**	.08
	5-YEAR HEIGHT GROWTH		
LCR	y = 0.8103 + 0.0062 (LCR)	17.5**	.23
LCR, HG5	y = 0.8514 + 0.0037 (LCR) + 0.0931 (HG5)	20.8**	.23
LCR, HG5, CV/CD	y = 0.8297 + 0.0049 (LCR) + 0.1048 (HG5) - 0.0116 (CV/CD)	22.7**	.22

[1]LCR = live crown ratio (percent); HG2 = height growth 2 years before release (feet); HG1 = height growth 1 year before release (feet); HG5 = height growth 5 years before release (feet); CV/CD = crown volume (cubic feet)/crown diameter (feet).

[2]$y = \sqrt{\text{Height growth in feet} + 0.5}$.

[3]Of transformed data.

**Significant at the 1-percent level.

Discussion

Although a reliable growth prediction equation could not be developed from the data, it is obvious that vigorous advance reproduction with full crowns (fig. 1) have a better chance of responding rapidly after overstory removal than do trees with smaller crowns (fig. 2). For example, only 16 percent of trees in this study with live crown ratios of less than 50 percent grew 1.0 foot or more in height in the 5-year period, but 47 percent of trees with live crown ratios greater than 50 percent grew at this rate.

Figure 1.--A vigorous, full-crowned tree. In 1974, the live crown ratio was 78 percent. During the 5 years after release, the tree grew 2.3 feet in height and 1.35 inches in diameter (measured 1 foot above the ground).

Figure 2.--A tree of low-vigor and small crown. In 1974, the live crown ratio was 34 percent. During the 5 years after release, the tree grew 0.3 foot in height and 0.15 inch in diameter (measured 1 foot above the ground).

Generally, the height growth of these trees was unchanged by release. Trees growing slowly before release usually grew slowly after release, whereas faster growing trees continued to grow at a faster rate similar to the response of grand fir in northern Idaho (Ferguson and Adams 1979). The lack of immediate response in height growth is similar to that for true firs in northern California, where no height growth response occurred until the 5th year after removal of the overstory (Gordon 1973). On the other hand, Seidel (1977) found an immediate height growth response of vigorous true fir in central Oregon. Apparently, the growth response of suppressed true fir saplings varies from place to place. Differences in response after release may be related to the degree of suppression provided by the overstory. A more rapid response might be expected of less severely suppressed true fir advance reproduction growing under a seral western larch or lodgepole pine overstory than of regeneration growing under a dense overstory of grand fir or Douglas-fir.

I had thought the variables crown volume and surface area and various ratios using these variables would explain a considerable amount of the variation in growth. This was not the case, however. It may be that the equations used to calculate these crown parameters are too crude to accurately describe the photosynthetic area of the tree.

Although height growth increased somewhat during the last 3 years compared with the first 2 years after release, the average growth rate was slow (about 0.2 foot per year). One factor in decisions concerning use of advance reproduction or planted stock is their potential rate of height growth. Slow growth of the advance true fir reproduction would favor planting of fast growing species, such as Douglas-fir or western larch. In areas where problems with pocket gophers or porcupines make establishment of seedlings difficult, however, retaining vigorous advance reproduction may be desirable even if a height growth comparison favors planted seedlings. It appears that only saplings having a live crown ratio of at least 50 percent should be considered as potential crop trees. Desirable crop trees are those with relatively full crowns and the greatest height growth before release.

Even after careful overstory removal and slash disposal, advance reproduction may be clumpy, requiring planting between clumps, along skid trails, and in landings.

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Appendix

A. Metric equivalents.

1 mile = 1.61 kilometers
1 foot = 0.3048 meter
1 inch = 2.54 centimeters
1 square foot per acre = 0.2296 square meter per hectare

B. Crown volume, crown surface area, and bole area equations.

1. Crown volume.
Crown volume was calculated as the volume of a cone for trees with a maximum crown diameter at the base of the crown.

$$\text{Crown volume} = \frac{\pi r^2 h}{3} = 1.0472\ r^2 h;$$

where r = crown radius at base, and h = crown length. For trees where the maximum crown diameter did not occur at the base of the crown, the volume of a cone frustum was added to the cone volume.

$$\text{Frustum volume} = \frac{\pi h_1}{3} (r_1^2 + r_1 r_2 + r_2^2);$$

where r_1 = radius at base of crown, r_2 = radius at maximum crown width, and h_1 = length from base of crown to point of maximum crown width.

2. Crown surface area.
Crown surface area was calculated as the surface area of a cone for trees with the maximum crown diameter at the base of the crown.

$$\text{Crown surface area} = \pi r \sqrt{r^2 + h^2}\ ;$$

where r = crown radius at base, and h = crown length.

For trees where the maximum crown diameter did not occur at the base of the crown, the surface area of a cone frustum was added to the cone surface area.

$$\text{Frustum surface area} = \pi (r_1 + r_2) \sqrt{h_1^2 + (r_1 - r_2)^2}\ ;$$

where r_1 = radius at base of crown, r_2 = radius at maximum crown width, and h_1 = length from base of crown to point of maximum crown width.

3. Bole area.
Bole area of each segment of the stem was calculated as:

$$\text{Bole area} = \frac{\pi h(d_1 + d_2)}{24.0}\ ;$$

where d_1 = diameter of large end of segment, d_2 = diameter of small end of segment, and h = length of segment.

C. Independent variables used in regression analyses.

X_1 Stem diameter 1 foot above the ground
X_2 Total height
X_3 Height growth in the past year (before release)
X_4 Height growth in the past 2 years (before release)
X_5 Height growth in the past 5 years (before release)
X_6 Live crown ratio (crown length/total height)
X_7 Crown volume
X_8 Crown surface area
X_9 Bole area
X_{10} Crown volume/bole area
X_{11} Crown surface area/bole area
X_{12} Aspect
X_{13} Slope
X_{14} Crown diameter
X_{15} Crown length
X_{16} Height to live crown
X_{17} Crown volume/height to live crown
X_{18} Crown surface area/height to live crown
X_{19} Crown volume/crown diameter
X_{20} Crown surface area/crown diameter
X_{21} Crown volume/crown length
X_{22} Crown surface area/crown length

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