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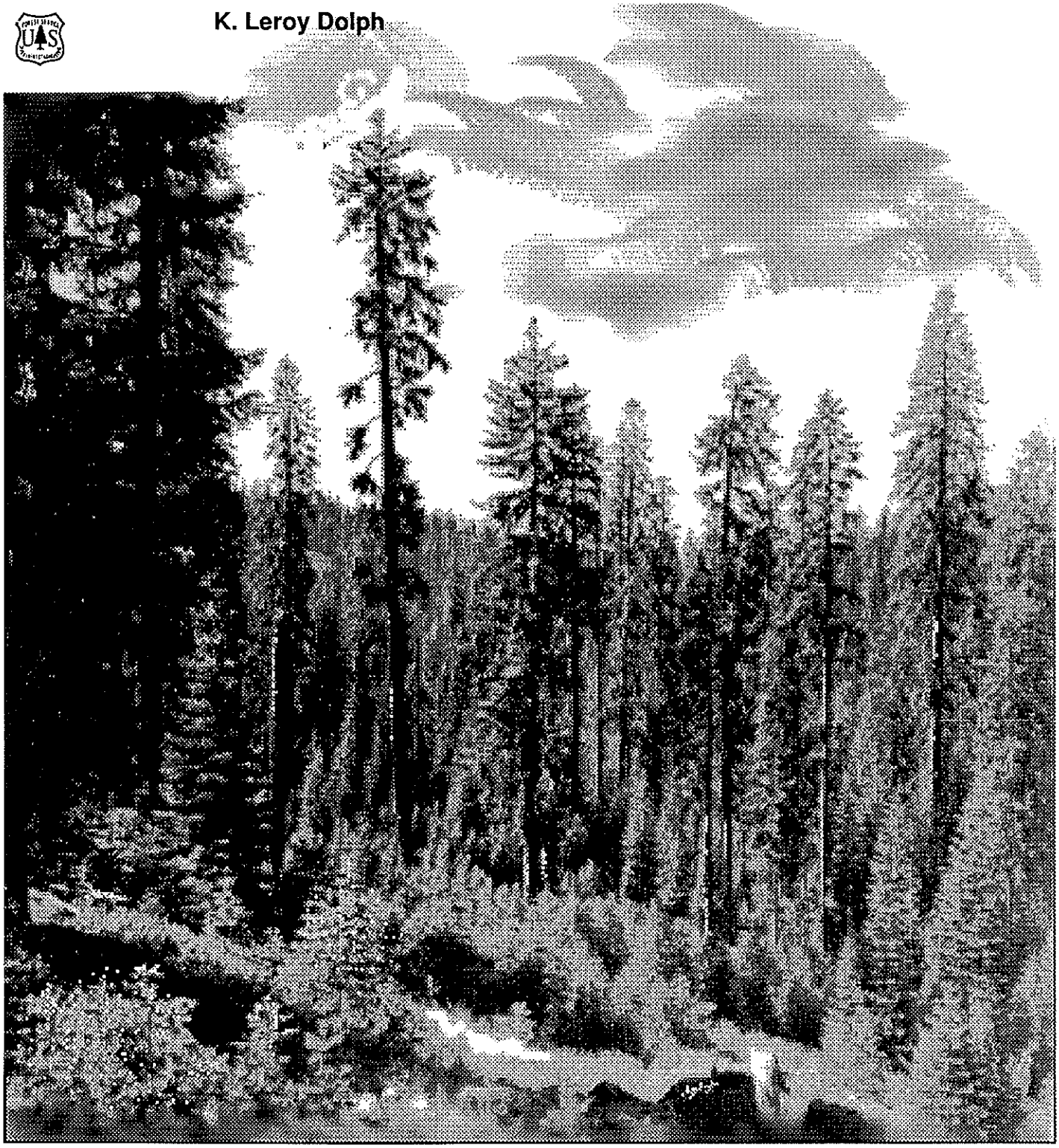
Polymorphic Site Index Curves for Red Fir in California and Southern Oregon

K. Leroy Dolph



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Polymorphic site index curves were developed from stem analysis data of 194 dominant red fir trees in California and southern Oregon. Site index was based on breast-height age and total tree height, with a base age of 50 years at breast height. Site index curves for breast-height ages 10 to 160 years are presented for approximate estimates of site index. For more precise estimates, tabular values of total tree height as a function of breast-height age and site index are given. Guidelines for selection of site trees and application of the site curves are discussed.

Retrieval Terms: site index, stem analysis, increment (height), red fir, *Abies magnifica*, California, Oregon

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IN BRIEF . . .

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Site index provides estimates of relative site potentials for a given species by relating tree height to age and is a proven and practical means of estimating relative potential productivity of forested land areas.

Polymorphic site index curves were developed from stem analyses of one dominant red fir tree on each of 194 sample plots. In addition to being from the dominant crown class, each suitable site tree showed no evidence of past suppression, no visible insect or disease damage, and no damage to the bole or top that would affect height growth. A modified Weibull height-growth equation, which expressed total tree height as a function of breast-height age and site index, was fit to the stem analysis data. Height estimates obtained from this equation were used to calculate curves for site indices 20 to 110 feet for breast-height ages 10 to 160 years. These height estimates are also presented in tabular form for making precise site index estimates when breast-height age and total tree height are known. Site index reference age is 50 years at breast height.

The curves and tabular data can be used for estimating relative site quality for red fir within its natural range in California and southern Oregon. Because the curves were based on one undamaged dominant site tree on an approximately one-third-acre plot, about three undamaged dominant site trees per acre should also be selected when the site index of an area is estimated.

INTRODUCTION

Schumacher (1928) has long been the standard source for estimating site indices for red fir. His curves were developed by measuring many stands at a single point in time, fitting an average curve (height as a function of age) to these data, and constructing a series of higher and lower curves with the same shape as the guide curve. The shape of these curves is anamorphic, that is, they do not vary from site to site. Two major problems have been found with curves constructed in this manner (Beck 1971). First, the guide curve is accurate only if the ranges of site indices are equally represented at all ages. Secondly, the assumption that the shape of the curves does not vary from site to site has been proven false for several species (Carmean 1972, Graney and Burkhart 1973, Hann and Scrivani 1987).

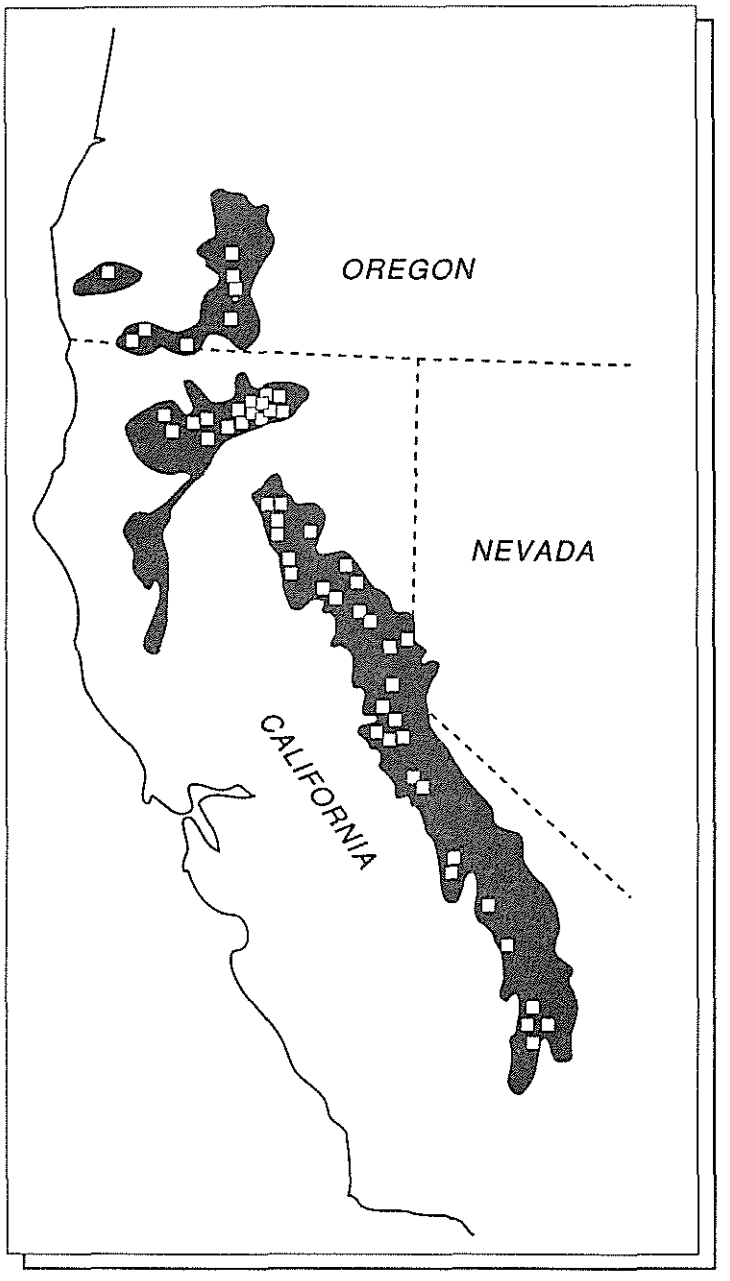

Figure 1—Natural range of red fir and site index study plot locations.

Site index curves based on stem analysis studies should provide a more realistic assessment of potential site productivity because (1) more information is obtained from each sample tree because stem analysis provides a continuous record of growth, (2) the stem analysis procedure allows for estimation of polymorphic height-growth patterns, and (3) the height of the site trees at index age is either observed or can be estimated with reasonable accuracy for each plot in a stem analysis study (Monserud 1984, Newnham 1988).

This paper presents height-growth equations and site index curves for dominant red fir in natural, young-growth stands in California, southern Oregon, and extreme western Nevada (*fig.1*). Because California red fir (*Abies magnifica* A. Murr.) and its commonly recognized variety Shasta red fir (*Abies magnifica* var. *shastensis* Lemm.) are considered to be almost identical in silvical characteristics (Hallin 1957), no attempt was made to distinguish between them during the sampling phase of the study. In this paper they are referred to collectively as red fir.

Because the new curves are polymorphic (vary in shape from one site to another), they represent natural curve shapes over the range of site quality and are generally considered more consistent with the known growth habits of trees (Brickell 1968). The new curves also are based on a reference age of 50 years at breast height (bh) instead of 50 years total age. Age at bh taken directly from increment cores is more convenient to use and more accurate than total age as an independent variable in site index estimates (Husch 1956, King 1966). Age at bh is more accurate because it eliminates the necessity of adding a constant as a correction factor to obtain total age.

METHODS

Fifty-six natural stands of young-growth red fir were sampled throughout the high-elevation forests of California and southern Oregon as part of a larger study to develop growth and soil

fertility models for red fir. The distribution of red fir extends from latitude 43° 35' N. in the southern Cascades in Oregon, to Lake County, California, in the Coast Range, and to the Kern River drainage in the Sierra Nevada, latitude 35° 40' N. Elevations range from about 5,000 to 9,000 feet.[1] Red fir strata were identified on National Forest timber type maps and randomly selected for sampling. Field crews then identified suitable young-growth red fir stands within the selected strata for plot installation and measurement.

Criteria for Plot Selection

Each sampled stand had a cluster of five plots arranged in an "L" shape, with plot centers 132 feet apart along north and east compass lines. This sample plot layout was selected to be consistent with procedures used in the Pacific Southwest Region's Compartment Inventory and Analysis (CIA) program. Each plot in the cluster was independently evaluated for study suitability by the following criteria:

- Homogeneous site—No more than one distinct soil type, slope percentage, or aspect was present within a 66-foot radius around the plot center.
- Significant amount of red fir—At least 20 percent of the trees 1.0 inches and greater in diameter at breast height (dbh) were red fir.
- Young-growth—No more than 25 percent of the plot trees were older than 120 years at breast height.

The sampling location was retained if at least two of the five plots met these three criteria.

Selection of Site Trees

One red fir site tree was selected at each plot for felling and stem analysis, if one was present within a 66-foot radius of the plot center. A plot with a 66-foot radius (approximately 1/3 acre in size) was used for selecting the site tree because it was half the distance to the center of an adjoining plot. A suitable site tree met the following criteria:

- Dominant crown position, and apparently so throughout its development. Dominant trees have well-developed crowns, in a superior position in the crown canopy, receiving full sunlight from above and at least partial sunlight from the sides.
- Increment core taken at breast height showed no irregular growth patterns caused by suppression or damage. A group of narrow annual rings on the increment core, indicating stress in the past, would be cause for rejection.
- Not visibly damaged by disease or insects.
- No observable damage to the bole or top that would affect growth.
- Age at bh at least 45 years and not greater than 120 years.

If more than one site tree were available on a plot, the best growing tree (based on crown characteristics and increment cores) was selected for stem analysis.

Description of Data

One dominant site tree was felled on each of 206 sample plots. Stem analysis was conducted on each tree with sectioning below approximately every 10th whorl, bh (4.5 feet), and at stump height (approximately 1.0 foot). Age at each sectioning point was determined by ring counts, and height above bh to each sectioning point was measured to the nearest 0.1 foot. The height-age pairs for each tree were then plotted and inspected for indications of top damage or height suppression. If suppression or damage on a particular tree was apparent from these graphs, that tree was deleted from subsequent analyses. This attempt to avoid underestimating site productivity reduced the number of site trees from 206 to 194.

The plotted points for the height-age pairs were connected with smooth hand-drawn curves. Heights above bh were read from these curves at bh age 10 and at every 5 years thereafter, to the age of the tree or age 120, whichever was less. Total tree height at bh age 50 determined the site index. This produced 2897 observations of height, age, and site index from the 194 trees.

Each tree was then assigned to a 5-foot site class based on tree height at bh age 50 years. Midpoints of the 5-foot site classes were multiples of 5 from 30 to 95 feet, making a total of 14 classes. One height-age curve for each class was produced by averaging the individual trees' curves within each class. These curves indicated the general pattern of height growth for each site class and were used to obtain initial parameter estimates of the height-growth function.

ANALYSIS OF DATA

Two basic mathematical models were tested initially to determine which most closely described the observed height growth patterns of the individual site index classes. The Richards growth function (Richards 1959) has been used to characterize the height growth patterns of several species (Brickell 1968, Lundgren and Dolid 1970, Beck 1971, Payandeh 1974, Burkhart and Tennent 1977, and others). The other model tested, a modified Weibull function (Yang and others 1978), is a mathematical function which seems to be capable of generating curve systems which adequately describe biological growth patterns.

The Richards function, expressed as

$$H - 4.5 = A \cdot [1 - e^{(-B \cdot Age)}]^C, \quad (1)$$

and the modified Weibull function, expressed as

$$H - 4.5 = A \cdot [1 - e^{(-B \cdot Age^C)}], \quad (2)$$

[1] To calculate metric equivalents of the English units reported here, use this table:

English/metric conversion table
1 inch = 2.54 centimeters
1 foot = 0.3048 meters
1 square foot = 0.0929 square meters
1 acre = 0.404686 hectares

in which

H = tree height in feet

e = constant base of natural logarithms (2.718282)

Age = age of tree at breast height

A, B, C = parameters to be estimated which describe maximum attainable tree height, scale, and shape of the height-growth curve, respectively,

were both fit to the height-age data for each site index class. Parameters for these and all other nonlinear regressions in this study were estimated using the secant, or DUD, method of the SAS NLIN procedure (SAS Institute Inc. 1982). The modified Weibull function produced better fits of the data for 10 of the 14 site class curves as evidenced by a lower mean squared error for the nonlinear regressions. The modified Weibull function was therefore selected as the basic model for development of the dominant height-growth function. Extensions to this basic model were developed as site index was introduced into the equation by relating site index and age to the parameters of the height-growth function.

After considerable experimentation with several possible model forms, an extended version of the modified Weibull function was used to express total height (H) as a function of breast-height age (Age), and site index (SI). The resulting equation is:

$$H=[(SI-4.5)\cdot(1-e^{(B\cdot Age^{b1})})]/[1-e^{(B_{50}\cdot 50^{b1})}]+4.5 \qquad (3)$$

in which

$$B=Age\cdot e^{(Age\cdot b3)}\cdot b2\cdot SI+[Age\cdot e^{(Age\cdot b3)}\cdot b2]^2\cdot b4+b5$$

$$B_{50}=50\cdot e^{(50\cdot b3)}\cdot b2\cdot SI+[50\cdot e^{(50\cdot b3)}\cdot b2]^2\cdot b4+b5$$

b1, b2, b3, b4, b5 = regression coefficients of the model which are estimated from the sample data, and other symbols remain as previously defined.

Steps in the development of this equation are described more fully in *appendix A*.

Data from the average height-age curves of the 5-foot site classes were used for development of the model form and for obtaining initial parameter estimates. The 2897 observations of height, age, and site index from the 194 individual site trees were combined to obtain the final parameter estimates.

RESULTS AND DISCUSSION

The final parameter estimates for equation 3 are:

Parameter	Estimate
b1	1.51744
b2	1.41512×10^{-6}
b3	-4.40853×10^{-2}
b4	-3.04951×10^{0}
b5	5.72474×10^{-4}
R^2= 0.9855	SE = 3.38 ft

Graphs of equation 3 using these parameter estimates for bh ages 10 to 160 years and site indices 20 to 110 feet are presented (*fig. 2*). The points for plotting the site index curves were obtained by substituting various values of age into equation 3 and solving for H. Since the parameters B and B_{50} in equation 3 have different values for each site index curve, the curves are obviously polymorphic.

Equation 3 expresses total tree height as a function of age and site index and cannot be solved explicitly for site index given age and height. In this situation, site index can be determined only by graphic interpolation or by tedious iterative computations (Clutter and others 1983). Therefore, to obtain an estimate of site index more easily, a site index table (*appendix B*) is presented which gives site index estimates for various combinations of age and total height.

The estimate of the adjusted coefficient of determination, R^2, was calculated using the formula

$$R^2 = 1 - [\Sigma(H-\hat{H})^2/\Sigma\ (H-\bar{H})^2] \cdot [(N-1)/(N-P)]$$

in which H, $\hat{H}$, and $\bar{H}$ are the observed, estimated, and average heights, respectively, N is the number of observations, and P is the number of parameters in the model.

The estimated R^2 and standard error (SE) values, though useful in comparing relative fit of alternative equations, are not unbiased estimates of the true population R^2 and SE, because stem analysis measurements constitute a series of successive measurements on the same individuals, and these individuals in turn are grouped by clusters. Successive measurements on the same sample tree are not independent; nor are measurements on two or more sample trees within a single cluster independent of each other (Curtis 1964). Because total tree height at bh age 50 (site index) is an explanatory or independent variable in the model, the variances and covariances are non-linear functions of age with minimum values at bh age 50. The SE given for the model (3.38 ft) and the R^2 value (0.9855) are therefore only average values across all age classes. That the samples are not independent of each other should not bias point estimates of height and associated site index values (Curtis and others 1974). In an analysis of the components of error, Monserud (1984) also found no evidence to question the traditional practice of ignoring the problem of successive measurements on the same trees when developing site index curves from stem analysis data, as long as point estimates are all that are needed. If confidence or prediction intervals are desired, some other model-fitting technique (such as maximum likelihood estimation) needs to be used which could estimate the mean and covariance parameters simultaneously because the variances and covariances are functions of bh age.

Several models that expressed site index (SI) as a function of age and height were also evaluated. However, examination of residuals revealed problems with bias in addition to low R^2 values for these models. For red fir, the conventional family of site index curves, where H = f(age, site index), provided the best site index estimates.

Equation 3 has many desirable characteristics as a height growth function. It passes through the natural origin of the

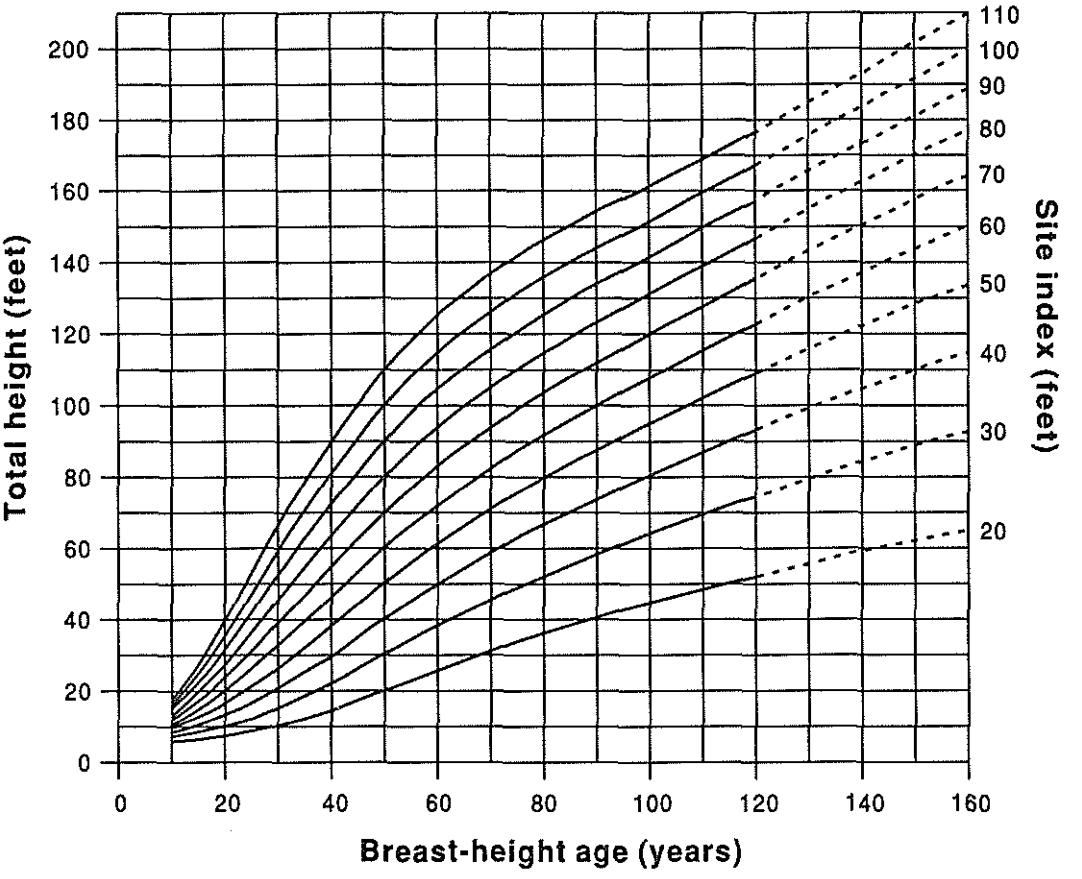

Figure 2—Site index curves for red fir in California and southern Oregon. Base age is 50 years at breast height. Dashes indicate extrapolations beyond the range of original data.

system (when bh age equals zero, total height equals 4.5 feet), it is sigmoidal in shape, it passes through H = SI at the index age, and it reaches a finite upper asymptote at bh ages greater than 160 years.

CURVE COMPARISON

The site index curves generated with equation 3 were compared with Schumacher's (1928) site curves for red fir at three levels of site index (*fig. 3*). Because Schumacher's curves are for total age, a conversion factor was needed to evaluate Schumacher's curves in terms of breast-height age. The stem analysis data of the 194 site trees revealed that an average of 10.5 years was required for trees to grow the 3.5 feet between stump height (1.0 ft) and breast height (4.5 ft). Because natural red fir seedlings are likely to require 5 to 10 years to attain a height of 1 foot (Hallin 1957), an average of 7.5 years was added to the 10.5 years to make a total conversion factor of 18 years. There was little correlation between rate of height growth below bh and site index for the 194 stem analysis trees, so 18 was subtracted from total age to approximate bh age at each level of site index.

The three curves used for comparison were high (site index 94), medium (site index 58), and low (site index 22). The curves differ substantially both below and above the index age of 50 years. Below the index age, Schumacher's curves show more height for a given age than the new curves. Above the index age, Schumacher's curves show less height for a given age on the low and medium sites and more height for a given age on high sites.

Several factors account for differences between the two sets of curves, the most important of which is the method used in curve construction. Based on stem analysis data, the new polymorphic curves reflect the changes in growth patterns with changes in the level of site index. Polymorphism of the new curves is most evident when the high and low site index classes are compared (*fig. 3*). The second major factor causing differences between the two sets of curves is the use of breast-height age for the new curves and the use of total age for Schumacher's curves. The use of a constant conversion factor to estimate bh

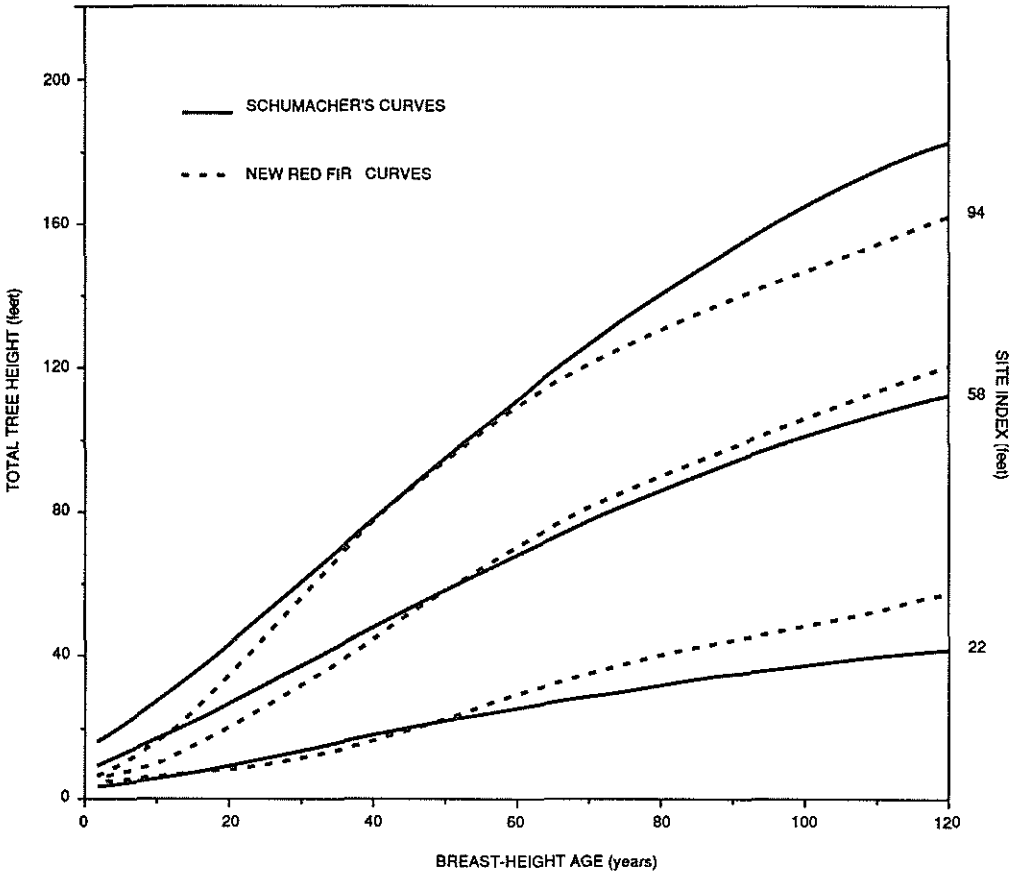

Figure 3—Site index curves for red fir with Schumacher's curves, converted to breast-height age, superimposed. The three levels of site index are high (site index 94), medium (site index 58), and low (site index 22).

age from total age does allow for comparison of curve shapes. However, because it is a very crude procedure, the use of a constant conversion factor makes comparison of actual height/age values difficult.

APPLICATION

The polymorphic site index curves apply to natural, young-growth stands of red fir in California and southern Oregon. They were developed from stem analysis data of one suitable site tree on each plot. If fixed-area sample plots are used for determining site index, it is recommended that plots not exceed 1/3 acre. Regardless of plot size, the critical criterion is that the site is homogeneous, especially with respect to soil type, slope percent, and aspect.

To estimate site index of a given plot, total height and age at breast height must be measured on one suitable site tree on the plot. The selected site tree should meet the following specifications:

- Crown position dominant and appears to have been so throughout the course of its development.
- Visibly free of insects and disease.
- No visible top damage (no broken or deformed top, crooks, scars, or forks).
- Increment core taken at breast height should not show any fire scars, mechanical damage, or any period of suppression followed by release.
- Age at bh, as determined from the increment core, should be at least 10 years. Site indexes calculated with trees older than 120 years at bh should be reasonable but used with caution since such estimates are made with extrapolations of the basic data.

If more than one tree on a plot is suitable for site index estimation, the best growing tree (based on increment cores) should be used for site index estimation.

The sampling intensity will depend on the variability within the stand being sampled. In uniform stands, or smaller components of operational stands that are uniform in species composition, density, soil type, slope, and aspect, it is recommended that at least three site-quality trees per acre be selected for measurement of total tree height and breast-height age.

A site index value should be estimated for each sample tree using the site index curves (*fig. 2*) or, preferably, the site index table (*appendix B*). The site index of the uniform stand or stand component (such as an even-aged group) is the arithmetic average of the individual site indices from that component.

CONCLUSIONS

The site index curves presented here reflect actual site potential for red fir within the high-elevation forests of California and southern Oregon better than Schumacher's (1928) red fir site curves. Differences in height-growth patterns between Schumacher's curves and the new curves have been demonstrated. The new curves, developed by fitting a modified Weibull height-growth function to stem analysis data, reflect the changes in growth patterns associated with changes in the level of site index.

The use of breast-height age rather than total age also overcomes several problems with site index estimation for red fir. Not only is bh age easier and more accurately determined than total age, bh represents a height at which the small trees have passed through their period of initial establishment and adjustment to the site.

To make site index estimates for red fir using Schumacher's curves, values must be interpolated between the site curves. Interpolating also makes the curves difficult to use and decreases the accuracy of the estimates. In this paper, additional ways are presented to make the estimation of site index easier and more accurate. The height-growth equation can be programmed for computer applications so estimates of total height are obtained for various combinations of age and site index. In addition to the site index curves generated by the height-growth equation, the precise values of site index are presented in the site index table for many combinations of bh age and total tree height.

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APPENDIX A

Model Development

The form of the modified Weibull equation used in this study is

$$H - 4.5 = A \cdot [1 - e^{(-B \cdot Age^C)}], \qquad (A1)$$

where H is total tree height at a given breast-height age (Age), e is the base of natural logarithms, and A, B, and C are parameters to be estimated. Introduction of site index into the model depended on the existence of a relationship between one or more of the parameters and site index. The following steps in the model-building process describe how these relationships were expressed.

Initial estimates of the A parameter.

To describe a family of polymorphic-disjoint curves (curves that do not cross each other within a specified age range) by equation A1, there needs to be a significant and positive relationship between site index and the A parameter, the maximum attainable height of the organism on a given site quality. However, estimates of A, produced by the fit of this equation to the height/age data for each site class, were not significantly correlated with site index, probably because the oldest trees in the study were only 120 years at bh. These estimates of A were also too low to be reasonable. For instance, the estimate of A for site class 80 was only 139 feet; however, tree heights of about 220 feet have been observed on Swain Mountain in northern California where the site index is about 80 feet at 50 years bh age.[1]

Using the Swain Mountain information, along with height data from Schumacher's curves, hand-drawn, smooth extrapolations of the site class curves, and other data on maximum attainable heights,[2] some new initial estimates of A were made for the site classes. Of several possible model forms tried, the expression best relating the new A estimates to site index seemed to be:

$$A = -315.795 + 194.427 \cdot SI^{0.238} \qquad (A2)$$

The estimated value of A for a given site index was considered to be only an educated guess at this time. However, it served as a starting point for introducing site index into the model and for making other initial parameter estimates. As shown later on, the final expression for the A parameter does not resemble equation A2.

Estimate of the C parameter.

The fitting of equation A1 to the height/age data for each site class revealed that the C parameter was apparently randomly distributed with respect to site index; the value of C for the 14 site class regressions ranged from 1.3 to 1.8. The actual value of C was therefore assumed to be a constant with a value somewhere within this range.

Relationship of the B parameter, age, and site index.

If age and the C parameter are fixed at constant values and the A parameter has been estimated in terms of site index, an estimate of the B parameter can be made for any level of site index using equation A1. Then, the relationship between the B parameter and site index at a given age and C value, if it exists, can be determined.

At each 5-year interval of bh age starting at age 10 and ending at age 120, the value of B was calculated for each site tree using C values of 1.3 to 1.8 (in increments of 0.1). For each value of C at each age interval, plotting of the data indicated a linear relationship between the B value and site index. A linear regression of the form

$$B = a_0 + a_1 \cdot SI \qquad (A3)$$

was then calculated for each 5-year age interval at the six values of C for ages 10 to 105. The older age classes (110, 115, and 120) were inadequately represented for this analysis.

At each specified value of C, the slope and intercept coefficients of these regressions (a_1 and a_0, respectfully) varied with age. However, at a C value of 1.5, both regression coefficients could be estimated as a continuous function of age:

$$a_1 = Age \cdot e^{(Age \cdot b3)} \cdot b2$$

and

$$a_0 = [Age \cdot e^{(Age \cdot b3)} \cdot b2]^2 \cdot b4 + b5.$$

By substituting these expressions for a_1 and a_0 into equation A3, the B parameter, rather than being a function of site index only, becomes expressed in terms of site index and bh age.

Conditioning the equation.

By definition, a necessary condition for any site index curve equation is that H = SI at the index age. When evaluating equation A1 at the index age, the predicted height will not necessarily equal site index. Therefore, the equation was conditioned to ensure that predicted height equals site index when age equals index age by writing the A parameter in terms of site index and the index age (50 years at bh):

$$A = (SI - 4.5) / [1 - e^{(-B_{50} \cdot 50^C)}]$$

where B_{50} equals the value of the B parameter when age equals 50. By substituting this expression for A in equation A1, the conditioned equation becomes

$$H = [(SI - 4.5) \cdot (1 - e^{(-B \cdot Age^C)})] / [1 - e^{(-B_{50} \cdot 50^C)}] + 4.5. \qquad (A4)$$

At the index age, because $B_{50} = B$ and $50^C = Age^C$, equation A4 reduces to H = SI.

[1]Unpublished data on file at Pacific Southwest Research Station, 2400 Washington Avenue, Redding, CA 96001.

[2]American Forestry Association. 1986. **National register of big trees.** American Forests 92(4): 21-52.

APPENDIX B

Site Index Table for Red Fir

The site index table on the following pages is for making rapid and precise estimates of site index when breast-height age and total tree height are known for selected red fir site trees. To use the table, find the page on which the total tree height and the breast-height age occur on the same line. At the top of the column in which the total height occurs, read the site index. Short interpolations between some tree heights may be necessary.

Site index estimates for trees with breast-height ages greater than 120 years will be made with extrapolations of the original data and should be used with care.

	Site index															
Bh Age	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
years	Total tree height (*feet*)															
10	6	6	6	6	7	7	7	7	7	8	8	8	8	9	9	9
11	6	6	6	7	7	7	7	8	8	8	8	9	9	9	9	10
12	6	6	7	7	7	7	8	8	8	9	9	9	9	10	10	10
13	6	7	7	7	7	8	8	8	9	9	9	10	10	10	11	11
14	6	7	7	7	8	8	8	9	9	9	10	10	11	11	11	12
15	7	7	7	8	8	8	9	9	10	10	10	11	11	12	12	13
16	7	7	8	8	8	9	9	10	10	10	11	11	12	12	13	13
17	7	7	8	8	9	9	10	10	10	11	11	12	12	13	14	14
18	7	8	8	8	9	9	10	10	11	11	12	13	13	14	14	15
19	7	8	8	9	9	10	10	11	11	12	13	13	14	14	15	16
20	7	8	9	9	10	10	11	11	12	13	13	14	14	15	16	17
21	8	8	9	9	10	11	11	12	12	13	14	15	15	16	17	17
22	8	8	9	10	10	11	12	12	13	14	14	15	16	17	18	18
23	8	9	9	10	11	11	12	13	14	14	15	16	17	18	18	19
24	8	9	10	10	11	12	13	13	14	15	16	17	18	18	19	20
25	9	9	10	11	12	12	13	14	15	16	17	17	18	19	20	21
26	9	10	10	11	12	13	14	15	15	16	17	18	19	20	21	22
27	9	10	11	12	12	13	14	15	16	17	18	19	20	21	22	23
28	10	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
29	10	11	12	13	14	14	15	17	18	19	20	21	22	23	24	25
30	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26
31	11	12	13	14	15	16	17	18	19	20	21	23	24	25	26	27
32	11	12	13	14	15	16	17	19	20	21	22	23	25	26	27	29
33	11	12	14	15	16	17	18	19	21	22	23	24	26	27	28	30
34	12	13	14	15	16	18	19	20	21	23	24	25	27	28	29	31
35	12	13	15	16	17	18	20	21	22	24	25	26	28	29	31	32
36	13	14	15	16	18	19	20	22	23	25	26	27	29	30	32	33
37	13	14	16	17	18	20	21	23	24	25	27	28	30	31	33	34
38	14	15	16	18	19	21	22	23	25	26	28	29	31	32	34	36
39	14	16	17	18	20	21	23	24	26	27	29	30	32	34	35	37
40	15	16	18	19	21	22	24	25	27	28	30	31	33	35	36	38
41	15	17	18	20	21	23	24	26	28	29	31	33	34	36	38	39
42	16	17	19	20	22	24	25	27	29	30	32	34	35	37	39	40
43	16	18	19	21	23	24	26	28	29	31	33	35	36	38	40	42
44	17	18	20	22	23	25	27	29	30	32	34	36	37	39	41	43
45	17	19	21	22	24	26	28	30	31	33	35	37	39	40	42	44

(continued)

Appendix B (continued)

Bh Age	Site index 20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
years	Total tree height (*feet*)															
46	18	20	21	23	25	27	29	30	32	34	36	38	40	42	43	45
47	18	20	22	24	26	28	29	31	33	35	37	39	41	43	45	46
48	19	21	23	25	26	28	30	32	34	36	38	40	42	44	46	48
49	19	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49
50	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
51	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51
52	21	23	25	27	30	32	34	36	38	40	42	44	46	48	50	52
53	22	24	26	28	30	32	35	37	39	41	43	45	47	49	51	53
54	22	24	27	29	31	33	35	38	40	42	44	46	48	50	52	55
55	23	25	27	30	32	34	36	38	41	43	45	47	49	51	54	56
56	23	26	28	30	33	35	37	39	41	44	46	48	50	52	55	57
57	24	26	29	31	33	36	38	40	42	45	47	49	51	54	56	58
58	24	27	29	32	34	36	39	41	43	46	48	50	52	55	57	59
59	25	27	30	32	35	37	39	42	44	46	49	51	53	56	58	60
60	26	28	31	33	35	38	40	43	45	47	50	52	54	57	59	61
61	26	29	31	34	36	39	41	44	46	48	51	53	55	58	60	62
62	27	29	32	34	37	39	42	44	47	49	52	54	56	59	61	63
63	27	30	32	35	38	40	43	45	48	50	52	55	57	59	62	64
64	28	30	33	36	38	41	43	46	48	51	53	56	58	60	63	65
65	28	31	34	36	39	42	44	47	49	52	54	57	59	61	64	66
66	29	32	34	37	40	42	45	48	50	53	55	58	60	62	65	67
67	29	32	35	38	40	43	46	48	51	53	56	58	61	63	66	68
68	30	33	36	38	41	44	46	49	52	54	57	59	62	64	67	69
69	30	33	36	39	42	45	47	50	52	55	58	60	63	65	68	70
70	31	34	37	40	42	45	48	51	53	56	58	61	63	66	68	71
71	31	34	37	40	43	46	49	51	54	57	59	62	64	67	69	72
72	32	35	38	41	44	47	49	52	55	57	60	63	65	68	70	73
73	32	35	39	42	44	47	50	53	56	58	61	63	66	69	71	74
74	33	36	39	42	45	48	51	54	56	59	62	64	67	69	72	74
75	33	37	40	43	46	49	52	54	57	60	62	65	68	70	73	75
76	34	37	40	43	46	49	52	55	58	61	63	66	69	71	74	76
77	34	38	41	44	47	50	53	56	59	61	64	67	69	72	74	77
78	35	38	41	45	48	51	54	56	59	62	65	67	70	73	75	78
79	35	39	42	45	48	51	54	57	60	63	66	68	71	74	76	79
80	36	39	42	46	49	52	55	58	61	64	66	69	72	74	77	79
81	36	40	43	46	49	53	56	59	61	64	67	70	72	75	78	80
82	37	40	44	47	50	53	56	59	62	65	68	71	73	76	79	81
83	37	41	44	47	51	54	57	60	63	66	69	71	74	77	79	82
84	37	41	45	48	51	54	58	61	64	66	69	72	75	77	80	83
85	38	42	45	48	52	55	58	61	64	67	70	73	76	78	81	84
86	38	42	46	49	52	56	59	62	65	68	71	74	76	79	82	84
87	39	43	46	50	53	56	59	63	66	69	71	74	77	80	82	85
88	39	43	47	50	54	57	60	63	66	69	72	75	78	81	83	86
89	40	43	47	51	54	57	61	64	67	70	73	76	78	81	84	87
90	40	44	48	51	55	58	61	64	68	71	74	76	79	82	85	87

(continued)

Appendix B (continued)

Bh Age	Site index 20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
years	Total tree height (*feet*)															
91	41	44	48	52	55	59	62	65	68	71	74	77	80	83	85	88
92	41	45	49	52	56	59	63	66	69	72	75	78	81	83	86	89
93	41	45	49	53	56	60	63	66	70	73	76	79	81	84	87	90
94	42	46	50	53	57	60	64	67	70	73	76	79	82	85	88	90
95	42	46	50	54	57	61	64	68	71	74	77	80	83	86	88	91
96	43	47	51	54	58	61	65	68	71	75	78	81	83	86	89	92
97	43	47	51	55	59	62	65	69	72	75	78	81	84	87	90	93
98	43	48	52	55	59	63	66	69	73	76	79	82	85	88	91	93
99	44	48	52	56	60	63	67	70	73	76	80	83	86	88	91	94
100	44	48	53	56	60	64	67	71	74	77	80	83	86	89	92	95
101	45	49	53	57	61	64	68	71	75	78	81	84	87	90	93	95
102	45	49	53	57	61	65	68	72	75	78	82	85	88	91	93	96
103	45	50	54	58	62	65	69	72	76	79	82	85	88	91	94	97
104	46	50	54	58	62	66	70	73	76	80	83	86	89	92	95	98
105	46	51	55	59	63	66	70	74	77	80	83	87	90	93	95	98
106	47	51	55	59	63	67	71	74	78	81	84	87	90	93	96	99
107	47	51	56	60	64	68	71	75	78	82	85	88	91	94	97	100
108	47	52	56	60	64	68	72	75	79	82	85	89	92	95	98	100
109	48	52	57	61	65	69	72	76	79	83	86	89	92	95	98	101
110	48	53	57	61	65	69	73	76	80	83	87	90	93	96	99	102
111	49	53	58	62	66	70	73	77	81	84	87	91	94	97	100	103
112	49	54	58	62	66	70	74	78	81	85	88	91	94	97	100	103
113	49	54	58	63	67	71	75	78	82	85	89	92	95	98	101	104
114	50	54	59	63	67	71	75	79	82	86	89	92	96	99	102	105
115	50	55	59	64	68	72	76	79	83	86	90	93	96	99	102	105
116	50	55	60	64	68	72	76	80	84	87	90	94	97	100	103	106
117	51	56	60	65	69	73	77	80	84	88	91	94	98	101	104	107
118	51	56	61	65	69	73	77	81	85	88	92	95	98	101	104	107
119	52	56	61	65	70	74	78	82	85	89	92	96	99	102	105	108
120	52	57	61	66	70	74	78	82	86	89	93	96	99	103	106	109
121	52	57	62	66	71	75	79	83	86	90	93	97	100	103	106	109
122	53	58	62	67	71	75	79	83	87	91	94	97	101	104	107	110
123	53	58	63	67	72	76	80	84	87	91	95	98	101	105	108	111
124	53	58	63	68	72	76	80	84	88	92	95	99	102	105	108	111
125	54	59	64	68	73	77	81	85	89	92	96	99	103	106	109	112
126	54	59	64	69	73	77	81	85	89	93	96	100	103	107	110	113
127	54	59	64	69	73	78	82	86	90	93	97	100	104	107	110	113
128	55	60	65	69	74	78	82	86	90	94	98	101	104	108	111	114
129	55	60	65	70	74	79	83	87	91	95	98	102	105	108	112	115
130	55	61	66	70	75	79	83	87	91	95	99	102	106	109	112	115
131	56	61	66	71	75	80	84	88	92	96	99	103	106	110	113	116
132	56	61	66	71	76	80	84	89	92	96	100	103	107	110	114	117

(continued)

Appendix B (continued)

Bh Age	Site index 20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
years	Total tree height (*feet*)															
133	56	62	67	72	76	81	85	89	93	97	101	104	108	111	114	117
134	57	62	67	72	77	81	85	90	94	97	101	105	108	112	115	118
135	57	62	68	72	77	82	86	90	94	98	102	105	109	112	115	119
136	57	63	68	73	78	82	86	91	95	98	102	106	109	113	116	119
137	58	63	68	73	78	83	87	91	95	99	103	106	110	113	117	120
138	58	63	69	74	78	83	87	92	96	100	103	107	111	114	117	121
139	58	64	69	74	79	83	88	92	96	100	104	108	111	115	118	121
140	59	64	69	74	79	84	88	93	97	101	104	108	112	115	119	122
141	59	65	70	75	80	84	89	93	97	101	105	109	112	116	119	122
142	59	65	70	75	80	85	89	94	98	102	106	109	113	116	120	123
143	60	65	71	76	81	85	90	94	98	102	106	110	113	117	120	124
144	60	66	71	76	81	86	90	95	99	103	107	110	114	118	121	124
145	60	66	71	76	81	86	91	95	99	103	107	111	115	118	122	125
146	61	66	72	77	82	87	91	95	100	104	108	112	115	119	122	126
147	61	67	72	77	82	87	92	96	100	104	108	112	116	119	123	126
148	61	67	72	78	83	87	92	96	101	105	109	113	116	120	123	127
149	61	67	73	78	83	88	92	97	101	105	109	113	117	120	124	127
150	62	68	73	78	83	88	93	97	102	106	110	114	117	121	125	128
151	62	68	73	79	84	89	93	98	102	106	110	114	118	122	125	129
152	62	68	74	79	84	89	94	98	103	107	111	115	119	122	126	129
153	63	69	74	79	85	90	94	99	103	107	111	115	119	123	126	130
154	63	69	74	80	85	90	95	99	104	108	112	116	120	123	127	130
155	63	69	75	80	85	90	95	100	104	108	112	116	120	124	127	131
156	64	69	75	81	86	91	96	100	105	109	113	117	121	124	128	132
157	64	70	75	81	86	91	96	101	105	109	113	117	121	125	129	132
158	64	70	76	81	87	92	96	101	105	110	114	118	122	126	129	133
159	64	70	76	82	87	92	97	101	106	110	114	118	122	126	130	133
160	65	71	76	82	87	92	97	102	106	111	115	119	123	127	130	134

Bh Age	Site index 52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
years	Total tree height (*feet*)															
10	9	9	10	10	10	10	11	11	11	11	12	12	12	12	13	13
11	10	10	10	11	11	11	12	12	12	12	13	13	13	14	14	14
12	11	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16
13	11	12	12	12	13	13	14	14	14	15	15	15	16	16	17	17
14	12	13	13	13	14	14	15	15	15	16	16	17	17	18	18	19
15	13	13	14	14	15	15	16	16	17	17	18	18	19	19	20	20
16	14	14	15	15	16	16	17	17	18	18	19	20	20	21	21	22
17	15	15	16	16	17	17	18	19	19	20	20	21	22	22	23	23
18	15	16	17	17	18	19	19	20	20	21	22	22	23	24	24	25
19	16	17	18	18	19	20	20	21	22	22	23	24	25	25	26	27
20	17	18	19	19	20	21	22	22	23	24	25	25	26	27	28	28
21	18	19	20	20	21	22	23	24	24	25	26	27	28	29	29	30

(continued)

Appendix B (continued)

Bh Age	Site index 52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
years	Total tree height (*feet*)															
22	19	20	21	22	22	23	24	25	26	27	28	28	29	30	31	32
23	20	21	22	23	24	24	25	26	27	28	29	30	31	32	33	34
24	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
25	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
26	23	24	25	26	27	28	29	30	32	33	34	35	36	37	38	39
27	24	25	26	27	29	30	31	32	33	34	35	36	38	39	40	41
28	25	26	28	29	30	31	32	33	35	36	37	38	39	41	42	43
29	26	28	29	30	31	32	34	35	36	37	39	40	41	42	44	45
30	28	29	30	31	32	34	35	36	38	39	40	42	43	44	45	47
31	29	30	31	33	34	35	36	38	39	40	42	43	45	46	47	49
32	30	31	33	34	35	37	38	39	41	42	43	45	46	48	49	51
33	31	32	34	35	37	38	39	41	42	44	45	47	48	50	51	52
34	32	34	35	37	38	39	41	42	44	45	47	48	50	51	53	54
35	33	35	36	38	39	41	42	44	45	47	48	50	52	53	55	56
36	35	36	38	39	41	42	44	45	47	49	50	52	53	55	56	58
37	36	37	39	41	42	44	45	47	49	50	52	53	55	57	58	60
38	37	39	40	42	44	45	47	48	50	52	53	55	57	58	60	62
39	38	40	42	43	45	47	48	50	52	53	55	57	58	60	62	64
40	40	41	43	45	46	48	50	52	53	55	57	58	60	62	64	65
41	41	43	44	46	48	50	51	53	55	57	58	60	62	64	65	67
42	42	44	46	47	49	51	53	55	56	58	60	62	63	65	67	69
43	43	45	47	49	51	52	54	56	58	60	61	63	65	67	69	71
44	45	46	48	50	52	54	56	57	59	61	63	65	67	69	70	72
45	46	48	50	51	53	55	57	59	61	63	65	66	68	70	72	74
46	47	49	51	53	55	57	58	60	62	64	66	68	70	72	74	76
47	48	50	52	54	56	58	60	62	64	66	68	70	71	73	75	77
48	50	52	53	55	57	59	61	63	65	67	69	71	73	75	77	79
49	51	53	55	57	59	61	63	65	67	69	71	73	75	76	78	80
50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
51	53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	84
52	54	56	58	61	63	65	67	69	71	73	75	77	79	81	83	85
53	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
54	57	59	61	63	65	67	69	71	73	75	78	80	82	84	86	88
55	58	60	62	64	66	68	70	73	75	77	79	81	83	85	87	89
56	59	61	63	65	67	70	72	74	76	78	80	82	84	86	89	91
57	60	62	64	67	69	71	73	75	77	79	81	84	86	88	90	92
58	61	63	66	68	70	72	74	76	78	81	83	85	87	89	91	93
59	62	64	67	69	71	73	75	78	80	82	84	86	88	90	92	95
60	63	66	68	70	72	74	77	79	81	83	85	87	89	92	94	96
61	64	67	69	71	73	75	78	80	82	84	86	89	91	93	95	97
62	65	68	70	72	74	77	79	81	83	85	88	90	92	94	96	98
63	66	69	71	73	75	78	80	82	84	86	89	91	93	95	97	99
64	67	70	72	74	77	79	81	83	85	88	90	92	94	96	98	101
65	68	71	73	75	78	80	82	84	87	89	91	93	95	97	100	102
66	69	72	74	76	79	81	83	85	88	90	92	94	96	99	101	103
67	70	73	75	77	80	82	84	86	89	91	93	95	97	100	102	104
68	71	74	76	78	81	83	85	87	90	92	94	96	99	101	103	105
69	72	75	77	79	82	84	86	88	91	93	95	97	100	102	104	106

(continued)

Appendix B (continued)

Bh Age	Site index 52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
years	Total tree height (*feet*)															
70	73	76	78	80	83	85	87	89	92	94	96	98	101	103	105	107
71	74	77	79	81	84	86	88	90	93	95	97	99	102	104	106	108
72	75	77	80	82	85	87	89	91	94	96	98	100	103	105	107	109
73	76	78	81	83	85	88	90	92	95	97	99	101	104	106	108	110
74	77	79	82	84	86	89	91	93	96	98	100	102	105	107	109	111
75	78	80	83	85	87	90	92	94	97	99	101	103	105	108	110	112
76	79	81	83	86	88	91	93	95	97	100	102	104	106	109	111	113
77	79	82	84	87	89	91	94	96	98	101	103	105	107	110	112	114
78	80	83	85	88	90	92	95	97	99	102	104	106	108	110	113	115
79	81	84	86	88	91	93	96	98	100	102	105	107	109	111	114	116
80	82	84	87	89	92	94	96	99	101	103	106	108	110	112	114	117
81	83	85	88	90	93	95	97	100	102	104	106	109	111	113	115	117
82	84	86	89	91	93	96	98	101	103	105	107	110	112	114	116	118
83	84	87	89	92	94	97	99	101	104	106	108	110	113	115	117	119
84	85	88	90	93	95	98	100	102	105	107	109	111	114	116	118	120
85	86	89	91	94	96	98	101	103	105	108	110	112	114	117	119	121
86	87	89	92	94	97	99	102	104	106	108	111	113	115	117	120	122
87	88	90	93	95	98	100	102	105	107	109	112	114	116	118	120	123
88	88	91	93	96	98	101	103	106	108	110	112	115	117	119	121	123
89	89	92	94	97	99	102	104	106	109	111	113	115	118	120	122	124
90	90	93	95	98	100	102	105	107	109	112	114	116	119	121	123	125
91	91	93	96	98	101	103	106	108	110	113	115	117	119	122	124	126
92	91	94	97	99	102	104	106	109	111	113	116	118	120	122	124	127
93	92	95	97	100	102	105	107	110	112	114	116	119	121	123	125	127
94	93	96	98	101	103	106	108	110	113	115	117	120	122	124	126	128
95	94	96	99	101	104	106	109	111	113	116	118	120	123	125	127	129
96	95	97	100	102	105	107	110	112	114	117	119	121	123	126	128	130
97	95	98	100	103	105	108	110	113	115	117	120	122	124	126	128	131
98	96	99	101	104	106	109	111	113	116	118	120	123	125	127	129	131
99	97	99	102	105	107	109	112	114	117	119	121	123	126	128	130	132
100	97	100	103	105	108	110	113	115	117	120	122	124	126	129	131	133
101	98	101	103	106	109	111	113	116	118	121	123	125	127	129	132	134
102	99	102	104	107	109	112	114	117	119	121	124	126	128	130	132	135
103	100	102	105	108	110	113	115	117	120	122	124	127	129	131	133	135
104	100	103	106	108	111	113	116	118	121	123	125	127	130	132	134	136
105	101	104	106	109	112	114	117	119	121	124	126	128	130	133	135	137
106	102	105	107	110	112	115	117	120	122	124	127	129	131	133	136	138
107	103	105	108	110	113	116	118	120	123	125	127	130	132	134	136	139
108	103	106	109	111	114	116	119	121	124	126	128	131	133	135	137	139
109	104	107	109	112	115	117	120	122	124	127	129	131	134	136	138	140
110	105	107	110	113	115	118	120	123	125	127	130	132	134	137	139	141
111	105	108	111	113	116	119	121	124	126	128	131	133	135	137	140	142
112	106	109	112	114	117	119	122	124	127	129	131	134	136	138	140	142
113	107	110	112	115	118	120	123	125	127	130	132	134	137	139	141	143
114	107	110	113	116	118	121	123	126	128	131	133	135	137	140	142	144
115	108	111	114	116	119	122	124	127	129	131	134	136	138	140	143	145
116	109	112	114	117	120	122	125	127	130	132	134	137	139	141	143	146
117	110	112	115	118	120	123	126	128	130	133	135	138	140	142	144	146

(continued)

Appendix B (continued)

Bh Age	Site index 52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
years	Total tree height (*feet*)															
118	110	113	116	119	121	124	126	129	131	134	136	138	141	143	145	147
119	111	114	117	119	122	125	127	130	132	134	137	139	141	144	146	148
120	112	114	117	120	123	125	128	130	133	135	138	140	142	144	147	149
121	112	115	118	121	123	126	129	131	134	136	138	141	143	145	147	150
122	113	116	119	121	124	127	129	132	134	137	139	141	144	146	148	150
123	114	117	119	122	125	127	130	133	135	137	140	142	144	147	149	151
124	114	117	120	123	126	128	131	133	136	138	141	143	145	148	150	152
125	115	118	121	124	126	129	132	134	137	139	141	144	146	148	151	153
126	116	119	122	124	127	130	132	135	137	140	142	145	147	149	151	154
127	116	119	122	125	128	130	133	136	138	141	143	145	148	150	152	154
128	117	120	123	126	128	131	134	136	139	141	144	146	148	151	153	155
129	118	121	124	126	129	132	134	137	140	142	144	147	149	151	154	156
130	118	121	124	127	130	133	135	138	140	143	145	148	150	152	154	157
131	119	122	125	128	131	133	136	139	141	144	146	148	151	153	155	157
132	120	123	126	129	131	134	137	139	142	144	147	149	151	154	156	158
133	120	123	126	129	132	135	137	140	143	145	147	150	152	155	157	159
134	121	124	127	130	133	135	138	141	143	146	148	151	153	155	158	160
135	122	125	128	131	133	136	139	141	144	147	149	151	154	156	158	161
136	122	125	128	131	134	137	140	142	145	147	150	152	155	157	159	161
137	123	126	129	132	135	138	140	143	145	148	151	153	155	158	160	162
138	124	127	130	133	136	138	141	144	146	149	151	154	156	158	161	163
139	124	127	130	133	136	139	142	144	147	150	152	154	157	159	162	164
140	125	128	131	134	137	140	142	145	148	150	153	155	158	160	162	165
141	126	129	132	135	138	140	143	146	148	151	153	156	158	161	163	165
142	126	129	132	135	138	141	144	147	149	152	154	157	159	161	164	166
143	127	130	133	136	139	142	145	147	150	152	155	157	160	162	165	167
144	128	131	134	137	140	142	145	148	151	153	156	158	161	163	165	168
145	128	131	134	137	140	143	146	149	151	154	156	159	161	164	166	168
146	129	132	135	138	141	144	147	149	152	155	157	160	162	165	167	169
147	129	133	136	139	142	145	147	150	153	155	158	160	163	165	168	170
148	130	133	136	139	142	145	148	151	153	156	159	161	164	166	168	171
149	131	134	137	140	143	146	149	151	154	157	159	162	164	167	169	171
150	131	134	138	141	144	147	149	152	155	157	160	163	165	168	170	172
151	132	135	138	141	144	147	150	153	156	158	161	163	166	168	171	173
152	132	136	139	142	145	148	151	154	156	159	161	164	167	169	171	174
153	133	136	140	143	146	149	151	154	157	160	162	165	167	170	172	175
154	134	137	140	143	146	149	152	155	158	160	163	165	168	170	173	175
155	134	138	141	144	147	150	153	156	158	161	164	166	169	171	174	176
156	135	138	141	145	148	150	153	156	159	162	164	167	169	172	174	177
157	135	139	142	145	148	151	154	157	160	162	165	168	170	173	175	177
158	136	139	143	146	149	152	155	158	160	163	166	168	171	173	176	178
159	137	140	143	146	149	152	155	158	161	164	166	169	172	174	177	179
160	137	141	144	147	150	153	156	159	162	164	167	170	172	175	177	180

(continued)

Appendix B (continued)

Bh Age	Site index															
	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
years	Total tree height (*feet*)															
10	13	13	14	14	14	14	15	15	15	15	16	16	16	16	17	17
11	14	15	15	15	16	16	16	17	17	17	18	18	18	19	19	19
12	16	16	17	17	17	18	18	18	19	19	20	20	20	21	21	21
13	17	18	18	19	19	20	20	20	21	21	22	22	22	23	23	24
14	19	20	20	20	21	21	22	22	23	23	24	24	25	25	26	26
15	21	21	22	22	23	23	24	24	25	25	26	27	27	28	28	29
16	22	23	23	24	25	25	26	26	27	28	28	29	29	30	31	31
17	24	25	25	26	27	27	28	29	29	30	31	31	32	33	33	34
18	26	26	27	28	29	29	30	31	31	32	33	34	34	35	36	37
19	28	28	29	30	31	31	32	33	34	34	35	36	37	38	38	39
20	29	30	31	32	33	33	34	35	36	37	38	38	39	40	41	42
21	31	32	33	34	35	35	36	37	38	39	40	41	42	43	44	45
22	33	34	35	36	37	38	39	40	41	41	42	43	44	45	46	47
23	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
24	37	38	39	40	41	42	43	44	45	46	47	48	50	51	52	53
25	39	40	41	42	43	44	45	46	48	49	50	51	52	53	54	56
26	40	42	43	44	45	46	47	49	50	51	52	53	55	56	57	58
27	42	44	45	46	47	48	50	51	52	53	55	56	57	59	60	61
28	44	46	47	48	49	51	52	53	55	56	57	58	60	61	62	64
29	46	48	49	50	52	53	54	56	57	58	60	61	62	64	65	67
30	48	50	51	52	54	55	56	58	59	61	62	63	65	66	68	69
31	50	52	53	54	56	57	59	60	62	63	64	66	67	69	70	72
32	52	54	55	56	58	59	61	62	64	65	67	68	70	71	73	74
33	54	55	57	58	60	62	63	65	66	68	69	71	72	74	75	77
34	56	57	59	61	62	64	65	67	68	70	72	73	75	76	78	80
35	58	59	61	63	64	66	67	69	71	72	74	76	77	79	80	82
36	60	61	63	65	66	68	70	71	73	74	76	78	79	81	83	85
37	62	63	65	67	68	70	72	73	75	77	78	80	82	84	85	87
38	63	65	67	69	70	72	74	75	77	79	81	82	84	86	88	89
39	65	67	69	71	72	74	76	78	79	81	83	85	86	88	90	92
40	67	69	71	72	74	76	78	80	81	83	85	87	89	90	92	94
41	69	71	73	74	76	78	80	82	83	85	87	89	91	93	94	96
42	71	73	74	76	78	80	82	84	85	87	89	91	93	95	97	98
43	72	74	76	78	80	82	84	85	87	89	91	93	95	97	99	100
44	74	76	78	80	82	84	86	87	89	91	93	95	97	99	101	103
45	76	78	80	82	84	85	87	89	91	93	95	97	99	101	103	105
46	78	80	81	83	85	87	89	91	93	95	97	99	101	103	105	107
47	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	109
48	81	83	85	87	89	91	93	95	97	99	101	103	104	106	108	110
49	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112
50	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
51	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116
52	87	89	91	93	95	97	99	101	103	105	107	109	111	113	115	117
53	88	91	93	95	97	99	101	103	105	107	109	111	113	115	117	119
54	90	92	94	96	98	100	102	104	106	108	110	112	115	117	119	121

(continued)

Appendix B (continued)

Bh Age	Site index 84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
years	Total tree height (*feet*)															
55	91	93	95	98	100	102	104	106	108	110	112	114	116	118	120	122
56	93	95	97	99	101	103	105	107	109	111	113	115	118	120	122	124
57	94	96	98	100	102	104	107	109	111	113	115	117	119	121	123	125
58	95	97	100	102	104	106	108	110	112	114	116	118	120	122	124	127
59	97	99	101	103	105	107	109	111	113	115	118	120	122	124	126	128
60	98	100	102	104	106	108	111	113	115	117	119	121	123	125	127	129
61	99	101	103	106	108	110	112	114	116	118	120	122	124	126	128	131
62	100	103	105	107	109	111	113	115	117	119	121	123	126	128	130	132
63	102	104	106	108	110	112	114	116	118	121	123	125	127	129	131	133
64	103	105	107	109	111	113	115	118	120	122	124	126	128	130	132	134
65	104	106	108	110	112	114	117	119	121	123	125	127	129	131	133	135
66	105	107	109	111	114	116	118	120	122	124	126	128	130	132	134	136
67	106	108	110	112	115	117	119	121	123	125	127	129	131	133	135	138
68	107	109	111	114	116	118	120	122	124	126	128	130	132	134	137	139
69	108	110	113	115	117	119	121	123	125	127	129	131	133	136	138	140
70	109	111	114	116	118	120	122	124	126	128	130	132	134	137	139	141
71	110	112	115	117	119	121	123	125	127	129	131	133	135	138	140	142
72	111	113	116	118	120	122	124	126	128	130	132	134	136	139	141	143
73	112	114	117	119	121	123	125	127	129	131	133	135	137	139	141	144
74	113	115	118	120	122	124	126	128	130	132	134	136	138	140	142	144
75	114	116	118	121	123	125	127	129	131	133	135	137	139	141	143	145
76	115	117	119	122	124	126	128	130	132	134	136	138	140	142	144	146
77	116	118	120	122	125	127	129	131	133	135	137	139	141	143	145	147
78	117	119	121	123	125	128	130	132	134	136	138	140	142	144	146	148
79	118	120	122	124	126	128	131	133	135	137	139	141	143	145	147	149
80	119	121	123	125	127	129	131	133	135	138	140	142	144	146	148	150
81	120	122	124	126	128	130	132	134	136	138	140	142	144	146	148	150
82	120	123	125	127	129	131	133	135	137	139	141	143	145	147	149	151
83	121	123	126	128	130	132	134	136	138	140	142	144	146	148	150	152
84	122	124	126	129	131	133	135	137	139	141	143	145	147	149	151	153
85	123	125	127	129	131	134	136	138	140	142	144	146	148	150	152	154
86	124	126	128	130	132	134	136	138	140	142	145	146	148	150	152	154
87	125	127	129	131	133	135	137	139	141	143	145	147	149	151	153	155
88	126	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156
89	126	128	131	133	135	137	139	141	143	145	147	149	151	153	155	157
90	127	129	131	133	136	138	140	142	144	146	148	150	152	154	155	157
91	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158
92	129	131	133	135	137	139	141	143	145	147	149	151	153	155	157	159
93	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160
94	130	132	135	137	139	141	143	145	147	149	151	153	155	157	158	160
95	131	133	135	137	140	142	144	146	148	150	151	153	155	157	159	161
96	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160	162
97	133	135	137	139	141	143	145	147	149	151	153	155	157	159	161	163
98	134	136	138	140	142	144	146	148	150	152	154	156	158	160	161	163
99	134	136	139	141	143	145	147	149	151	153	155	156	158	160	162	164

(continued)

Appendix B (continued)

Bh Age	Site index 84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
years	Total tree height (*feet*)															
100	135	137	139	141	143	145	147	149	151	153	155	157	159	161	163	165
101	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	166
102	137	139	141	143	145	147	149	151	153	155	157	159	161	163	164	166
103	138	140	142	144	146	148	150	152	154	156	158	160	161	163	165	167
104	138	140	142	145	147	149	151	153	155	156	158	160	162	164	166	168
105	139	141	143	145	147	149	151	153	155	157	159	161	163	165	167	169
106	140	142	144	146	148	150	152	154	156	158	160	162	164	166	167	169
107	141	143	145	147	149	151	153	155	157	159	161	163	164	166	168	170
108	141	144	146	148	150	152	154	156	158	160	161	163	165	167	169	171
109	142	144	146	148	150	152	154	156	158	160	162	164	166	168	170	172
110	143	145	147	149	151	153	155	157	159	161	163	165	167	169	171	172
111	144	146	148	150	152	154	156	158	160	162	164	166	168	169	171	173
112	145	147	149	151	153	155	157	159	161	163	165	166	168	170	172	174
113	145	147	150	152	154	156	158	160	162	163	165	167	169	171	173	175
114	146	148	150	152	154	156	158	160	162	164	166	168	170	172	174	175
115	147	149	151	153	155	157	159	161	163	165	167	169	171	173	174	176
116	148	150	152	154	156	158	160	162	164	166	168	170	172	173	175	177
117	149	151	153	155	157	159	161	163	165	167	169	170	172	174	176	178
118	149	151	154	156	158	160	162	164	166	167	169	171	173	175	177	179
119	150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	179
120	151	153	155	157	159	161	163	165	167	169	171	173	175	177	178	180
121	152	154	156	158	160	162	164	166	168	170	172	174	176	177	179	181
122	153	155	157	159	161	163	165	167	169	171	173	174	176	178	180	182
123	153	155	158	160	162	164	166	168	170	172	173	175	177	179	181	183
124	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	183
125	155	157	159	161	163	165	167	169	171	173	175	177	179	181	182	184
126	156	158	160	162	164	166	168	170	172	174	176	178	180	181	183	185
127	157	159	161	163	165	167	169	171	173	175	177	179	180	182	184	186
128	157	159	162	164	166	168	170	172	174	176	178	179	181	183	185	187
129	158	160	162	164	167	169	171	173	174	176	178	180	182	184	186	188
130	159	161	163	165	167	169	171	173	175	177	179	181	183	185	187	188
131	160	162	164	166	168	170	172	174	176	178	180	182	184	186	187	189
132	160	163	165	167	169	171	173	175	177	179	181	183	185	186	188	190
133	161	163	166	168	170	172	174	176	178	180	182	184	185	187	189	191
134	162	164	166	168	171	173	175	177	179	181	182	184	186	188	190	192
135	163	165	167	169	171	173	175	177	179	181	183	185	187	189	191	193
136	164	166	168	170	172	174	176	178	180	182	184	186	188	190	192	193
137	164	167	169	171	173	175	177	179	181	183	185	187	189	191	192	194
138	165	167	170	172	174	176	178	180	182	184	186	188	190	191	193	195
139	166	168	170	173	175	177	179	181	183	185	187	189	190	192	194	196
140	167	169	171	173	175	177	180	182	184	186	187	189	191	193	195	197
141	168	170	172	174	176	178	180	182	184	186	188	190	192	194	196	198
142	168	171	173	175	177	179	181	183	185	187	189	191	193	195	197	199
143	169	171	174	176	178	180	182	184	186	188	190	192	194	196	198	199
144	170	172	174	177	179	181	183	185	187	189	191	193	195	196	198	200

(continued)

Appendix B (continued)

Bh Age	Site index 84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
years	Total tree height (*feet*)															
145	171	173	175	177	179	182	184	186	188	190	192	194	195	197	199	201
146	171	174	176	178	180	182	184	186	188	190	192	194	196	198	200	202
147	172	174	177	179	181	183	185	187	189	191	193	195	197	199	201	203
148	173	175	177	180	182	184	186	188	190	192	194	196	198	200	202	204
149	174	176	178	180	183	185	187	189	191	193	195	197	199	201	203	204
150	175	177	179	181	183	186	188	190	192	194	196	198	200	201	203	205
151	175	178	180	182	184	186	188	190	193	195	197	198	200	202	204	206
152	176	178	181	183	185	187	189	191	193	195	197	199	201	203	205	207
153	177	179	181	184	186	188	190	192	194	196	198	200	202	204	206	208
154	178	180	182	184	187	189	191	193	195	197	199	201	203	205	207	209
155	178	181	183	185	187	189	192	194	196	198	200	202	204	206	208	209
156	179	181	184	186	188	190	192	194	197	199	201	203	205	206	208	210
157	180	182	184	187	189	191	193	195	197	199	201	203	205	207	209	211
158	181	183	185	187	190	192	194	196	198	200	202	204	206	208	210	212
159	181	184	186	188	190	193	195	197	199	201	203	205	207	209	211	213
160	182	184	187	189	191	193	195	198	200	202	204	206	208	210	212	214

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The Forest Service, U.S. Department of Agriculture, is responsible for Federal leadership in forestry. It carries out this role through four main activities:

- Protection and management of resources on 191 million acres of National Forest System lands
- Cooperation with State and local governments, forest industries, and private landowners to help protect and manage non-Federal forest and associated range and watershed lands
- Participation with other agencies in human resource and community assistance programs to improve living conditions in rural areas
- Research on all aspects of forestry, rangeland management, and forest resources utilization.

The Pacific Southwest Research Station

- Represents the research branch of the Forest Service in California, Hawaii, American Samoa and the western Pacific.