SITE INDEX EQUATIONS FOR LODGEPOLE PINE AND WHITE SPRUCE IN ALBERTA

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ABSTRACT

Site index equations for white spruce and lodgepole pine were developed from stem analysis data obtained in well stocked stands within the commercial forest zone of Alberta. The equations are based on a model $\frac{H}{SI} = a + bA + cA^2$ that accurately represents the basic data for all site and age classes.

RÉSUMÉ

Des équations d'indice de station pour l'épinette blanche et le pin tordu latifolié ont été mises au point à partir de données obtenues par l'analyse des tiges en peuplements serrés dans la zone forestière commerciale de l'Alberta. Ces équations se fondent sur la formule $\frac{H}{SI} = a + bA + cA^2$ qui représente de façon précise les données de base pour toutes les classes d'âges et de station.

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INTRODUCTION

This report presents site index equations and curves for Alberta's principal coniferous tree species: white spruce (Picea glauca (Moench) Voss) and lodgepole pine (Pinus contorta Dougl. var. latifolia Engelm.). Site index is here defined as the total height of dominant and codominant trees at a selected index age of 70 yr taken at 1.0-ft[1] above the ground. The equations and curves are intended for use by managers concerned with forest growth and yield.

Methods for the preparation of site index curves are numerous. In the past, site index curves were based on measurements of tree height and age of a large number of standing trees in order to establish average height-age relationships for dominants and codominants of various species. This approach may be biased by the unequal representation of sites in different age-classes. A preferred approach is to obtain stem analayis data for the construction of site index curves as indicated by Brickell (1968), Curtis (1964, 1966), Heger (1968, 1969, 1971), and Mitchell (1970). The site index equations presented here are based on data obtained from stem analysis.

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[1] Conversion of feet to metres is accomplished by multiplying number of feet by 0.3048.

METHODS AND RESULTS

Field Measurements

Field data were obtained in a cooperative study with the Alberta Forest Service adjacent to their growth survey plots. These plots were established in clusters of four in what appear on aerial photographs to be well stocked stands with greater than 30% crown closure in a homogeneous forest cover and site type. Adjacent to each growth plot, one dominant or codominant tree with no apparent defect was selected for stem analysis. Each tree was felled and then sectioned at 1.0 and 4.5 ft above ground and at 8.0-ft distances above the 10-ft section. The age at each section was determined, and from these data height-age curves were drawn for each sample tree. From these height-age curves, total height at 10-yr intervals was interpolated. Trees with obvious abnormalities in growth pattern were rejected from the data set. The stem analyses of 96 lodgepole pine and 243 white spruce were used in the analysis.

Analysis of Data

The heights of individual trees at 10-yr intervals were placed on punch cards for regression analysis using the following models:

Model

$$H = a + bA + cA^2 \qquad (1) \quad \text{(2nd degree parabola)}$$

$$H = \frac{A^2}{a + bA + cA^2} \qquad (2) \quad \text{(after Prodan, 1968)}$$

$$\frac{H}{SI} = a + bA + cA^2 \qquad (3)$$

Where: H = total height in feet of dominant and codominant trees.

A = age of tree at 1.0-ft above the ground.

SI = site index (height of dominant and codominant at stump age 70).

a,b,c = intercept value and coefficients to be determined.

For each species, equations were derived for 10-ft site index classes, and for all site index classes combined. Equations 1 and 2 based on Model 3 were considered the most suitable for practical application because:

1. They accurately and concisely represent the basic data.
2. There was insufficient measurement in all site index classes to derive equations for individual 10-ft site index classes.
3. The equations are easily applied in methods for predicting growth and yield using computers.

Equation

Lodgepole pine $$\frac{H}{SI@70} = -.0287 + .0198(A) - .0000723(A)^2 \qquad (1)$$

$R^2 = .96$ N = 907

White spruce $$\frac{H}{SI@70} = -.0935 + .0189(A) - .0000474(A)^2 \qquad (2)$$

$R^2 = .95$ N = 2574

Where: H = total height in feet of dominant and codominant trees.

SI@70 = total height of trees in feet at 1.0-ft stump age.

A = age of tree at 1.0-ft stump.

The validity of the model used to derive equations 1 and 2 is dependent upon a linear relationship between site index and height for various age-classes. Figures 1 and 2 present the relationship of site index (SI) to height at stump age of 10, 20, 30, etc. The scatter of individual observations around the regression lines suggests that a linear relationship with zero intercept is a valid assumption for most of the cases presented, as indicated by Johnson and Worthington (1963). The scattergrams indicate a high correlation of site index with the height trees attain at various stump ages. Even at a stump age of 10 there is a high correlation between site index and height.

The regression of the $\frac{H}{SI}$ ratio and age obtained from equations (1) and (2) was plotted on Fig. 3 and compared with the reciprocal of the average values obtained from the basic data and presented in Figs. 1 and 2. There is close agreement between the predicted and actual $\frac{H}{SI}$ ratios, further supporting the suitability of the model.

Predicted heights using equations (1) and (2) were compared with averages of observed values for 10-yr and 10-ft site index classes. In most cases the average heights were within $\pm$ 2 ft of the predicted height except where the data base was weak. The standard error of site index estimates (SE_E) using equations (1) and (2) for each age class by species was calculated from the basic data and is presented in Table 1. Site index estimates are most precise at or near index age, and least precise at a stump age of 20 or younger because small differences in total height produce large differences in site index.

Site index curves for 10-ft site index classes were derived from equations (1) and (2) and are given in Figs. 4 and 5. The equations and curves presented are reliable up to 100 yr for lodgepole pine and 120 yr for white spruce.

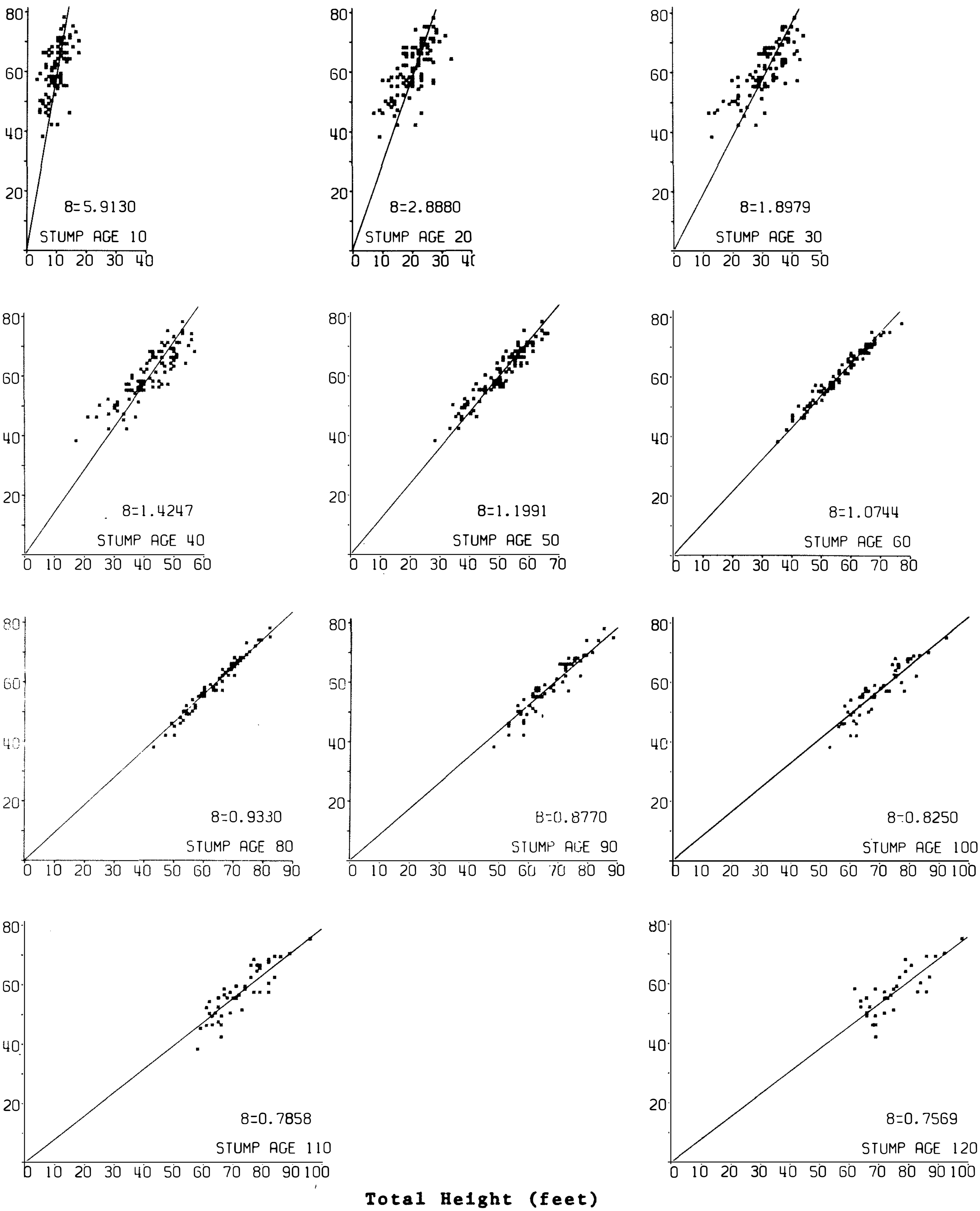

Figure 1. Site index over dominant and codominant height at various stump ages for Lodgepole Pine

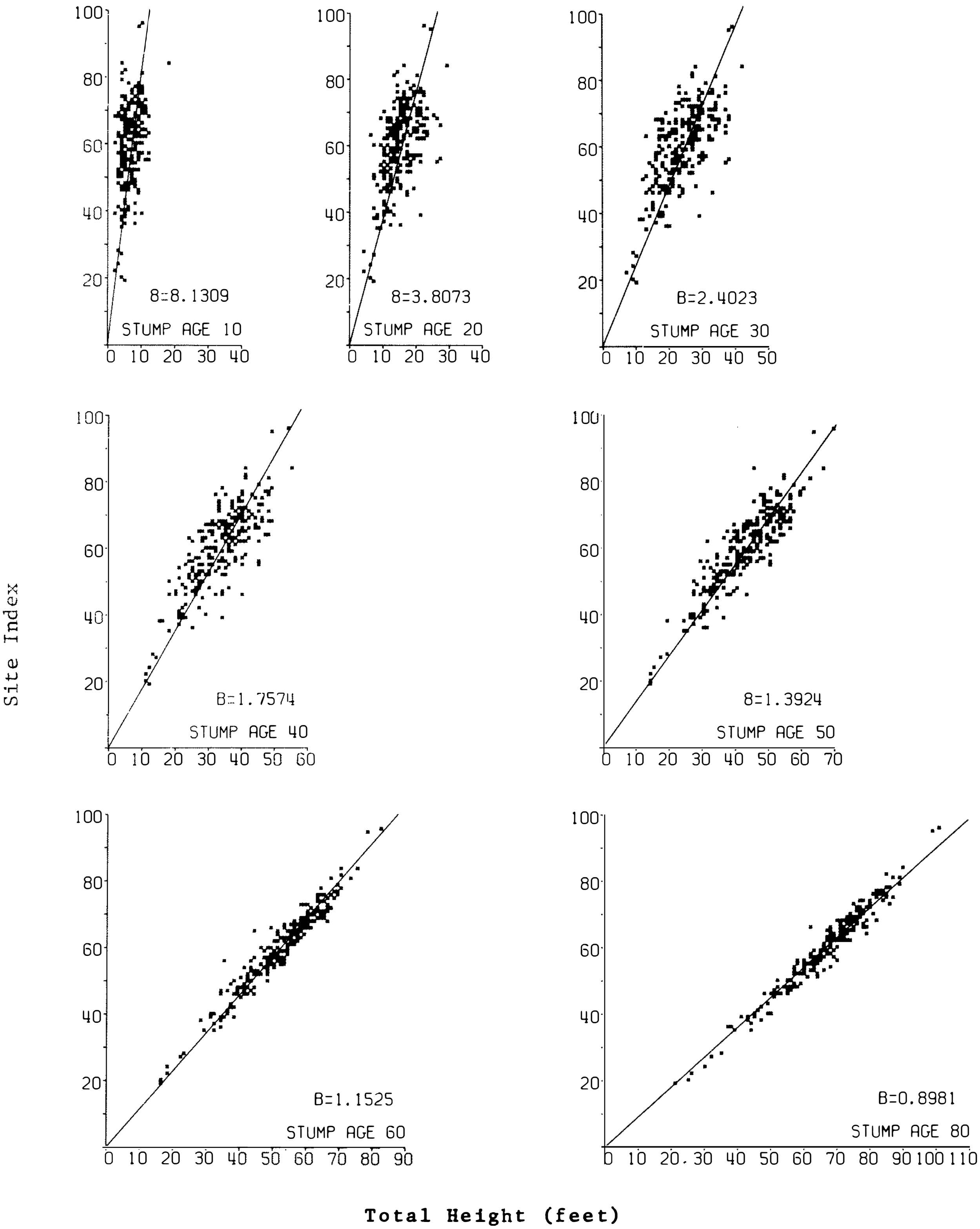

Figure 2. Site index over dominant and codominant height at various stump ages for White Spruce.

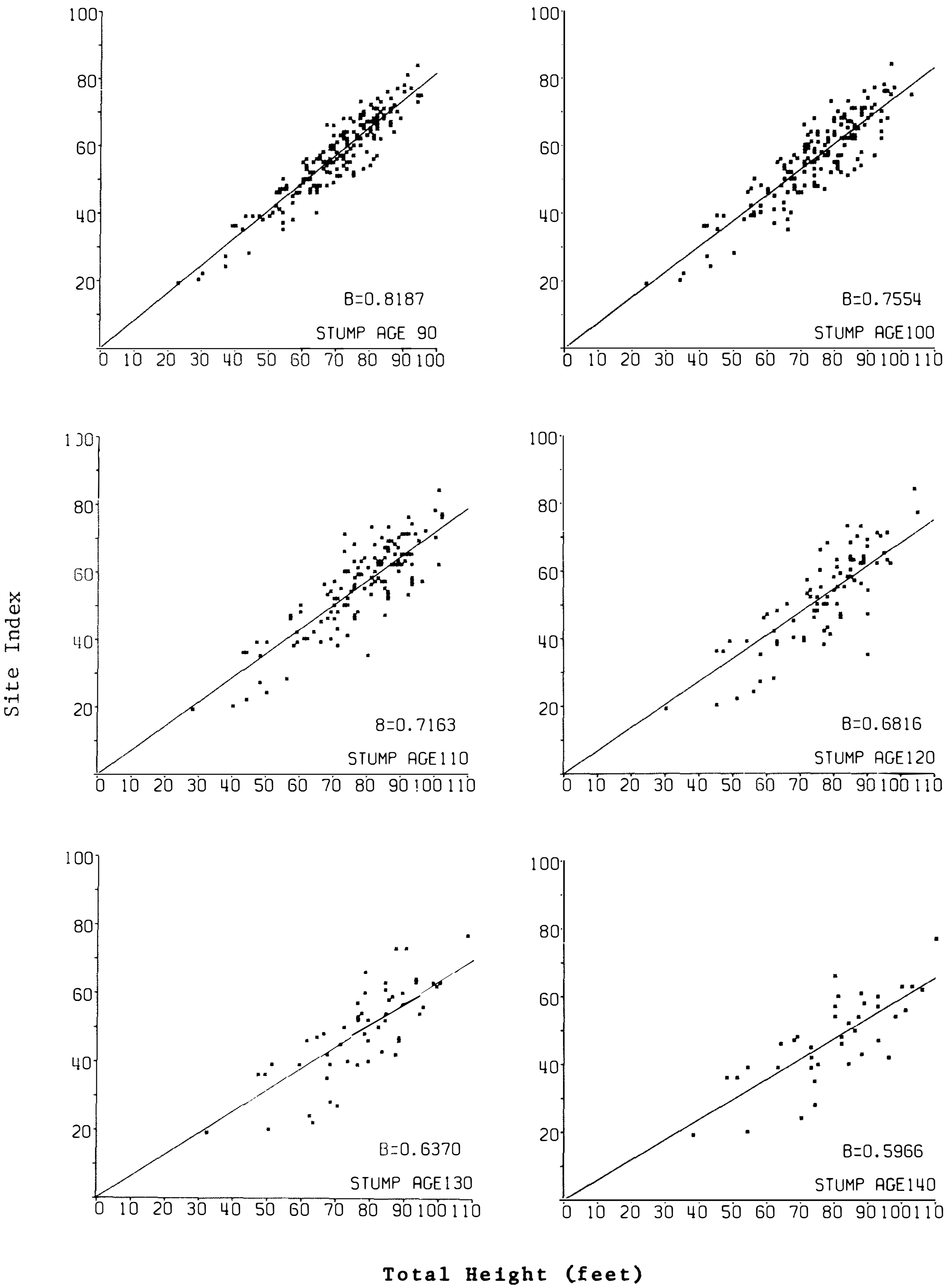

Figure 2 cont'd. Site index over dominant and codominant height at various stump ages for White Spruce.

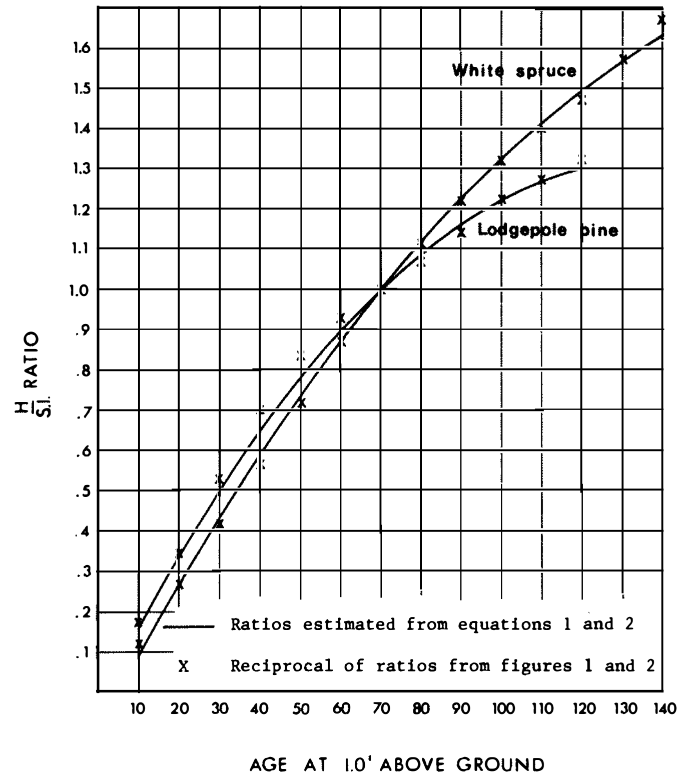

Figure 3. Ratios of $\frac{H}{SI}$ estimated from equations 1 and 2 and reciprocal of "b" values obtained from figures 1 and 2.

TABLE 1. PRECISION (SE_E)[1] OF SITE INDEX ESTIMATES USING EQUATIONS 1 and 2.

Age at 1.0 feet above ground	Lodgepole Pine	White Spruce
20	11.8	15.0
30	8.6	12.2
40	7.2	9.1
50	4.9	6.5
60	2.6	4.2
[2]70	0	0
80	2.2	2.9
90	3.4	4.4
100	3.9	5.8
110		7.3
120		8.6

[1] SE_E (Standard error of estimate) $= \sqrt{\frac{\sum(\text{deviation ot observed-predicted values})^2}{n - 3}}$

[2] Index Age.

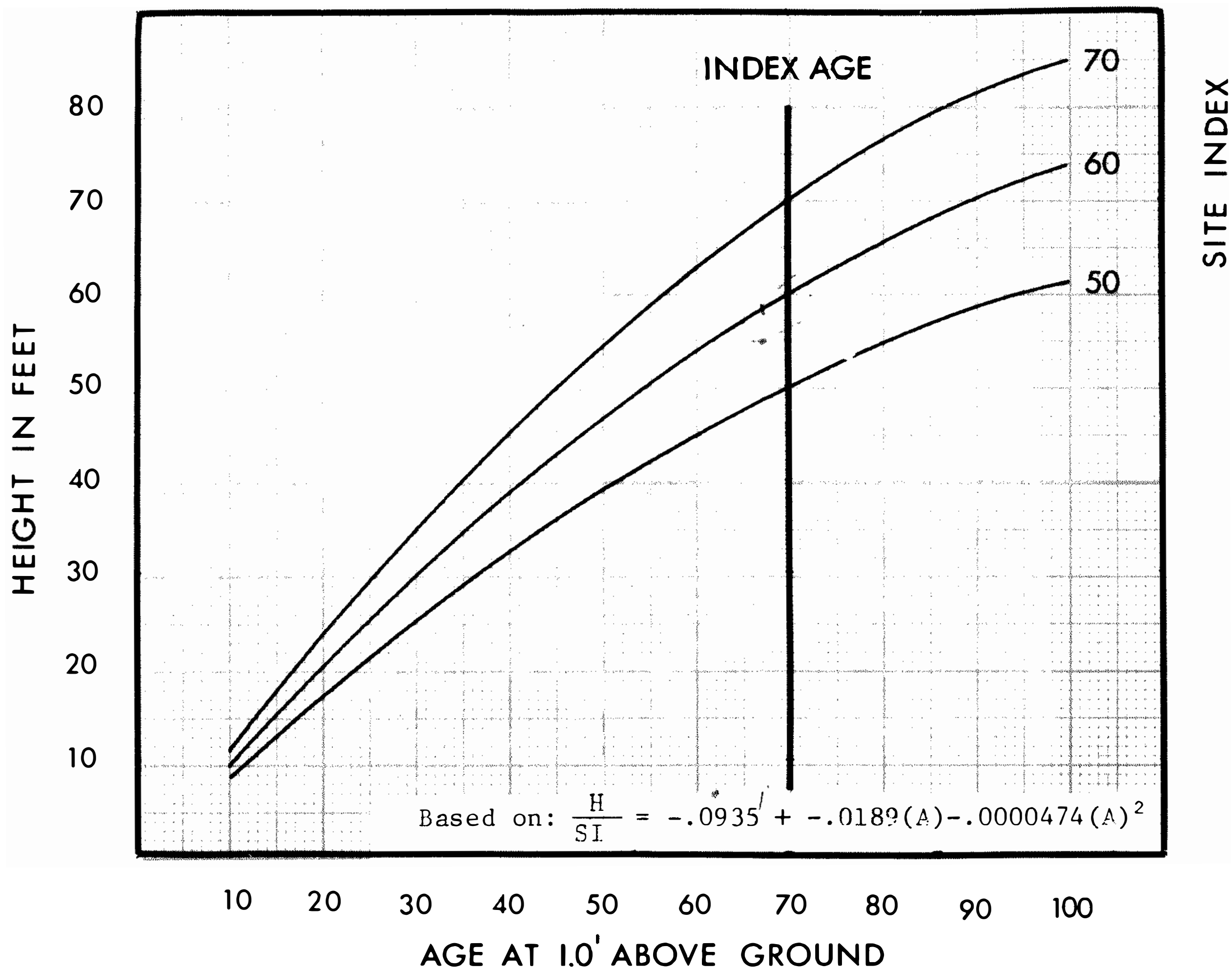

Figure 4. Site index curves for lodgepole pine.

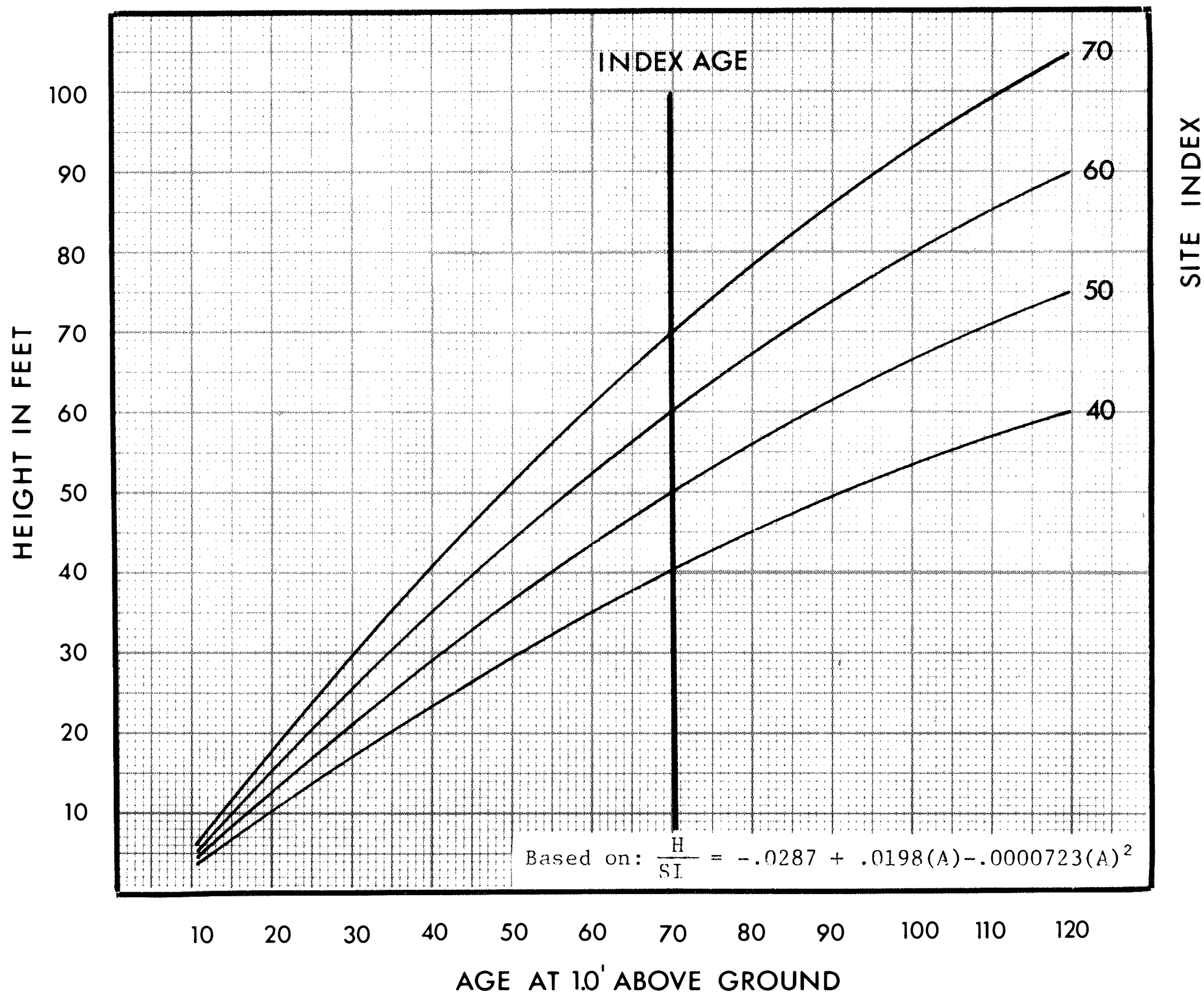

Figure 5. Site index curves for white spruce.

APPLICATION

To estimate site index, the age of the selected dominant and codominant trees is determined with an increment borer at 1.0 ft above the ground and tree height is estimated to the nearest foot.

Estimation of site index may be made to the nearest foot by determining $\frac{H}{SI}$ ratio from Fig. 3 and solving the following equation

$$SI = \frac{H}{\frac{H}{SI} \text{ ratio @ age}} \quad \text{(determined from Fig. 3)}$$

Example: for a 100-yr-old spruce tree (at 1.0 ft) with a total height of 53 ft the $SI = \frac{53}{1.325} = 40$

Site index estimates may also be made from the site index curves presented in Figs. 4 and 5.

Average site index determinations for a uniform forest cover and habitat type should have a standard error of the estimate less than ± 5 site index units. To classify an area into three or four statistically significant site index classes as done by Lesko and Lindsey (1973) would require this level of precision. For example, four randomly selected dominant and codominant spruce trees in uniform cover and habitat had site indices of 68, 72, 71, and 62, and their average site index was 68.2 with a standard error of the mean at the 95% probability level of ± 5 site index units. This indicates that the average height of four trees should provide a sufficiently precise estimate of site index so that significant differences in groupings by 10-ft site index classes could be demonstrated. The number of site index estimates required will of course depend on the homogeneity of the sampling unit and the precision required.

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