Site-index Curve Shape in Spruce

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Abstract

Sets of site-index curves were prepared from stem analyses of white spruce (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Mill.) BSP.) from various regions in the boreal forest of Canada. Ordinates of the site-index curves, computed for 5-year breast-height age intervals up to 75 years, and for 10-foot site-index intervals up to 70 feet, were compared within the species for the same values of site index and age. For breast-height ages below 55 years and for site index below 70 feet, the maximum absolute difference among the ordinates did not exceed 2.0 feet in white spruce, and 1.6 feet in black spruce; the corresponding average deviations were 0.75 and 0.80 feet. For breast-height ages above 55 years, these differences increased with age and, at 75 years, reached 8.8 feet in white spruce, and 3.8 feet in black spruce; the corresponding average deviations were 4.40 and 1.53 feet.

Résumé

L'allure des courbes de l'index de station pour l'épinette noire, et pour la blanche dans les provinces centrales du Canada, de Terre-Neuve et du Labrador.

On a tracé une série de courbes de l'index des stations à partir d'analyses de la croissance des épinettes blanche (*Picea glauca* (Moench) Voss) et noire (*P. mariana* (Mill.) BSP.) de diverses régions de la forêt boréale canadienne. On a établi les ordonnées des courbes d'indice des stations en se fondant sur le nombre de cercles de croissance à hauteur de poitrine à intervalles de cinq ans pendant 75 ans et sur l'indice de croissance du site par unités de 10 pieds jusqu'à 70 pieds; on a ensuite comparé ces ordonnées entre elles pour chacune des essences. Dans le cas de l'âge à hauteur de poitrine inférieur à 55 ans, et de l'indice de croissance du site inférieur à 70 pieds, l'écart maximal absolu entre les ordonnées n'a pas dépassé 2.0 pieds chez l'épinette blanche et 1.6 pieds chez l'épinette noire, pour un écart moyen de 0.75 et de 0.80 pied respectivement. Dans le cas de l'âge à hauteur de poitrine supérieur à 55 ans, ces écarts ont augmenté avec l'âge et à 75 ans ils étaient de 8.8 pieds chez l'épinette blanche et de 3.8 pieds chez l'épinette noire, pour un écart moyen de 4.40 et 1.53 pieds respectivement.

"... most of the ... differences among the ... curves
... did not exceed 2 feet ..."

The problem of accurate site-index determination would be greatly simplified if the average height-age relationships, observed on sites of a given quality, had sufficiently close agreement within regions, or within the entire botanical range of a species. Information about the degree of this agreement is scarce; however, site-index curves and height-age growth trends of individual trees have been compared to obtain it. For example, Lemmon, Johnson and Krauter (1955) compared the standard site-index curves for lodgepole pine (*Pinus contorta* Dougl.) in the pumice area of Central Oregon with those used in the northern Rocky Mountains and in British Columbia. Significant variations in the shape of these sets of curves were found; these variations were considered to be an indication of the growth differences among the various geographical areas.

In another comparison, Spurr (1955) used the height-age trends of individual red pines (*P. resinosa* Ait.) from plantations and from natural stands. The trends showed a slight variation in height growth for ages up to about 40 years. This was surprising because the basic data were from plantations on various soils and from permanent sample plots within the entire range of red pine. The tight grouping of the height curves suggested that soil type did not influence the growth of this species to the extent that other species were affected.

However, it was subsequently maintained that certain soil conditions have a marked effect on the shape of the red pine growth curve, and that special site curves need to be designed for sites where growth does not follow the "normal" pattern (Eck and Whiteside, 1963). Zahner (1962) developed three different height-age relationships for loblolly pine (*P. taeda* L.) on three soil groups in the Southern Pine Region.

Site-index curves found unreliable for general use within a region were considered to be accurate only if used for stands close to the standard age. It was assumed that, with a standard age of 50 years, measurements from stands 40 to 65 years old should yield quite precise estimates of site index; estimates from stands below 25 years should generally be considered inaccurate (Hodgkins, 1960).

This narrow range of ages for which the site-index curves are accurate can be extended if the geographical range of their applicability is known. The present study was made to recognize, to a limited

Table 1. Description of the basic samples

Sample	Origin	Latitude	Longitude	Soil or soil parent material	Soil moisture regime	Number of trees dom. codom. intermed. unclass.			
White Spruce									
1	Alberta (Mixedwood Forest Section) ¹	54°—58°N	Probably: 110°—115°W	Till	Well- and moderately well-drained	205			
2	Alberta, Manitoba					21	36	10	13
3	Manitoba			Till, dumped till	1 to 6	12			38
4	Newfoundland	Probably: 48°—50°N	Probably: 54°—59°W						32
Black Spruce									
1	Manitoba, Saskatchewan	52½°—54½°N	101°—107°W	Probably: loam to clay-loam till; sand to clay of till or lacustrine origin ²	Probably: moderately fresh to poorly-drained ²	33	11		71
2	Labrador	52¼°—53½°N	57¼°—66½°W						85
3	Newfoundland	Probably: 48°—50°N	Probably: 54°—59°W	Probably: sand loam to loam till ³					64

1 Duffy (1965)

2 Jameson (1964)

3 Damman (1964)

degree, this range in spruce (*Picea* spp.) from various regions in the boreal forest of Canada.

Data

The stem analysis data for white spruce and for black spruce used in this study were collected over several decades by various workers, and for various purposes. Consequently, adequate site descriptions were not always available. Annual rings of the trees in the basic samples were counted at BH, and for a number of sections, above BH. This number was either constant and equal to 10, or it varied from tree to tree. The minimum BH age of these trees was the same for all the trees included in a sample, i.e., either 50 or 75 years. Dominant, codominant, nonclassified and, in 50-year-old white spruce, some intermediate trees were used. The basic samples are described in Table 1. In this table, the information about soil or soil parent material, soil moisture regime, latitude and longitude was taken either from field records or inferred from publications dealing with the sampled areas.

Methods and Results

Total heights (H_i) of individual trees in the basic samples were obtained for the 5-year BH age intervals (i) by linear interpolation.

Regressions

$$\hat{H}_i = a_i + b_i + (SI) \quad (1)$$

where site index (SI) = H_{50} , were derived for all the samples and for intervals (i) = 5, 10 . . . 75 (Heger, 1968). Their statistics are listed in a previous report.²

The linear fit in the relationships described by regressions (1) was compared with the parabolic fit in the regressions

$$\hat{H}_i = a_i + b_i (SI) + c_i (SI^2) \quad (2)$$

by analysis of variance. In white spruce, the parabolic fit was not significantly better than the linear fit for all samples and for all but one value of i at the 5% probability level. In black spruce, and for $i > 5$, the parabolic fit was better than the linear fit in five regressions. These five regressions¹ were derived for black spruce from Newfoundland, and for $i \geq 55$.

Ordinates ($\hat{H}_i$) of the site-index curves were calculated from regressions (1) and (2) for 10-foot site-index classes. Their range was given by the ranges of the values for SI in the basic samples.

The ordinates were then compared, by species, for the same values 2 of SI and i . Some of the curves determined by these ordinates are shown in Figures 1 and 2.

The maximum difference among the ordinates of the curves for white spruce did not exceed 2.0 feet for $i \leq 55$, and for $SI \leq 60$. The average deviation corresponding to this difference was 0.75 feet. Larger differences, not above 4.6 feet, were observed in the 70-foot site-index class group; they were caused by the divergent shape of the curve for white spruce from Manitoba. Differences as large as 8.8 feet existed for $i > 55$; they were caused by the divergent shape of the curves for white spruce from Newfoundland.

The largest difference among the ordinates of the curves for black spruce was 1.6 feet for $i \leq 55$, and 3.8 feet for $i > 55$. The corresponding average deviations were 0.80 and 1.53 feet.

The ordinates calculated from regressions (1) did not differ from those calculated from regressions (2) by more than 1.4 feet.

¹Heger, L. 1968. Site-index curve shape in spruce from Alberta, Manitoba, Saskatchewan, Labrador, and Newfoundland. Dept. For. and Rural Development, Internal Report FMR-8.

Discussion

The stem analysis data used in the present study were obtained by inconsistent methods from trees selected, as far as is known, from three crown classes. The criteria used to select these trees are not known; the information about the soils which supported the trees is incomplete. Although it is probable that a large majority of the sampled trees were dominants and codominants and that most

soils were derived from the tills, the moisture regime of these soils was not uniform. Moreover, the sampled areas were separated by approximately 60 degrees or more of longitude and 10 degrees or more of latitude.

Despite the heterogeneity of the basic data, most of the observed differences among the site-index curves were small; for BH ages up to 55 years and for site indices below 70 feet, they did not exceed 2 feet in either species. These differences were smaller than the magnitude of errors inherent in the measurement of heights by standard instruments in stands of conifers higher than 30 feet (Ker, 1951; Warren, 1958). Hence, the errors in site index due to differences between the true heights and heights measured by standard instruments may outweigh site-index errors assignable to the observed differences in curve shape.

It is thus doubtful that any practical advantages would be gained by using separate sets of curves for black spruce in the investigated sites and regions during the initial 55 years of growth above BH. However, anomalies in height growth were frequent in white spruce. Additional comparisons based on an adequate sampling design can show whether separate sets are necessary for various regions, or conditions of soils, supporting white spruce.

The high degree of similarity observed among the height-total-age trends of pine (Spurr, 1955) is also present among the height-BH age trends of spruce. The geographical range within which a single set of site-index curves is applicable may thus coincide with the botanical range of a species for periods lasting more than 50 years.

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Fig. 1: A comparison of site-index curves for white spruce from various regions.

Fig. 2: A comparison of site-index curves for black spruce from various regions.