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Predicting Site Index of Lodgepole Pine and Interior Spruce in the Sub-boreal Spruce Zone

Introduction

Knowledge of ecological site characteristics and tree growth on different sites is fundamental for silvicultural decision-making and planning. With biogeoclimatic ecosystem classification in place in British Columbia, silvicultural management has been given an ecological foundation; however, relationships between growth and site quality have not yet been fully investigated. The purpose of this study was to determine how site conditions within the SBS zone affect the height growth of lodgepole pine (Pl) and interior spruce (Sx).

We adopted site index (ht @ 1.3m age 50) as a species-specific measure of forest productivity, recognizing that it gives a temporal indication of height growth. Site index cannot be considered a true measure of the ecological quality of the site nor can ecological site quality be considered a true measure of forest productivity as two different species on the same site may have different site indices, or the same tree species may have the same site index on two ecologically different sites.

If forest productivity is correlated with ecological measures of site quality, what site factors should be used quantify the relationships? Because of compensating effects, the many possible site factors can be reduced to four key determinants that impact plant establishment and growth: climate (light and temperature), soil moisture, soil nutrients, and soil aeration (not used in this study).

Study Stands and Methods

Ninety three Pl plots and 77 Sx plots were located in naturally established, unmanaged, even-aged (from 25 to 154 years @ 1.3m) stands without a history of damage or supression. The stands were located in the Dry Cool and Moist Cold subzones of the SBS zone (SBSdk and SBSmc subzones, respectively) across a wide range of elevation, aspect, and soil conditions. In each stand, a 20 x 20 m plot was established to represent an individual ecosystem with relatively uniform vegetation and topography. The site relative soil moisture regime (SMR) and soil nutrient regime (SNR) were estimated in the field and then converted to actual qualitative values.

In each plot, the five largest diameter trees of the study species were measured for age @ 1.3m with an increment borer, and top height with a clinometer. Site index for both species was taken from height growth tables. Biogeoclimatic subzone (identified from maps and representing climate), actual SMR, and SNR were used as independent categorical variables. Multiple regression analysis was used to examine relationships between site index, climate, actual SMR, and SNR.

Results

Relationships between site index and climate

Stratification of study stands by subzones did not indicate any significant difference in site index of either species between climates. Comparison using zonal (intermediate) sites indicated a trend of increasing Pl site index from the SBSdk to SBSmc subzone (from 18.9 to 21.1 m), and decreasing Sx site index from the SBSdk to SBSmc (17.8 to 17.4 m).

Relationships between site index and soil moisture

There were similar and strong relationships between site index of both species and actual SMR. Mean site index of both species increased from very dry to fresh sites, reached a plateau (approximately at 20 m) on fresh and moist sites - the edaphic conditions of highest growth for both species - and decreased from moist to very wet sites. Although the Sx site index was lower than that of Pl on very dry and wet sites, interspecific differences were not significant for any SMR (Table 1).

Table 1. Number of stands (n) and standard deviations (in parentheses) of site index (ht @ 1.3m age 50) of Pl and Sx stratified by actual SMR. Values in the same row with different uppercase superscripts or in the same column with different lowercase superscripts are significantly different ($p \leq 0.05$; Tukey's test).

Species	Very dry	Moderately dry	Slightly dry	Fresh	Moist	Very moist	Wet	Very wet
Pl	$14.2^{B,a}$ (6.1) n = 2	$15.2^{B,a}$ (2.2) n = 18	$17.9^{A,a}$ (1.2) n = 25	$20.8^{A,a}$ (2.5) n = 22	$20.1^{A,a}$ (2.0) n = 10	$17.0^{B,a}$ (3.6) n = 13	$15.2^{B,a}$ (2.1) n = 2	8.9 n = 1
Sx	$8.0^{D,a}$ (1.6) n = 3	$14.4^{C,a}$ (1.7) n = 12	$17.9^{B,a}$ (2.0) n = 16	$20.4^{A,a}$ (2.6) n = 25	$19.7^{AB,a}$ (1.2) n = 8	$18.8^{AB,a}$ (3.4) n = 10	$10.9^{CD,a}$ (6.9) n = 2	4.3 n = 1

Relationships between site index and soil nutrients

Stratification of study stands by SNRs showed different relationships for each species (Table 2). Mean Pl site index increased from very poor to medium sites but there were no significant differences ($\alpha = 0.05$) between medium, rich, and very rich sites. In comparison, the Sx site index increased consistently from very poor to very rich sites, reaching a maximum of approximately 23 m.

Table 2. Number of stands (n) and standard deviations (in parentheses) of site index (m @ 50 yr bh) of Pl and Sx stratified by SNR. Values in the same row with different uppercase superscripts or in the same column with different lowercase superscripts are significantly different ($p \leq 0.05$; Tukey's test).

Species	Very poor	Poor	Medium	Rich	Very rich
Pl	$12.3^{C,a}$ (1.3) n = 8	$16.1^{B,a}$ (2.3) n = 29	$19.2^{A,a}$ (1.5) n = 30	$20.6^{A,a}$ (2.2) n = 23	$20.2^{A,a}$ (4.1) n = 3
Sx	$6.2^{E,b}$ (0.2) n = 2	$13.5^{D,b}$ (3.0) n = 12	$16.9^{C,b}$ (1.8) n = 23	$19.3^{B,a}$ (3.2) n = 32	$22.9^{A,a}$ (2.5) n = 8

Relationships between site index, climate, soil moisture, and soil nutrients

Regression models were developed to quantify relationships between site index and categorical measures of site quality (Table 3). Climatic models showed no relationships with site index, and inclusion of subzone into other models had no effect. Each SMR and SNR model explained some proportion of site index, but the combined SMR & SNR (edatope) model accounted for the largest proportion of the variation in site index (R^2 >0.80) and gave the lowest standard error (from 1.4 to 1.6 m).

Table 3. Models for the regression of Pl (n = 93) and Sx (n = 77) site index (m @ 50 years bh) on SMR and SNR. All models are significant at $\alpha = 0.05$. SEE - standard error of estimate; abbreviations for SMRs: VD – very dry, MD – moderately dry, SD – slightly dry, F – fresh, M – moist, VM – very moist, W – wet, VW – very wet; abbreviations for SNRs: VP – very poor, P – poor, M – medium, R – rich, VR – very rich.

Site index model

Lodgepole pine

[1] SI = 8.90 + 5.25(VD) + 6.68(MD) + 9.04(SD) +11.92(F) + 11.18(M) + 8.08(VM) + 6.30(W) + 0.00(VW)
Adjusted R^2 = 0.45, SEE = 2.4 m

[2] SI = 20.23 – 7.98(VP) – 4.11(P) – 1.09(M) –0.51(R) + 0.00(VR)
Adjusted R^2 = 0.60, SEE = 2.0 m

[3] SI = 14.17 – 9.27(VP) – 5.27(P) – 3.11(M) – 1.72(R) – 0.00(VR) + 4.17(VD) + 6.85(MD) + 8.13(SD) + 9.33(F) + 8.48(M) + 6.97(VM) + 1.89(W) + 0.00(VW)
Adjusted R^2 = 0.82, SEE = 1.4 m

Interior spruce

[4] SI = 4.30 + 3.67(VD) +10.08(MD) + 13.59(SD) +16.05(F) + 15.38(M) + 14.45(VM) + 6.55(W) + 0.00(VW)
Adjusted R^2 = 0.65, SEE = 2.5 m

[5] SI = 22.89 – 16.74(VP) – 9.43(P) – 6.03(M) –3.58(R) + 0.00(VR)
Adjusted R^2 = 0.58, SEE = 2.7 m

[6] SI = 7.13 – 10.09(VP) – 7.17(P) – 5.05(M) – 2.83(R) – 0.00(VR) + 9.25(VD) + 13.01(MD) + 15.37(SD) + 16.10(F) + 15.58(M) + 14.97(VM) + 10.58(W) + 0.00(VW)
Adjusted R^2 = 0.85 SEE = 1.6 m

Discussion

Despite a limited representation of certain edatopes, the large amount of variation explained by the edatope model (Equations [3] and [6]) revealed strong relationships between site index of Pl and Sx and selected measures of site quality. Productivity of these species is expected to increase from cool to warm and from dry to wet climates. Insignificant differences in site index between zonal sites of both species indicated that the two study subzones either are climatically similar or, because of compensating effects, have similar actual evapotranspiration. In consequence, site index – site quality relationships can be examined within the study area without considering climate.

Sx site index was significantly lower than Pl on all but the richest sites. On all other sites, Pl site index was higher, with the difference in favour of Pl increasing with decreasing nutrient supply and increasing water deficit or surplus. These relationships suggest Pl is less nutrient-demanding than Sx, which is more sensitive to extremes in water supply and soil nitrogen than Pl. The best growth of both species occurred on fresh or moist, very rich sites where Pl and Sx attained site indices of 25 and 24 m, respectively.

Conclusions

Site index of Pl and Sx varied with soil moisture and soil nutrients, but not with climate represented by two adjacent, climatically similar biogeoclimatic subzones. The pattern of change in site index relative to soil moisture was similar for both species but differed relative to soil nutrients. Sx site index was significantly lower than Pl on nitrogen-deficient sites. The regression model using soil moisture and nutrient regimes as categorical variables had the strongest relationships with site index of both study species ($R^2 > 0.80$; SEE <1.6 m).

Reference

Wang, Q., G.G. Wang, K.D. Coates, and K. Klinka. 1994. Use of site factors to predict lodgepole pine and interior spruce site index in the Sub-boreal Spruce zone. Research Note No. 114, BC Ministry of Forests, Victoria BC. 26 pp.

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