FOREST RESEARCH LABORATORY

RESEARCH NOTE 66

AN EVALUATION OF EIGHT INTERTREE COMPETITION INDICES

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INTRODUCTION

Intertree competition indices have been important in growth simulation methodology since Newnham (1964) introduced a distance-dependent stand model for Douglas-fir. Indices developed by other authors also require data on intertree distances; however, their calculations vary for crown overlap, angle measures, and diameter breast height (d.b.h.) ratios of competitors to subject trees. The purpose of this study was to evaluate the ability of eight such indices to predict diameter growth in thinned stands. Those tested fall into two groups, one basing the indices on crown or adjusted crown overlap and the other on diameter, or distance to a neighboring tree (Table 1).

A set of FORTRAN algorithms developed by the Pacific Forest Research Centre, Victoria, B.C., to evaluate the competition indices were made available to the School of Forestry at Oregon State University.

TABLE 1.
BASIS OF COMPUTATION FOR THE EIGHT INTERTREE COMPETITION INDICES.

Author	Date	Crown or adjusted crown overlap	Diameter/ distance to neighboring tree
Arney	1971	X	
Bella	1970	X	
Ek and Monserud	1973	X	
Hegyi	1973		X
Lin	1969		X
Newnham	1964	X	
Staebler	1951	X	
Quenet	1975		X

GROWTH DATA USED IN THE EVALUATION

Data used to evaluate the indices were taken from a study by Berg and Bell (1979) established in 1963 on land near Hoskins, Oregon owned by Starker Forests. Average stand age was 20 years. The Hoskins study was designed to examine the effect of different levels of growing stock on wood production, tree size, and ratios of growth to growing-stock. It comprises eight treatments and a control, each replicated three times. A calibration thinning was made in 1963 and treatment thinnings were made in 1966 and 1970. We used data from treatments 1, 3, 5, and 7, representing four levels of growing stock in descending order from heavy to light thinning, and from two growth periods, 1966-1970 and 1970-1973.

Each of the four treatments contained three square 0.2-acre plots (93.33 x 93.33 ft). An interior square (50 x 50 ft) was used to model growth; therefore, any trees outside the interior that could inhibit growth (crown overlap) could be accounted for accurately. The interior square also contained a large enough number of trees for a reasonable growth analysis representing different thinning treatments. All trees within the 0.2-acre plots had been numbered and stem mapped.

DATA ANALYSIS

The data were analyzed in two ways. First, we regressed periodic increment in d.b.h. on initial diameter, initial competitive stress index, and change in the competitive stress index due to different thinning treatments on individual plots at the beginning of each growth period. The correlation coefficient (R^2) and mean square error (MSE) for each thinning treatment were then averaged. Second, we combined data for all trees on all plots and regressed periodic diameter increment on the associated initial diameter, initial competition index, and change in competition index due to thinning.

The basic growth model for the comparison analysis is that used by Smith (1977):

$$\Delta D = a + bD_0 = c(CSI_0) + d(\Delta CSI_0)$$

where

ΔD = the change in d.b.h. (in.),

n_0 = the d.b.h. at the beginning of the growth period (in.),

CSI_0 = the Competitive Stress Index at the beginning of the growth period, and

ΔCSI_0 = the change in CSI due to thinning before the beginning of the growth period.

This model was chosen because it had the highest R^2 and the lowest MSE of all the models that Smith (1977) tried. The following are his results using data from the Hoskins study:

Growth model $\Delta D = f(D_0, CSI_0, \Delta CSI_0)$.

	1966-1970	1970-1973
R^2	0.674	0.808
MSE	.094	.042

In our analysis, we substituted CI_0 for CSI_0 and ΔCI_0 for ΔCSI_0, where CI_0 refers to one of the eight competition indices being compared.

Therefore, our basic growth model is

$$\Delta D = a + bD_0 + c(CI_0) + d(\Delta CI_0) \qquad [1]$$

Open-grown crown width is used by Arney, Bella, Ek, Newnham, Lin, and Staebler in determining their competition indices. The crown width formula is that used by Arney (1973) in his analysis combining data from British Columbia and Oregon:

$$CW = 4.0223 + 2.1223\,(DOB) - 0.0220\,(DOB)^2$$

where

CW = crown width (ft), and

DOB = diameter outside bark (in.).

Input data to the program were x-y coordinates of each tree, the tree number, initial diameter at breast height (D_0), diameter at breast height (D_1) at the end of the growth period, and plot number. The output contained plot number, tree number, the author's assigned number, D_0, ΔD, CI_0, and ΔCI_0.

The basic growth model, Equation 1, was then fitted to the data. We averaged R^2 and MSE over each treatment (three plots) and over all plots for the two growth periods.

CORRELATING PREDICTION WITH MEASURED GROWTH

In the analysis by treatment (Table 2), the model using Lin's competition index had the highest correlation with measured growth for both growth periods, 0.684 and 0.804, and the lowest MSE, 0.104 and 0.029. Quenet's competition index produced the lowest R^2, 0.616 and 0.695, and the highest MSE, 0.125 and 0.044.

In the 1966-1970 growth period, growth data from the heaviest thinning treatments, 1 and 3, fit the model best with R^2 0.759 and

TABLE 2.

CORRELATION OF GROWTH MODELS USING EACH OF EIGHT COMPETITION INDICES (CI_0) WITH GROWTH DATA FOR FOUR THINNING TREATMENTS IN THE HOSKINS STUDY. MEAN SQUARE ERROR IN PARENTHESES.

Treat-ment	Average sample size per plot	Arney	Bella	Ek	Hegyi	Lin	Newnham	Quenet	Staebler	Treatment average
				1966-1970 GROWTH MODEL: $\Delta D = a + bD_0 + c(CI_0) + d(\Delta CI_0)$						
1	12	0.801	0.778	0.774	0.699	0.821[a]	0.750	0.652[b]	0.796	0.759
		(.062)	(.068)	(.070)	(.083)	(.049)	(.072)	(.100)	(.063)	(.071)
3	16	.755	.753	.755	.786[a]	.736[b]	.741	.743	.757	.753
		(.092)	(.093)	(.092)	(.076)	(.100)	(.097)	(.093)	(.090)	(.092)
5	17	.571	.566	.569	.582	.558	.567	.515[b]	.602[a]	.566
		(.195)	(.188)	(.186)	(.194)	(.180)	(.190)	(.203)	(.189)	(.191)
7	18	.584	.616	.614	.613	.623[a]	.572	.554[b]	.565	.593
		(.096)	(.089)	(.089)	(.092)	(.086)	(.100)	(.105)	(.101)	(.095)
Mean		.677	.678	.678	.670	.684[a]	.657	.616[b]	.680	.668
		(.111)	(.110)	(.109)	(.111)	(.104)	(.115)	(.125)	(.111)	(.112)
				1970-1973 GROWTH MODEL: $D = a + bD_0 = c(CI_0) + d(CI)$						
1	6	0.813	0.786	0.784	0.802	0.887[a]	0.750[b]	0.771	0.787	0.798
		(.023)	(.027)	(.027)	(.022)	(.016)	(.038)	(.034)	(.031)	(.027)
3	11	.700	.767	.772	.686	.833[a]	.700	.574[b]	.677	.714
		(.038)	(.028)	(.027)	(.039)	(.024)	(.036)	(.051)	(.042)	(.036)
5	12	.731[b]	.763	.765	.813[a]	.791	.766	.732	.737	.762
		(.037)	(.027)	(.027)	(.020)	(.022)	(.027)	(.037)	(.040)	(.030)
7	16	.754	.755	.755	.737	.706	.744	.704[b]	.773[a]	.741
		(.047)	(.046)	(.047)	(.048)	(.054)	(.047)	(.054)	(.045)	(.049)
Mean		.750	.768	.769	.760	.804[a]	.740	.695[b]	.744	.754
		(.036)	(.032)	(.032)	(.032)	(.029)	(.037)	(.044)	(.040)	(.035)

[a]Highest R^2 for the treatment.
[b]Lowest R^2 for the treatment.

0.753, respectively. Treatments 5 and 7 had correlations of 0.566 and 0.593, respectively. In the 1970-1973 growth period, the growth model for each of the eight authors fit observed growth nearly equally. Treatment 1, the most heavily thinned, had a correlation of 0.798.

We combined growth and competition-index data for 1966-1970 and 1970-1973 and for treatments 1, 3, 5, and 7 for analysis by author only. Criteria for evaluating the effectiveness of each index were R^2 and MSE. Four models were fit to the data:

$$\Delta D = f\ (\Delta CI_0)$$

$$\Delta D = f\ (CI_0)$$

$$\Delta D = f\ (CI_0,\ \Delta CI_0)$$

$$\Delta D = f\ (D_0,\ CI_0,\ \Delta CI_0)$$

For the two growth periods, the fourth model had the highest correlation and lowest MSE. However, among the eight overall averages for authors, no one index is clearly superior to the others. (Table 3).

COMPUTATION TIME

An important criterion for selecting a competition index is the computation time required. Table 4 lists the time required with each index to evaluate a forest plot 50 by 50 feet in a stand of approximately 280 trees per acre. Six indices are within 40 percent of the fastest model (the Hegyi model). The Staebler competition index was notably slower.

LIMITATIONS OF DATA

The reader should note that this analysis was performed on a single set of plots and a single tree species within a restricted set of conditions. A direct comparison of the results by no means establishes the true relationship among the methods. Alemdag (1978), in a similar study, found that although some competition indices gave better results with a given data set, there was no consistent pattern among sets. He believed the order of results might have been purely accidental. This study seems to support Alemdag's findings. However, Hegyi's model required the least computation time.

TABLE 3.

CORRELATION OF FOUR GROWTH MODELS AND EIGHT COMPETITION INDICES WITH COMBINED GROWTH DATA FROM THE HOSKINS STUDY PLOTS. DATA IN LEFT COLUMNS BENEATH EACH VARIABLE ARE FOR 187 TREES, 1966-1970; IN RIGHT COLUMNS FOR 133 TREES, 1970-1973. MEAN SQUARE ERROR IN PARENTHESES.

Author	Model Variables							
	ΔCI_0		CI_0		CI_0, ΔCI_0		D_0, CI_0, ΔCI_0	
Arney	0.102	0.034	0.114	0.314	0.298	0.453	0.592	0.718
	(.236)	(.173)	(.233)	(.124)	(.185)	(.099)	(.108)	(.052)
Bella	.025	.006	.371	.578	.511	.697	.603[a]	.735
	(.256)	(.179)	(.165)	(.076)	(.129)	(.055)	(.106)	(.049)
Ek	.016	.013	.379	.574	.513	.696	.598	.732
	(.258)	(.178)	(.163)	(.077)	(.129)	(.055)	(.107)	(.049)
Hegyi	.030	.012	.441	.685	.566	.729	.603[a]	.741[a]
	(.255)	(.178)	(.147)	(.057)	(.115)	(.049)	(.106)	(.047)
Lin	.060	.015	.381	.542	.533	.651	.585	.681
	(.247)	(.177)	(.163)	(.083)	(.123)	(.062)	(.110)	(.058)
Newnham	.052	.001	.326	.579	.496	.686	.599	.728
	(.249)	(.180)	(.177)	(.076)	(.133)	(.057)	(.107)	(.050)
Quenét	.052	.003	.221	.450	.348	.475	.546[b]	.660[b]
	(.249)	(.180)	(.205)	(.099)	(.173)	(.095)	(.121)	(.062)
Staebler	.135	.080	.015	.131	.135	.274	.588	.709
	(.259)	(.166)	(.228)	(.157)	(.211)	(.132)	(.110)	(.053)

[a]Highest R^2.
[b]Lowest R^2.

TABLE 4.

AVERAGE COMPUTATION TIME USING THE EIGHT COMPETITION INDICES IN THE EQUATION $\Delta D = f(D_0, CI_0, \Delta CI_0)$.

Author	Seconds per plot	Percent slower than fastest time
Hegyi	0.369	--
Quenet	0.386	4.5
Lin	0.391	5.8
Bella	0.425	15.2
Ek	0.444	20.3
Arney	0.462	25.2
Newnham	0.515	39.6
Staebler	2.182	491.5

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