AN INDEX OF COMPETITION BASED ON RELATIVE CROWN POSITION AND SIZE'

Dwight D. O'Neal, Allan E. Houston, Edward R. Buckner, and James S. Meadows'

Abstract4 nsw competition Index, the Crown Position Index (CPI) was evaluated using a 41-year-old, well stocked, upland hardwood stand in southwestern Tennessee. CPI was based on relative crown position and crown size as expressed by crown projections and relative heights of crop trees and their competitors. Comparisons were made among CPI, the Hegyi (1974) index, end a value of Direct Sunlight from the Side (DSS). Correlations of each measure of competition with 1 and 2 year crop tree diameter growth were used as criteria for analysis. The highest r-values were calculated using DSS followed by the Hegyi index and CPI respectively.

INTRODUCTION

Indices that effectively quantify competition among individual trees are elusive concepts. Common density measurements such as basal area are useful for estimating total stand growth but are usually not effective for evaluating the growth response of individual trees to various treatments (Moore et al. 1973 and Biging and Dobbertin 1992). The need to evaluate factors influencing individual tree growth is especially important with the increasing interest of culturing individual "crop trees" (Heitzman and Nyland 1991).

EXISTING INDICES

Holmes and Reed (1991) recognized 3 types of competition indices: (1) influence zone overlap indices, (2) growing space indices, and (3) size ratio indices. Size ratio indices, derived from relative tree size and intertree distance comparisons, are computationatly the simplest form of competition index *Several* authors (Daniels 1976, Daniels et al. 1986, Lorimer 1983 Holmes and Reed 1991) using a range of species, reported that size ratio indices performed as well or better than the more complex influence zone overlap and growing space indices. The one index that was most consistent was the Hegyi (1974) index

Hegyi's original (1974) competition index for jack pine (*Pinus banksiana* Lamb.) was calculated as follows:

$$CI_i = \sum_{j=1}^{n} (D_j/D_i)/DIST_{ij}$$

where CI_i = competition index of subject tree i

D_i = diameter at breast height (d.b.h.) of subject tree I
D_j = d.b.h. of competitor tree j
$DIST_{ij}$ = distance between subject tree I and competitor j
N = number of competitors.

Hegyi (1974) originally defined N to include all trees within a 1 O-foot radius of the subject tree. Daniels and Burkhart (1975) modified the index incorporating a diameter-distance relationship to select competitors. Daniels (1976) found that higher correlations with diameter growth were achieved when the index included more competitor trees (i.e. using a lower basal area factor). Using a basal area factor of 10, Daniels (1976) obtained a correlation coefficient (r) of -0.415 between the index and diameter growth in managed loblolly pine plantations.

The Hegyi index assumes that the relative d.b.h. and distance between the subject and competitor tree reflects their competitive interaction. However, the degree of competition among individuals at a given stocking level depends on crown characteristics (Perry 1985). For example, two trees could have the same d. b. h. and be the same distance from the subject tree, but have crowns that are very diierent in their influence on the subject tree. The crown of one tree may not project towards the subject tree at all, while the other may overtop the subject tree. While the difference in competitive influence is apparent, indices based solely on d.b.h. and intertree distance would give identical competition values. Incorporating crown characteristics in a competition index should strengthen its performance, especially when measuring the degree of

'Paper presented at the Eighth Biennial Southern Silvicultural Research Conference, Auburn, AL, Nov. 1-3, 1994.

[2]Graduate Research Assistant, University of Tennessee, Knoxville TN; Research Assistant Professor of Forestry, Ames Plantation, Grand Junction TN; Professor of Forestry, University of Tennessee, Knoxville TN; and Silviculturist, USDA Forest Service, Southern Forest Experiment Station, Stoneville MS.

competitive release for a subject tree when **only** one of two equal diameter trees is removed.

A possible measure of competition that incorporates crown characteristics is the Direct Sunlight from the Side (DSS) value used in a Point System for Hardwood Crown Classes developed by Meadows et al. (unpublished)[1]. DSS provides a numerical rating (ranging from O-to-l 0) of the amount of sunlight from the sides reaching the upper 50 percent of a tree's crown. An open grown tree would receive a DSS point value of 10 (i.e. 100 percent of the upper **half** of the crown is receiving direct sunlight from the side). If only 50 percent of the tree's crown is receiving direct sunlight from the side then it would receive a DSS value of 5. DSS requires no direct measurement of competing trees.

CROWN POSITION INDEX

The two crown characteristics that may best describe a tree's competitive status are crown position (both horizontally and vertically) and crown size. Foresters make thinning decisions partially based on these 2 factors as well as stem qualii. A competition index based on the measurement of these criteria would incorporate **traditional** judgement in the evaluation of tree competition.

The Crown Position Index (CPI) evaluated in this study incorporates these variables. It is calculated as follows:

$$CI_i = \sum_{j=1}^{n} ((CP_j + MCR)/D_{ij})(CP_j/MCR)((HT_j - D_{ij})/HT_i)$$

where CI_i = competition index of subject tree i
CP_j = crown projection of competitor j measures in a straight line towards subject tree I
MCR = mean crown radius of subject tree I
D_{ij} = distance between subject tree i and competitor j
HT_i = total height of subject tree i
HT_j = total height of competitor j
N = number of competitors, as determined by a 10 BAF prism point taken 2 feet west of the crop tree.

OBJECTIVE

The objective of **this** study was to evaluate CPI as a measure of competition for upland hardwood crop trees. Specifically, the study compared CPI, the Hegyi index and DSS.

[1]Meadows, **James** S., Hodges, John D., Burkhardt, **E.C.** and **Johnson,** Robert L. [in preparation]. Numerical Rating System to Distinguish Crown Classes of Southern **Hardwood** Trees. (unpublished manuscript).

STUDY AREA

The study was conducted on Ames Plantation, a research unit of The University of Tennessee Agricultural Experiment Station, located in southwestern Tennessee. Topography was gently rolling (5 to 20 percent slopes), with soils that were well drained (primarily of the Lexington and Smithdale series). These soils were well suited to upland oaks with an average site index (base age 50 years) of 75 to 85 feet (Flowers 1960).

The study stand was well stocked (average basal area per acre of 120 square feet) and even-aged (41 years old) with a small component of larger, older trees. The primary overstory species were white oak (***Quercus alba*** L.), southern red oak (Q. ***falcata*** Michx.), scarlet oak (Q. *coccinea* Muenchh.), black oak (Q. ***velutina*****),** **black** cherry (***Prunus serotina*** Ehrh.), hickory (***Carya spp.*****),** red maple (***Acer rubrum*** L.) and black tupelo (***Nyssa sylvatica*** Marsh.).

METHODS

A randomized complete block design containing 5 blocks each with 2 replicates was used in the study. Each replicate contained 36 cells (**35-** by **35-** feet) and was surrounded by a **35-foot** non-treated buffer zone. Treatments were a control and a crop tree release.

The trees in each cell were evaluated and where criteria were met, a single crop tree was selected. The tree that exhibited the greatest potential for attaining the highest value at maturity was selected. Selection was based primarily on stem **quality,** crown position, and species, with white oak being the most desirable. When possible black oak was selected as the crop tree if no desirable white oak were available. Other **acceptable** species included southern red oak, scarlet oak and black cherry. Baseline data were taken in the winter of 1992-I 993. A summary of the crop tree data is given in Table 1.

Table l-Average d.b.h. (inches), total height (feet), and number of crop trees selected in a **41-year-old** upland hardwood stand in southwest Tennessee.

Crop Tree Species	N	Average **D.b.h.**	Average Total Heiaht
white oak	445	9.9	65
southern red oak	101	9.9	*64*

Crop trees were released in March of 1993. Each crop tree was released on at least 3, and preferably 4, sides. Any tree (except adjacent crop trees) that was impeding the expansion of the crop tree's crown was felled. Crop tree d.b.h. was remeasured in January 1994 and October 1994. DSS was also remeasured in October 1994.

Crop tree diameter growth was assumed to **reflect** competitive influence. Correlation coefficients (r) were calculated between diameter growth and each measure of competition. Both 1 year and cumulative 2 year diameter growth were tested. For the control treatment, index values (CPI and Hegyi) were calculated using the baseline data (initial competition). For the release treatment, index values represent the amount of competition removed (i.e. initial competition • competition removed = residual competition). Correlations of diameter growth with DSS for both control and release treatments were made using the values measured in October **1994.** Only whiie oak and southern red oak were tested as small sample size precluded testing other species.

RESULTSANDDISCUSSION

Correlations of 1 year growth in the control treatments with the Hegyi index (r = -0.484) and DSS (r = 0.479) were significant for southern red oak (Table 2). For white oak only DSS had a significant correlation with 1 year growth (r = 0.436). Correlations **with** 2 year growth were significant for all measures of competition for both whiie and southern red oak in control treatments. Correlation coefficients with 2 year white oak diameter growth were r = -0.210, r = -0.242, and r = 0.544 for CPI, Hegyi and DSS respectively. Correlation coefficients with 2 year southern red oak diameter growth were r = -0.484, r = -0.514, and r = 0.623 for CPI, Hegyi and DSS respectively. Negative **r-**values for CPI and Hegyi indices indicate that as values of competition increased diameter growth decreased. Positive r-values for DSS demonstrate that d.b.h. growth increased with increasing side light

Table 2-Correlation analysis of 1 and cumulative 2 year diameter growth of crop trees in the control treatment with the Crown Position Index (CPI), the Hegyi index and Direct Sunlight from the Side (DSS).

	r-values			
Competition	white oak		southern red oak	
Measure	Year 1	Year 2	Year 1	Year 2
CPI	**-0.191**	-0.210’	-0.345	-0.484’
Hegyi Index	-0.133	-0.242’	-0.484’	**-0.514***
DSS	**0.436****	0.544”	0.479”	0.623”

. P < 0.05
** P < 0.01

These results are consistent with the findings of Holmes and Reed **(1991).** The correlation between d.b.h. and crown size appears to be strong enough to allow d.b.h. alone to consistently reflect competitive status in even-aged stands. Crown projection may be overemphasized in CPI as it failed to account for significantly more variation in d.b.h. growth than did the **Hegyi** index. More definitive guidelines for measuring crown projection should improve CPI. For example, crown projection in the lower portion of a competing crown could have less influence on a subject tree than crown projections in the upper crown. Selecting competitors based on a heightdiince relationship as reported by Biging and **Dobbertin (1992)** might also improve CPI.

Although CPI did not perform better than the Hegyi index it is still apparent that crown characteristics are important when evaluating competition as demonstrated by the **correlations** between diameter growth and DSS. DSS maaaures crown position as affected by all above ground competition for light, a recognbed biological factor influencing individual tree growth. From a practical standpoint DSS is more efficient than either index since only 1 measurement of the subject tree is needed versus arduous measurement of several competing trees. Also DSS emulates a field forester’s subjective **assessments** more closely than CPI. Foresters are trained to evaluate competition in terms of relative crown position. DSS is a quantitative measure of a subject tree’s position relative to its immediate competitors.
None of the 3 measures of competition were **significantly** correlated with diameter growth of released crop trees. A better evaluation will be possible when the crop trees have had more time to fulty respond to the release treatments.

CONCLUSIONS

All 3 measures of competition correlated significantly with 2 year diameter growth for both white and southern red oak. Relative crown position **as** expressed by CPI did not provide a more effective measure of competition than did relative d.b.h. as expressed by the Hegyi index. However, some measure of crown position, such as DSS, was shown to be a better evaluation of competition than using d.b.h. as a surrogate for actual crown characteristics.

ACKNOWLEDGMENTS

The authors would like to thank the U.S. Forest Service, the University of Tennessee Agricultural Experiment Station at Ames Plantation, Tennessee and the Trustees of the Hobart Ames Foundation for their support of this project

LITERATURE CITED

Biging, Greg S.; **Dobbertin,** Matthias. **1992.** A comparison of **distance-dependent** competition measure for height and basal area growth of **individual** conifer trees. For. Science **38:695-720.**

Daniels, Richard F. 1976. Simple competition indices and their correlation with annual **loblolly** pine tree growth. For. Science **22:454-456.**

Daniels, Richard F.; Burkhart, Harold E. 1975. Simulation of individual tree growth and stand development in managed loblolly pine plantations. FWS-5-75. Blacksburg, VA Virginia Polytechnic Institute and State University, Diion of Forestry and Wildlife Resources. 20 pp.

Daniels, Richard F.; Burkhart, H.E.; Clason, T.R. 1986. A comparison of competition measures for predicting growth of loblolly pine tress. Can. J. For. Res. 16:1230-1237.

Flowers, Robbie L. 1960. Soil survey of Fayette County, Tennessee. U.S. Dept of Agric., Soil Cons. Ser. Series 1960 No. 13.

Hegyi, Frank. 1974. A simulation model for managing jack pine stands. pp. 74-90. In: Growth models for tree and stand simulation, Fries, Joran. ed. Stockholm, Sweden: Royal College of Forestry.

Heitzman, Eric; Nyland, Ralph D. 1991. Cleaning and early crop-tree release in northern hardwood stands: a review. North. J. Appl. For. 8:11 l-l 15.

Holmes, Michael J.; Reed, David D. 1991. Competition indices for mixed species northern hardwoods. For. Science 37:1338-1 349.

Lorimer, C.G. 1983. Test of age-independent competition indices for individual tree competitive status. Can. J. For. Res. 3:495-500.

Moore, James A.; Budelsky, Carl A.; Schlesinger. 1973. A new index representing individual tree competitive status. Can. J. For. Res. 3:495-500.

Perry, D.A.; 1985. The competition process in forest stands. In: Attributes of trees as crop plants. M.G.R. Cannell and J.E. Jackson, eds. Hunts, England: Institute of Terrestrial Ecology.