NEIGHBORHOOD APPROACHES FOR ASSESSING WEED IMPACTS IN YOUNG FORESTS

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Summary
Decisions to control forest weeds should be based on a quantitative understanding of interspecific competitive influences on the growth and survival of young forest trees. Reliable methods for assessing these impacts, however, have not been developed. Neighborhood or individual-tree approaches to assessing the effects of interspecific competition provide a number of advantages over other methods. Using controlled experiments, the importance of the 1) abundance, 2) height, 3) distance, 4) azimuth, and 5) spatial arrangement of woody plants surrounding young trees can be evaluated. Using this approach, practical indices of forest weed competition can be developed for forest managers. Neighborhood approaches also provide a basis for analyzing potential mechanisms involved in competitive interactions, and for developing predictive computer models. Results from experiments in young Douglas-fir (Pseudotsuga menziesii Mirb. Franco) plantations of the U.S. Pacific Northwest are reviewed.

Introduction
Lack of quantitative techniques for evaluating the effects of interspecific competition imposes a major limitation to improving the basis for decisions about forest vegetation management (Walstad and Kuch 1987). Effects of interspecific competition on forest trees can be quantified using either a whole-stand or individual-tree (neighborhood) approach (Tappeiner and Wagner 1987). Whole-stand approaches estimate the yield of the average tree or whole stand from average measures of vegetation abundance throughout the stand. The individual-tree or neighborhood approach estimates yield of an individual tree from the degree of local crowding by neighboring plants.

Although both approaches can quantify growth losses in young conifer stands as forest weed abundance increases, competition processes among plants cannot be examined in detail with the whole- stand approach. Individual trees in young stands generally are surrounded by plants of various species, growth forms, ages, origins, densities, proportions, and spatial arrangements that change through time. Thus, understanding the influence of interspecific competition on stand dynamics requires analysis at the individual-plant level (Firbank and Watkinson 1987).

Recent work in the Oregon Coast Range has sought to develop a practical competition index for young Douglas-fir stands (Wagner 1989; Wagner and Radosevich 1991a, 1991b). Competition indices for individual Douglas-fir seedlings were developed by systematic examination of neighborhood factors. Potential mechanisms for competitive interactions expressed in the best competition indices also were examined.

Methods
Four sites, representing a range of environments in the Oregon Coast Range, were selected for study. Woody and herbaceous vegetation were manipulated by hand from 1985 through 1987 around 700 Douglas-fir seedlings on the four sites. The vegetation was removed in a manner that created a wide range of

neighbor densities, proportions, and spatial arrangements around individual Douglas-fir seedlings on each site. The range of neighborhood conditions included seedlings growing without neighbors on bare ground to seedlings completely suppressed by fast-growing woody vegetation. The dominant woody species neighboring the Douglas-fir seedlings was salmonberry (Rubus spectabilis Pursh). A range of grass and forb species served as herbaceous neighbors on the four sites.

Seedling growth (height and stem diameter) was measured annually from 1985 through 1987. Neighboring plants around each seedling also were measured annually. Woody vegetation was quantified using two approaches. One approach grouped all plants by species in a circular 0.0014 ha plot with a radius of 2.1 m, centered on the stem of each seedling. Percent crown coverage (visually estimated to the nearest 5%), average height, and the distance from the seedling stem to the nearest and farthest crown edges of each species within the plot boundary were recorded. The other approach considered each woody plant individually. The species, azimuth, and distance from the seedling stem, crown diameter, and height were recorded for each woody plant with a crown edge falling within the plot. When a neighbor's crown edge overtopped the seedling, a negative distance indicating the degree of crown overlap was recorded. Cover (to the nearest 5%) of all herbaceous species also was estimated visually.

The neighborhood data were analyzed using approaches by Wagner and Radosevich (1991a), Silander and Pacala (1985), and Pacala and Silander (1987). Multiple regression analysis was used in an iterative fashion with each of the neighborhood factors. Regression models were sought that minimized the relative mean square residual (1 minus adjusted r-square) for predicting Douglas-fir growth. The best neighborhood expression of competition was developed from this analysis.

Results of neighbourhood factor analysis

1) Neighbor Abundance

Interspecific competition indices (ICIs) were developed from seven measures of abundance for neighboring woody plants. Three measured woody plant abundance in the neighborhood at the species level: 1) percent cover, 2) height, and 3) crown volume (percent cover x height), each summed for all species. Four measured individual plant abundance: 1) crown area; 2) height; and 3) crown volume, each summed for all individual plants; and 4) number of woody plants.

Visual estimates of percent cover provided the best measure of neighbor abundance among the abundance measures tested. Similar conclusions have been obtained in other neighborhood studies (Wagner and Radosevich 1991a; Simard 1989; Coates 1987).

2) Neighborhood Height

To examine whether the neighborhood models could be improved by stratifying neighbors on the basis of their height, woody neighbors were systematically excluded from the ICI based on their height relative to that of the subject tree. At a neighborhood height of zero, all neighbors were included in the ICI. As neighborhood height increased, neighbors that fell below a specific relative height were excluded from the ICI.

Significant improvement (5 to 10%) in the neighborhood models resulted from excluding neighbors from the ICI based on their relative height. The optimum neighborhood height was different depending on the seedling growth parameter being examined. Douglas-fir diameter growth was more sensitive than height growth to shorter neighbors. Similar results were found in other work by Wagner and Radosevich (1991a). Defining an optimum neighborhood height in the ICI provided a means to account for the effects of asymmetric competition.

3) **Neighbor height**

Weighting woody species by their vertical distance below the optimum neighborhood height did not improve the models. The best models resulted by not including shrubs in the model that were shorter than the optimum neighborhood height. Slightly improved models resulted from weighting neighbors above the optimum neighborhood height. The best weighting function indicated that the competitive influence of neighboring shrubs increased as their height relative to the optimum neighborhood height increased.

4) **Neighborhood Radius**

To determine whether varying the neighborhood size could improve the models, woody neighbors were systematically excluded from the ICI based of their distance from the subject tree. Individual neighbors were included in the index if the distance to their center from the subject tree was less than or equal to the neighborhood radius. At zero radius, no ICI was included in the models. Increasing the neighborhood radius expanded the area around each tree in which neighbors were included in the index.

No improvement in the models resulted from changing the neighborhood radius when the sum of species cover was used as the neighbor abundance measure. The radius at which the visual cover estimates were made provided the best models. More detailed analyses using the individual-plant data indicated that the optimum radius was about 0.3 m from the seedling. The optimum neighborhood radius appeared to be defined by those neighbors whose crowns intermingled with the Douglas-fir.

5) Neighbor Distance

When using the optimum neighborhood height and radius, no improvement in the models resulted when including the nearest distance to a neighbor. If neighbors outside the optimum radius were included in the ICI, however, weighting neighbors by their distance from the subject tree did improve the models. These results indicated that the best ICI was distance independent as long as the optimum neighborhood radius was used. Conversely, the best neighborhood models were distance dependent when using a larger than optimum radius.

6) Neighbor Azimuth

No model improvements resulted from considering the azimuth or direction of the neighbors. Therefore, neighbor competitive effects appeared to be independent of their azimuth from the seedling.

7) Neighbor Spatial Arrangement

The spatial arrangement of neighbors has been proposed by Mack and Harper (1977) as a means to improve neighborhood models. Angular dispersion (after Zar 1974) of the neighbors was tested in the ICI. Angular dispersion values range from 0 (complete aggregation of neighbors) to 1 (complete dispersion of neighbors). Angular dispersion was incorporated into the ICI by adjusting neighbor abundance with the angular dispersion value. Weighting the ICI with the angular dispersion value did not improve the models.

Best neighbourhood measure of interspecific competition

This study and previous work (Wagner and Radosevich 1991a) are consistent. The sum of species cover above an optimum neighborhood height provided the best expression of neighborhood competition for Douglas-fir seedlings. Expressions that include more complicated and time-consuming measurements did not improve the models. Therefore, these studies suggest that quick and simple vegetation measures can be used to obtain reliable estimates of competitive stress in young Douglas-fir plantations.

Relation of neighbourhood competition to resource availability

Neighborhood influences of woody and herbaceous vegetation on light and soil water availability also were examined for 3 years in the above study. Available sky (calculated from hemispherical photographs) and cumulative soil water potential at four depths (measured with a neutron probe), were negatively correlated with the abundance of woody neighbors. Herbaceous vegetation did not influence light availability, but decreased soil water down to a 0.6 m depth. Patterns of light and soil water availability were consistent with 1) the best neighborhood measures of interspecific competition for Douglas-fir growth, 2) relative competitive abilities of woody and herbaceous vegetation, and 3) asymmetric competitive effects on Douglas-fir seedlings.

Experimental control in neighbourhood studies

Neighborhood studies have involved use of controlled, semi- controlled, and uncontrolled experiments. Controlled experiments systematically create a wide range of neighbor densities around target plants, and repeat measurements of target-plant performance and neighbor conditions are made. Semi-controlled experiments involve retrospective interpretations of neighborhood interactions following previous manipulations of neighbor densities. Uncontrolled or natural experiments use naturally occurring differences in neighbor densities around target plants, and a retrospective interpretation of neighborhood interactions.

Uncontrolled or natural experiments should not be used to interpret neighborhood interactions among plants (Connell 1983; Goldberg and Werner 1983; Underwood 1986; Mitchell-Olds 1987). Naturally occurring plant densities often result from specific environmental or disturbance factors. Therefore, spurious correlations between neighbor density and target-plant performance can result from experimental bias. Hypotheses of competition can not be tested using uncontrolled experiments.

Semi-controlled experiments can remove many biases associated with natural experiments, but are often limited by their retrospective nature and an inadequate range of densities. There is no direct causal relationship between neighbor abundance and target-plant size at the same point in time. Significant regression relationships between neighbor abundance and target-plant size can exist due to a correlation between present and historical neighbor abundance. Although semi-controlled experiments may overcome the possibility of spurious correlations found with natural experiments, the wide range of neighbor densities required to establish neighborhood relationships are often not available in semi-controlled experiments.

Wherever possible, only controlled experiments should be used in developing competition indices with the neighborhood approach. Controlled experiments should provide a wide range of neighbors densities and sufficient control over important environmental factors to reduce the possibility of spurious correlations and conclusions about the effects of plant competition.

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