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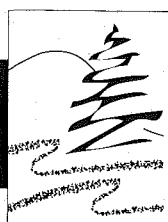
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DENSITY MANAGEMENT GUIDE FOR RED ALDER

by

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Table of Contents

Introduction	1
Data Base	1
Development of the Density Diagram	2
Lines	2
Zones	3
Application	4
Conclusion.....	5
Literature Cited	6

Introduction

Red alder (*Alnus rubra* Bong.) is a fast-growing pioneer species in the Pacific Northwest. It has invaded many areas after disturbances and now covers 13 percent of the commercial forest land in western Oregon and Washington (Resch 1988). Over the last two decades, the value of red alder lumber has increased and the hardwood industry has expanded. While current growth exceeds harvest (Plank *et al.* 1990), a shortfall in red alder wood is expected in 10 to 20 years because vegetation management over the past 20 years has eliminated natural red alder from conifer plantations and few red alder seedlings have been planted. As a result, there is little red alder growing stock younger than 30 years old. The expected shortfall has led to interest in establishing red alder plantations and more intensively managing existing red alder stands.

Density management provides opportunities to influence stand yield, individual tree size, stem form, and wood quality. One of the most useful tools for making decisions regarding stand density is the stand density diagram. A stand density diagram is based on the concept of self-thinning (i.e., the relationship between average tree size and stand density), is relatively easy to apply, and has the flexibility to include different management objectives.

First attempts to develop a density diagram for red alder were published by Hibbs (1987) and Hibbs and Carlton (1989). These diagrams were based on limited data and therefore were preliminary. This paper is intended as an extension of that work. It refines the existing density guidelines because it rests on a broader data base. It provides a detailed rationale for the positioning of lines and zones that characterize stand density and density management. Finally, it also gives examples to illustrate the use of the diagram.

Data Base

The data used to develop the density diagram came from three sources. A large portion came from studies of natural stands (Hibbs and Carlton 1989; Puettmann 1990; S. Greene, Pacific Northwest Research Station, Corvallis, Oregon, unpublished). These studies include both one-time measurements and long-term remeasurements. The second component is data from red alder spacing studies (D.S. DeBell, unpublished; D.E. Hibbs, unpublished). A third component is red alder thinning studies in previously unmanaged stands (Berntsen 1961; Bormann 1985; Hibbs *et al.* 1989; S. Greene, unpublished; D.E. Hibbs, unpublished).

Development of the Density Diagram

Stand density diagrams present relationships between mean tree size, usually presented as diameter, and stand density measured as number of stems per unit area. If the axes are scaled in logarithmic terms, parallel lines can be drawn to define zones with similar patterns of mortality and growth.

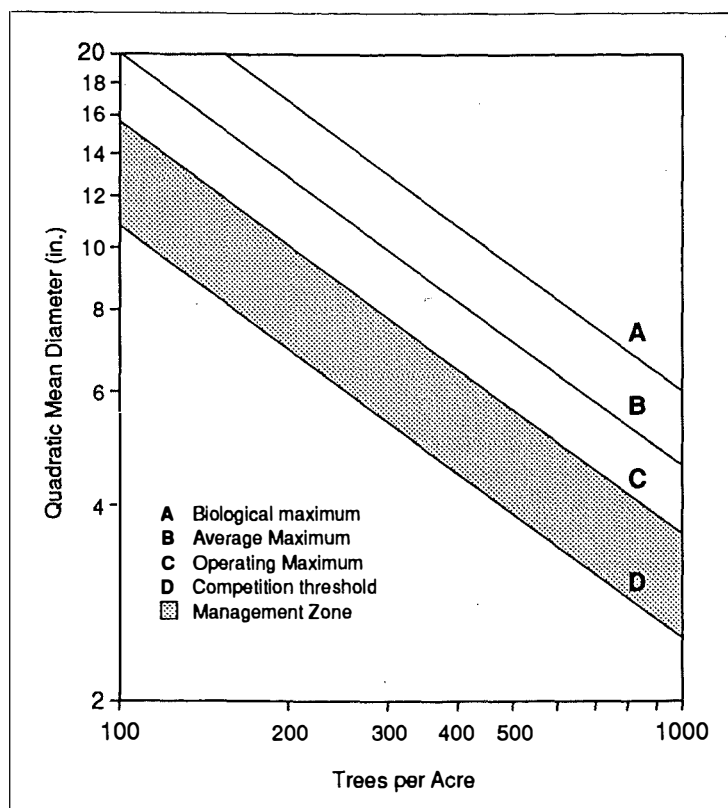


Figure 1. Density management diagram for red alder.

Many possible lines can be represented on a stand density diagram. On ours (Figure 1), we give four lines: "biological maximum," "average maximum," "operating maximum," and "competition threshold."

All of these lines have a slope of -0.64. This value was determined statistically by Puettmann (1990) for the operating maximum and the average maximum. This value matches closely the value developed by Reineke (1933) for a variety of tree species. The data base was not sufficient for statistical determination of the slope of the biological maximum and the competition threshold. Because all of these relationships are closely associated with crown size, the biological maximum and competition threshold were assumed to be parallel to the operating maximum. Visual analysis of the data base confirms the reasonableness of that assumption.

For discussion purposes, we use an index size—a diameter at breast height (dbh) of 6 inches—and present the density in trees per acre (tpa). Relative density was calculated as percentage of the biological maximum density.

Lines

- A The biological maximum (1,000 tpa at 6 inches dbh) defines the potential maximum diameter attainable for any given density. The position of the line was determined by size-density combinations observed in natural stands that were very highly stocked and juvenile high-density plantations that were intensively managed, i.e., that had complete weed control and were irrigated.
- B The average maximum (650 tpa at 6 inches dbh) is the average relative density that stands will approach as trees grow and mortality reduces their numbers. While individual stands may have

densities above or below this line, it constitutes a regional average. It was mathematically derived from data on mature natural stands and from spacing studies at high densities.

- C The operating maximum (450 tpa at 6 inches dbh) is the line above which considerable mortality occurs. It is therefore the upper limit of growing stock in managed stands. Its location can be determined by visual inspection of mortality patterns in natural stands and spacing studies. We derived this line from the self-thinning trajectories calculated by Puettmann (1990); it represents the level at which approximately 20 percent of the trees initially present have died.
- D The competition threshold (250 tpa at 6 inches dbh) is considered the lower limit of growing stock in managed stands. Its location was determined by two factors. First, it is the line above which average diameter growth becomes significantly reduced by competition and below which the limiting resource(s) of the site are not fully utilized. Second, several stands thinned heavily to levels below this line have shown a temporary reduction in height growth coupled with an immediate increase in diameter growth. Finally, plantations established at levels below this line have had poor height growth and stem form compared with more densely planted stands.

Zones

The lines divide the size-density graph into four zones. Below the competition threshold (line D) is the zone of little to no competition; it is characterized by a relative density of less than 25 percent. In this zone, competition does not significantly reduce diameter growth. Diameter and biomass growth of individual trees may be maximized, but productivity per acre and height growth are reduced. Stem form is poor, approximating that of a bush for 5 to 10 years.

The recommended management zone lies between the competition threshold and the operating maximum (line C); relative density there is between 25 and 45 percent. Managing at a lower relative density would provide little gain in growth of individual trees, and doing so at higher relative densities would lead to substantial mortality and reduction in growth of individual trees. Thus, under the most common management objectives, this zone defines an area in which a reasonable compromise between individual tree growth and stand yield is achieved.

The mortality zone lies between lines B and C. Here competition is strong, tree growth is restricted, and mortality is high. As a stand exceeds the operating maximum (C) and approaches the average maximum (B), mortality gradually increases to the point where each increment of growth is associated with a proportional mortality rate that causes the stand to follow the trajectory of line B.

Understanding of the factors and processes associated with the zone between lines A and B is limited. Some natural stands and plantations

actually reach this zone, but its unclear how the processes of growth and mortality interact to place the stand in this zone or how long it can remain there. In some instances, this may be a temporary state resulting because mortality is episodic rather than continuous. Research is needed to determine the genetic, site, and management factors associated with stands that develop in this zone and whether the trajectories merely reflect short-lived aberrations or whether they reflect real differences in stockability (DeBell *et al.* 1989) and productivity.

Application

In using the diagram to manage stand density, one should consider the entire life of the stand from establishment (or the present state for existing stands) to final harvest. Although optimal stand density may be maintained continuously only by many thinnings, such frequent entries in red alder stands are unlikely for economic and biological reasons. Regardless of their numbers, all entries should be coordinated to complement the others. Thus, spacing at time of planting must be determined by expected size at the next entry, whether that be a first thinning or final harvest. Indeed, the opportunity to perform an intermediate thinning will permit a wider range of initial spacings (or thinning levels) than if the stand is to be grown to final harvest without further regulations of density.

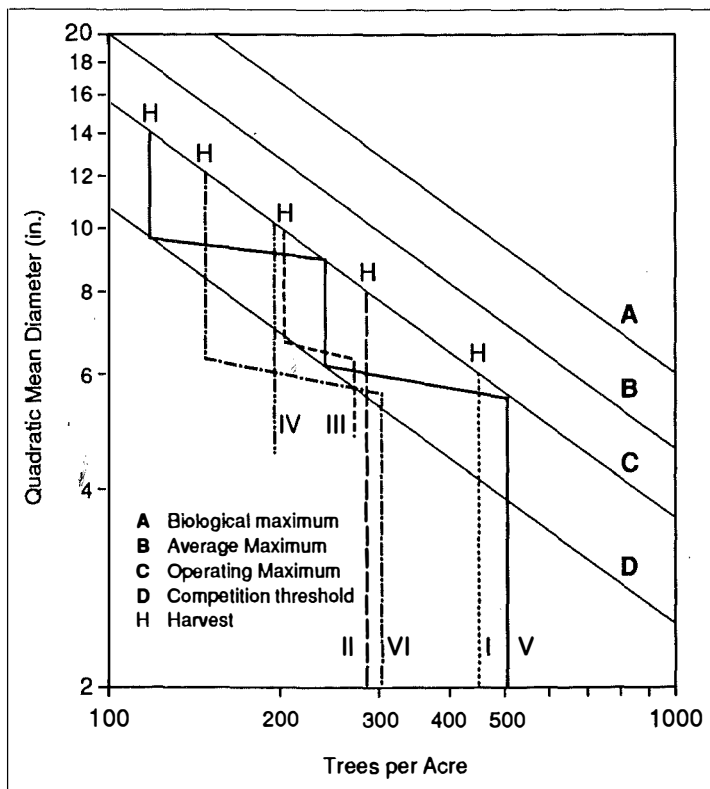


Figure 2. Size-density trends for different management regimes as shown on the density management diagram for red alder. The various management regimes are discussed in text by stand number (indicated both in text and on the diagram by Roman numerals).

In light of this principle, we can now illustrate the use of the density management diagram for several planting and thinning decisions. The following regimes are illustrated on Figure 2 by stand number.

Stands I and II. The simplest case involves instances in which no thinning is planned and initial spacing or spacing density will be retained to final harvest. For example, stands grown for pulpwood or fuelwood with a 6-inch target diameter at harvest (stand I) should be planted at a density of 450 tpa and those with an 8-inch target diameter (stand II) should be planted at a density of 280 tpa. The stocking level ensures that the target size is attained as stands reach the operating maximum (line C), prior to the onset of appreciable competition-related mortality.

Stands III and IV. What about existing natural stands or plantations obtained from previous owners who may have had other objectives in mind? Let us assume that the new owner wants to harvest stands at a mean diameter of 10 inches. Because only 200 trees per acre can be grown to that size without substantial mortal-

ity, thinning is appropriate if the existing stand contains more than 200 tpa and the owner wants to accelerate growth and lessen time to final harvest (stand III). Conversely, if the stand contains 200 or fewer stems, thinning is not needed (stand IV).

Stand V. This stand has been planted or spaced very young to about 510 tpa and grows toward the operating maximum. When it reaches this level (average diameter of 5.5 inches), it is thinned to the level of the competition threshold. Because thinning from below increases the average diameter to slightly more than 6 inches, the stand is subsequently thinned to a density of 230 tpa. When the average diameter of the stand again reaches the operating maximum (9 inches), the stand is thinned to 120 tpa and then grows until final harvest at a diameter of 14 inches. This regime encourages natural pruning and will produce clear boles. In addition, two thinnings will allow the highest quality trees to be favored for the final harvest.

Stand VI. This stand has been planted or spaced to about 300 tpa. At a fairly young age, when the diameter averages nearly 6 inches, the stand is thinned to 150 tpa. While the stand will temporarily grow below the level represented by the competition threshold, a reduction in height growth is unlikely because the thinning was done when relative density was low. A harvestable diameter of 12 inches will be attained before mortality becomes appreciable and the stand develops beyond the management zone.

Finally, one should recognize that the boundaries of the management zone are approximate. For example, stands might be thinned to some level below that represented by line D. Diameter growth is thereby increased and time to obtain a given target diameter is thus minimized. Such a course also delays the need for another thinning. However, this course may result in a temporary loss in height growth and a deterioration in stem quality. Stands can also be allowed to grow above the level represented by line C. This choice will result in increased mortality, but dominant trees will continue to grow and stand volume to increase.

Conclusion

Our diagram is intended to provide general guidance in density management of red alder. The management zone defines a reasonable compromise between individual-tree and stand growth and mortality. Factors considered in its formation include desired tree size at harvest, growth rate, and yield per acre. Social and legal constraints, as well as wildlife habitat and other non-timber-related considerations, may affect how the guide is applied in developing a management plan.

It must be remembered, however, that the density management diagram is only a statistical construct and does not account for events and processes that are not density-related. Developing complete management plans requires that these other factors also be considered. D.E. Hibbs and D.S. DeBell are now preparing a review of the various factors to be considered throughout a full rotation of red alder.

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A diameter-based density management guide (diagram) was developed for red alder. The lines defining the guide are the "biological maximum" (1,000 trees per acre at a 6-inch diameter), "average maximum" (a relative density of 65% in comparison with the biological maximum), "operating maximum" (45% relative density), and "competition threshold" (25% relative density). All lines have a slope of -0.64. The operating maximum and competition threshold define a management zone and allow planning and evaluation of management regimes. Use of the diagram is illustrated with several management regimes having different objectives.

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