

# SILVICULTURE OPTIONS IN COASTAL SMALL DIAMETER STANDS

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## ABSTRACT

Past management strategies for young coastal stands of the Pacific Northwest have been strongly influenced by a supply of young, dense, naturally regenerated stands and early plantations that were established at high densities. Precommercial thinning was, and still is, commonly applied near the end of the initiation stage of stand development to enhance tree growth, survival, and ultimately the value of the future crop trees in these dense stands. However, changes during the last two decades in markets, wood processing, and harvesting technologies, and the prospect of a future log supply coming almost entirely from plantations are causing silviculturists to rethink their strategies for managing young plantations and what is defined as a "dense" stand. They are asking, "What roles should planting density, precommercial thinning, early commercial thinning, and pruning play in managing young stands to achieve various ownership objectives?" Since the threat from fire, insects, and diseases is of much less concern in young coastal forests of the Pacific Northwest than in drier eastside forests, decisions for managing these young, small diameter stands are strongly driven by production economics rather than health issues. However, accumulated knowledge on how initial stand density and early density control can influence subsequent tree growth, stand development and understory plant development has not been lost on those silviculturists interested in managing for nontimber values. The recent increase in attention given to nontimber values has resulted in the development of management strategies in young stands that emphasize previously ignored species and variable spacings regimes on both public and private lands.

**Keywords:** density management, fertilization, precommercial thinning, pruning, Douglas-fir

## INTRODUCTION

The conifer-dominated temperate coastal forests of Oregon and Washington are among the most productive forests in the world (Franklin and Dyrness 1973). The most important conifer of the region is Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). Since the mid-1800's, a large forest products industry has developed in the region. Initially the focus of this industry was on the harvest of the vast natural forests. Today the emphasis is on managing forests that begin as plantations. Once stands are established, silviculturists may use pruning, fertilization, and thinning treatments to meet their management objectives.

During the last decade, interest in pruning young Douglas-fir has increased. The objective of pruning is to increase the value of trees by producing high quality clear

lumber. Clear lumber has traditionally come from old-growth trees, which are no longer being harvested. Pruning is necessary to produce clear wood since the branches of Douglas-fir persist for many years. Fight and others (1993) have shown that pruning young Douglas-fir on good sites can be profitable. As a general rule of thumb, to maximize the amount of clear wood produced, pruning should be applied at as young an age as possible while maintaining about 50% of the live crown (O'Hara 1991). A multiple lift approach has been suggested as the best method to produce the smallest diameter knotty core. Pruning may also be combined with fertilization and thinning to maximize individual tree growth and clear wood production. Other species, such as western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and red alder (*Alnus rubra* Bong.), might also be pruned to produce higher value clear lumber, but require more research to define optimum prescriptions. While increasing tree value is a primary objective of most pruning operations, pruning may have other benefits such as increased fire resistance by removing fire ladders, improved access in dense stands and increased production of ground vegetation. Application of pruning seems to have peaked in the mid-1990's and the acres being pruned has decreased (Briggs and Trobaugh 2001) due primarily to the uncertainty of future quality premiums for clear logs.

Fertilization of Douglas-fir has been practiced since the early 1970's as a way to increase wood production. Traditionally nitrogen, in the form of urea, has been applied at a rate of 200 lbs per acre. Responses, while variable, have been shown to occur over a wide range of sites (Miller et al. 1986; Chappell et al. 1992). Initially, fertilization efforts were in mid-rotation stands where increases in volume were put on merchantable stems and the volume gains would be realized sooner since these stands were close to harvest. More recently, however, younger stands are also being fertilized and can show positive responses (Heath and Chappell 1989; Turnblom and Harrison 2002) and are often refertilized at 7-10 year intervals. The trees in younger stands tend to have more efficient crowns and if thinned tend to have a greater response to added nitrogen. Fertilization has been shown to increase growth in both thinned and non-thinned stands. However, the probability of response to fertilization may be somewhat higher in thinned stands. Fertilization increases the rate of stand development and accumulation of growing stock. This can result in increased competition-induced mortality depending on the initial stand density and years to harvest. Thinning will reduce mortality and potentially capture more of the gains from fertilization that could be lost to mortality in denser non-thinned stands (Chappell et al. 1992). While greater relative growth response is usually achieved on the less productive sites, application of fertilizer on sites of moderate and high productivity can also be profitable since the increased growth is being put on faster growing and larger trees. Most of the

nutrition research in the region has been focused on nitrogen applied to Douglas-fir. Future research is needed to investigate the application of a broader range of nutrients, which to date have shown high variability in response. Limited research in other coastal species suggests that western redcedar (*Thuja plicata* Donn) may respond to nitrogen fertilization while western hemlock's response has not been consistent.

Of the treatments applied in juvenile stands, thinning has the greatest impact on stand development. Precommercial thinning (PCT), while decreasing in prevalence (Briggs and Trobaugh 2001), has been a common treatment in the region for many years to enhance survival, growth and the value of future crop trees. In drier eastside forests early density control often can be dictated by the threat from fire, insects and diseases. These factors are of much less concern in young coastal forests so that production economics rather than health issues tend to drive the decision to thin young, small-diameter stands.

The guidelines given by Reukema (1975) have provided the basis for PCT prescriptions for several generations of silviculturists. Recommendations are that juvenile spacing should be applied near the end of the stand initiation stage and before stem exclusion begins and tree growth is reduced due to competition. This is usually at about 10-15 years of age. Precommercial thinnings usually retain the most valuable larger trees at relatively even spacing. The numbers of tree in the stand is typically reduced to a level that minimizes mortality and maintains or accelerates crop tree growth. The number of crop trees left will depend on when the next harvest is anticipated. If the next harvest is going to be a commercial thinning, then PCT will decrease the time required for the crop trees to become merchantable.

While PCT treatments are still widely applied today, many things have changed since Reukema (1975) prepared his guidelines. Some of these changes suggest that silviculturists review their use of this treatment. Some changes are:

- The resource has changed. In the late 1960's and early 1970's many managers were working in young stands that were naturally regenerated in the 1940's or dense early plantations. These early plantations were established at spacings as close as 6 feet (1210 trees per acre). Today wider spacings of 10 feet (436 trees per acre) and up to 15 feet (200 trees per acre) are practiced (Curtis et al. 1998). Use of high quality planting stock and vegetation management in plantations today ensures high survival, rapid early growth and greater uniformity in stands and trees.
- Technologies have changed. Equipment is now available that allows for efficient harvesting and processing of large numbers of small logs on vehicle accessible terrain.
- Markets have changed. With the elimination of the supply of old-growth logs, the forest products industry has adapted to a supply of smaller logs. In some cases, premiums once paid for larger logs have nearly disappeared and in other cases have been replaced by penalties charged for large logs.

- Our information on stand development has improved. The guidelines of Reukema (1975) were based on the normal yield table for Douglas-fir (McArdle et al. 1961). Since then, research has provided the region with simulation models that can project stand development for a wide range of stand conditions and management options. An example of a recent finding in young Douglas-fir stands which has potential management implications is that within limits, both average tree height and diameter become progressively larger with increasing planting density (Scott et al. 1998; Turnblom 1998). This trend of an early benefit from competition appears in plantations throughout the region and is visually apparent as early as 3 years after planting, but reverses as stands age. Thus it is often called the "cross-over" effect (Turnblom 1998).

## REVIEW OF THE ROLE OF PRECOMMERCIAL THINNING IN DOUGLAS-FIR

To illustrate some of the factors in evaluating whether or not to do a PCT, the SMC-ORGANON model will be used (Hann et al. 1997) to simulate the development and treatment of two stands. This is an individual tree model that projects the growth of Douglas-fir in western Oregon and Washington. It includes options for thinning, fertilization, and pruning and also an option for providing wood quality information (taper, branch size, and juvenile wood core) for harvested trees.

The model will be used to simulate PCT and no PCT options on data from a Stand Management Cooperative Type III research installation (Chappell et al. 1987; Maguire et al. 1991) located in western Oregon. The stand was planted in early 1989 with 2-1 Douglas-fir seedlings in several acre blocks with the target planting densities within blocks ranging from 100-1200 trees per acre. The plots to be used in this example were planted at the target densities of 450 and 600 trees per acre. Plots were established in the stands in 1993 and were remeasured in the fall of 1999 when the stand's total age was 13 years old (7 years old at breast height). A summary of the 1999 inventory is given in Table 1. The stand's site index is estimated to be 130 feet at 50 years (King 1966).

This simplified example will look at two decision points for PCT: at the time of thinning in an existing stand, and at the time of planting. The following assumptions are made:

- PCT treatments will be applied at total age 13 years and thinned to leave 220 trees per acre.
- The cost of the PCT is \$100 and \$125 per acre for 450 and 600 trees per acre respectively.
- Planting cost is \$0.44 per seedling (cost of seedling and labor).
- The actual trees per acre over the target planting density are the result of trees that naturally fill in after planting.
- The Pond values are taken from the 1st quarter of 2001 to represent current conditions of low size/quality premiums and from the 3rd quarter of

Table 1.—Summaries for the two plots used in the example and measured at total age 13 years.

| Plot no. | Target planting density | Actual numbers of trees | Basal area            | Quadratic mean diameter | Height of the 40-largest |
|----------|-------------------------|-------------------------|-----------------------|-------------------------|--------------------------|
|          | per acre                | per acre                | ft <sup>2</sup> /acre | in.                     | ft.                      |
| 4        | 450                     | 452                     | 24.3                  | 3.3                     | 25.8                     |
| 6        | 600                     | 695                     | 54.3                  | 3.8                     | 30.4                     |

1996 to represent a historically large premium for log size and quality (Figure 1) (Table 2).

- Discount rates of 6% and 4% will be contrasted.
- The analysis will be before taxes and will not include inflation factors or changes in prices.

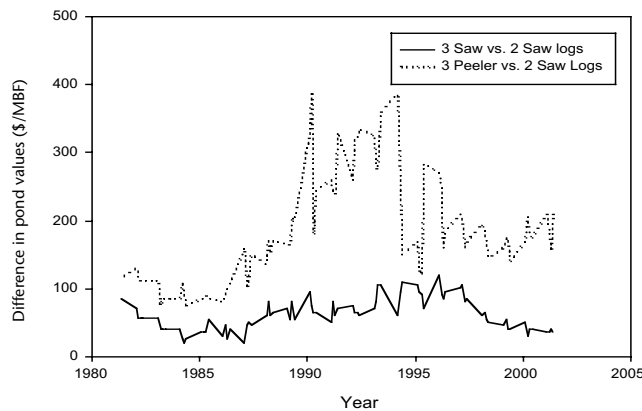


Figure 1.—Historic differences in pond values (\$/MBF delivered) between No. 2 and No. 3 grade saw logs (solid line) and between a No. 2 saw log and a No. 3 peeler log (dotted line). (Oregon Department of Forestry, current web site)

Table 2.—Pond values (\$/1000 board feet delivered) for log grades in the Willamette Valley and Northwestern Oregon. (Oregon Department of Forestry, current web site)

| Log grade     | Low quality premium 3rd Q 2002 | High quality premium 1st Q 1996 |
|---------------|--------------------------------|---------------------------------|
| Special Mill  | 645                            | 790                             |
| No. 2 Saw log | 585                            | 710                             |
| No. 3 Saw Log | 545                            | 590                             |
| No. 4 Saw log | 470                            | 545                             |
| Utility       | 65                             | 100                             |

One of the first expected results from a PCT is that it will increase tree growth. Looking at the five-year period following the thinning, we see in Figure 2 that the trees did show an increase in average diameter and average cubic foot volume growth in the stands that received the PCT. But can we expect this increase in tree growth to result in an increase in stand growth? Figure 3 shows that the result of the PCT was to decrease the stand's growth in total stem cubic foot volume per acre for the five-year period following thinning. While the trees in the thinned stands are growing more rapidly individually, there are fewer trees on which to put this increased growth. This is a demonstra-

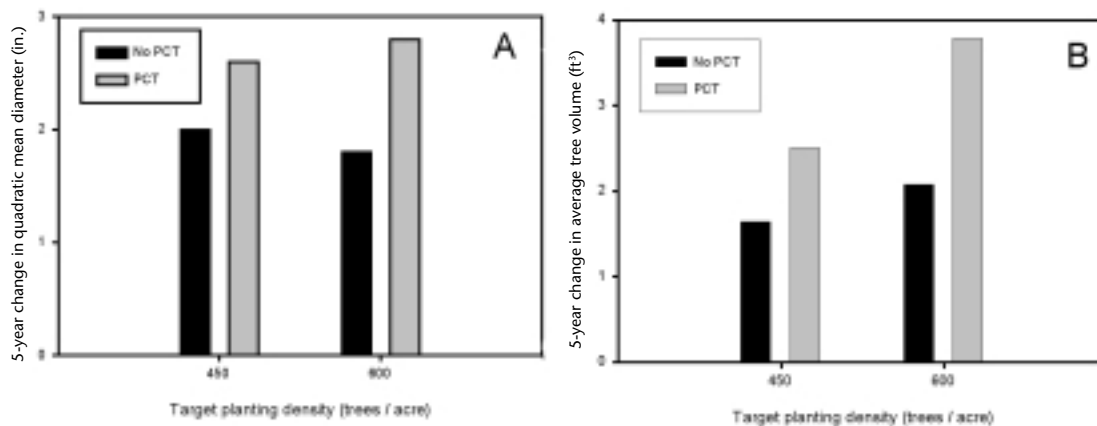


Figure 2.—Projected five-year change after precommercial thinning, in (A) quadratic mean diameter and (B) average total stem cubic foot volume of a tree for two target planting densities (age 13-18years).

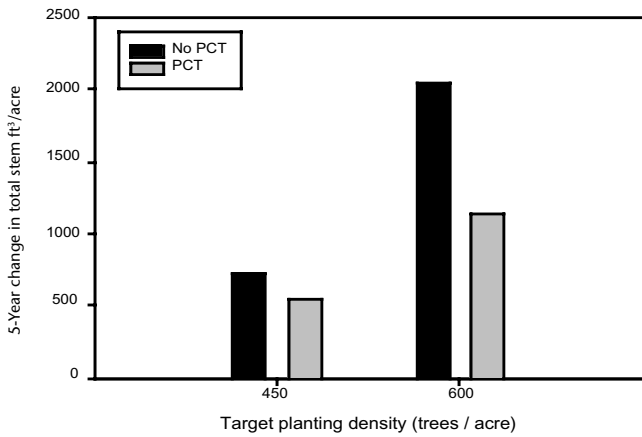


Figure 3.—Projected five-year change after precommercial thinning, in total stem cubic foot volume per acre for two target planting densities (age 13-18 years).

tion of basic growth-growing stock relationships. The trade-off between tree growth and stand growth in young stands has been documented in many research studies (e.g., Turnblom and Harrison 2002; Curtis and Marshall 1986). One important reason for this result is that in young Douglas-fir height growth is rapid and is a large component of total stand volume growth. Height growth will be similar for the thinned and nonthinned stands, but there is more growing stock (basal area) to put that height growth on in the non-thinned stands (Curtis and Marshall 1986).

How long stand growth is reduced will depend on how heavily the stand was thinned (or how much growing stock

was retained) and how fast the growing stock accumulates. The latter depends on the vigor of the residual trees and the stand’s productivity. For the stands in our example, Figure 4 shows that the merchantable (6-inch top diameter) cubic foot volume per acre of the thinned stands did not catch up to the denser non-thinned stands until about age 45.

A commonly held idea is that thinning will produce “free” or “bonus” wood. This would be a result of the yield from the thinned stand, which experiences faster tree growth and little mortality, exceeding the yield from the non-thinned stand, which experiences slower tree growth and greater losses due to mortality. From Figure 4 we can see that in the short run (prior to about 45 years) this is not the case. At age 53, the stands that received the thinning exceed the non-thinned in merchantable cubic foot volume by only 8% and 10% for the 450 and 600 trees per acre target planting densities. This gain in volume reflects the increase in tree growth and accumulation of growing stock in the thinned stands during the “holding period” after the thinning and increasing tree mortality in the denser non-thinned stands.

Figure 5 shows the stand tables at age 43 for the two stands with and without PCT. Here we can see that we have more trees in the largest diameter class for the thinned stands as a result of the increased tree growth. However, in the non-thinned treatment, many of the trees that would have been thinned have survived and are contributing merchantable volume to the stand. The question is, “Do the larger number of big trees in the thinned plots provide greater value?”

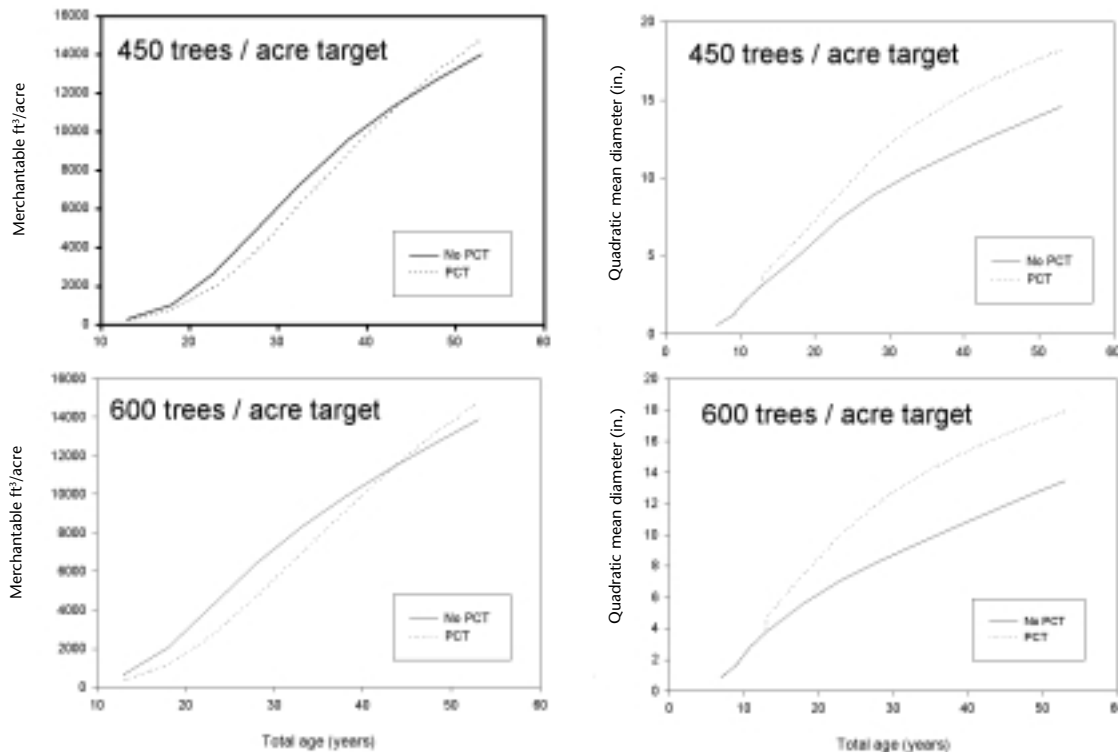


Figure 4.—Projected merchantable yield (ft³/acre to a 6-inch top) and quadratic mean diameter for two target planting densities through total age 53 years in non-thinned (solid line) and thinned (dotted line) stands.

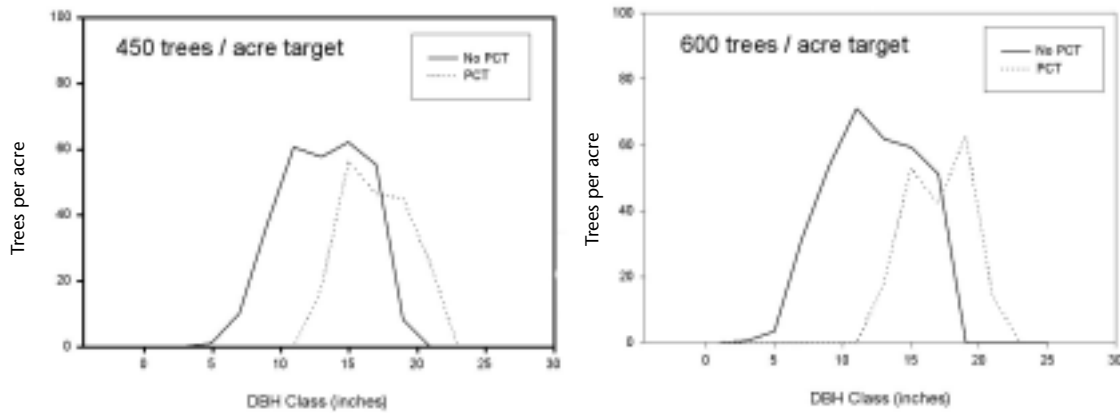


Figure 5.—Projected stand tables for two target densities projected to a total age of 43 years in non-thinned (solid line) and thinned (dotted line) stands. Diameter classes are 2-inches.

One way to compare the contribution of a PCT is to look at the change in net present value (NPV) between the PCT and non-PCT treatments as presented in Table 3. The conclusion, based on the above assumptions, is that a PCT should not necessarily be a foregone conclusion in Douglas-fir stands up to nearly 700 trees per acre since the negative values indicate a decreased return in current dollars for the PCT investment compared to no PCT. By applying a PCT, growing stock is reduced, which in turn reduces stand

volume growth. In this example, maximum NPV is usually reached between stand ages of 38 and 43 years. From Figure 4 we see that it is not until about age 45 that the volume in the thinned stand catches up to the non-thinned stand. Time is required to accumulate growing stock and it takes longer in the denser stands that was thinned heavier. In the meantime, trees do grow larger and stand volume and value increase in the thinned stands (Table 4). While a little more volume does reach a higher grade of saw log

Table 3.—Percent change in net present values by precommercial thinning. Values are given at the time of the precommercial thinning (total age 13 years) and at the time of planting at 450 and 600 trees per acre densities assuming a 6% and 4% discount rates and with and without price premiums for log size and quality.

| Target planting density | With low log quality premium |          | With high log quality premium |          |
|-------------------------|------------------------------|----------|-------------------------------|----------|
|                         | Decision Point               |          | Decision Point                |          |
|                         | PCT                          | Planting | PCT                           | Planting |
| 6 percent               |                              |          |                               |          |
| 450                     | -2.3%                        | -2.7%    | 1.6%                          | 1.8%     |
| 600                     | -5.5%                        | -4.5%    | -0.9%                         | -1.0%    |
| 4 percent               |                              |          |                               |          |
| 450                     | 2.9%                         | 3.1%     | 10.7%                         | 11.3%    |
| 600                     | 3.8%                         | 4.1%     | 17.4%                         | 18.7%    |

Table 4.—Per acre summary of harvested stand volume (1000 board feet per acre), quadratic mean diameter, and net harvestable value for precommercially thinned and non-thinned stands with and without premiums for log size and quality at ages 43 and 58 years.

| Target planting density | No precommercial thinning |                             |  |   | Precommercial thinned   |                             |  |   |
|-------------------------|---------------------------|-----------------------------|--|---|-------------------------|-----------------------------|--|---|
|                         | Standing volume MBF/ac.   | Quadratic mean diameter in. | Net harvestable value Low log premium \$1000/ac. | Net harvestable value High log premium \$1000/ac. | Standing volume MBF/ac. | Quadratic mean diameter in. | Net harvestable value Low log premium \$1000/ac. | Net harvestable value High log premium \$1000/ac. |
| 43 years                |                           |                             |  |   |                         |                             |  |   |
| 450                     | 40.8                      | 12.5                        | 16.5   | 18.7  | 38.6                    | 16.1                        | 16.7   | 19.6  |
| 600                     | 41.9                      | 12.9                        | 16.3   | 18.3  | 16.1                    | 20.4                        |  |   |
| 58 years                |                           |                             |  |   |                         |                             |  |   |
| 450                     | 62.7                      | 15.7                        | 27.1   | 32.4  | 66.8                    | 19.1                        | 29.7   | 36.4  |
| 600                     | 63.0                      | 16.2                        | 26.8   | 31.9  | 68.3                    | 18.8                        | 30.5   | 37.2  |

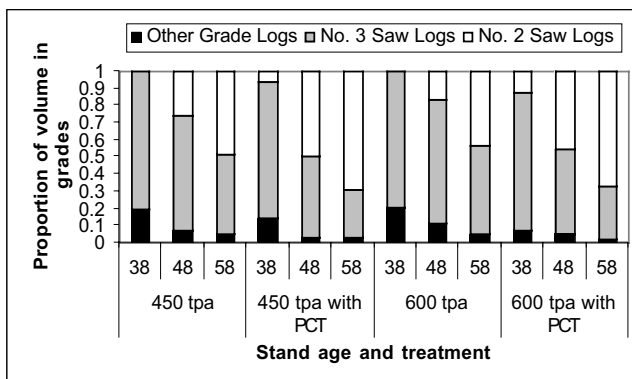


Figure 6.—Projected proportion of volume in log grades for PCT and non-PCT stands of 450 and 600 trees per acre at ages 38, 48, and 58 years.

sooner in the thinned stand (Fig. 6), without a strong size/quality premium there is little total added value above the stand value associated with increasing total volume. A large jump to the high value of relatively clear logs does not happen within the time of this example because of persistent branches. This situation may not change, without pruning, until the stands reach 80 or more years old and natural pruning occurs (Kachin 1940).

The above results are generally consistent with findings from research plots. However, specific results can vary greatly with treatment, merchantability and quality assumptions, different costs, site quality and growth model used. Some of these are discussed below:

- Branch size does not have a major impact in the above example. However, heavier and earlier thinning treatments could increase the branch sizes so that they might impact visual grades and would cause branches to persist even longer.
- The above analysis was done using a Scribner log scale, which has a greater premium associated with it than a cubic scale. If a cubic scale had been used, PCT would have been less attractive.
- Early density control will also increase the proportion of juvenile wood in trees. While this may not have much effect on conventional log grades, it could have an impact if lumber is stress-graded. Stands on lower productivity sites will accumulate growing stock more slowly, but the impact of PCT may be greater in terms of reaching merchantability sooner (Reukema 1975).
- The above analysis also assumed that there was no impact, other than volume harvested, on harvesting cost. This is probably not a bad assumption for this example since the cost/piece-size curve is flattening out by the time of final harvest. However, PCT may have an effect on piece-size and harvesting costs in some situations, such as on less productive sites.
- None of the currently available growth models for the region take into account the young stand “cross-over” effect. This has important implications for when competition begins and tree growth is reduced and when trees become merchantable.
- The crown dynamics in these young stands is another area that requires more work to improve models.

The profitability of a precommercial thinning should be considered on a case-by-case basis. Some of the factors that make a precommercial thinning more profitable are:

- lower precommercial thinning costs.
- higher size/quality premiums for larger logs.
- lower discount rates.
- longer post thinning “holding periods” or rotations (related to lower discount rates and higher premiums).

In this example the stand planted at 600 trees per acre actually had nearly 700 trees per acre. This was assumed to be from ingrowth of naturally seeded trees. Ingrowth into plantation can occur in some cases, especially near the coast where western hemlock regenerates well, and can reach very high densities where the benefit of a PCT much clearer. Figure 7 provides an example of a Douglas-fir plantation near Clallam Bay (Hoyer and Swanzy 1986) that was virtually replaced by western hemlock natural regeneration. At total age of 11 years the stand was precommercially thinned to 4.0-, 7.4-, 9.2-, and 12.3-foot spacings. If a stand was required to have a quadratic mean diameter of 8-inches to be considered merchantable then the ages at which the spacings would reach merchantability would be 37, 27, 24 and 23 years for the dense to widest spacing (Fig. 7a). As Reukema (1975) shows, decreasing the time for a stand to reach merchantability is an important result of PCT. However, as Figure 7b shows, this reduced time to merchantability comes at the price of reduced stand yields in the short term.

With the recent changes in harvesting technologies and markets that make handling and selling small wood possible, there may be advantages for avoiding the PCT and instead, conducting an early commercial thinning (ECT). In some cases mills are buying logs that are a minimum of 18-feet in length and have a 2.5-inch diameter top. Depending on logging costs and log prices, delaying the thinning to a commercial size at about age 18–22 years on highly productive sites may provide a positive cash flow of a few hundred dollars per acre rather than a PCT cost. At age 23 the stands projected in the above example have average crown ratios greater than 50%, and they should respond well to a thinning, but not as well as to an earlier PCT. Of course, the same growth-growing stock relationships will be at work. As with a PCT, it is expected that individual tree growth will increase following an ECT, but that stand growth will be reduced for a period of time following the reduction in growing stock. A similar caution applies to ECT that we discussed for PCT: NPV gain may be difficult to demonstrate without large quality premiums and/or higher than projected growth response to thinning. The early income from ECT will generally make achieving a positive NPV easier than for PCT.

## JUVENILE SPACING TO CONTROL STAND STRUCTURE AND COMPOSITION

Density management, especially in young stands, is an important way to create or accelerate the development of certain structural characteristics within stands. Stand structure describes the distribution of plants (both trees and understory) by their size, species composition and arrangement, both horizontally and vertically, and is important

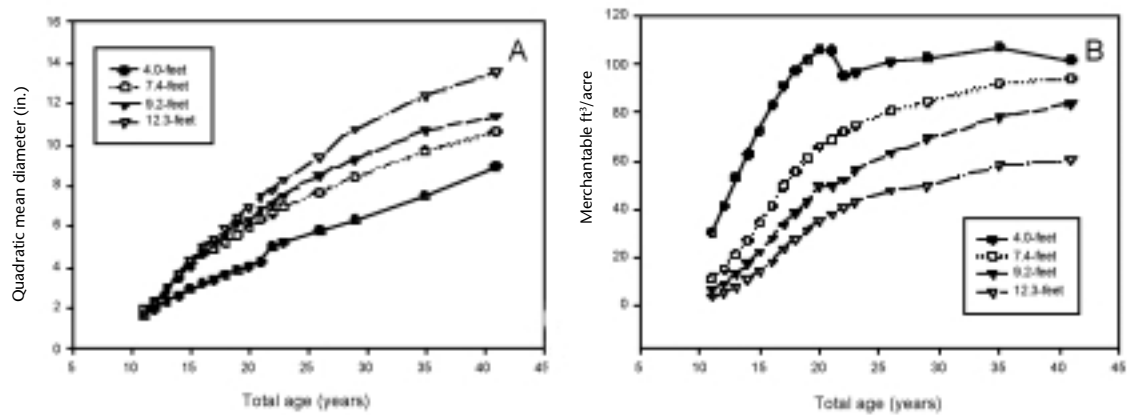


Figure 7.—Development from total ages 11 - 41 years at Clallam Bay western hemlock plots for spacings of 4.0-, 7.4-, 9.2- and 12.3-0feet: (a) quadratic mean diameter and (b) merchantable cubic foot volume (6-inch top diameter)

in providing a variety of forest habitats. By modifying traditional thinning prescriptions, development of within stand structural diversity can be encouraged. Parks and McCulloch (1993) provide guidelines for maintaining diversity during thinning in juvenile stands. These guidelines include the retention of the full range of tree species found in the stand (including hardwoods), retention of wildlife trees, varying spacing to create stand differentiation and small gaps, and identification of special attributes including streams, ponds, trails and rock outcrops. Variable density thinning can be especially important. Wider spacings will accelerate stand development to create larger trees, while the denser portions of stands will develop to provide a source of snags, down wood and can discourage undesirable understory species, like exotics. Small gaps will increase the development of understory forage and cover species normally shaded out by tree crown closure.

## CONCLUSIONS

Silviculturists have a number of tools available to them for managing the productive forests of the Pacific Northwest Coast Range. These include pruning, fertilization and density control. The management of density in young stands is an important tool for influencing stand development. This has traditionally been applied in young stands in coastal Pacific Northwest forests as precommercial thinning. The decision of whether or not to apply a PCT should consider the five generalized conclusions about the impacts of precommercial thinning demonstrated in this paper:

- PCT will cause short-term increases in tree growth.
- PCT will cause short-term decreases in stand volume growth.
- PCT is not expected to provide much “free” or “bonus” wood in the short-term.
- PCT will not cause large increases in stand value in the short-term unless there are premiums paid for large saw logs.
- Allowing adequate time between PCT and final harvest is important in accumulating growing stock; however, this holding period may come at a cost depending on the discount rate used. For organizations where longer rotations are practiced,

the addition of commercial thinning may have many added benefits (Curtis et al. 1998, pages 47-50).

For silviculturists who are charged with managing for structural elements, early density management offers a way to increase within stand structural diversity and accelerate stand development.

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