Can Selection Thinning Convert Even-Age Douglas-Fir Stands to Uneven-Age Structures?

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ABSTRACT: *Uneven-age management of Douglas-fir* (Pseudotsuga menziesii) *stands can be used to address aesthetic, wildlife habitat, biodiversity, and sustainability concerns, but there has been little long-term experience with this type of management. To develop timely information on converting even-age stands to uneven-age forests, we used retrospective stand reconstruction methods to document harvest frequency, intensity, and stand structural development at four sites in western Oregon. We studied stands managed by selection thinning and identified strategies for creating and managing uneven-age forests. Selection thinning benefited mid- and understory trees and stimulated natural regeneration. Although stand growth was less than expected from low thinning, growth per unit of growing stock was similar to that in unmanaged stands. Douglas-fir often dominated regeneration and had satisfactory vigor at stocking levels about half that considered full stocking for even-age management, but good growth of regeneration may require even lower overstory stocking. Shade-tolerant grand fir and western hemlock, however, were more abundant at higher stocking levels. Selection thinning of young Douglas-fir stands can sometimes be effective in promoting viable regeneration while providing regular income and biodiversity. Because this was a retrospective study only, further, long-term testing is necessary. West. J. Appl. For. 16(1):35–43.*

Key Words: *Pseudotsuga menziesii*, uneven-age management, Douglas-fir.

In the Douglas-fir (*Pseudotsuga menziesii*) region, west of the Cascade Mountains in the Pacific Northwest, many forest owners, managers, and the public are interested in management alternatives to standard clearcutting (Franklin et al. 1986, Emmingham 1998). Uneven-age management may reduce reliance on clearcutting, improve aesthetics, create periodic income, and provide diverse wildlife habitats (McComb et al. 1993, Guldin 1996, O'Hara 1998). Little experimental documentation exists on how uneven-age management might be applied in the Douglas-fir region. Early attempts to implement uneven-age management in mature and old growth forests (Kirkland and Brandstorm 1936) were later deemed failures (Munger 1950, Isaac 1956, Smith 1972). However, these alternative management schemes have recently been reevaluated more positively in light of the crude logging systems and old-growth starting conditions at the time of the early attempts (Curtis 1998). The question of how more intensively managed, young Douglas-fir stands might succeed as uneven-age forests remains unanswered.

Many believe Douglas-fir cannot regenerate or grow vigorously under its own canopy because it is considered shade-intolerant (Isaac 1943). Minore (1979), however, classified it as moderately shade-tolerant, while Franklin (1963) found that Douglas-fir regenerated well in forest gaps as small as 0.25 ac on the west flank of the central Cascade Mountains. Douglas-fir, therefore, may be more flexible in the shade under managed conditions than is generally assumed.

Lack of information on creating and managing uneven-age forests could be a serious problem for Pacific Northwest forest managers if anticlearcutting ballot initiatives are enacted in Oregon and Washington. We used a retrospective approach to study selection thinning as a way of converting even-age Douglas-fir stands to uneven-age structures. Retrospective documentation of stand development (Oliver and Larson 1996) and growth (Tappeiner et al. 1997, Acker et al. 1998) has been widely used to derive management implications for Pacific Northwest forests.

Throughout the Douglas-fir region, thinning is an important silviculture practice. A wide variety of approaches are applied but, while there are strong opinions among foresters about which is best, we found no good long-term studies documenting different methods. Daniel et al. (1979) and Smith et al. (1997) described important differences

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among three basic thinning approaches. Low thinning removes mostly smaller trees to favor dominant and codominant trees, whereas crown thinning removes dominant and codominant trees to favor other dominant and codominant trees. In contrast, selection thinning removes dominant trees to favor subordinate crown classes. In practice, most thinning systems also improve stand value and forest health by removing insect-infested, deformed, or diseased trees. In early guides for thinning in the Douglas-fir region, Worthington and Staebler (1961) described a thinning strategy for variable naturally regenerated stands, whereby selection or crown thinning was applied in young stands to remove rough dominant trees at an age/size that would not support a low commercial thinning. Later, low thinning was used to maintain growth.

Now that Douglas-fir stands are being established at uniform, high densities of over 300 tpa, and profitable utilization of small diameter trees (<8 in. dbh) is possible, early low commercial thinning at 20–25 yr is feasible, and low thinning has been the most common approach (Wierman and Knapp 1986). Selection thinning is less common, with some contending that it is high-grading.

Some nonindustrial private forest (NIPF) owners have found that continued selection thinning (i.e., removal of larger trees from the dominant crown classes throughout the life of the stand) suits their needs for periodic income, helps spread harvest from a small, fixed landbase over a longer period, keeps forest values lower (avoiding high inheritance tax liability), and satisfies a range of stewardship objectives such as prolonging stand life and possibly avoiding clearcutting (Emmingham and Hanley 1986). Daniel et al. (1979) describe this as Borggreves' variation of selection thinning. As applied in our study stands, this thinning approach removes <20% of the stand volume and treats every tree (even intermediate or suppressed) as a potential crop tree. We examined the potential role of this type of selection thinning to convert an even-age stand to an uneven-age structure.

We developed a retrospective study that focused on four sites with long histories of selection thinning in Douglas-fir forests of western Oregon. Our specific study objectives were to

1. document the history of stand conditions and thinning practices;

2. evaluate thinning intensity as it influences current stand structures;

3. compare growth and yield from selection thinning (actual stands) with yield table values for similar stocking levels and with published values for other thinning approaches;

4. evaluate the success of natural regeneration under selection thinning; and

5. determine the suitability of selection thinning as a way to transform an even-age stand to an uneven-age stand structure.

Study Areas and Methods

Site Selection

We queried extension forestry agents, consulting foresters and NIPF owners because they had the most experience with selection thinning. Our search was confined to the Douglas-fir forest types west of the Cascade crest, north of Douglas County (OR), and south of Lewis County (WA). We located 21 potential sites where selection thinning had been used exclusively. Most were stands with two canopy layers and some natural and/or planted regeneration. Four sites were chosen for intensive sampling (Figure 1). These naturally regenerated stands represented various ages, site qualities, and thinning intensities. Criteria for site selection included multiple commercial thinning entries, consistent use of selection-thinning methods, and development of a diverse vertical stand structure. The last thinning was conducted 5 to10 yr before we made our measurements.

The study stands ranged from 12 to 40 ac and were predominantly Douglas-fir (>85% of basal area, BA), with some hardwoods [bigleaf maple (*Acer macrophyllum*), Oregon white oak (*Quercus garryana*), and chinkapin (*Castanopsis chrysophylla*)] or shade-tolerant conifers [grand fir (*Abies grandis*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*)]. Common tall shrub species included vine maple (*Acer circinatum*) and California hazelnut (*Corylus cornuta*, var. *californica*). Pacific dogwood (*Cornus nuttallii*), oceanspray (*Holodiscus discolor*), and red huckleberry (*Vaccinium parvifolium*) also were present, depending on the site. Dominant ground cover or low shrubs typically were some combination of sword fern (*Polystichum munitum*), bracken fern (*Pteridium aquilinum*), salal (*Gaultheria shallon*), Oregongrape (*Berberis nervosa*), and/or *Rubus* sp.

All four study stands had been marked before each thinning, then logged with ground-based equipment, including rubber tire skidder, crawler tractor, or horses. Landowners personally directed harvesting and supervised contract loggers at two stands. At a third stand, a consulting forester marked harvest trees and supervised loggers. On the fourth stand, the owner performed both

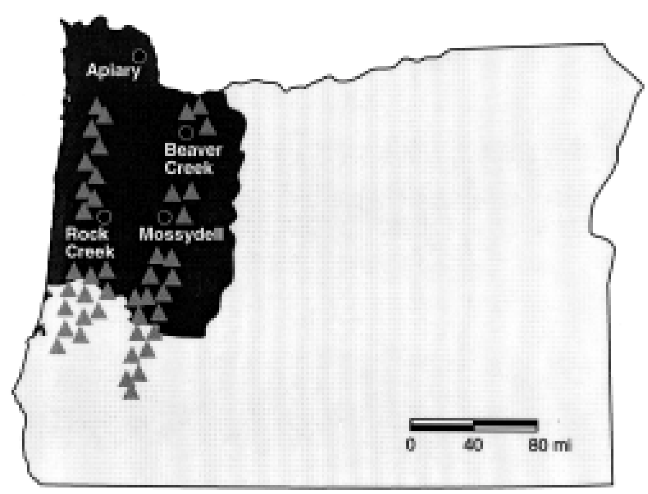

Figure 1. Study sites (o) within the Oregon Douglas-fir region (shaded area).

tree selection and harvesting. Examination revealed a generally consistent application of the selection system and a high level of care in harvesting.

Plot Measurement

Ten 0.10 ac square plots (slope-corrected) were systematically located at each site. Data were collected during the winter and early spring of 1996 and included species, dbh, crown class, and 5 yr diameter increments over the past 30 yr for all trees >3.0 in. dbh. Site index (SI) was calculated, based on 10 trees/site (one/plot) measured for total height and age. We carefully selected the most dominant of the residual trees (on or off the plot) in order to best reflect site potential. SI was underestimated at Beaver Creek and Rock Creek because most of the earliest dominant and codominant trees had already been harvested. Timber volumes for each stand were determined with the tarif system (Turnbull et al. 1980), by measuring dbh and total height of 25 to 35 tarif trees/site. This allowed for local variations in tree form and more accurate volume estimations.

All stumps were located on each plot, with year of harvest determined from neighboring tree-release evidence, root graft dissection, and/or owner records. Stump height, outside bark diameter, and 5 yr radial increments for the last 30 yr (where evident) were recorded. Trees killed by windthrow or logging damage were dated as accurately as possible.

Regeneration subplots were located at each corner of the tree/stump plot. We used a circular 0.02 ac plot (17.6 ft radius), consistent with regeneration assessment under the Oregon Forest Practices Act. All conifer seedlings >1.0 ft tall and up to 3.0 in. dbh were tallied by species, size class, and vigor class. Size classes were Small (1.0 to 4.5 ft tall), Medium (4.5 to 10 ft tall), and Large (>10 ft tall, up to 3.0 in. dbh). Judgments about vigor class were subjectively based on crown volume, needle color, and leader growth. Vigor classifications were Vigorous (annual height growth, 1–3 ft), Stable (height growth 6–12 in. but responsive to release), or Poor (growing poorly, questionable release potential). Shrub and ground cover was recorded by species. For the best conifer seedling or sapling (i.e., tallest tree with good growth and full crown) on each subplot, we recorded species, caliper, vigor class, total height, 5-yr height increments, and logging or animal damage. Similar measurements were recorded for a randomly selected conifer of any vigor class. The best seedling/sapling was representative of crop trees that would be selected to leave in a thinning. The randomly selected conifer may have represented the average.

Analysis

Previous stand conditions [tpa by diameter class, BA, and board-foot volume/ac (mbf)] were reconstructed for each 5 yr period between 1965 and 1995. Cut-tree volumes were calculated from stump diameter to dbh conversion formulas (Curtis and Arney 1977) and added to stand table values at the year of harvest. Study stands were compared for site quality, growth and yield, thinning intensity, and regeneration response.

Growth rates were compared with those of naturally regenerated stands that were (1) unmanaged (using Empirical Yield Table Formulas, Chambers 1980) or (2) managed with low thinning (using estimates generated by DFSIM, Curtis et al. 1982). Chambers' formulas predict growth based on stand age, SI, and stand BA. Percentage of normal basal area (% NBA) adjusts predicted yield based on the ratio of stand BA to normal or predicted basal area for a certain SI. Curtis' estimates were for a naturally regenerated stand on SI 125 for a 44-yr period (age 39 to 83) with a systematic low thinning regime that required a minimum of 20 ft^2 of volume in trees averaging >8 in. dbh before harvest was allowed.

Results

The four sites had a range of applications of the selection-thinning system, and responses to thinning varied. The properties were typical of small private ownerships in the region, with SI from 99 to 132 (50 yr base, King 1966) and gentle to moderate slopes. Each stand was predominantly even-age at the beginning of its management period.

Stand ages at first thinning were 22 to 55 yr, with current ages of 50 to 85 yr (Table 1). Current volumes ranged from 15 to 35 mbf/ac, with 68 to 141 tpa and BA of 84 to 170 ft^2/ac. The variation in current stocking levels among stands resulted from stand age, initial stand condition, and thinning intensity.

Stand Dynamics

Harvest entries were frequent but light. In the 16 to 33 yr management period, study stands were thinned two to five times (Table 1). A relatively small number of larger trees were cut during each entry (8 to 30 tpa; 2.8 to 8.1 mbf/ac removed), with mean cut-tree dbh 13.8 to 24.5 in. (Table 2). Current mean stand diameters range from 14.6 to 16.3 in., and the average dbh in all stands has remained relatively constant (about 16 in.) over the management period.

Table 1. Site characteristics.

Site	SI*	Stand size (ac)	Current age	Age at 1st thin	Years managed	Thinnings (no.)	Ave cut cycle (yr)	Current stand structure: Volume† (MBF/ac)	BA (ft^2/ac)	TPA	Dbh (in.)	% NBA††
			·········· (yr)	··········								
Apiary	132	23	50	28	22	3	4.4	21.6	113	78	16.3	51
Beaver Creek	125	40	52	22	30	5	6.0	30.2	163	141	14.6	74
Mossydell	109	13	58	42	16	2	8.0	35.0	170	137	15.1	79
Rock Creek	99	12	85	55	30	4	7.5	15.0	84	68	15.1	32

* 50-yr Site Index (King 1966).
† Scribner Scale.
†† % NBA = percent of normal basal area for natural, unmanaged stands, from WA DNR Empirical Yield Tables (Chambers 1980).

Table 2. Stand dynamics—harvests and growth.

Site	Harvest averages: Vol at 1st thin	Volume/ entry	TPA cut/entry	Cut tree volume (bf)	Cut tree dbh (in.)	Stocking: Ave % NBA*	Growth: Total cut vol†	Growth plus cut†	Annual growth (bf/ac/yr)	Annual % growth††
	··········(MBF/ac)······						····· (MBF/ac)······			
Apiary	7.5	2.8	8.0	352	24.5	47	8.5	23.0	1,045	10.1
Beaver Creek	9.0	3.5	20.6	172	13.8	76	17.7	38.7	1,290	11.8
Mossydell	26.0	8.1	30.5	264	17.6	92	16.1	26.1	1,631	6.5
Rock Creek	17.0	5.7	15.3	376	18.9	38	22.9	20.9	697	4.8

* % NBA = percent of normal basal area for natural, unmanaged stands from WA DNR Empirical Yield Tables (Chambers 1980).
† Volumes are from Scribner Scale.
†† Annual percent growth was calculated as a weighted mean for the entire measurement period.

Harvest frequency varied both among sites and within each site over time (Figure 2) because of changing market opportunities, shifting personal needs, and silvicultural requirements. At Apiary and Rock Creek, thinnings were heaviest; stands were maintained at BA of 60 to 110 ft^2/ac. Thinning intensities were lighter at Beaver Creek and Mossydell, with densities of 120 to 180 ft^2/ac. These higher densities were close to the average for stands thinned from below in even-age management (King 1986).

Before the first thinning, stands ranged from somewhat understocked to fully stocked, i.e., 60 to 100% of normal stocking (Chambers 1980). The average percentage of normal stocking (Table 2) over the management period ranged from 38 to 92%. Annual volume growth over the management period ranged from about 700 bf/ac for understocked stands to over 1600 bf for stands near full stocking. Annual board-foot volume growth rates averaged 4.8 to 11.8% (Table 2).

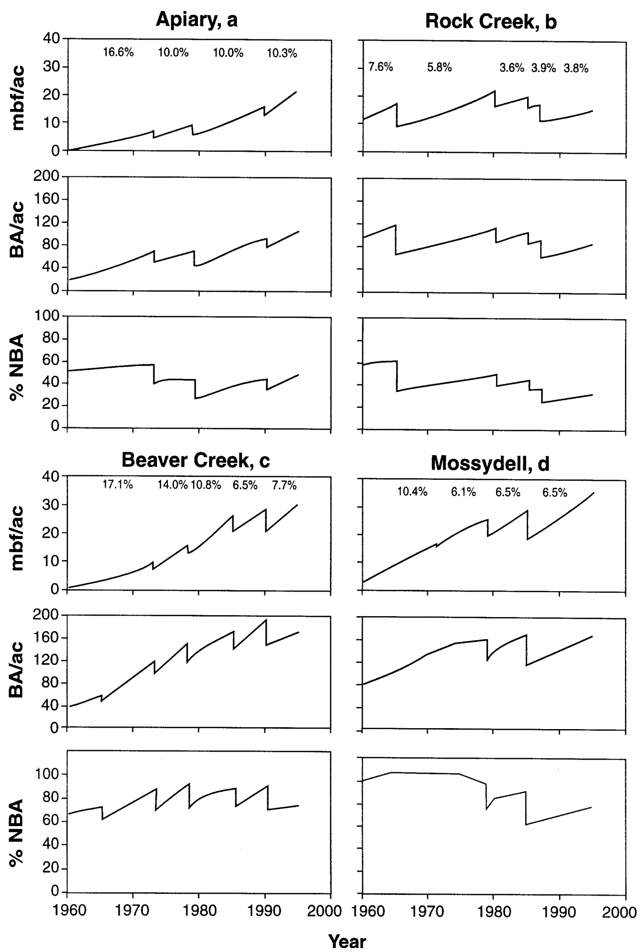

Figure 2. Standing board-foot volumes with periodic annual volume growth (percent), basal area (BA), and percent normal basal area (% NBA; Chambers 1980) of managed Douglas-fir stands in western Oregon, periodically thinned over 16 to 30 yr.

Volume growth exceeded, by 25%, the yields predicted by Chambers (1980) for even-age, unmanaged stands of comparable stocking (percent normal basal area), SI, and age. Volume growth exceeded Chambers' yields by 4% in sensitivity analysis where we estimated Chambers' yields for stands of SI one 10-ft class higher. This compensated for potential underestimation of site class due to removal of dominant trees. Growth as a percentage of growing stock averaged 5%, which was 1.5 and 1.1% less than predicted by Chambers for site classes similar to or higher than those we measured. Growth was relatively constant over a broad range of stocking levels.

Simulated periodic growth estimated by DFSIM (Curtis et al. 1982) for a fully stocked, naturally regenerated Douglas-fir stand with low commercial thinning from age 39 to 83 was 1,418 bf/ac/yr. The simulated stand grew from 15 mbf at age 39 to 66 mbf at age 83, while two commercial thinnings removed 11.4 mbf.

Regeneration

During the management period, all four stands developed significant understories of advance conifer regeneration (from 160 to 440 conifers/ac), as well as other competing vegetation. Regeneration was generally distributed throughout each stand (not just on skid trails) and often included a high

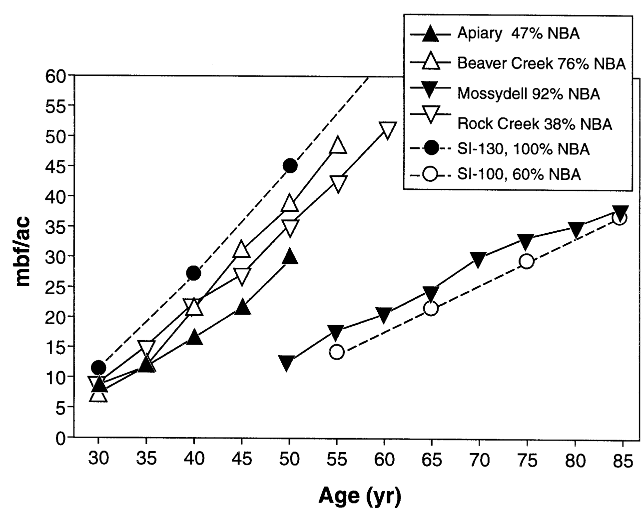

Figure 3. Actual cumulative volume (growth plus harvest) compared to WA DNR Empirical Yield Tables (SI of 100 and 130; Chambers 1980).

percentage of Douglas-fir. While rarely free to grow, most seedlings/saplings had full, healthy crowns, were judged vigorous enough to respond to release, and were growing at rates from one-third to one-half of potential SI height growth. Among all the sites, tree size and vigor class distributions were similar (Figure 4), with most of Small or Medium size (<10 ft tall), and in the Stable vigor class (not vigorous, but able to release).

From 70 to 90% of the regeneration plots contained at least one conifer seedling. Douglas-fir dominated the regeneration on three stands and was selected as the best seedling on 60 to 70% of the plots. In all stands, a greater percentage of shade-tolerant grand fir, hemlock, or redcedar (depending on site) was found in the regeneration than in the overstory stand, but these species were seldom the best potential crop trees. At Beaver Creek, Douglas-fir seedlings numbered only 3/ac.

Douglas-fir regeneration was more abundant and grew better in stands thinned more frequently and to lower stocking levels (Figure 4a). Stands maintained at a lower BA (Apiary and Rock Creek) also tended to have a greater proportion of Douglas-fir regeneration compared with shade-tolerant species, as well as a greater proportion of vigorous seedlings. At higher stocking levels (Figure 4b), there was a greater proportion of unstocked regeneration plots, and more plots with predominantly shade-tolerant grand fir, redcedar, and hemlock.

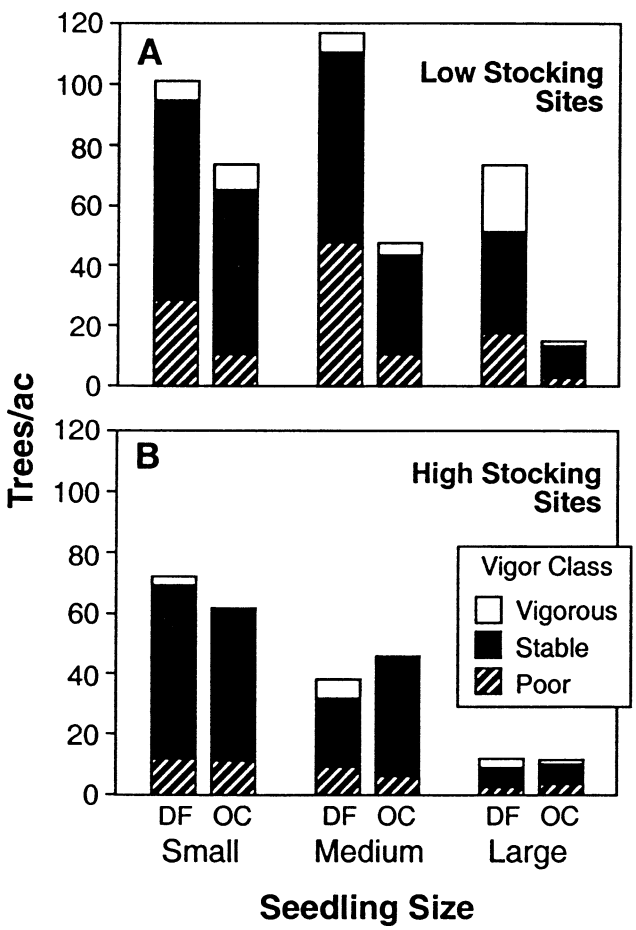

Figure 4. Vigor of Douglas-fir (DF) and other conifer (OC) regeneration by size classes at A: sites with low stocking levels (average of Apiary and Rock Creek); and B: sites with high stocking levels (average of Beaver Creek and Mossydell). Size classes: Small = 1.0 to 4.5 ft tall, Medium = 4.5 to 10.0 ft tall, Large = >10.0 ft tall to 3.0 in. dbh; Vigor classes: Vigorous = growing well, Stable = moderate growth, but able to respond to release; Poor = growing poorly, questionable release potential. [Note that the amount of DF regeneration is greater than for OC, especially at low overstory stocking levels.]

Logging damage was not quantified, but very low levels of damage were observed on seedlings or residual trees. Five to ten years after the last harvest we found minimal impacts; gentle topography, directional felling, short-log skidding, and designated skid trails apparently minimized damage.

Competing vegetation was prevalent at all sites. Shrub and ground cover densities varied considerably, with wide differences among related subplots. Patches of dense shrub and ground cover often excluded conifer regeneration, but other areas supported a mix of conifer and shrub. Levels of competitive vegetation apparently were not related to either SI or overstory BA. Vegetation levels increased with stand age and frequency or intensity of harvests.

Discussion

General Observations

These four property owners chose to continue selection thinning for different reasons, ostensibly because it best satisfied ownership objectives. Though each had unique situations and goals, all desired periodic income while building long-term property equity. Most wanted to avoid clearcutting and were concerned with harvest aesthetics while wishing to maintain a range of future management options. Their timber resources were major financial assets, though none relied on timber receipts as a sole source of income.

Selection thinning allowed these owners to vary the frequency and timing of harvests, thus balancing silvicultural requirements and market opportunities with shifting personal financial needs. High value was captured at each thinning, while assuring future periodic harvests. Irregular stands that were either previously high-graded (Rock Creek) or regenerated naturally over an extended time period (Apiary) were soon brought under a desired management scheme with early commercial harvests. At Beaver Creek, selection thinning maximized the opportunity to harvest high-value poles. For these owners, selection thinning was an attractive alternative to low thinning, clearcutting, and replanting.

Selection Thinning versus Low Thinning

Thinning is an important practice in Douglas-fir management. Low thinning is well understood and widely applied (Reukema and Bruce 1977) and proves effective in producing high volumes of timber, especially from relatively uniform, high-density stands. Our study showed that some of the benefits of low thinning, e.g., deriving periodic income, building high-value growing stock, maintaining stand vigor, and capturing (or avoiding) mortality, could also be achieved by careful application of selection thinning.

Low thinning maintains or improves growth rates of residual dominant and codominant trees. While early harvest volumes and values are often low, low thinning can build high volume and value over a long cutting cycle. Selection thinning allows for earlier commercial harvests than does low thinning, beginning here at ages 22 to 28, while also providing for frequent entries and a long rotation. Only recently have improvements in plantation establishment, small-log value, and harvest technology made low thinning of 20-to 30-yr-old stands commercially viable. This is primarily because timber value has increased dramatically while logging costs have remained stable (Kellogg et al. 1996).

Tree Selection Criteria in Selection Thinning

Although the reasons our owners used selection thinning were varied, harvest techniques and tree selection criteria were quite consistent. Harvest frequency was determined by stand stocking and fluctuating market values, with flexibility for the economic needs of the owner also a factor. The need to harvest was signaled by impending crown closure and actual or impending loss of vigor in trees in the subdominant crown classes.

Successful selection thinning requires careful attention to tree selection. Individual trees are candidates for harvest when they have reached their maximum potential product value class; their harvest will release three to seven neighboring overstory trees or advance regeneration; they are the least vigorous among several otherwise suitable candidates; or they have been damaged by logging, insects, or disease. A large number of candidate trees could satisfy at least one of those criteria. To prevent overharvesting, a number of constraints must be considered, including (1) maintaining or building growing stock and stand volume over time; (2) releasing a tree on no more than two sides at each harvest cycle; and (3) leaving high-quality growing stock for cutting at the next entry.

Timber marking may also be used to recognize, maintain, or enhance stand diversity as indicated by species composition, tree size and vigor, and distribution of open patches or dense clumps. A conservative marking strategy with a short cutting cycle can help control understory competition, minimize damage to advance regeneration, limit slash accumulation, and allow nearly complete salvage of incidental mortality. A frequent entry cycle can be deleterious, however, unless soil compaction is limited either by always using the same minimal skid-trail system or by implementing light-impact harvest systems.

Growth and Yield

Advocates of selection thinning argue that adherence to the marking guidelines mentioned above will not unduly decrease stand volume production. Those who promote low thinning, however, believe that yield will suffer because of the slow response of sub-canopy trees to thinning. Periodic stand growth in the four selection-thinned stands was equal to or greater than that in unmanaged stands of similar site quality and stocking in Chambers' Empirical Yield Tables (1980). Even if we underestimated site quality by 10 ft. three of the four stands still exceeded Chambers' estimated yields.

During the time period measured, our stands produced only half the volume growth predicted by DFSIM for naturally regenerated stands with low thinning. Stand growth on a given site is generally a function of growing stock (Curtis and Marshall 1986) and stand structure (Oliver and Murray 1983, O'Hara 1990). Therefore, selection-thinned stands probably cannot perform as well as intensively managed, even-age plantations during the peak years of stand production, especially if selection thinning reduces growing-stock levels below those resulting from low thinning (Smith et al. 1997).

We speculate, however, that stands thinned with the selection method might perform quite favorably in the long run when in-growth, lower regeneration costs, multiple cutting entries, and value production are considered. Significant in-growth occurred in each stand over the management period as intermediate and suppressed trees grew into merchantable size classes. Increased light intensity and frequent thinning reversed trends of declining vigor and imminent mortality in suppressed trees. Thinning shock (i.e., slowing of diameter growth after thinning) was not apparent regardless of position within the canopy. With ORGANON, Stringer (1999) compared projected yields for long-rotation selection and short-rotation (50 yr) low-thinning strategies for a tract with six different stand types. Using current stand conditions as a starting point, he simulated 100 yr yields and found 9.7% greater tract yield for the short-rotation low-thinning regime. However, the selection-thinning system maintained 2.8 times the standing volume and produced larger saw logs than the short-rotation scenario. More research is needed to compare production from different thinning and silviculture systems.

Selection thinning may also compare well in total value production. Because we did not know the log grade of previously harvested trees we could not quantify timber value. However, in all our stands most of the current log volume was in high-quality export grades, with few knots, low taper, and high ring count—all important considerations for high-value logs. Heavy low thinning can produce stand conditions conducive to growth of large trees, but selection thinning maintained trees of high wood quality and modest diameter. This may be an advantage because most sawmills in the Pacific Northwest cannot handle logs >40 in. in diameter, and many now prefer logs <24 in. in diameter, sometimes paying premium prices for smaller-diameter logs.

Selection Thinning as an Approach to Uneven-age Management

None of the owners identified developing uneven-age stand structures as a specific management objective. While the majority of selection-thinning experience to date has been within the context of even-age management, our stands were beginning to develop multiage stand structures. At Apiary and Rock Creek, where thinning intensity was heaviest (% NBA = 47 and 38, respectively), the stands were beginning to develop a variety of *age* classes, and their *diameter* class structure closely approximated the inverse J-shape of some uneven-age stands (Figure 5). Although uneven-age stands do not necessarily exhibit an inverse J-shape diameter distribution (O'Hara 1998), this condition in two stands (Figure 5) certainly was indicative of an opportunity to manage the stand toward that goal. Tree height distribution also varied greatly.

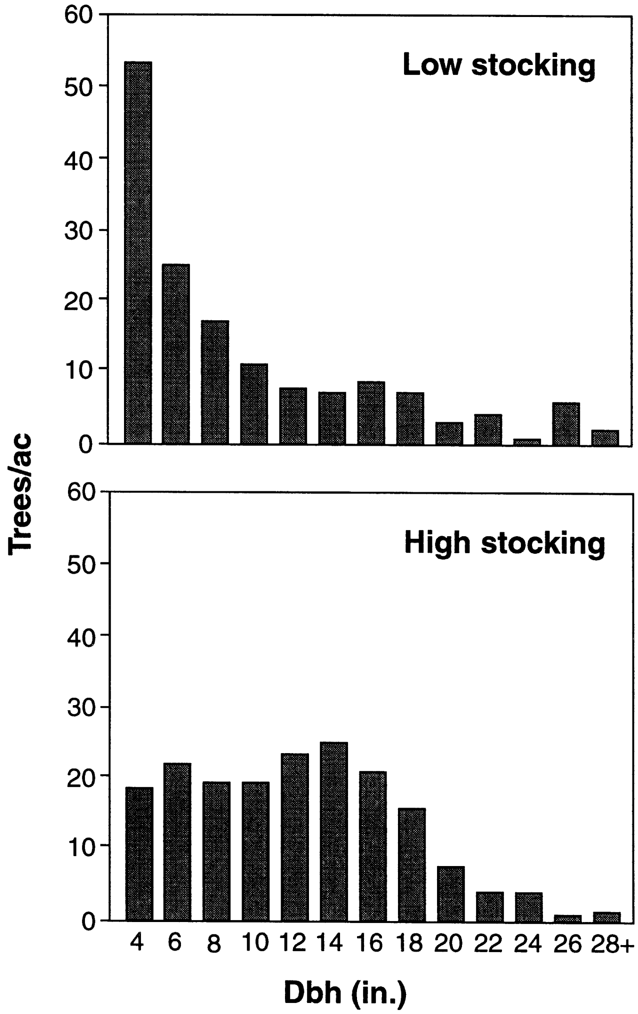

Figure 5. Diameter distribution in stands with low and high stocking levels. Low stocking is average of Apiary and Rock Creek; high stocking is average of Beaver Creek and Mossydell.

Selection thinning may be an effective tool for intentionally creating and perpetuating an uneven-age stand structure in the individual tree-selection sense (Matthews 1989) when thinning criteria encourage species, diameter or age-class diversity. Except at Beaver Creek, the current number of seedlings exceeds that needed for recruitment into mid-canopy size classes. Selection thinning, with frequent harvests, can maintain vigor in sub-dominant trees, but must be linked with careful logging to protect regeneration.

Regeneration

Selection thinning may be a way to approach uneven-age management, but many foresters express concern about regenerating and maintaining a predominance of Douglas-fir. Natural regeneration of this species was well represented at three of our four sites. Competing vegetation, however, became increasingly well established with time under selection thinning. Successful natural regeneration of Douglas-fir may require control of competing understory vegetation on many sites. Maintaining relatively low stocking levels is also essential in establishing natural regeneration. These factors become increasingly critical when managing more productive sites, where vegetative competition is more intense and assertion of overstory dominance is more rapid.

Moderately shade-tolerant Douglas-fir does not germinate and grow under full shade, but thinned stands offer partial shade and often have Douglas-fir regeneration (Bailey and Tappeiner 1998). Maintaining stands at about 40 to 50% NBA (80 to 120 ft^2) should provide light levels conducive to establishment and growth of Douglas-fir natural regeneration (Hayes et al. 1996) and provide good but not optimum overstory volume growth rates. In the Siskiyou Mountains of southwestern Oregon, Emmingham and Waring (1977) found that height growth of Douglas-fir was similar to that of two true firs [Shasta red fir (*Abies magnifica* var. *shastensis*) and white fir(*Abies concolor*)] at 10 to 75% full light. Although an increasing proportion of shade-tolerant species can be expected, thinning of the shade-tolerant species to favor Douglas-fir could maintain desired species composition.

On good sites or in more fully stocked stands, short intervals between thinning (5 to 8 yr) may maintain seedling vigor, whereas on poorer sites and with more open stands, thinning intervals can probably be extended. If continued uneven-age structures were desired in the study stands, the current overstory stocking and modest growth rates of understory conifers suggest that another selection thinning should be done soon to stimulate growth of regeneration, especially in the two stands with over 160 ft^2 BA.

Underplanting of conifers in thinned stands is another option for securing regeneration and controlling the species composition of the future stand (Emmingham 1996). Maas (1996) found high early survival rates where five Northwest conifers, including Douglas-fir, were underplanted in thinned Douglas-fir stands on Coast Range sites.

Regeneration that accumulates in selection thinning over time may be released by a shelterwood or overstory removal. Growth of released trees can be predicted based mostly on vigor and crown structure of seedlings/saplings prior to release (Ferguson and Adams 1980, Helms and Standiford 1985, Tesch et al. 1990). Tesch and Korpela (1993) showed that advance regeneration of both Douglas-fir and grand fir responded well to overstory removal on Sites V-III in southwestern Oregon. Tesch et al. (1990) also showed that a high percentage of seedling and sapling Douglas-fir injured in overstory removal recovered enough to be considered future crop trees.

Vegetation Management

Control of competing vegetation may increase germination and early seedling growth, whether through mechanical, chemical, or other means, and may be essential on high-quality sites (SI >115). Spot scarification and light grazing appeared important to seedling establishment at Apiary. Where no vegetation control was used on a similar site at Beaver Creek, few seedlings were found, and few of these were Douglas-fir.

In some instances, competing vegetation may be discouraged through careful timing of harvests. First thinning of fully stocked stands in the “stem exclusion” stage of development, and before the “understory reinitiation” stage of stand development (Oliver and Larson 1996), may encourage significant regeneration without vegetation control, as was observed at Mossydell. Moderate to heavy thinning at this stage of development may be conducive to natural reseeding of conifers before competing vegetation is well established. Minore et al. (1996) observed that competing understory vegetation responded slowly to release by thinning of the overstory during the stem exclusion stage.

Summary and Conclusions

The selection-thinning approach can provide both periodic timber harvests and avoid clearcutting. In 16 to 30 yr of management with repeated selection-thinning entries, our four stands developed toward more or less uneven-age structures. They grew at levels acceptable for the region under a selection-thinning regime. Surprisingly, Douglas-fir was well represented in regeneration and has grown as well as more shade-tolerant conifers. Stocking levels at about 40 to 50% NBA (80 to 120 ft^2 BA) stimulated abundant natural regeneration that grew at acceptable rates and provided recruitment possibilities into a mid-story canopy. Building higher stocking levels (e.g., 160 ft^2 BA) provided less regeneration and less vigor. In the future, these stands could be managed toward either even- or uneven-age conditions without high regeneration costs. Extrapolation of our results must be done with caution because this was a retrospective study of four selected stands. More rigorous and long-term comparative studies are necessary

Successful long-term management of uneven-age stands will likely be more difficult than with even-age methods. Maintaining optimum stocking levels is more critical and requires more detailed monitoring. Management and harvesting of uneven-age stands will also be more labor-intensive, calling on special skills of both foresters and loggers. Many questions remain concerning the suitability of uneven-age management for the Douglas-fir region. Can the conversion methods discussed here be successfully applied across a wide variety of site classes, stand types, and vegetative communities? How much will more-intensive uneven-age management cost? Nevertheless, the preliminary experiences of several small private owners were encouraging. Selection thinning could play an important role in converting even-age to uneven-age Douglas-fir stands.

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