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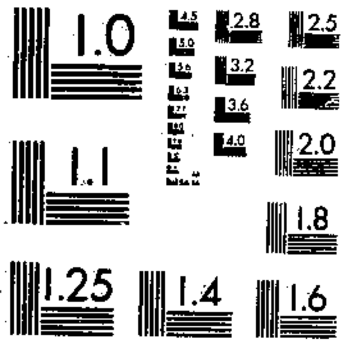

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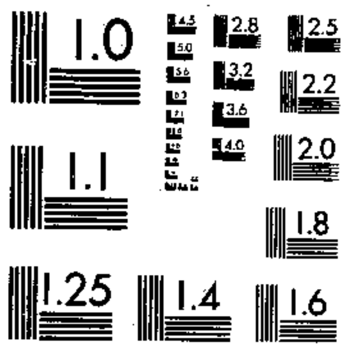

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Technical Bulletin No. 1230

U.S. DEPARTMENT OF AGRICULTURE

Forest Service

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By
Norman P. Worthington and George R. Staebler
Pacific Northwest Forest and Range Experiment Station

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for furnishing land, timber, and in some cases thinning crews. Without their contributions and close cooperation, thinning experiments and trials, which have provided a large share of the information for this publication, could not have been attempted.

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Commercial Thinning of Douglas-Fir in the Pacific Northwest

by

Norman P. Worthington and George R. Staebler*

Pacific Northwest Forest and Range Experiment Station

INTRODUCTION

Thinning is probably the major silvicultural practice characterizing intensive forestry. Its aim is to increase production in established stands and to mold stands and trees to some desired and defined end. Thinning is therefore a positive cultural practice, in contrast to those measures designed only to protect and save what we have. Forest protection and planned forest regeneration, which keep forest lands productive, are basic to any forestry program, but not until positive cultural practices, principally thinning, are undertaken can forestry properly be called intensive.

Thinning itself is also characterized by degree of intensiveness. As a purely silvicultural measure, it is independent of disposition of material removed. From a more immediately practical viewpoint, not only must cutting of the trees have a salutary effect on the stand, but the wood removed must also have a sale value. Going one step farther, if the value of material removed equals or exceeds cost of extraction, the thinnings are class as "commercial."

Commercial thinning as used here is defined as "a thinning that produces merchantable products that have a value equal to or greater than the cost of extraction." [1]

It is natural in the evolution of forestry that commercial thinning should be the first kind of thinning extensively practiced. Although precommercial thinning may be very worthwhile, its ultimate value is more difficult to appraise and the practice is very likely to be slowly accepted.[2]

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*Now with Weyerhauser Co.

[1] Hawley and Smith define commercial thinning as thinning in which the felled trees are converted to useful products regardless of whether or not their value is enough to defray the costs of the operation (*19, p. 405*). For the purposes of this bulletin, the "at-least-break-even" definition seems preferable since at the present stage of development, thinnings that will not pay their way, regardless of how close they come, are rarely practiced.

Italic numbers in parentheses refer to "Literature Cited," p. 90.

[2] Limited resarch has demonstrated that increased early production of merchantable products may easily justify the expense of precommercial thinning (*59*). Yield of British plantations first thinned at age 13 also exceeds that for natural American stands (*5, 23*). Even without thinning, American plantations commonly support above-normal volumes (*66, p. 57; 69, p. 30*), which is probably attributable to early uniform spacing of trees. It is plausible that the same increase in yield could be achieved by precommercial thinning of natural stands.

This bulletin is concerned only with commercial thinning. The background theories discussed, although applying equally well to many species raised in even-aged stands, are related specifically to the silvical characteristics of Douglas-fir (*Pseudotsuga menziesii*) in the Douglas-fir subregion. Sections on application of thinning are meant to apply only in this area.

The Douglas-fir subregion includes Washington and Oregon west of the summit of the Cascade Range. Douglas-fir reaches maximum development within this region. The range of the coast variety (*Pseudotsuga menziesii menziesii*) of Douglas-fir includes, in addition to western Oregon and western Washington, southwestern British Columbia and northern California west of the Sierra Nevada. Blue Douglas-fir (*P. menziesii glauca*) has a much wider range in the Rocky Mountain region of western United States and Canada. It differs markedly in silvical characteristics from the coast variety.

In the Douglas-fir subregion the species occurs chiefly in the Pacific Douglas-fir and Douglas-fir–western hemlock types (*47*). Occupying a zone with a mild, humid climate and good forest soils, these types are among the most productive forest types in the United States.

Even-aged young-growth stands of pure, or nearly pure, Douglas-fir, resulting from abundant regeneration following burning or cutting of the old-growth forest, occupy vast areas (fig. 1). Extensive plantations have been established to supplement natural regeneration and, in late years, large areas have been artificially seeded.

This young-growth forest—the forest in which commercial thinning may be practiced—is bound to become increasingly important as the old-growth forest is depleted, and as markets and utilization improve. Increased values, coupled with increasing professional skill in managing the young forest, will greatly stimulate commercial thinning.

Young-growth forests are those less than 160 years old (*13*). The area of these young forests suitable for commercial thinning is not known. However, from 1953 data (*67*) shown in table 1, it is estimated that at least 5 million acres might be so classified.[3]

At the level of management now practicable, commercial thinning of 5 million acres should add 3½ million cords or 1¾ billion board feet to the annual cut of western Oregon and Washington forests without impairing their productivity. Kirkland (*33*) estimated that commercial thinning of dense stands and clear cutting of thinly stocked spots would yield an annual harvest of 2.5 billion board feet from 6 million acres. He does not specify the proportion of Douglas-fir in this estimate.

[3] This estimate was developed as follows: Of the 14,031,000 acres of young growth in medium- or well-stocked stands—those with over 40 percent stocking (*68*)—72 percent or 10,102,000 acres is estimated to be Douglas-fir type, assuming the proportion found in total commercial forest land applies. Much of the type acreage, because of stand age (either too old or too young), terrain, site, inaccessibility, markets, etc., cannot be considered for present day commercial thinning. About one-half, or 5 million acres, could be classified as potential thinning area under existing standards and conditions, though, of necessity, this is an estimate based on very little factual information.

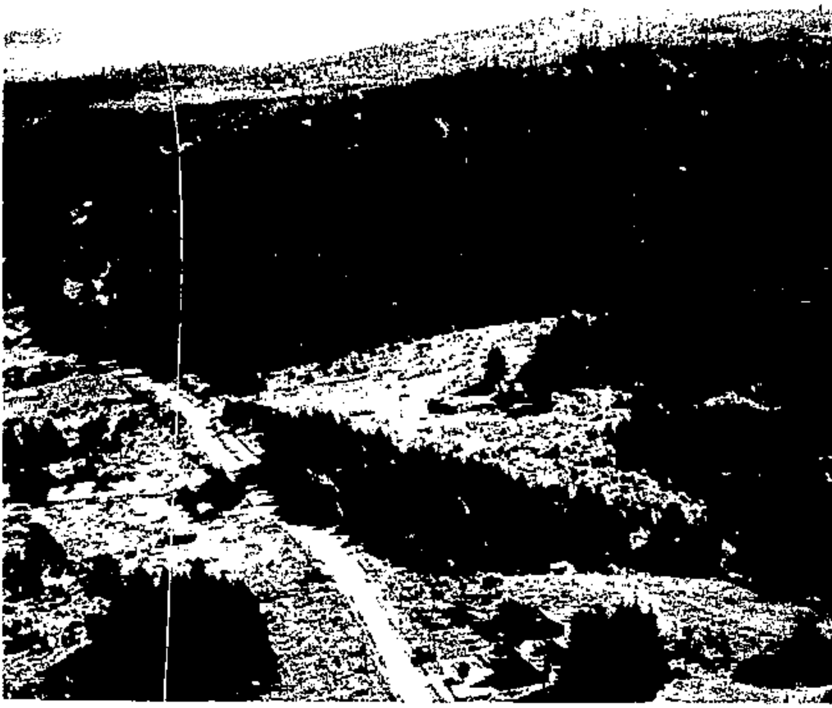

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FIGURE 1. An estimated 5 million acres of young-growth Douglas-fir in western Washington and Oregon are suitable for commercial thinning under management that is feasible at present. First attempts should be in young-growth stands on favorable topography and accessible from established roads.

TABLE 1. *Commercial forest land in the Douglas-fir region by stand class and stocking* [1]

Stand class	Total	Medium or well stocked	Poorly stocked
	Thousand acres	*Thousand acres*	*Thousand acres*
Young-growth, total	15, 945	14, 031	1, 914
Sawtimber	7, 143	6, 829	314
Pole timber	4, 542	4, 096	446
Seedlings and saplings	4, 260	3, 106	1, 154
Old-growth	7, 468		
Nonstocked	2, 042		
Total commercial forest land	25, 455		

[1] Adapted from table 20, Appendix Basic Statistics in *Timber Resources for America's Future.* U.S. Forest Service. U.S. Dept. Agr. Forest Resource Rpt. 14, pp. 199-625. 1958.

Although not yet widely practiced, the commercial thinning of Douglas-fir has enormous potentialities.

Techniques for carrying out the physical job of thinning have been developed and, in general, can be defined more explicitly than silvicultural aspects. Research in thinning Douglas-fir has not been carried on long enough to develop optimum thinning schedules from a silvicultural standpoint. It is therefore too soon to draft specific rules and definitive thinning schedules. Instead, the forester must rely heavily on judgment based on silvical knowledge of the species and stand, and a thorough understanding of thinning theory.

This bulletin therefore devotes considerable space to the theory and objectives of thinning as applied to Douglas-fir. Based on current knowledge of stand development and silvical characteristics of Douglas-fir, these provide a background for field application of thinning. Effects of thinning on management, largely from a theoretical standpoint, are also discussed.

Sections on application and financial aspects of thinning describe how commercial thinning should be carried out and explain some of the economic considerations involved. Actual experience with commercial thinning, experimental and otherwise, is drawn on heavily for these sections.

Although commercial thinnings may be made in young-growth stands older than 100 years, harvest or preharvest cuttings are more likely after this age. Discussion and data in this bulletin are confined principally to the 30- to 100-year age group, with emphasis on the lower half of this age range. Data are also limited to sites II, III, and IV.[4] Site I occurs only on limited areas; and commercial thinning is not likely to figure prominently in the management of site V.

Where rotation age is assumed for illustrative purposes, 100 years has been used, not because it is recommended or expected to be the chosen rotation, although within the range of acceptable rotation ages, but simply for convenience. By using 100 years it is possible to present trends and a span of information from which data for shorter rotations may be extracted if desired.

THEORY OF THINNING AS APPLIED TO DOUGLAS-FIR

Forestry, based in part of biological sciences, has not been, and undoubtedly never can be, grounded on a mathematical foundation alone. It must be applied as an art based on the practitioner's judgment. Thinning is no different from any other aspect of forestry in this respect. Judgment required for application of thinning must be based on an understanding of thinning theory and the way in which the characteristics of a particular tree species relate to theory.

[4] Based on height of average dominant and codominant tree at 100 years: Site II, 170 feet; site III, 140 feet; and site IV, 110 feet.

OBJECTIVES

Thinning, like any forestry practice, is undertaken for economic gain. Two major objectives, if realized, will result in economic gain. These are (1) redistribution of growth potential of the stand to optimum advantage, involving tree size and quality considerations; and (2) utilization of all merchantable material produced by a stand during a rotation (*19, p. 343*). The first objective is usually implied when we say, "Thinning speeds the diameter growth of remaining trees"; the second, when we say, "Thinning makes possible salvage of dead trees or trees about to die."

In addition, there are secondary objectives to thinning, which should perhaps be called advantages incidental to a well-conducted operation. These include reduced fire hazard, prevention of disease and insect attacks, and genetic improvement of the stand.

Redistribution of Growth

In the first objective we recognize that widely spaced trees grow rapidly in diameter, while closely spaced trees grow slowly. Total volume growth of a few rapidly growing trees may equal the growth of many small trees. Indeed, within fairly wide limits of number of trees or growing stock per acre, a fixed growth should be expected for a given forest type, site, and age.[5]

To obtain a measure of this fixed maximum growth, cubic volume increase of the entire stem of all trees, including those that die during the measurement period, must be counted as increment (*19, p. 354*). This fixed volume production for a given forest type and site may thus be grown on few or many trees at the forester's discretion—redistribution of growth potential.

Continued concentration of the potential wood production of an acre on few trees results in large trees; dividing this concentration among many results in small trees. Well-known advantages of large trees include (1) cheaper logging and milling costs, and (2) a greater variety of generally more valuable products available for manufacture.

Skillful thinning begun at an early age will produce more *usable* volume, though *total* volume production remains constant. Total volume production includes total stem volume, as already pointed out. Not all trees will be large enough to be profitably marketed, however, and not all the stem volume of marketable trees can be utilized. It is common practice, therefore, to measure only the salable portion of trees large enough to be merchantable. Increase in the usable volume of stands through thinning comes from two sources:

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[5] The extensive literature, mostly European, on investigations of this concept of equal growth over a wide range of growing stock has been reviewed by several authors, including Hawley and Smith (*19, p. 351*), Braathe (*7, p. 42*), Hiley (*22, p. 107*), and Heiberg (*37*). The concept has not been adequately tested for Douglas-fir.

(1) Trees reach usable size at an early age. Hence, little of the stand's production will be wasted in trees that die before reaching usable size. This gain is largely sacrificed if stands are allowed to remain unthinned until merchantable products can be removed;

(2) The merchantable part of a large tree is a greater proportion of the total stem volume than that of a small tree. In addition, the board-foot/cubic-foot ratio is greater in a large tree than in a small one.

To gain the maximum possible increase in usable volume from the sources listed, dense stands must be thinned early; otherwise, much volume will be lost in trees that fail to reach usable size before being crowded out of the stand. When thinning is delayed until diameter growth has been restricted by competition, gains from redistribution of growth depend on whether remaining trees will speed their diameter growth sufficiently to make up for the loss in growth of the trees removed. This feature—response to release—is of most concern in commercial thinnings.

Although physiological factors controlling response to release are not completely understood, considerable evidence indicates that the ability of trees to increase their diameter growth in response to thinning decreases with age. It is likely that increased growth depends mostly on an increase of crown surface, at least where the limiting factor in growth is the tree's photosynthetic capacity. The older the tree, the slower its crown growth. Any site curve provides evidence that height growth of trees decreases rapidly after a certain age. Potential lateral growth is probably also greatly reduced (*46*). In short, an old tree will take longer than a young tree to fill a certain airspace made available when a neighboring tree is removed. Hence the older tree fails, or is slow, to respond with increased diameter growth.

Response is also likely to be better on good sites than on poor. In addition, certain trees respond better than others, depending on their position in the stand and crown size. Trees with small, weak crowns generally are unable to make quick and certain use of new growing space. Sudden and heavy release is, moreover, apt to cause physiological difficulties or "shock," particularly where a tree's crown before thinning was inadequate for good growth.

Generally, the growth potential of an area can be more readily channeled to the desired trees if thinnings are begun early and crowns are kept vigorous and of optimum size. In contrast, if crown development is greatly restricted, attainment of full growth after thinning may take several years. In the latter case, part of the forest area remains out of production after thinning while slow-growing crowns are filling the manmade spaces. Hence, some reduction can be expected before growth has been redistributed satisfactorily.

So far in this discussion we have assumed that the main reason for trying to redistribute growth is to produce larger trees more quickly. Production of better quality trees, over and above that represented by increased size, is also important. Control of quality factors such as size and number of limbs, bole form, decay, and compression wood can often be attained through thinning. Removal of low-quality trees early in the life of the stand, while redistribution of growth is still possible, channels a higher percentage of the total growth over the rotation to selected quality trees.

Artificial pruning, which is aimed at the production of quality trees in terms of limb-free logs, is also influenced by both size and quality. Pruned trees must grow rapidly in order to produce enough clear wood to justify the expenditure (*43*, *45*). This rapid growth can, in turn, be fostered by thinning, which concentrates stand growth on pruned trees.

Redistribution to trees of the desired species may also be important when low-value species, principally alder, occur in the stand. In such instances, the alder should be removed early to allow the Douglas-fir to occupy its space.

Possibilities of realizing the greatest gain from redistribution of growth by commercial thinning of Douglas-fir will be discussed under the heading "Silvicultural Factors."

Utilization of All Merchantable Material

In the natural development of even-aged stands, many trees must die before the stand reaches harvestable age. Much of the mortality volume may be in merchantable trees.

Harvesting these losses is the second major objective of thinning. Commercial thinning started late in the life of the stand is mostly concerned with attaining this objective. Opportunities for redistribution of growth may be very limited in these older stands, but failure to harvest the substantial amount of mortality that frequently occurs needlessly sacrifices production of the site.

Suppression is the predominant cause of normal mortality; occasionally, single dominant trees succumb to insects, disease, or windthrow. Trees that die of suppression are generally the smaller trees in a stand. Only in older stands are such trees of merchantable size. Accordingly, a thinning designed to harvest natural mortality is ordinarily a low thinning since trees in the lower crown classes have the poorest life expectancy.

Where trees most likely to die are below merchantable size, one alternative is to keep them alive by harvesting an equivalent volume of merchantable competitors in the dominant and codominant crown classes. The objective would be to keep the poor-risk subordinate trees alive long enough to become merchantable, either through increase in size or lowering of minimum merchantability standards. Normally, such trees would not be retained for final crop trees since they may be genetically undesirable. Where slow growers (potential mortality) are kept alive, they must be capable of increasing diameter growth sufficiently to compensate for the growth of the trees removed; otherwise, total wood production per acre will be reduced. A thinning that keeps intermediate and suppressed trees alive may thus effectively forestall natural mortality but fail to fully redistribute potential growth.

In a young, vigorous stand where growth may be easily redistributed, equivalent normal mortality may be removed in trees that are not expected to die soon. In older, less responsive stands, only the dead, dying, and poor-risk trees can be successfully removed without reducing the stand's growth.

Other Objectives

Secondary objectives of thinning are accomplished almost automatically in a thinning designed to carry out the major objectives, as explained in the following discussion.

Reduced Fire Hazard

Thinning provides a cleaner, more accessible forest, thus reducing fire hazard. In frequently thinned stands, amount of fuel is minimized because of the salvage and prevention of mortality. The very large numbers of trees that die during the development of a normal stand substantially increase the fire hazard. Those trees that fall or shed their limbs provide abundant fuel for a ground fire; those that remain standing serve to carry fires to the tree crowns (*51*) (fig. 2).

Thinning, of course, does produce some slash, which may increase the hazard for a short time. Slash from thinnings usually decomposes rapidly, however, because the tops and limbs are usually small and mostly sapwood. In addition, moisture and humidity generally favor rapid decay. Utilization largely determines fire hazard since

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FIGURE 2.—In the 1951 Forks fire on the Olympic Peninsula, Wash., dead trees and dead branches on the boles of live trees in the unthinned, unpruned stand carried the ground fire to the dense crowns where it spread rapidly from tree to tree (*left*). In the thinned, pruned stand, although the trunks were fire blackened for several feet, the fire crowned only rarely and some 75 percent of the merchantable trees and volume survived the fire (*right*).

it controls the quantity of slash remaining from thinnings and the amount of mortality that can be forestalled or salvaged in the smaller tree sizes.

Ease of accessibility to all parts of a frequently thinned forest is important from a fire control standpoint. Skid roads and trails, developed and kept open through frequent use, provide readymade fire lines. Roads built for thinning may also serve for protection. In fact, a road system may not always be feasible for either thinning or protection alone, but jointly the two uses may justify construction.

Prevention of Disease and Insect Attack

Good thinning practice unquestionably favors the development of healthy, vigorous trees. Vigorous trees, in turn, tend to resist attack by many insects and some diseases.

Prompt harvest of infested or infected trees, dead or alive, not only saves wood but may also help to prevent buildup of populations of destructive insects and to remove sources of disease infection.

Since thinning generally favors trees of better form, it helps to develop stands with greater resistance to damage by wind, snow, and ice. Again, wood is saved and the vigor of the stand is kept high.

Genetic Improvement

Removal in early thinnings of inferior trees that otherwise would live to the end of the rotation leaves the better trees as seed bearers. This byproduct of a thinning regime is especially important when the next stand is to be established by natural regeneration. Although the quality factors that are transmissible to a tree's progeny are largely unknown, nothing can be lost by leaving only the best trees for the final stand. To the extent that the good characteristics are heritable, the practice will improve succeeding generations.

SILVICULTURAL FACTORS

Knowledge and understanding of the silvical characteristics that control development of trees and stands are necessary for the intelligent application of thinning. Important characteristics of Douglas-fir that influence thinning practice are tolerance to shade; variation among trees; growth in height, diameter, and form; wood and tree quality factors; windfirmness; and resistance to disease and insects. These factors are discussed in the following sections.

Stand Development

Formation

Douglas-fir stands are universally even-aged; range in age does not exceed 20 percent of rotation age. The coast variety is considered intolerant of shade (*26*). For that reason it is incapable of reproducing itself beneath its own canopy. Regeneration on open cutovers and burns characteristically occurs over a period of years as a slow filling-in process (*24*).

Stocking varies widely in seedling and sapling stands that, on the average, are well stocked. The reasons for this variation need not be detailed here. Isaac (*24*) and others have made extensive observations and studies of natural regeneration. Of interest to the forester charged with a thinning program is the fact that many stands are well stocked and in need of thinning at early ages. Stocking, however, is apt to vary widely even on small areas, so that closely spaced clumps of trees interspersed with trees with ample room to grow (potential rough dominants) are more the rule than the exception (fig. 3).

Crown Class Differentiation

Crown class differentiation takes place early in the life of a Douglas-fir stand and proceeds rapidly (*70*). Four reasons for this may be cited:

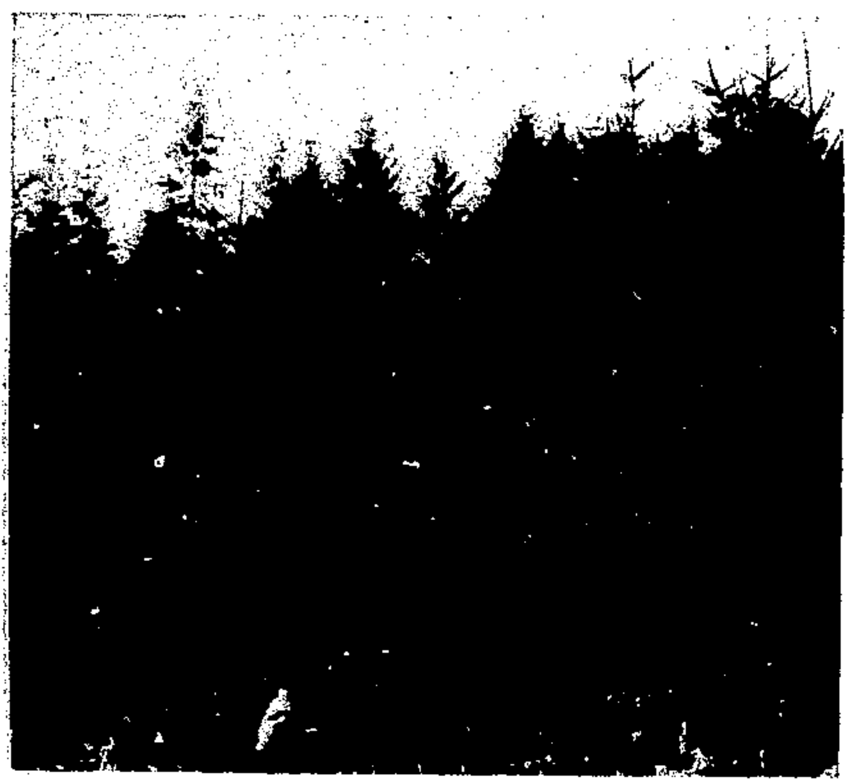

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FIGURE 3.—Variable age and development of individual trees and uneven stocking in most seedling and sapling stands result in early crown class differentiation and in size and limbiness of trees.

1. The filling-in process during regeneration results in trees of varying age and height. The older trees, being taller, have considerable advantage in the race for dominance.
2. Site heterogeneity within a stand often favors certain trees at the expense of their neighbors.
3. Intolerance accentuates the difference between dominant and subordinate trees, so that the latter fall behind rapidly.
4. A wide natural variation in growth rate among individual trees gives some trees an inherent advantage.

Early and certain crown class differentiation effectively prevents stagnation in Douglas-fir stands. Only on the very poorest sites does one find anything resembling the locked condition common in ponderosa pine or lodgepole pine.

As stands grow older, suppressed trees die rapidly. A constant and rapid diminution in number of trees per unit area results. The Douglas-fir yield tables (*35*) strikingly demonstrate the rapid reduction in normal stands. However, compared with many species, such as the pines, Douglas-fir forms remarkably dense stands.

Diameter Range

Early uneven stocking in the new stand and subsequent distinct separation into crown classes result in wide variation in diameter growth among trees. As a consequence, diameters span a wide range in stands of thinnable size (fig. 4). Roughly, diameter range is equal to the average diameter of the stand plus 2 to 3 inches [4] (fig. 5). Average diameter falls about midway in the range. Thus, the forester ordinarily has a wide range of tree sizes to work with.

Height Growth and Crown Development

Height growth of Douglas-fir is rapid after a 5- to 10-year establishment period (fig. 6). Like some other species native to the Northwest coastal climates, this rapid rate of height growth is well maintained as trees grow older. Douglas-fir grows 35 to 40 percent as much in height between 40 and 60 years as it does between 20 and 40 years (*35*). This continued rapid height growth is important in thinning because it is the means (along with lateral growth) by which a tree builds its crown. Size and vigor of crown at time of thinning, in turn, govern the ability of a tree to respond to release after thinning.

Height growth has classically been considered independent of stocking, and hence unaffected by thinning. Evidence is mounting, however, that height growth is more rapid in less dense stands of Douglas-fir (*16*, *58*). On the other hand, very heavy thinning may induce shock resulting in reduced height growth (*58*).

Change in crown length is controlled by rate of dying of lower branches, which subtracts from the crown, as well as by height growth,

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[4] As calculated from stand table alinement chart (*35*): Diameter range excluding the largest 2 percent and smallest 2 percent of the trees = 1.8 + 1.05 (average d.b.h).

FIGURE 1.—Tree diameters span a wide range in stands of the same size.

which adds to it. Rate of branch dying is probably controlled by several factors: Individual tree tolerance, which determines the lower threshold of light below which needles cannot function; and stand density, which controls amount of light available to lower branches. Factors that influence root development and general health and vigor of the tree must also affect branch dying, though indirectly. No really definitive data are available from managed stands to show just how

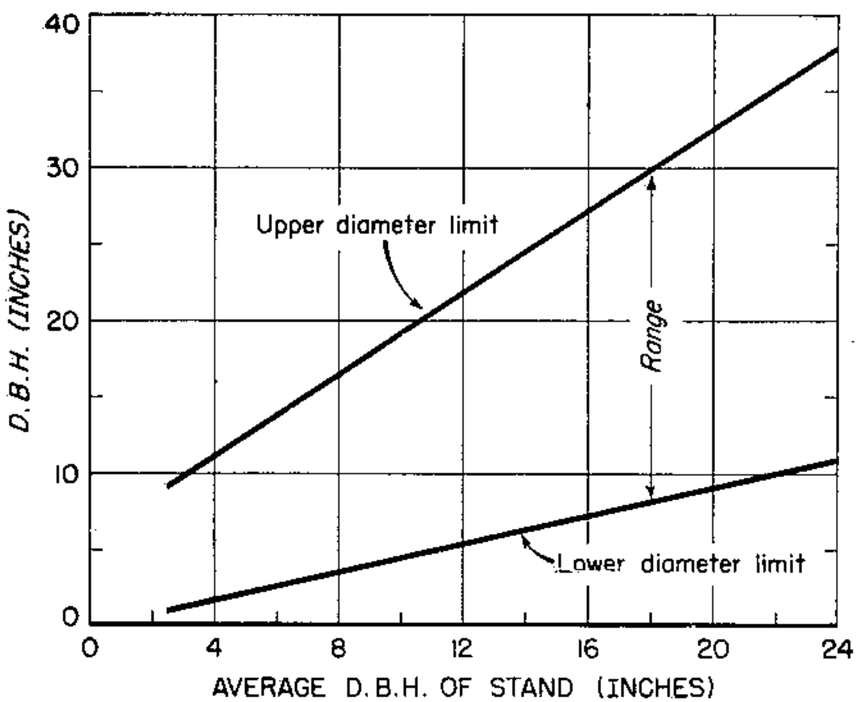

FIGURE 5.—Range in diameter of 96 percent of trees in normal stand by average diameter of stand. Excludes largest 2 percent and smallest 2 percent of the trees. Derived from figure 17 of "The Yield of Douglas-fir in the Pacific Northwest" (35).

Douglas-fir crowns react under management. However, the rate of dying is rapid and crowns in dense natural stands are characteristically short (fig. 7).

The average tree in a 66-year-old well-stocked site II stand on the Gifford Pinchot National Forest had 36 percent of its total height in live crown. Height to the base of the live crown increased with diameter in this stand, but total height increased much faster (fig. 8), so that 10-inch trees (near the suppressed end of the scale) had 29 percent of their height in live crown, while 30-inch trees had 39 percent. Doubtless the short crowns of small trees, located as they are below the main canopy, are also less efficient food manufacturers, so that the difference in growth rate between large and small trees cannot be accounted for by the length of crown alone.

Although optimum length of live crown is not known for Douglas-fir, the rapid death of lower branches suggests that fairly wide spacing is required for large crowns and rapid growth.

In the taller, older stands where commercial thinnings are most feasible, branches of adjoining trees seldom interlace. Presumably the intolerance of Douglas-fir is a major cause, along with the mechanical interference related to the whipping action of tall, slender trees. Thus, the crown of each tree characteristically occupies a distinct and

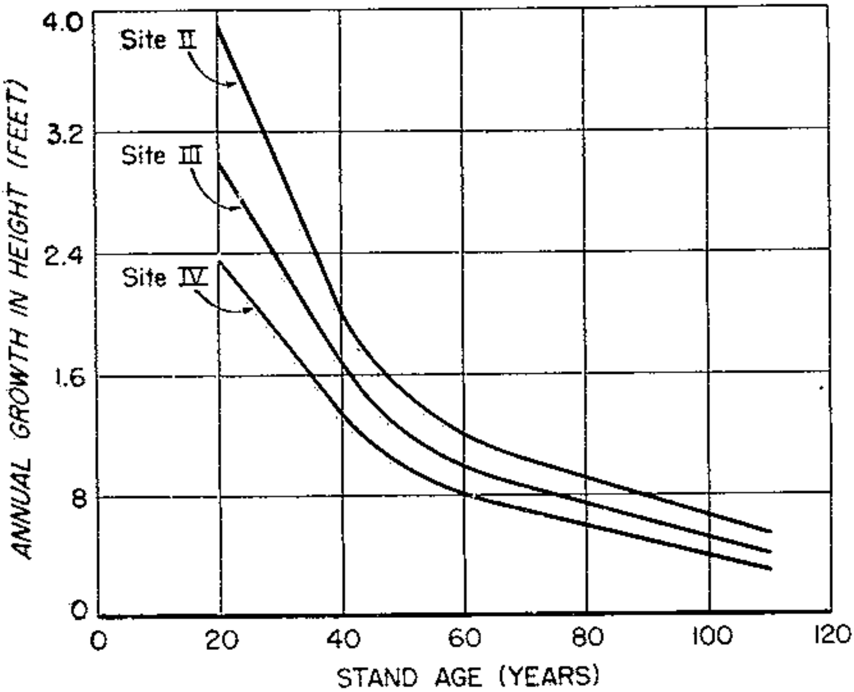

FIGURE 6.—Annual height growth of dominant and codominant trees by age of stand and site quality. Derived from table 1 of "The Yield of Douglas-fir in the Pacific Northwest" (*35*).

exclusive area within the stand. This characteristic also suggests the need for wider spacing in Douglas-fir, to favor development of wide, deep crowns.

Diameter Growth

Diameter-growth attributes of a species are of utmost importance in the development of thinning practices, because the control of diameter growth is a primary objective of thinning. Diameter growth, as previously emphasized, depends largely on size of live crown (*32*), which in turn is controlled by spacing and by the genetically controlled growth capacity of the individual tree. In addition, site features, including availability of water and nutrients, also exercise indirect control.

Douglas-fir, particularly on good sites, generally is a very fast-growing species. Rapid diameter growth, even in heavily stocked, unmanaged stands, is sustained even past ages of 70 and 80 years. Danish experience with intensively managed plantations has shown that a rate of diameter growth greater than that found in natural,

FIGURE 7.—Crowns in well stocked unthinned stands are characteristically short. As a result, diameter growth, even on dominant trees, is frequently less than that attainable or desirable.

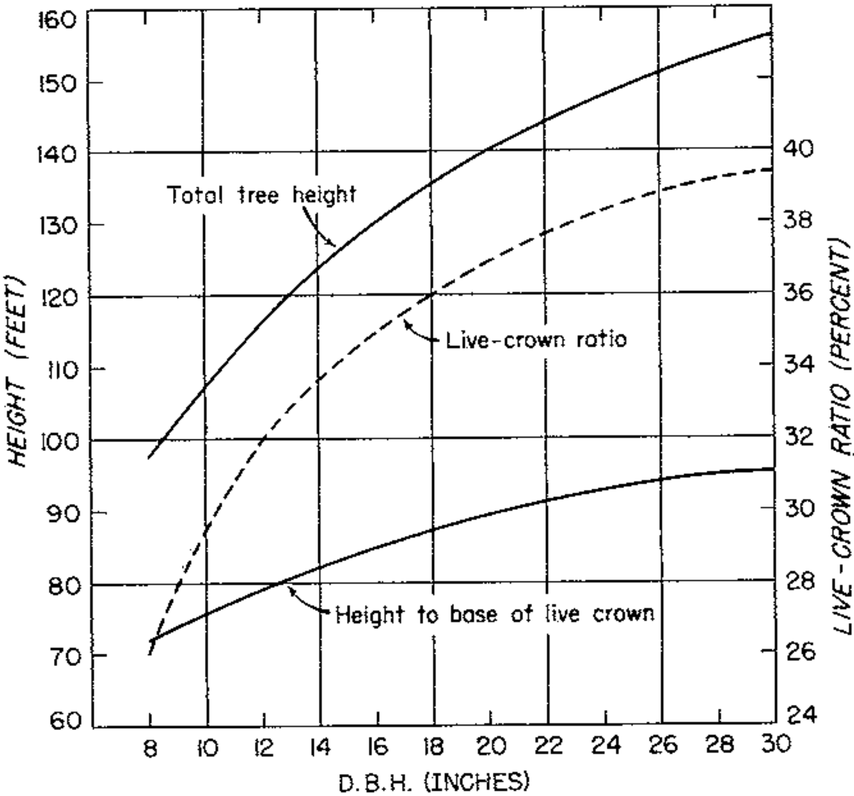

FIGURE 8.—Total height, height to base of live crown, and live-crown ratio by d.b.h. for 66-year-old, site II, well-stocked stand. Derived from data from growth plots 1–5, Gifford Pinchot National Forest.

well-stocked stands (*13, p. 111*) can be achieved and sustained through a program of periodic thinnings.

Achieving an average diameter growth about equal to that of the largest trees in a natural stand would seem to be a conservative goal of thinning. As previously pointed out, live crowns on the largest trees in natural stands seldom exceed 40 percent of the tree's total length. Thus, it may be assumed that trees in a continuously thinned stand would easily reach an average size comparable to the largest 10 or 20 percent of trees in a normal stand. For example, on site II the lower diameter limit of the largest 5 percent of trees in the normal stand is 13.8 inches d.b.h. at age 40 and 26.2 inches at 80 years (table 2). Such trees are apparently growing about 3 inches or better per decade at 50 years, and more than 2 inches at age 80.

Diameter growth characteristically lessens as trees grow older; at a given age the small trees in a stand are the slowest growers, the large trees the fastest.

TABLE 2.—*Lower diameter limit of largest 5 and 10 percent of trees in normal stands, by age and site quality*[1]

Age (years)	Lower limit of diameter breast high					
	Largest 5 percent			Largest 10 percent		
	Site II	Site III	Site IV	Site II	Site III	Site IV
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
20	6.9	------	------	6.1	------	------
30	10.2	8.1	------	9.2	7.3	------
40	13.8	10.9	8.1	12.5	9.9	7.3
50	17.5	13.7	10.1	16.0	12.5	9.2
60	20.7	16.5	12.2	19.0	15.0	11.1
70	23.8	19.0	14.2	21.9	17.2	13.0
80	26.2	21.3	16.0	24.1	19.5	14.8
90	28.6	23.2	17.6	26.4	21.2	16.1
100	31.0	25.0	19.0	28.6	23.0	17.4
110	32.8	26.4	20.3	30.2	24.2	18.6
120	35.0	27.9	21.6	32.2	25.9	19.9

[1] Derived by method described on pp. 63–64 of U.S. Dept. Agr. Tech. Bul. 201 (35).

Basal Area Growth

Small trees in a stand grow so slowly that they do not contribute to growth of the stand in proportion to their basal area or volume. Data from two permanent sample plots (one in a 50-year-old stand on site index 180, the other in a 92-year-old stand on site index 150)[7] showed that the 20 percent of the stand basal area contained in the smallest trees contributed only 9 percent of the total gross basal area increment (fig. 9). Though the two stands were dissimilar in age and site, trees smaller than average diameter on both plots contained approximately 27 percent of the total basal area. Growth of these below-average-diameter trees made up only 16 percent of the total. Thus, removal during thinning of one-fourth of the basal area in the smaller trees would be expected to reduce growth only 13 percent, even if the remaining trees were incapable of responding to release.

Wood Quality

Effect of growth rate on wood quality is probably the first relationship that comes to mind in any discussion of thinning Douglas-fir. Full discussion of the effect of ring width on wood quality is beyond

[7] The site II plot was established in 1927 in a 52-year-old stand on the Gifford Pinchot National Forest. The site III plot is on the Wind River Experimental Forest and was established in 1914 in a stand 72 years old. Both plots have been remeasured periodically since establishment.

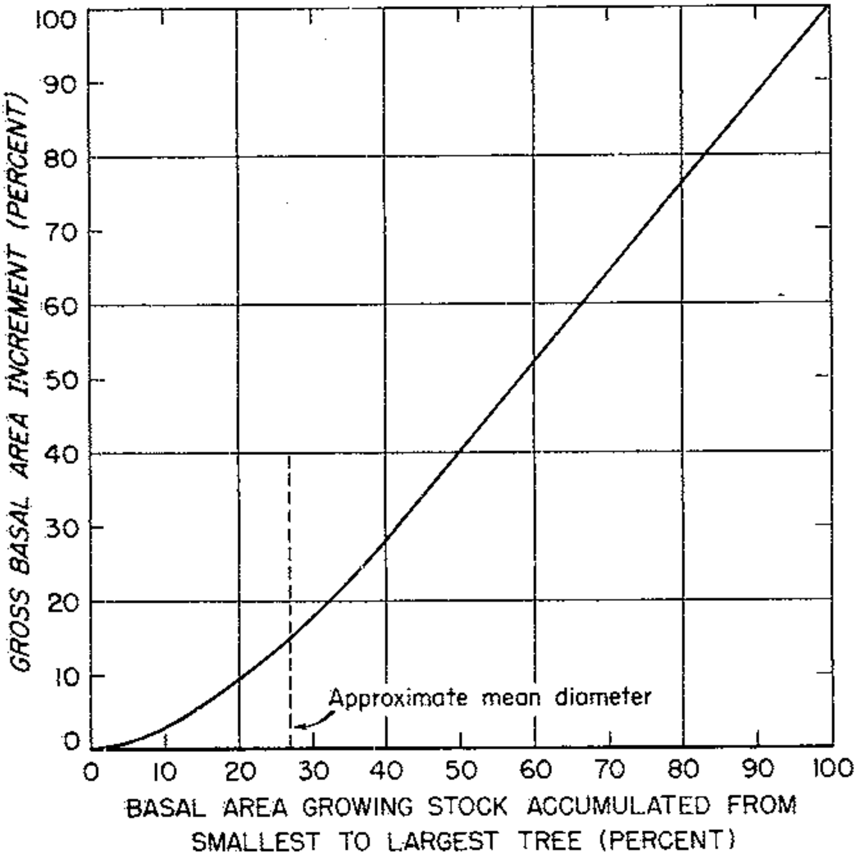

FIGURE 9.—Percent of total gross basal area increment contributed by any given percent of the basal area growing stock; percent of growing stock accumulated by d.b.h., beginning with the smallest tree and ending with the largest. Derived from data from growth plot 1, Gifford Pinchot National Forest, and plot 4, Wind River Experimental Forest.

the scope of this bulletin. Grading rules, however, discriminate against wood with fewer than 6 rings per inch; this point is commonly used as a dividing line between "desirable" and "less desirable" wood. Growth rates, outside bark, required to produce wood with 6 to 12 rings per inch are shown in the tabulation below. These rates are based on studies of bark thickness at breast height, which show that wood growth is 90.6 percent of outside bark growth for trees less than 10 inches d.b.h., and 84.6 percent for larger trees (*30*), or approximately 86 percent for trees from 5 to 25 inches d.b.h.

Rings per inch:	*Approximate annual diameter growth outside bark at breast height (inch)*
6	0.39
8	.29
10	.23
12	.19

Little data are available to indicate how much wood is produced in managed stands with growth rates exceeding those shown above. However, table 2 shows that on good sites even the fastest growing 5 percent of trees in normal stands do not grow faster than six rings per inch after 20 years of age. However, very young trees commonly exceed this rate of growth. In a stand old enough for a commercial operation, thinning is not likely to stimulate diameter growth of Douglas-fir sufficiently to produce wood with fewer than six rings per inch. Indeed, it is questionable if Douglas-fir trees can be grown at six rings per inch for any extended period.

Knots and limbiness are two other major quality factors that influence thinning practice, although knots are less serious in Douglas-fir than in many other species such as the pines. Dead limbs are very persistent on Douglas-fir (*40*). Their size depends mostly on stand density (which controls the age at which they die) and, to an increasingly recognized extent, on the genetic makeup of the tree. Coarse-limbed and fine-limbed trees which are not the result of growing conditions can be readily recognized in a Douglas-fir forest. Geneticists believe tests will show that these characteristics are heritable (*15*, *25*). Yet, for most trees, limb size is obviously the result of growing space and the forester must recognize that keeping stands dense enough to restrict limb size also restricts crown size and decreases diameter growth.

These relationships suggest the desirability of artificial pruning for stands thinned heavily enough at young ages to permit large limbs to develop. At present, commercial thinning is normally not begun until the lower branches have died. In future years, however, the complementary practices of thinning and pruning at young ages will doubtless become commonplace.

Insect and Disease Resistance

Douglas-fir is singularly free of insects and diseases that affect tree quality or directly influence thinning practice. A root rot, *Poria weirii*, is serious in many stands of thinnable size, but the only recommended modification in practice is always to remove dead or affected trees. *Fomes subroseus* is the only wood-rotting fungus of importance in stands of thinnable age.

Windfirmness

Douglas-fir, particularly young growth, is relatively windfirm. On deep, well-drained soils the tree is firmly anchored by a well-defined taproot and several main laterals that run diagonally down into the soil (*36*). Where a hardpan or high water table restricts root development of Douglas-fir to a shallow surface layer, however, windthrow is not uncommon (*34*, *60*) (fig. 10). On slopes, Douglas-fir normally develops an extensive root system parallel to the surface on the downhill side of the tree. On the uphill side, in contrast, the roots extend only a short distance before turning downward (*60*).

FIGURE 10.—Douglas-fir is a moderately windfirm species, but on excessively damp soils may be shallow rooted. On such soils thinnings must be light and care- [illegible]

The tree is therefore more resistant to upslope than to downslope winds. Apparently, this asymmetrical root system on slopes helps to explain why windfall is most severe on lee slopes (*42*).

Windfall, when associated with partial cutting, usually results from one of three causes:

1. *Very heavy cuts, not properly classified as thinnings.*—In such operations, stands are usually cut to a diameter limit and leave trees are slender for their height and fully exposed. Even so, leave trees are commonly tipped or broken rather than completely uprooted.

2. *Trees shallowrooted because of a hardpan or high water table.*—Thinning must be skillfully applied on such soils to minimize windthrow.

3. *Root-rot infections.*—Thinning infected stands hastens windthrow of afflicted trees. However, such trees would have succumbed to windfall sooner or later even if the stand had remained unthinned.

Slender intermediate trees recently exposed by thinning are subject to breakage by wind and occasionally snow or sleet, but such damage is also common in unthinned stands. The dimension to watch is the height-diameter ratio of the tree. One desirable aim of thinning should be the production of trees whose ratio does not exceed 80 : 1 (*31*). If slender trees with a greater height-diameter ratio are already present in the stand, they should not be unduly exposed. Overly slender trees that are merchantable may, of course, be cut.

Summary of Stand Development

Stand development of Douglas-fir as conditioned by silvical characteristics may perhaps be most clearly summarized by considering a typical stand ready for its first commercial thinning.

Such a stand is composed of trees varying widely in size and quality. Size ranges from small suppressed trees to large dominants. Quality ranges from codominant trees with good form, small limbs, and comparatively clear boles to rough, large-limbed dominants with rapid taper. Even trees of equal size that have apparently grown under similar conditions may differ greatly in quality—especially in size and persistence of dead branches—because of differences in microsite and genetic characteristics. The stand will also normally contain forked trees, trees with broken or bayonet tops, and occasionally fire-scarred and partially rotten trees. At least some centers of *Poria weirii* infection should be expected, and some infected trees may be identified around their borders. Many salvable dead trees, including those killed by root rot, will normally be found in a previously unthinned stand.

Mortality Characteristics

Utilization of as much as possible of the merchantable material produced by a stand is a major objective of thinning. Trees that die in the unmanaged forest provide the biggest new source of wood in the managed forest (fig. 11).

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FIGURE 11.—A very considerable portion of the production of well-stocked Douglas-fir stands is lost in normal mortality. These trees died from root rot in a 78-year-old site II stand on the Gifford Pinchot National Forest. Thinning probably would not have prevented their death, but would have insured their salvage.

Although normal mortality in Douglas-fir results largely from suppression, a considerable volume in larger trees is lost from other causes. Longtime records from permanent growth plots show that the percentage of trees expected to die during the next decade can be predicted from equations for the dominant-codominant and intermediate-suppressed segments of the stand (*49*). For dominants and codominants, the equation is:

$$\text{Percent dying in 2-inch class} = 1.96 + 0.08(\text{age}) - 0.11(\text{d.b.h.})$$

This equation, among other things, demonstrates that some mortality must be expected in the upper crown classes. Such losses probably occur regardless of stand density. The positive sign for age coefficient indicates that the percentage of trees dying in a given diameter class increases as stands grow older. The negative sign for d.b.h. coefficient shows that in stands of a given age, small trees are much more vulnerable than large ones.

The equation for intermediate and suppressed trees represents suppression mortality more closely:

$$\text{Percent dying} = -13.0 + 0.54(\text{site index}) + 0.61(\text{age}) - 7.83(\text{d.b.h.})$$

This equation (applicable only to well-stocked stands like those from which the basic data were obtained) shows that among trees of the same size in stands of a given age suppression mortality is greater on better sites, probably because of more certain expression of dominance. However, since site and diameter are correlated (larger trees on better sites), the smallest trees normally present in a stand of given age die at about the same rate on good and poor sites. As among dominant and codominant trees, the percentage of trees dying on a selected site is greater at older ages and among smaller trees.

Predicting which dominants or codominants are going to die is often impossible. Hence, thinnings should be frequent enough to permit salvage while dead trees are still usable. Intermediate and suppressed trees likely to die can be more easily recognized; moreover, since they are usually inefficient growers, little is lost if they are prematurely cut.

Further analysis of data from the permanent growth plots shows that the average size of trees that die is closely related to size of average live tree (*50*) (fig. 12). Thus, in a stand in which the live trees average 200 board feet (International ¼-inch), the trees that die in the following decade will average about 60 board feet. When live

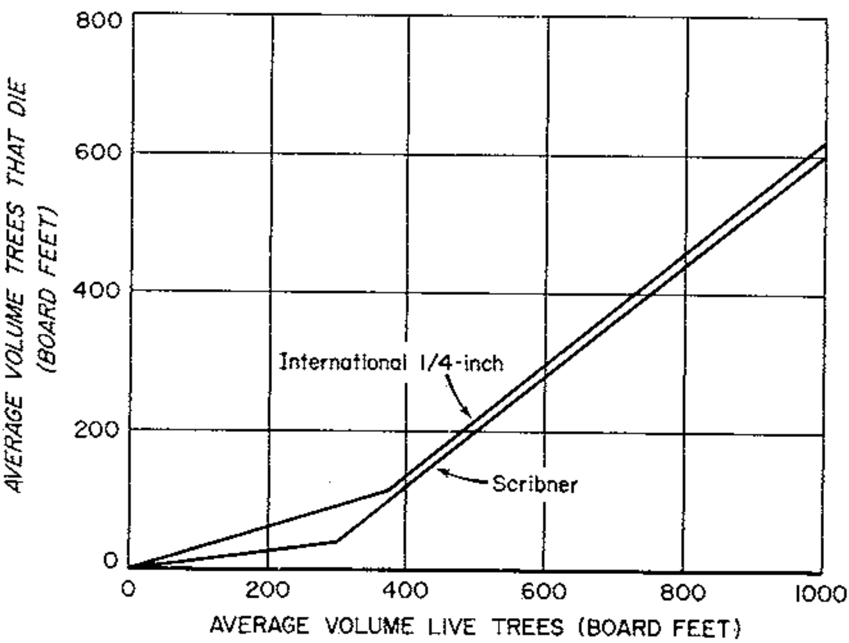

FIGURE 12.—Relation of average board-foot volume of trees that die in a 10-year period to average volume of live trees in stand at beginning of period. Source: "Extending the Douglas-fir Yield Tables to Include Mortality" (*50*).

trees average 500 board feet (Scribner), trees that die average about 200 board feet.

Annual mortality on the 33.13 acres of permanent growth plots averaged 83 cubic feet (total stem volume) per acre for all ages and sites. Annual losses in trees over 12 inches averaged 284 board feet (Scribner) during the same period (*29*).

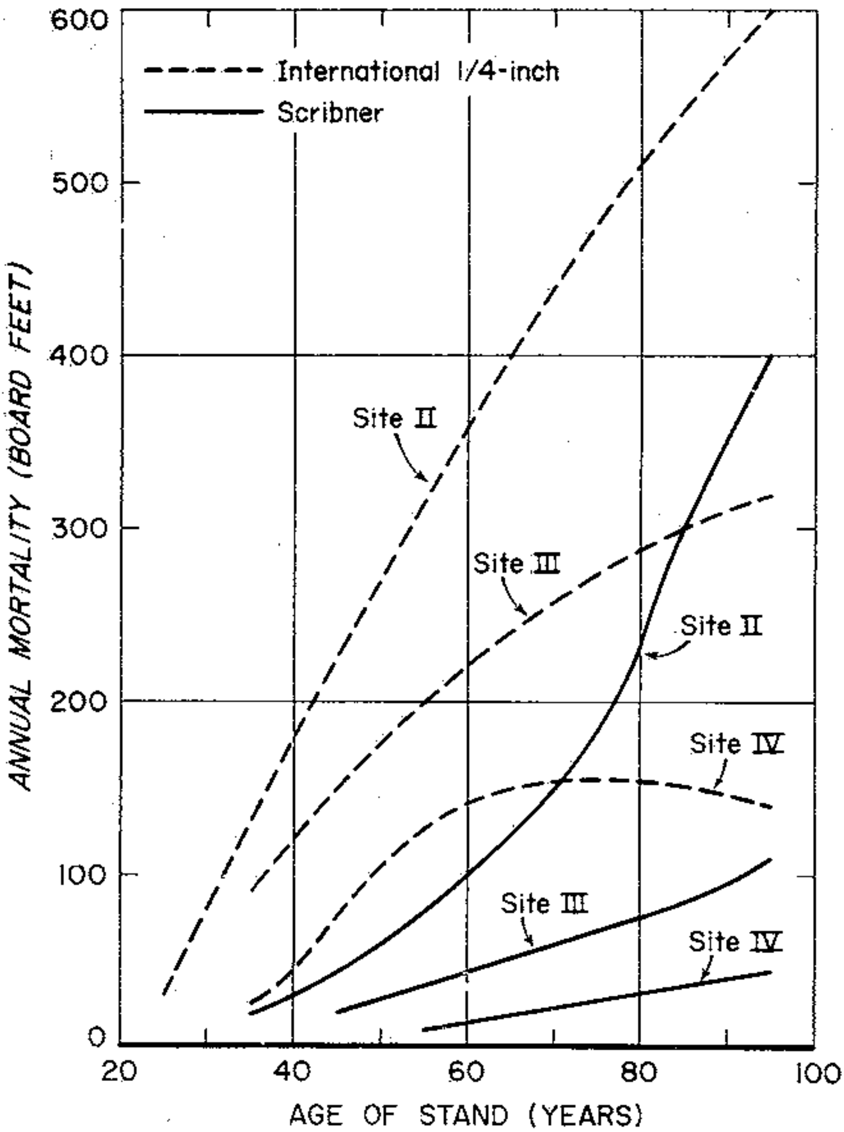

FIGURE 13.—Periodic annual board-foot mortality in normal stands by site quality and stand age. Ten-year periods are used. Derived from tables 2c and 2d of "Gross Yield and Mortality Tables for Fully Stocked Stands of Douglas-fir" (*52*).

Gross yield tables for Douglas-fir (*52*) give the expected mortality by age and site for normal stands (fig. 13). International volume includes trees 7 inches in diameter and larger to a 5-inch top; Scribner volume includes trees 12 inches and larger to an 8-inch top. Since these losses are merchantable in terms of size of tree, they should also be considered an integral part of total volume yield per acre.

The contribution of mortality to total yield of managed stands will be discussed more fully under the section "Forecast of yield."

Response to Release

Improved diameter growth after thinning depends largely on a tree's ability to take advantage of additional room and build a new crown. In Douglas-fir this ability (1) lessens as the tree grows older, (2) is greater on good sites than on poor, and (3) is greatest in trees that have neither too much nor too little crown.

Unfortunately, critical values for these three criteria have not been established. In a 40-year-old, well-stocked, site III stand of Douglas-fir, trees of all crown classes responded to release (*54*). Dominants responded best in terms of diameter growth, presumably because they had adequate crown and root development to take advantage of increased growing space. Diameter growth of the study trees increased more in the first 4 years when the two nearest competitors were cut than when only one competitor was removed. Little additional growth resulted, however, from cutting three rather than two competitors. Thinning in a 97-year-old stand of Douglas-fir on site III resulted in only a very slight increase in diameter growth of residual trees (*56*).

It is important to know whether trees left in thinning will respond to release. Although experimental data are lacking, the following tabulation is presented as a tentative guide to the ages after which little or no response to a crown thinning should be expected on dominant and codominant trees:

Site:	*Short crown (years)*	*Medium crown (years)*
II	60	70
III	50	60
IV	40	50

In preparing this tabulation, crowns covering less than about 40 percent of a tree's height were classed as "short"; crowns covering 40 to 50 percent of a tree's height, as "medium." After trees reach the ages shown (and it must be remembered that the figures given rest on inadequate evidence), thinning will have little chance of speeding up the growth of residual trees sufficiently to make up for the growth of trees cut; hence, little gain can be expected from redistribution of growth potential. Growth that would have been made by cut trees had they been retained is lost. In stands that exceed the critical ages, only those trees that contribute very little—less than their share—to total stand productivity should be cut. For these older stands, a low thinning, which removes the small, slower growing trees and poor risk trees is therefore most applicable. Such a low thinning will be highly beneficial because most suppression mortality will be forestalled and the more efficient segment of the stand will be retained for further growth (fig. 9).

EFFECT ON MANAGEMENT

Management aspects of thinning are not always distinct from silvicultural aspects. In this discussion, however, effects of thinning on level of growing stock, rotation, and total yield are considered management problems, although they are largely controlled by silvicultural factors.

Level of Growing Stock

In stands thinned periodically, growing stock may be held at a much lower level than in normal unmanaged stands, with little or no sacrifice of increment. This is true for three reasons:

1. Trees that will die before the next thinning do not have to be retained as part of growing stock. Since their growth is negligible, harvesting them will not affect increment.
2. Every well-stocked stand includes many trees that contribute far less than their share to total increment (fig. 9). Cutting trees that are growth laggards may reduce increment slightly, but far less than the corresponding reduction in growing stock.
3. Diameter growth in a well-stocked, normal stand is far below the maximum possible. If a stand will respond to release—if growth can be redistributed—growing stock may be reduced with no effect on increment.

The first two reasons are obvious and require no elaboration. The third reason, which is of great importance, merits further discussion.

The amount of growing stock required to produce a given increment in a stand varies with diameter growth and size of trees (*55*) (fig. 14). Basal area increment of a tree is nearly equal to width of radial growth times circumference. Thus, a given width of annual ring requires a certain length of circumference to attain a given increment in square feet. The narrower the ring, the greater the circumference required, and hence, the greater the growing stock. A given total circumference distributed among many small trees encompasses a smaller basal area—growing stock—than the same circumference distributed over a few large trees. Both relationships are shown in figure 14.

European work has shown that maximum increment may be obtained over a wide range of growing stock.[5] This is easily understood from reference to figure 14. Simply, this finding means that a few trees growing rapidly will produce as much volume per acre as many trees growing slowly. If commercial thinning is applied primarily to produce maximum increment, it is essential that remaining trees speed their growth sufficiently to compensate for those removed—redistribution of growth. When thinnings are first started in a fully stocked

[5] Specific references for this statement have been cited by a number of authors who have investigated this phase of thinning. See Baker (*4*), Hawley and Smith (*19*), Spurr (*48*) for discussions.

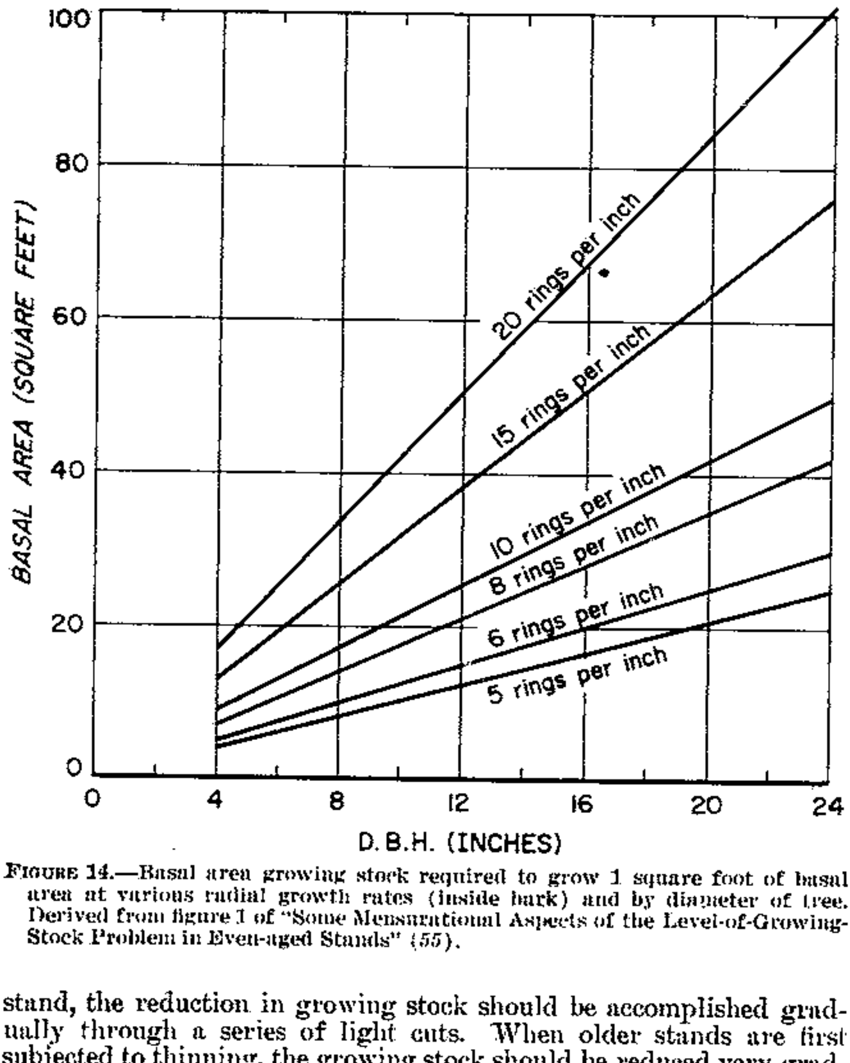

FIGURE 14.—Basal area growing stock required to grow 1 square foot of basal area at various radial growth rates (inside bark) and by diameter of tree. Derived from figure 1 of "Some Mensurational Aspects of the Level-of-Growing-Stock Problem in Even-aged Stands" (*55*).

stand, the reduction in growing stock should be accomplished gradually through a series of light cuts. When older stands are first subjected to thinning, the growing stock should be reduced very gradually because older trees are less capable of responding to release. Thus Heiberg and Haddock, in their proposed cutting plan, gradually reduce basal area from normal at age 28 to slightly over 50 percent at 85 years (*20*). Briegleb's recommended stocking (*8*) recognizes that a higher level of growing stock must be maintained after initial thinning in stands above average in height for a given average diameter (that is, stands resulting from high density). This relationship is consistent with the finding, previously explained, that short-crowned, older trees are much slower to respond to release.

Preliminary analysis of 30 permanent plots on the Voight Creek Experimental Forest, which had received various degrees of thinning, shows that 100 square feet of basal area grew 4.0 square feet per acre annually in the first 3 years following thinning, while 200 square feet grew 5.6 square feet. In other words, doubling the growing stock increased growth 40 percent. These plots are in a site III stand, thinned for the first time at age 37. In the second 3 years, doubling the growing stock from 100 to 200 square feet increased growth 37 percent, from 4.9 to 6.7 square feet annually.

That increment is constant over any considerable range of basal area stocking could not be definitely determined from the Voight Creek plots, which ranged from 79 to 218 square feet per acre in growing stock. However, it is apparent that the lower levels of growing stock are much more efficient producers, particularly in the second period after thinning. Thus, if the 6.7 square feet of growth is assumed optimum, 73 percent of the optimum can be grown with half of the growing stock. Based on the trend during the first two periods, this relationship can be expected to improve as the stand becomes adjusted to thinning.

The Voight Creek data do not help to define the minimum desirable level of growing stock; they amply demonstrate, however, that growing stock in well-stocked stands can be reduced greatly without impairing growth. As stands become older at time of first thinning, growing stock must be reduced more gradually, and the final level of growing stock increased.

Length of Rotation

Although full discussion of financial rotations is beyond the scope of this bulletin, certain aspects must be considered in order to understand the influence of thinning.

Financial rotations must be based on a money-yield table, which shows the value of a stand at any age, and the values of prior thinnings. The money-yield table is constructed from a managed-stand yield table showing tree sizes and stand volumes at various ages. For Douglas-fir, thinning has not yet progressed to the point where such yield tables may be constructed.

However, we can be sure that rotations selected for thinned stands will be different from those selected for unthinned stands if the same financial criteria are applied. Whether thinned stand rotations will be longer or shorter may be fairly easily determined, but present information is not adequate to calculate how much longer or shorter.

Forest Rent

Harvest age may be timed to coincide with maximum forest rent: i.e., mean annual increment in money. Age at which maximum forest rent occurs is, in turn, determined largely by culmination of mean annual increment. However, when a premium is paid for stems of larger size and better quality, forest rent will reach a maximum some years after mean annual increment culminates. For Douglas-fir the increased value of larger trees results mostly from lower logging and milling costs, and hence is less than for species where quality also commands a substantial premium. Since yield tables for managed stands of Douglas-fir have not been developed, age of culmination of mean annual increment for managed stands is also unknown. It may be reasoned, through use of gross yield tables, however, that thinning will delay culmination age (*18*, *50*, *52*). Mortality offsets an increasing proportion of gross annual increment as stands grow older. As a result, periodic and mean annual gross increments are equal at a later age than is true of net increment (figs. 15–20). Thus thinnings, which make it possible to harvest a timber volume somewhere between net and gross yield, must also delay culmination of mean annual increment.

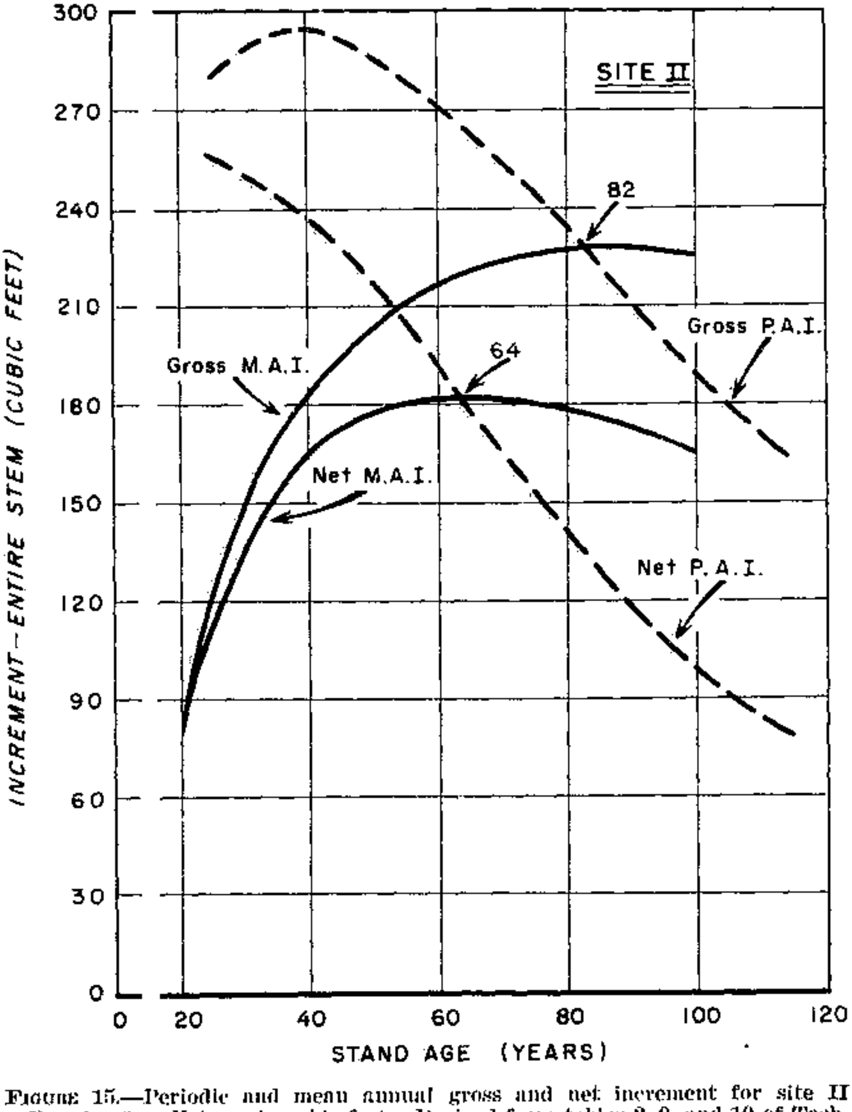

FIGURE 15.—Periodic and mean annual gross and net increment for site II Douglas-fir. Volume in cubic feet. Derived from tables 2, 9, and 10 of Technical Bulletin 201 (*35*) and table 1b of Gross Yield and Mortality Tables (*52*).

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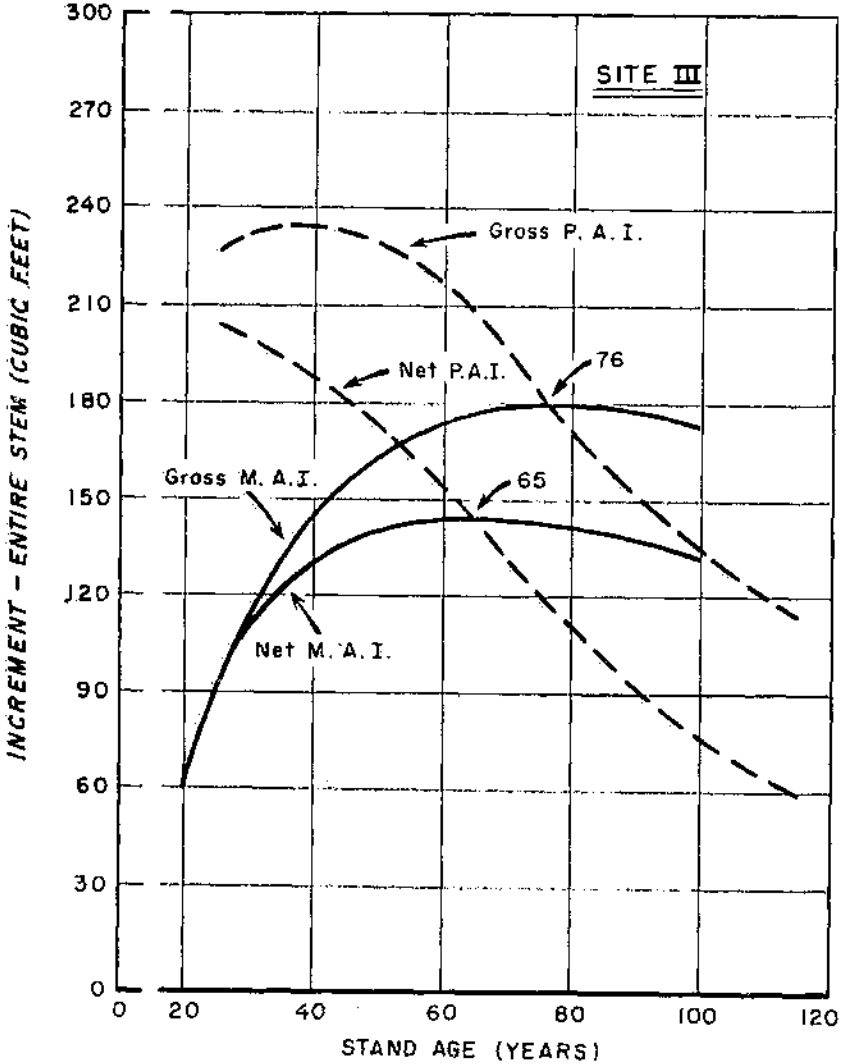

FIGURE 16.—Periodic and mean annual gross and net increment for site III Douglas-fir. Volume in cubic feet. Derived from tables 2, 9, and 10 of Technical Bulletin 201 (35) and table 1b of Gross Yield and Mortality Tables (52).

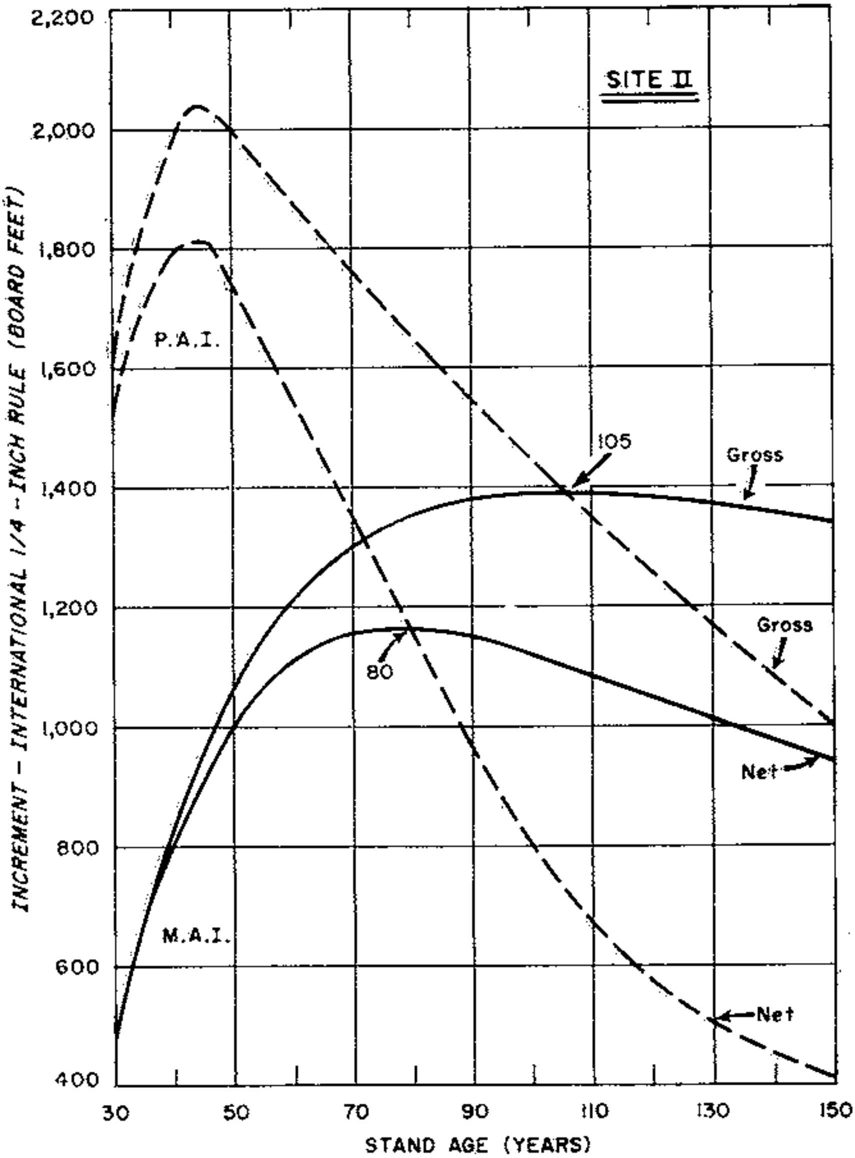

FIGURE 17.—Periodic and mean annual gross and net increment for site II Douglas-fir. Volume in board feet, International ¼-inch rule. Derived from tables 2, 9, and 10 of Technical Bulletin 201 (*35*) and table 1c of Gross Yield and Mortality Tables (*52*).

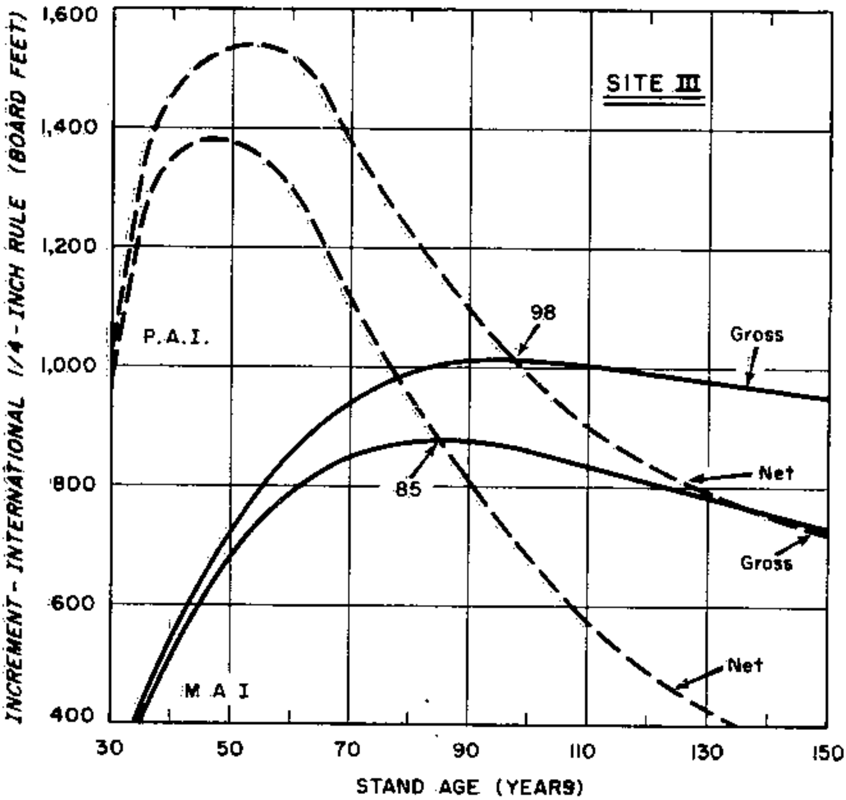

FIGURE 18.—Periodic and mean annual gross and net increment for site III Douglas-fir. Volume in board feet, International ¼-inch rule. Derived from tables 2, 9, and 10 of Technical Bulletin 201 (35) and table 1c of Gross Yield and Mortality Tables (52).

For Douglas-fir on sites II and III, gross cubic-foot increment culminates about 20 years later than net, while for board feet (Scribner) it is approximately 30 years later. When measured by the International rule, gross increment culminates about 25 years after net on site II, and about 15 years later on site III. By any of the three measures, the curve of mean annual gross increment shows a much less clearly defined maximum than the net curve, so that harvest may be delayed beyond age of culmination with little loss in mean annual increment.

The board-foot calculations, based on the gross yield tables, make no allowance for increased production resulting from growing larger trees. Where this happens the periodic annual increment would be raised still higher and culmination further delayed. If thinning also increases the unit value of increment, then age of maximum forest rent is delayed even more than age of culmination of mean annual increment.

Thus, rotations controlled by forest rent are certain to be longer for thinned stands than for unthinned.

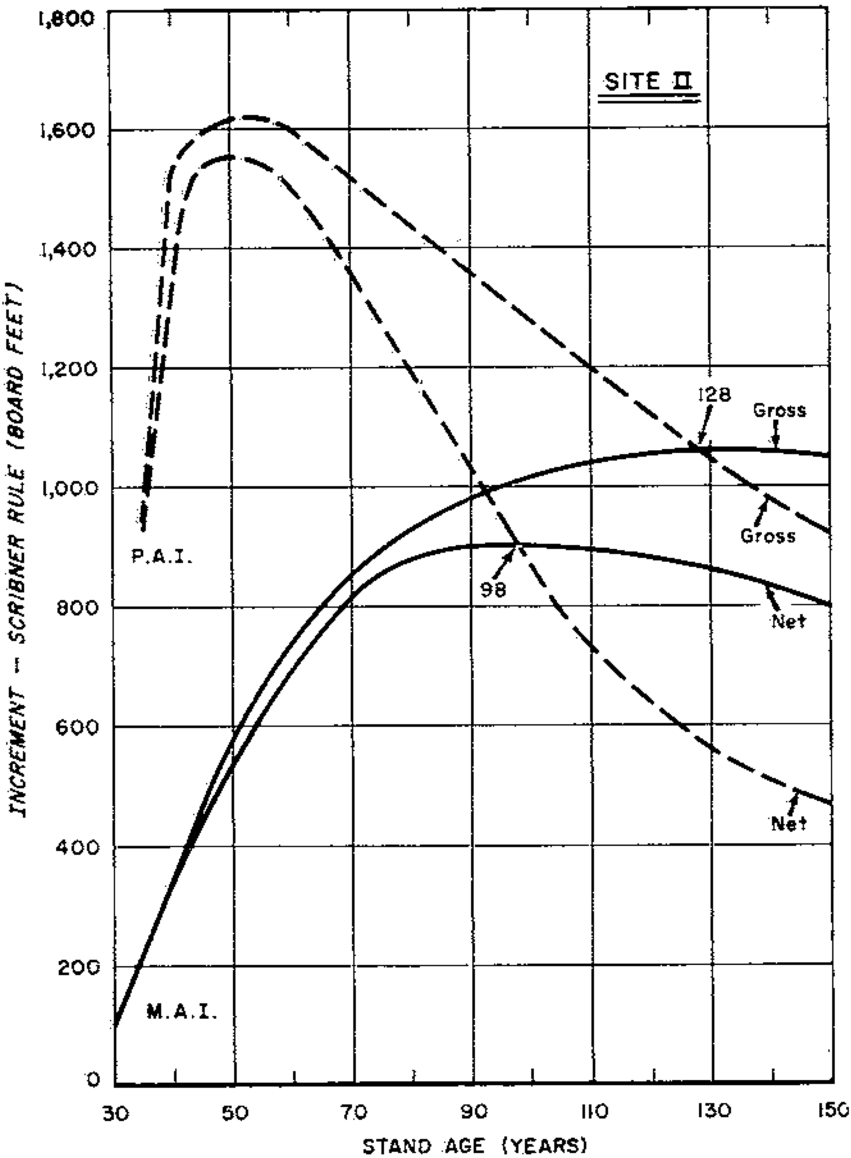

FIGURE 19.—Periodic and mean annual gross and net increment for site II Douglas-fir. Volume in board feet, Scribner rule. Derived from tables 2, 9, and 10 of Technical Bulletin 201 (85) and table 1d of Gross Yield and Mortality Tables (52).

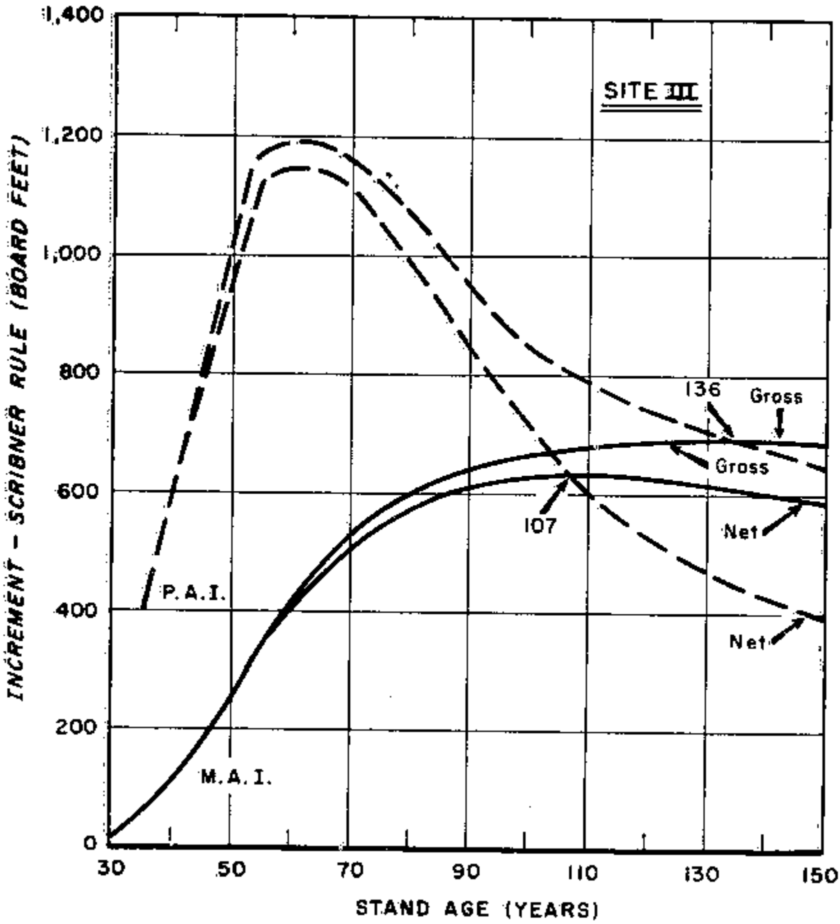

FIGURE 20.—Periodic and mean annual gross and net increment for site III Douglas-fir. Volume in board feet, Scribner rule. Derived from tables 2, 9, and 10 of Technical Bulletin 201 (*35*) and table 1d of Gross Yield and Mortality Tables (*52*).

Soil Rent

Financial rotation may also be set from soil rent calculations. Rotations so established are expected to insure a given return (interest) on capital invested in a forestry business. From a strictly financial point of view, soil rent rotations are more defensible than those set by forest rent. Generally speaking, the soil rent rotation will be very much shorter than forest rent rotation, unless the chosen interest rate is very low.

Rotations based on the financial maturity concept are identical, or nearly so, to those determined for soil rent if the same interest rate is used in both calculations (*14*). The effect of thinning on rotations is more easily visualized, however, in the financial maturity calculation.

A stand is financially mature when the annual value increase in percent equals the interest rate available from alternative investments (*14*). Stand age at financial maturity equals rotation age. Obviously, the value-increment percent is closely controlled by volume-increment, or growth, percent. However, since current growth is usually more valuable per unit volume than past growth (or the entire tree), value-increment percent is characteristically higher than growth percent.

One major effect of thinning is a reduction in the amount of growing stock required to produce a given increment, and an increase in growth percent. This effect, in turn, alters the age at which a stand becomes financially mature.

Thinning in older stands, financially mature or nearly so, prolongs the rotation by increasing growth percent. First, net increment is increased through prevention or salvage of mortality. Second, slow-growing or nongrowing trees are harvested, reducing the growing stock base upon which growth percent is calculated.

The effect of repeated thinnings starting at young ages on rotation length is less clear because the pattern of diameter growth is greatly altered. Generally, reduced growing stock results in higher growth percent, tending to delay financial maturity; but thinning also produces large trees, and the growing stock required for a given amount of increment is greater for large trees than for small (fig. 14) (*55*). The possible effect on rotation is best illustrated by reference to the value-increment table prepared by Heiberg and Haddock (*20*) for individual trees in a 50-year-old stand (table 3).

For example, a 16-inch tree growing 16 rings per inch and a 23-inch tree growing 6 rings per inch both have a value increment of approximately 4 percent. It is evident that faster diameter growth permits raising trees to a larger size before they reach financial maturity.

If what happens to single trees in a stand is characteristic of the whole stand, then the same concept would apply to stands. What, then, is the effect on rotation length? We might assume, in order to clarify the factors involved, that a 16-inch tree with a growth rate of 16 rings per inch is typical of an unthinned stand, and a 23-inch tree with a growth rate of 6 rings per inch is typical of a thinned stand. Both trees, and presumably stands, are financially mature if 4 percent is the minimum acceptable rate. Which requires the longer rotation? Obviously, the answer depends on the silviculture practiced. A stand of 23-inch trees capable of growing six rings per inch undoubtedly must have been permitted to make rapid growth in the past. The stand, then, would be comparatively young. The slow growth of the 16-inch trees in the unthinned stand is evidence of past crowding and past slow growth. In all likelihood this stand is older than the thinned stand.

TABLE 3.—*Value-increment percent (annual) for Douglas-fir by tree diameter and growth rate* [1]

D.b.h. (inches)	Stumpage value	Rings per inch							
		4	5	6	8	10	12	16	20
	Dollars	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
10	0								
11	0.55	64	52	43	33	26	21	16	13
12	1.15	39	31	26	19	15	13	9.7	7.7
13	1.90	28	22	18	14	11	9.3	7.0	5.6
14	2.80	22	18	15	11	8.8	7.4	5.6	4.4
15	3.85	18	14	12	8.8	7.0	5.9	4.4	3.5
16	5.00	15	12	10	7.7	6.1	5.1	3.8	3.1
17	6.30	14	11	9.4	7.0	5.0	4.7	3.5	2.8
18	7.80	12	9.4	7.8	5.9	4.7	3.9	2.9	2.3
19	9.35	10	8.1	6.7	5.1	4.0	3.4	2.5	2.0
20	10.95	8.9	7.1	5.9	4.5	3.6	3.0	2.2	1.8
21	12.60	8.0	6.4	5.3	4.0	3.2	2.7	2.0	1.6
22	14.30	7.0	5.6	4.7	3.5	2.8	2.3	1.8	1.4
23	16.00	6.3	5.0	4.2	3.1	2.5	2.1	1.6	1.3
24	17.70	5.5	4.4	3.7	2.8	2.2	1.8	1.4	1.1
25	19.35	5.0	4.0	3.4	2.5	2.0	1.7	1.3	1.0
26	21.00	4.5	3.6	3.0	2.3	1.8	1.5	1.1	.9

[1] Adapted from table 4, "A method of thinning and forecast of yield in Douglas-fir" by Heiberg and Haddock. Jour. For. 53: 10–18. 1955 (*20*). Tree values (col. 2) above 22 inches d.b.h. have been curved. Value-increment percent is calculated by assuming that 1-year increase in value bears the same relationship to the total value difference between 1-inch diameter classes that 1-year diameter increment bears to 1.0 inch. Diameter increment o.b. at breast height is assumed to be 1.182 times wood growth, calculated from rings per inch.

From this hypothetical example we might reason: A thinning program that keeps trees growing rapidly will permit one to raise trees to a large size before they reach financial maturity. Without thinning, trees grow slowly and reach financial maturity at smaller sizes. The time required to raise large trees with a high growth rate is probably shorter than that required to raise small trees at a slow rate of growth, although actual differences will depend on thinning practiced. Rotation is not necessarily shortened by thinning because trees can be raised to a larger size in less time than with no thinning; it would be shortened only if the objective is to produce trees of a given size (technical rotation) regardless of financial considerations.

Policy Considerations

Even though financial rotations may apparently be rigorously calculated, actual rotations are still largely a matter of policy determination and depend on many factors not pertaining strictly to the stand in question. Thinning, however, may still play an important part and a good understanding of how thinning affects rotation length should provide a powerful stimulus for avoiding premature harvest.

For small ownerships of essentially unmanaged stands, policy may be simply one of opportunism; i.e., cut and sell for an immediate cash return. Even when stands are to be cut, either by design or through ignorance, as soon as trees will produce minimum-size logs, thinning may still be important in further shortening an already short rotation.

For managed forests, policy is likely to be more soundly based, but may still overlook the possibilities of altering rotations by thinning. Thinning holds particular promise in this respect for those ownerships with an unbalanced growing stock when the policy is aimed at achieving a regulated forest in the shortest possible time. The following situations may exist:

1. The forest may consist of a limited amount of old growth and extensive immature young growth. The old growth will last *x* number of years; then the operation must shift to what will still be immature stands. An active thinning program in the young growth will have two important effects: (*a*) Thinnings can supply part of the annual wood requirements, making it easier to stretch the old growth, with the result that the young stands will be somewhat older when they have to support the entire cut than if not thinned; (*b*) if thinning increases diameter growth beginning at young ages, the stands may be brought to financial maturity earlier. The separate effects of (*a*) and (*b*) will be to make age at cutting more nearly coincide with optimum rotation. In addition, since financial maturity will be reached at a larger size than with no thinning, an added advantage will result from having larger trees at time of harvest.

2. Where there is an abundance of old growth in the ownership, policy frequently dictates that no young growth at all be cut until the old growth is liquidated. The ownership also includes advanced young growth that is mature and actually returning very little on the investment in growing stock. Here it is possible for thinning to prolong the young-growth rotation by stepping up growth percent. This comes from increasing net growth by salvaging or presalvaging mortality while reducing growing stock by removing nongrowing trees in the stand. When cutting is shifted entirely to young growth, the stands will not be as far past ideal rotation as they would have been without thinning.

In summary, it is evident that financial rotation can be changed, perhaps greatly, by thinning. Rotations set by culmination of mean annual increment or forest rent will most certainly be lengthened by thinning. Rotations set by soil rent or financial maturity doctrines may be lengthened or shortened, depending mostly on the age at which thinning is begun and the intensity with which it is practiced. Possibilities of altering rotations by thinning give the forester new techniques for carrying out existing policy, or new criteria for establishing new policy.

Total Yield

As already explained under the section on objectives, thinning will increase the usable yield from a forest through salvage of normal mortality and production of larger trees. Estimates of the extent to which yields can be increased through thinning are discussed in the present section.

Gross yield tables for Douglas-fir (*52*) show the estimated cumulative volume of mortality in normal stands (figs. 21 and 22). Frequent thinning would be expected to recover a substantial portion of the volume dying after the thinning program is launched. The percent increase over normal net yield at age 100, made possible by thinnings beginning at various ages, is shown in table 4. Thus thin-

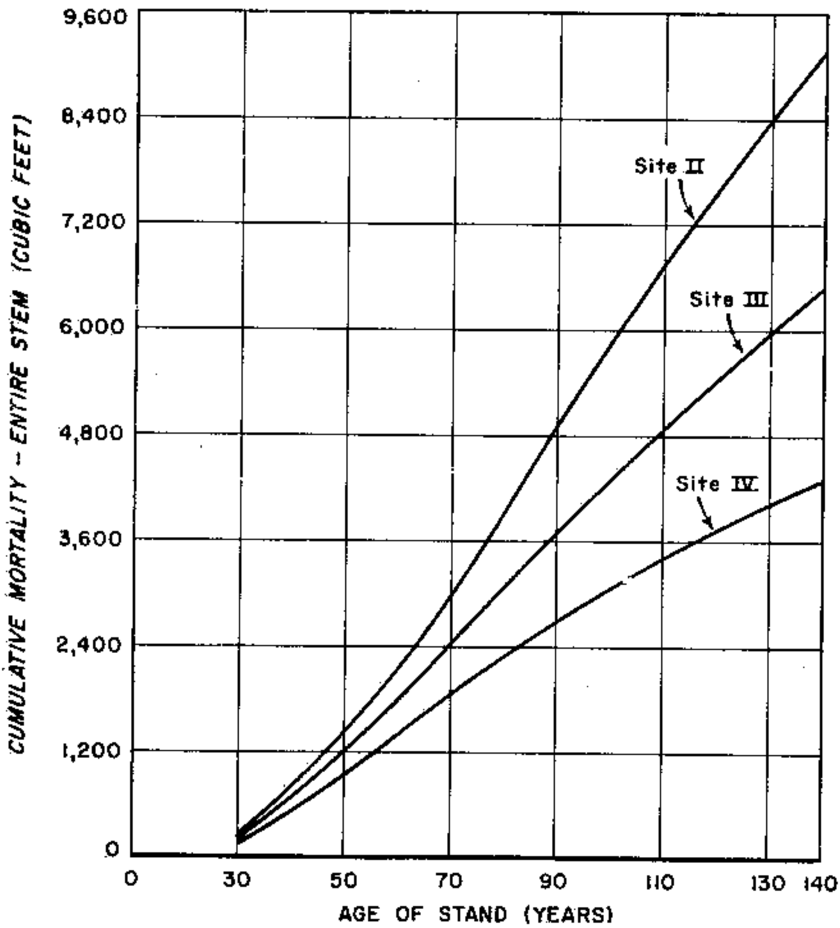

FIGURE 21.—Cumulative mortality (cubic feet) in normal stands for sites II, III, and IV. Derived from data from Gross Yield and Mortality Tables (*52*).

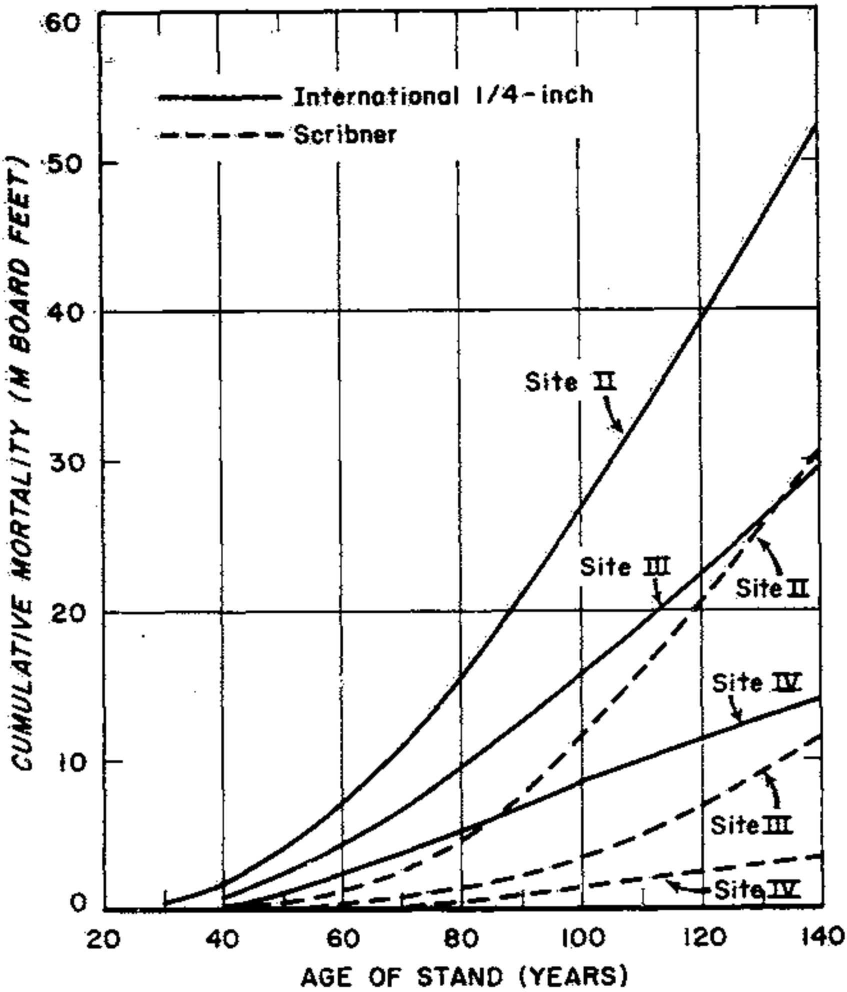

FIGURE 22.—Cumulative mortality (board feet) in normal stands for sites II, III, and IV. Derived from data from Gross Yield and Mortality Tables (52).

nings started at age 30 and conducted with sufficient frequency to salvage all mortality prior to a rotation age of 100 years[9] would increase International board-foot yield by 24 percent on site II. If thinnings are started at age 60 instead of 30, the increase in yield would be 18 percent.

Not all mortality can be recovered. Some deterioration will inevitably take place before salvage is possible. Breakage will be higher than in normal operations, and salvage of the occasional small dead tree in locations remote from a road may not be feasible.

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[9] Use of 100 years as rotation age throughout this section is for convenience only. Principles brought out would be equally true for shorter or longer rotation.

TABLE 4.—*Increase in yield expected at age 100 if all mortality is salvaged from time of first thinning*

Age at first thinning (years)	Increase in yield								
	Cubic-foot volume [1]			International volume [2]			Scribner volume [3]		
	Site II	Site III	Site IV	Site II	Site III	Site IV	Site II	Site III	Site IV
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
30	33	30	31	24	18	16	13	6	4
40	30	27	28	23	17	15	12	6	4
50	26	23	23	21	15	14	12	6	4
60	22	18	18	18	13	12	11	5	4
70	16	14	13	14	10	9	10	4	4
80	11	9	9	10	7	6	8	3	3

[1] Based on volume of trees in 2-inch class and over for entire stem, including stump and tip.
[2] Based on volume of trees in 7-inch class and over to a 5-inch top.
[3] Based on volume of trees in 12-inch class and over to 8-inch top.

Also, in most thinnings an attempt is made to forestall mortality as well as to salvage it. It is inevitable that some trees will be cut that would have added measurable growth had they been allowed to stand until they died. If the remaining trees do not make up this growth by responding to release, then increment is lost.

Hence, if diameter growth fails to accelerate after thinning, the increase in yields shown in table 4 should be considered as the maximum possible.

On the McCleary Experimental Forest, described on pages 42 and 97, mortality in the thinned stand averaged 115 board feet (Scribner) per acre annually, all of which was salvaged during thinnings (*71*). Although the thinning cycle is 5 years on this forest, nearly all the area is visited at 2-year intervals to recover mortality. Salvaged volume was 14 percent of net increment. Apparently, thinning also forestalled much mortality; annual losses in the unthinned stand were 418 board feet annually.

If thinnings are begun early enough to increase the size of trees produced, additional yield is obtained from trees that would not otherwise reach merchantable size before dying. Added yield also results from higher board-foot/cubic-foot ratios in larger trees. However, additions to yields from these sources are difficult to estimate, since yield tables for managed stands are lacking.

Tables for British and European managed stands of Douglas-fir indicate much higher yields than for untended American stands (*23; 13, p. 111*). Although first thinning in these stands would be precommercial by American standards, commercial thinning begun at the earliest possible moment undoubtedly would increase yield substantially.

Heiberg and Haddock (*20*) estimated yield for thinned stands at 85 years as 82,360 board feet (Scribner) for Site Index 150. This is 32 percent greater than the gross yield expected in normal stands. Most of this increase is due to an assumed cubic-foot growth rate about 30 percent higher than the gross increment in normal stands; the remainder is mostly a result of early production of board-foot size trees.

Theoretical yields may be calculated from gross (*52*) and normal (*35*) yield tables. For site III and a 100-year rotation, gross yield is 17,500 cubic feet, distributed as follows:

Live standing at 100 years:		
Larger than 12 inches d.b.h.	12,620	
Smaller than 12 inches d.b.h.	650	13,270
Mortality, age 20 to 100:		
Larger than 12 inches d.b.h.	[1] 900	
Smaller than 12 inches d.b.h.	3,330	4,230
Gross yield		17,500

[1] Estimated from the yield table figure of 3,700 bd. ft. in this size class, assuming that the average tree that died had a bd.-ft./cu.-ft. ratio of 4.1—equal to that of a 12-inch, 110-foot tree.

Thus, of a total production of 17,500 cubic feet, 13,520, or 77 percent, finally attained board-foot size (trees larger than 12 inches d.b.h.), including 900 cubic feet in trees dying prior to age 100. The objectives of thinning are to increase the proportion of total stand production that ends up in larger trees; to control (frequently, to maximize) the size of tree produced; and to salvage as much as possible of what normally dies.

What may conceivably be possible in pursuing these objectives? In the absence of experience data, some estimates may be made and resulting yields determined. We may assume that by thinning the stand used in this example, the following will be accomplished:

(*a*) Transfer to trees larger than 12 inches d.b.h. the 650 cubic feet in trees less than 12 inches in the 100-year normal forest;

(*b*) Salvage the 900 cubic feet that died in trees larger than 12 inches d.b.h. in the normal forest;

(*c*) Transfer one-third—1,110 cubic feet—of the normal mortality occurring in trees smaller than 12 inches to trees larger than 12 inches;

(*d*) Produce a stand averaging 21.5 inches in diameter at 100 years—equal to the lower diameter limit of the largest 15 percent of the trees in the normal forest.

The production in trees larger than 12 inches d.b.h. will be 15,280 cubic feet, or 87 percent of the total stand production, 10 percent more than without any thinning. We assume that this can be accomplished by removing 40 percent of the total production, or 6,112 cubic feet, as thinnings from age 25 to 95, and leaving 60 percent, or 9,168 cubic feet, for harvest at age 100. The final harvest volume would be contained in 75 trees averaging 21.5 inches. The stand would have 69 percent of normal cubic volume.

The board-foot equivalent of this cubic volume may be estimated roughly by using average board-foot/cubic-foot ratios. The ratio in the final stand is estimated as 5.2, equal to that in a 21.5-inch, 140-foot tree. The ratio in the thinnings is assumed equal to that in a 15-inch, 114-foot tree, or 4.5. The chosen diameter is halfway between 12 inches, the minimum tree size used in the calculations, and 18.4 inches, the average size in a 100-year-old normal forest. The height is equal to that of a 65-year-old tree, the age midway in the thinning period. The estimated board-foot yield is:

Thinnings	6,112 cu. ft. × 4.5=27.5 M bd. ft.
Final cut	9,168 cu. ft. × 5.2=47.7 M bd. ft.
Total yield	75.2 M bd. ft.

Normal net yield for this stand is 62,800 board feet. Normal gross yield is 66,500 board feet. Thus, these rather modest increases assumed for tree diameter and proportion of total stand production utilized would increase board-foot gross yield by 13 percent. Increase over normal unmanaged stands would be 20 percent. Total cubic-foot production remains the same as in a normal forest.

These gains are possible because thinning salvages normal mortality and redistributes growth, resulting in larger trees and more complete utilization.

APPLICATION OF THINNING TO DOUGLAS-FIR

The theoretical basis for thinning, with particular reference to Douglas-fir, has been discussed in the previous sections. Knowledge of silvical characteristics of a species is essential for the intelligent application of thinning. Now comes the practical problem of applying that knowledge to a going operation, in combination with equally important management, organizational, and engineering features.

Much of the material in the following sections is based on unpublished data from thinnings in four experimental forests on private land in the Puget Sound area. The owners have leased these forests to the U.S. Forest Service for research purposes.[10] Experimental thinning sales on national forests have also provided some data. A third source has been published data from experimental forest and other thinnings in the region and in British Columbia.

DETERMINING PRACTICALITY OF A THINNING

A commercial thinning is practical if it can be done at a profit and is silviculturally desirable, or at least not undesirable.

The decision regarding silvicultural desirability should be based on the material in sections just presented. Here we are concerned with physical and economic factors influencing profit from thinning. Some factors, such as the unavailability of labor, are completely limiting, regardless of other features. Others, such as the sizes of trees available for cutting, are a matter of degree and depend on markets or equipment available.

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[10] These forests and their leasing owners are Hemlock Experimental Forest, St. Regis Paper Co.; Hood Canal Experimental Forest, Pope & Talbot, Inc.; McCleary Experimental Forest, Simpson Logging Co.; Voight Creek Experimental Forest, St. Paul & Tacoma Lumber Co. (now a part of St. Regis Paper Co.).

Labor

The thinning operation must be highly flexible; i.e., adaptable to weather extremes, variable markets, and changes in the kind of stands thinned. Small (often one-man) efficient crews are needed, requiring men willing and able to work alone with a minimum of supervision. Commercial thinning is a small-profit-margin operation, at least in its initial stages, which makes it necessary to keep nonproductive time, chiefly travel time, to a minimum. Travel time is all the more important when horses, requiring weekend care, are used for skidding.

The unique labor requirements of such an operation are best met by local men who do not demand full-time, year-long employment in thinning. As a corollary, the thinning operation that is best adapted to the needs of the local labor force is also apt to be most successful.

However, once a thinning program gains momentum it can and should become a full-time operation, at least on large ownerships. Administration may be simplified by assigning a forester full time to the job. Advantages accrue from nonfluctuating, predictable weekly or monthly production. Also, a full-time program makes it possible to attract or develop experienced labor specializing in thinning.

Accessibility

Under current conditions and with current values, nearness to existing roads may absolutely limit thinning, regardless of other aspects of the operation. The cost of extensive access roads is usually too great to be financed by thinnings alone. For this reason, first thinnings should be confined to areas near existing roads where additional construction costs will be light.

However, roads, particularly on larger properties, have other values; for example, they can be used for fire control, salvage, and final harvest. Putting them in early enough to accommodate commercial thinning is often a good investment. These financial aspects of the road problem are treated at length in a later section.

Markets

Obviously, markets must exist for the products to be harvested in thinning. The forester must determine the location and nature of available markets and the delivered price of woods products. In general, an adequate market should exist for small material, accessible by good roads and within 25 or 30 miles of the stand under consideration.

The maximum distance, however, depends on value of product and cost of material when loaded on the truck at thinning site. Thus, small pulpwood loaded on the truck in the woods may represent an investment of $11 per cord (including $1 for stumpage), leaving perhaps $5 for hauling—enough for only 20 or 25 miles. Larger trees made into saw logs, on the other hand, might easily have a margin of $13 per thousand available for hauling, and markets no closer than 50 or 60 miles might make the thinning entirely feasible. Pulpwood prices often reflect the length of haul, with higher prices being paid for wood from greater distances.

Except for special products of limited demand, pulpwood markets are the only outlets for the smallest material. Trees 6 or 7 inches in diameter will make pulpwood. Under the most favorable conditions, saw logs may be produced from 8-inch trees. Specialized products such as poles and piling usually require larger trees. The forester must be continually on the lookout for new, often limited, often transitory markets to provide outlets for his thinnings. Where thinning depends on this kind of market, however, the need for a highly flexible operation is apparent.

Stand and Topography

Given accessible stands, a labor supply, and good markets, the practicality of a thinning is dependent on still another factor; namely, physical features of the site and stand, and how they affect extraction costs.

Topography is a most important consideration, principally because of its effect on skidding. Unfavorable topography may rule out thinning, even though all other factors are favorable. Terrain without sudden breaks or rock outcrops is most desirable, regardless of the skidding medium.

If horses are used for skidding, very little adverse slope can be tolerated. Steep favorable slopes are also limiting. Steep slopes may also limit tractor skidding, although adverse grades can be more easily surmounted. Slope limitations are discussed more fully in the section on extraction.

New equipment and techniques are being developed for thinning on ground too steep for use by either horses or tractors. As these methods are perfected, topography will become less of a limiting factor in thinning. The methods of skidding on steep ground are discussed in the section on skidding.

Frequently, stand characteristics determine whether a thinning will be practical. Obviously, tree size must match available markets. Usually, a good proportion of the trees in the stand must be above the minimum size specified for the product to be sold. For example, although 6- or 7-inch trees may be just big enough for pulpwood, an operation based entirely on trees of this size is apt to be unprofitable. The matter of size is important. Many thinning projects have failed because they ran too close to a commercial minimum. A good rule of thumb is that the average-sized tree in a stand should be at least as big as the minimum-sized salable tree.

Tree size exerts a major influence on the practicality of thinning. Other features, though, must also be considered. A certain minimum volume per acre must usually be available for cutting, though this minimum is much lower than is usually considered necessary. Experience has shown that cuts down to 6 cords or 3,000 board feet per acre are entirely feasible where the proper equipment (inexpensive and highly mobile) is used (*72*). The forester should recognize, however, that tree size is more important than volume cut per acre, and that if trees cut are too small to be extracted profitably, a heavier cut per acre will not compensate for it.

If fixed costs are high, the acreage available for thinning must also be considered in appraising the practicality of an operation. Fixed costs such as moving in, roadbuilding or necessary repair, line running, etc., may have to be charged to the thinning of a single tract. Occasionally, this may rule out thinning very small areas.

CHOOSING A METHOD

Choosing a thinning method requires a careful balancing of silvicultural requirements of the stand with economic considerations. Three generally recognized thinning methods are applicable to natural stands of Douglas-fir: selection, crown, and low thinning. Age, condition of the stand, availability of markets, equipment to be used, all determine what method is most practical.

The largest trees of the stand are removed in selection thinning. In crown thinning, trees whose crowns extend into the upper canopy are cut. Such trees are usually all above average diameter. In low thinning, the smallest trees in the stand are removed. Although there is no reason why one method must be applied to the total exclusion of the others (most commercial thinnings are a mixture of all three), certain principles discussed under silvicultural factors should be thoroughly understood and kept constantly in mind.

In very young stands, only the largest trees are marketable, and only a selection thinning is feasible (fig. 23). The system may also be entirely satisfactory silviculturally in such stands. Many of the largest trees will undoubtedly develop into low-quality trees if left in the stand. However, they are also the fastest growers, and the forester should be certain that remaining trees have adequate crown to respond to release and quickly make up for growth of trees removed. Young stands making rapid height growth often contain a substantial number of low-quality dominant stems.

As practiced in Denmark, selection thinnings are made very lightly and repeated at 1- or 2-year intervals (*37*). In a test in Pierce County, Wash., four selection thinnings, 2 years apart, were made in a stand 27 years old at the time of first thinning (*12*). The test indicated that growth had been satisfactorily redistributed. However, average diameter in the stand remained constant because only the largest trees had been removed at each thinning. In a practical thinning regime, selection thinning should now give way to crown thinning to permit selected larger trees to make the most rapid growth of which they are capable.

Crown thinning, probably the most widely practiced method for Douglas-fir, is well suited to young stands where the objective is to develop good quality dominants and codominants (fig. 24). The trees removed, though not exclusively the largest in the stand, are usually big enough to make valuable products. The forester needs to remember, however, that he is removing trees that are contributing substantially to volume increment. In stands older than the tenta-

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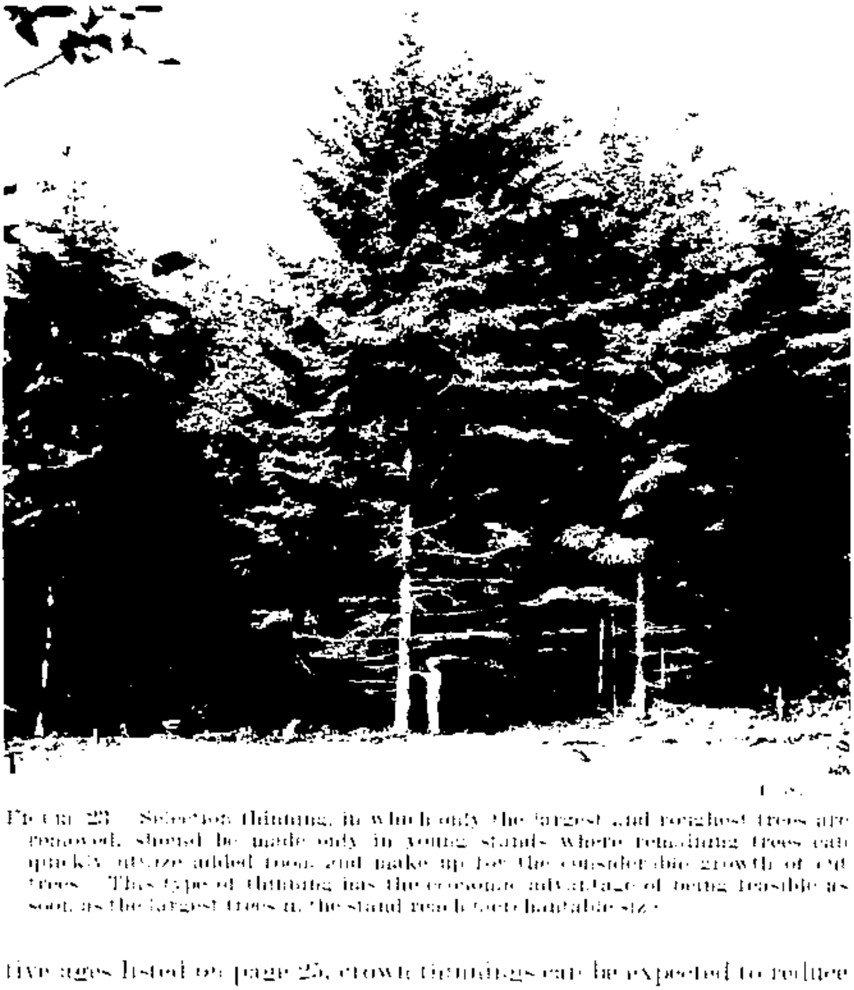

FIGURE 23.—Selection thinning, in which only the largest and roughest trees are removed, should be made only in young stands where remaining trees can quickly utilize added room and make up for the considerable growth of cut trees. This type of thinning has the economic advantage of being feasible as soon as the largest trees in the stand reach merchantable size.

tive ages listed on page 25, crown thinnings can be expected to reduce increment.

In older stands only a low thinning is silviculturally feasible, unless the forester is definitely reconciled to reduced increment (fig. 25). If the smaller increment is acceptable and a crown thinning is decided upon, it would have to be light and skillfully applied to prevent excessive loss in the residual stand due to windfall or breakage. Low thinnings, on the other hand, are easy to apply and silviculturally safe. Economically, the success of low thinning depends on markets for the size of material produced in a given stand. The lower crown class trees removed in such a thinning are ordinarily of good quality because of their fine grain. Pulp yields are also high because wood of such trees is normally of above average specific gravity (74).

The ideal sequence of commercial thinning would probably be as follows: If the largest trees in a young stand (ranging from 20 years on site II to 40 years on site IV) are merchantable, a selection thin-

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FIGURE 21. Crown thinning, in which trees that are part of the main crown canopy are removed, is suitable to young, vigorous stands having an abundance of trees with deep crowns. Crown thinning permits continued development of desirable dominants and codominants, and at the same time produces trees large enough for valuable products.

FIGURE 25.—Low thinning is the only feasible method for older stands where trees cannot be expected to respond except after a very heavy release. The subordinate stems removed very often are suitable for valuable products. Since they contribute very little to stand growth, their removal will greatly improve efficiency of the growing stock.

ning may be made. After the largest, roughest trees have been removed in one or two light selection thinnings, crown thinning should be started to favor potential crop trees. Crown thinnings should normally be continued until it is no longer possible to redistribute growth to trees in either the upper or lower crown classes. By this time trees in the lower crown classes will probably be of merchantable size and low thinnings will be practicable. Normally, a series of low thinnings would then be made prior to final harvest.

If the first thinning is delayed, selection thinning will likely not be practicable except that a few of the very roughest trees can probably be removed. Crown thinnings applied should succeed in promoting the development of crop trees.

If first thinning is delayed still later, the initial and all succeeding cuts will probably be low thinnings.

The marking rules recommended in the next section more or less integrate the effects of stand age, stand characteristics, and minimum merchantability standards to provide a sequence of thinning methods very similar to the one just described.

MARKING (GUIDES, METHODS, AND COSTS)

Marking is the key to successful thinning. In making a proper choice of trees to cut, the marker must mentally synthesize all silvicultural, economic, marketing, and harvest features of the operation. Although fairly definite marking rules may be drawn up on paper, their proper application in the woods requires the forester's best judgment, based on his knowledge of the pertinent factors.

The following marking guides are believed to be nearly universally applicable for commercial thinning of Douglas-fir:

Priority 1: Merchantable trees (*a*) that are dead, (*b*) that will not live until the next thinning, or (*c*) whose growth rate is negligible when compared with other trees in the stand. Priority 1 trees are mostly badly suppressed, but they also include trees whose poor or declining vigor is attributed to insects, disease, or injury (fig. 26).

Priority 2: Rough, limby dominants, whose removal will release trees of better form and quality (fig. 27).

Priority 3: Trees whose removal will improve the spacing and growth of remaining trees, provided that reserved trees are capable of responding to release (fig. 28).

Priority 4: Merchantable diseased, misshapen, and broken trees that do not fall in any of the first three priorities (fig. 29).

Figure 30 shows schematically the probable distribution of trees marked for removal, by priority class in a first thinning, in stands ranging from young to old. In a young stand, the bulk of the trees marked would be priority 2—large, rough dominants. No trees in priority 1 would be large enough to be marketable. Those priority 3 trees that are large enough to be merchantable could be marked if the stand is not opened sufficiently by the removal of priority 2 trees. Diseased, misshapen, and broken trees almost always fall in one of the first three priorities. If not, the only reason for removing them is to increase the cut (at the expense of the growth they would have made)

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FIGURE 26.—Priority 1 trees include merchantable trees that are dead, will die before next thinning, or whose growth is negligible compared with other trees in the stand. They are mostly badly suppressed, as the tree pictured, or are of poor or declining vigor because of insects, disease, or injury.

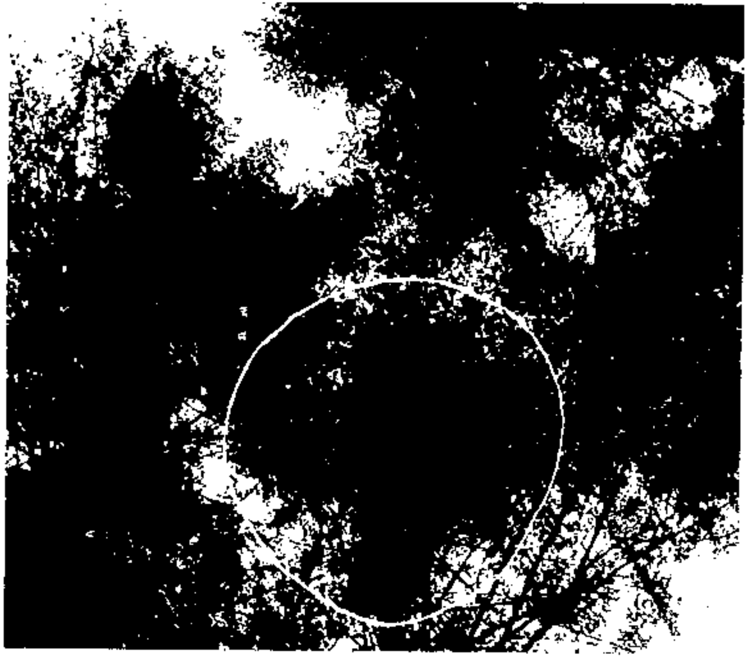

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FIGURE 27.—Priority 2 trees are the rough, limby dominants whose removal will release trees of better form or quality. Trees released must receive major consideration in deciding which rough trees to cut. Only in young, fast-growing stands will the released trees have adequate crown and vigor to quickly utilize the comparatively large space left unoccupied by cutting the rough trees.

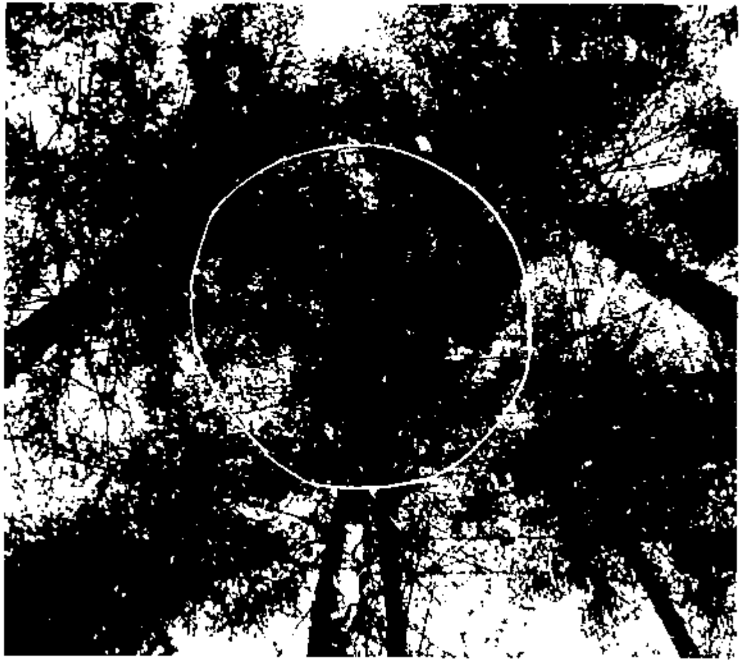

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FIGURE 28.—Priority 3 trees are marked to improve the spacing of remaining trees, provided that reserved trees are capable of responding to release. Major redistribution of growth comes from removal of priority 3 trees. Generally, there is little difference in form or quality between the marked tree and those remaining, spacing being the major consideration.

F [illegible]

FIGURE 29. Priority 4 trees are the merchantable diseased, deformed, and broken trees. Usually such trees will fall in one of the first three priorities. If not, since there are no reserved trees to make up for their potential increment, they will be removed for reasons of stand health or simply to increase the volume cut.

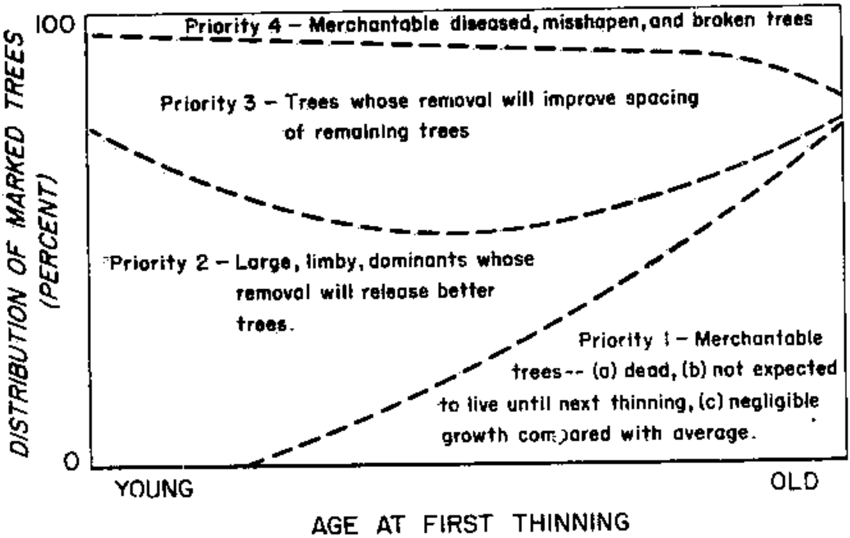

FIGURE 30.—Distribution of marked trees by priority class for initial thinning of stands ranging from young to old. The illustration is purely schematic.

or to eliminate them as seed bearers, possible sources of infection from disease, or harborers of insects.

In contrast, in an old stand being thinned for the first time, most of the trees marked would be priority 1; i.e., the poor risk trees and those making very slow growth. Opportunity for removal of large, limby dominants would be restricted because surrounding trees are not capable of responding to release. Marking trees solely to improve spacing will likely fail to achieve its only objective—redistribution of growth. Probably more diseased and misshapen trees would be marked than at younger ages just to improve the health of the stand. Mostly, however, they would be marked as priority 1 trees because of poor growth or poor risk.

The percentage of trees in priority 1 will increase with the increase in age of stands being thinned for the first time. The percentage of rough dominants that may be marked for removal declines sharply as the trees in the stand become more and more incapable of responding to release. Percentage of trees marked to improve spacing should increase at first simply because the number of trees of merchantable size will increase. After the critical age at which it is no longer possible to redistribute growth, the percentage of such trees marked will decrease. A relatively high percentage of malformed trees would probably be marked in thinnings initiated only a short time prior to final harvest to eliminate them as seed bearers.

Thus, application of these marking guides will result in a thinning that follows no classical system. A first thinning in a young stand will resemble a selection thinning. Begun later it will resemble a crown thinning; and in older stands, a low thinning. In practice, trees would be marked by priority until the desired leave stand is attained. Thus, it might take one or several thinnings to remove all priority 2 trees in a young stand. In the application of the rules the forester should, of course, recognize small homogeneous areas of the stand being marked. For example, priority 2 trees in a young stand might not all be marked for a single thinning of an area well supplied with such trees. Another area, however small, in the same stand might have no priority 2 trees, and marking would be entirely in priority 3 trees.

Certain precautions in the application of these guides should be observed in order to control the intensity of thinning. The best rule probably is that given by Tinney and Malmberg (*63*), which stipulates that remaining trees should not be released on more than one side at any one thinning. Close adherence to this rule will automatically control the number of trees marked. Removal of trees in the lower crown classes would not be restricted since they will not release trees in the main canopy. It is unlikely that any restriction on cutting lower crown classes is silviculturally desirable in commercial thinning of Douglas-fir. More complete discussion of the desirable amount to mark will be found in the next section, "Severity of Thinning."

Marking techniques vary largely with the personal preferences of the markers. Paint applied with hand paint guns, and metal or paper tags stapled to the trees are probably the most common methods of designating trees for cutting. Blazing and stamping with an ax is seldom used because the method is slower and increases the cost of marking. Further, changing a marked tree to a leave tree is impossible, once it is blazed.

The advantage of marking trees with tags, fastened with a stapling gun or hammer, is that tags are easily visible. Also, they may be put on in rainy weather, whereas paint applied to wet trees may not last as long as necessary. Changing marked trees is simple, an advantage to the experienced as well as the novice marker. However, the ease with which tags may be removed or duplicated may be a disadvantage, especially where rigid controls on cutting are necessary.

Paint applied with guns is probably the fastest method of marking (fig. 31). The marker need get no closer than 5 to 10 feet of a tree to mark it—a real advantage with limby trees. Distinctive paint may be used and, if desired, applied to stump as well as bole, thus providing a good check on the cutting. A large, conspicuous mark is an aid to the faller who must seek out the marked trees. Conspicuous marks also have a psychological advantage where the trees marked may otherwise appear from casual observation to be distressingly few and far between.

Marking is best accomplished by dividing the area to be thinned into long, narrow strips and marking one strip at a time. Inexperienced markers may designate the strips with a lime-sock mark on line trees. Marked strips are also useful where a close control of the volume removed is wanted. The marker can then easily keep track of the acreage covered and the volume marked. After the initial thinning, the experienced marker can usually keep track of where he is by noting skid roads and other landmarks.

Marking can become tedious. For best results, the job should be planned so that one man need not mark continuously.

FIGURE 31.—Most foresters prefer to use a paint gun for marking. Readily visible, not easily duplicated marks may be rapidly made without getting closer than 5 or 10 feet from a tree.

Cost of marking is largely controlled by number of trees marked. That is, cost per tree marked is nearly constant, although varying somewhat with topography and number marked per acre (which influences walking time). Cost per unit volume varies widely depending upon size of material marked. Unfortunately, cost per unit volume is greatest in young stands of small average diameter where prices received for thinnings are least able to bear it.

Table 5 shows marking time required per tree and per unit volume for three areas. Time required per 100 cubic feet and per 1,000 board feet is much greater for the 40-year-old stand than for the older stands, undoubtedly because the average tree marked is smaller. Time required per tree, however, is about one-third less in the younger stand, probably because there is a larger number of marked trees per acre.

TABLE 5.—*Time required per tree and per unit volume to mark stands of different ages*

Age (years)	Area marked	Total time required	Marked per acre			Marking time per—		
			Trees	Volume	Volume	Tree	C cu. ft.	M bd. ft.
	Acres	*Man-hours*	*Number*	*Cu. ft.*	*Bd. ft.*	*Man-hours*	*Man-hours*	*Man-hours*
40	35	18	40	430	1, 100	0. 013	0. 120	0. 468
60	35	14	18	750	3, 400	. 022	. 053	. 118
80	83	48	27	1, 020	4, 300	. 021	. 057	. 134

SEVERITY OF THINNING

Practical application of thinning requires an answer to the question, "How much should be cut and how often?" Unfortunately, the question cannot be answered with a simple prescription. Inevitably, condition of the stand controls both the desirable frequency of thinning and the volume that should be removed at any one time. Available markets are also a controlling factor through their effect on size of merchantable tree.

In marking a stand for thinning, the forester should be guided by what he hopes to accomplish by thinning and by his best judgment of how to accomplish it, rather than by a preconceived idea of volume to be removed.

Severity of thinning is determined by two complementary factors: volume removed in a single cut, and frequency of cuts. Light cuts made at short intervals may be as "severe" as heavier cuts applied at long intervals. Severity of thinning cannot be defined without considering both factors.

Frequency of thinning should ideally be related to a tree's capacity to absorb new growing space created by thinning. This capacity depends on rate of crown growth, which is greater in young trees than in old, and greater on good sites than on poor. Height growth is a good measure of capacity of crowns to expand. Thus, thinning may be timed to coincide with some fixed increment in height, such as 10 feet, which is sometimes recommended for Douglas-fir (*17*). Another rule of thumb, also predicated on ability of crowns to expand following thinning, is to make the thinning interval approximately equal to one-tenth the age of stand being thinned.

Commercial thinnings, however, are usually expected to salvage trees that die between thinnings. Thus, knowledge of deterioration rates is also required. Decay of windthrown timber is negligible the first year, but thereafter proceeds rapidly. In small logs with a high proportion of sapwood, losses in volume are excessive 5 years after windthrow (*9, 11*). Systematic salvage every 5 years should successfully recover a high percentage of the volume of killed timber. The thinning interval should therefore be set at 5 years if special salvage operations are undertaken as soon as possible after unusually heavy mortality. If reconnaissance shows insignificant mortality since previous thinning, the interval may be lengthened in older stands.

For all except young stands on the best sites, 5 years is a shorter interval than that based on the 10-foot-height-increment rule. In young, good-site stands, the interval probably need never be less than 3 years.

The proper amount to cut should be visualized as the difference between the stand before thinning and the desirable residual stand, in order to help focus attention on the importance of leaving a thrifty stand capable of making optimum growth.

The desirable leave stand depends largely on the condition of the present stand and its development history. A useful, easily recognized indicator of past development is the height-diameter ratio, a reflection of density under which the present stand has grown. Briegleb's analysis of high-producing stands in Europe and Western Washington showed that number of stems per acre was dependent on average diameter and height, regardless of age and site (*8*). Stands of a given average diameter require more tall trees (large height-diameter ratio) per unit area for full stocking than short trees (small height-diameter ratio). For stands of a given height, more small diameter trees are required than large diameter trees. Briegleb prepared a table of the standard number of trees per acre, depending on height and diameter (table 6). Stands having the standard number of trees are expected to make approximately 93 percent of maximum growth possible for the site. Growth falls off rapidly for densities less than those given in table 6, and increases slowly for greater densities.

It follows that use of table 6 as a guide to a desirable leave stand recognizes the influence of past stand development. The proper amount to cut is the difference between what is present in the stand and the stand called for in the table. Briegleb recommends that high density stands (over 130 percent of standard) should be reduced to the standard in several light cuts rather than in one heavy cut.

In practice, trees removed in thinning are not the same size as those left, and thinning by number of trees would be difficult to carry out consistently. That is, more trees than called for in the table should be removed if they are smaller than average, and fewer trees if larger than average. This suggests that a standard basal area be reserved (table 7) and excess basal area cut. Basal area control of growing stock is believed adequate for extensive application of thinning. As long as the guides of good silviculture are followed, basal area removed may be contained in many small trees or few large ones.

In the absence of more extensive experience data, Briegleb's tables are probably the best available guides to desirable leave stands.

Keeping in mind the necessity of leaving the best stand possible, it is generally true that first thinnings will ordinarily be heavier than subsequent thinnings. In young stands, response to thinning occurs

TABLE 6.—*Standard number of trees per acre by average diameter and average height*[1]

Average d.b.h. (inches)	Number of trees when average stand height in feet is—														Average d.b.h. (inches)
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	
4	935	1,425	1,912												4
5	486	773	1,061												5
6		457	643	828											6
7		294	423	553	682										7
8			292	386	480	575									8
9			207	278	350	422									9
10				206	261	317	372								10
11				155	199	243	288	332							11
12				119	155	191	227	262	298						12
13					122	152	181	211	241						13
14					98	124	149	174	199	224					14
15						100	121	142	163	184	205				15
16						83	102	120	138	156	175				16
17							85	100	116	132	147	163			17
18							73	86	100	114	128	142	156		18
19							62	74	86	98	111	123	135		19
20								64	74	85	96	107	117	128	20

[1] Source: Table 2, An Approach to Density Measurement in Douglas-fir (*8*).

TABLE 7.—*Standard basal area per acre by average diameter and average height* [1]

Average d.b.h. (inches)	Basal area per acre when average stand height in feet is—														Average d.b.h. (inches)
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	
	Sq. ft.	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	*Sq. ft.*	
4	82	124	167												4
6		90	126	163											6
7		79	113	148	182										7
8			102	135	168	201									8
9			91	123	155	186									9
10				112	142	173	203								10
11				102	131	160	190	219							11
12				93	122	150	178	206	234						12
13					112	140	167	194	222						13
14					105	133	159	186	213	238					14
15						123	148	174	200	226	252				15
16						116	142	168	193	218	241				16
17							134	158	183	208	232	257			17
18							129	152	177	201	226	251	276		18
19							122	146	169	193	219	242	266		19
20								140	161	185	209	233	255	279	20

[1] Source: Table 3, An Approach to Density Measurement in Douglas-fir (*8*).

so quickly that although a heavy cut may temporarily reduce increment the loss is of short duration. In older stands, a backlog of trees of poor thrift and growth in the lower crown classes may safely be removed all at once; therefore, in stands of this type, first thinnings may also be comparatively heavy.

On the Voight Creek Experimental Forest, initial thinnings in a 37-year-old site III stand ranged from 15 to 40 percent by cubic volume (*63*). Even the heaviest cuts apparently did not reduce increment (*64*). These were crown thinnings, inasmuch as the smallest trees marked were 6½ inches d.b.h. On this forest, thinning interval is 3 years for the light cuts, 6 years for the moderate cuts, and 9 years for the heavy cuts.

On the McCleary Experimental Forest in a 55-year-old site II stand, 15 to 22 percent of the Scribner board-foot volume was removed in initial thinnings (*65*). These were predominantly low thinnings, though some rough dominants were also cut. Less than 10 percent of the stand is removed in repeat thinnings at 5-year intervals.

Second and later thinnings are ordinarily lighter than the first cuts, assuming that the planned interval between thinnings is short. Although blanket prescriptions are dangerous, careful analysis indicates that perhaps up to half of the cubic-foot increment between thinnings may be removed at each thinning. If less than one-third of the increment is left in the stand, growth will almost certainly be reduced (*55*).

CARRYING OUT THE THINNING OPERATION

Success of commercial thinning depends to a large extent on how the actual thinning operation is conducted. Engineering principles and practices of conventional logging must be modified considerably to adapt them to the particular requirements of commercial thinning. The contrast between logging old growth and thinning young growth is probably greater in the Douglas-fir subregion than in any other forest region in the country. Equipment requirements, in particular, are greatly different. No less important, perhaps, is a fresh viewpoint, deviating widely from old growth concepts of size of material, massive equipment, and highball operations.

Road requirements, equipment, crew organization, and the extraction process are discussed in this section.

Road Standards and Spacing

Permanent roads should be built at time of first thinning. They should be constructed to a standard that will permit continuous use with a minimum of maintenance for the balance of the rotation. Stands first thinned at age 40 should normally be thinned many times prior to final harvest 40 to 60 years later. Temporary roads are not compatible with such a program and will inevitably prove uneconomic.

Roads constructed for thinning should also be usable for harvest of the final crop. Grades and alinement should be established with this in mind.

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Experience in building roads for thinning on experimental forests in the Puget Sound area indicates that a 16-foot roadbed with a 3-foot allowance for ditches, when necessary, is most statisfactory (fig. 32).[21]

The right-of-way should be cleared 5 feet beyond edge of slope to permit adequate drying. Ditches must not be neglected. Adequate drainage is the chief requisite of a permanent road; anything less will result in needless trouble and expense.

Whenever possible, road grades should be allowed to settle for a year before surfacing and use. Some saving over heavy-duty roads may be made on surfacing, since thinning traffic is usually light and not continuous. In most cases, pit run gravel applied at the rate of 1,500

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FIGURE 32.—Roads built for thinning should be constructed to serve for the balance of the rotation and for final harvest. They should be adequately drained, well alined, and graded. This 16-foot road plus ditch and clearing allowance is on the Voight Creek Experimental Forest.

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[21] Approximate specifications for U.S. Forest Service 1-lane, class SN-16 standard road.

cubic yards per mile may be sufficient for a first application, recognizing of course that actual surfacing requirements vary with soil conditions and grade.

A road in gentle to moderate topography constructed to these standards will result in an average right-of-way width of 35 feet, occupying 4.24 acres per mile of road. Somewhat more would be necessary on steeper ground. For example, roads on the H. J. Andrews Experimental Forest in west central Oregon required 6.42 acres per mile (*44*). Here, the terrain is comparatively rough and roads were built for harvest of old-growth timber.

Often, stumpage on the right-of-way will substantially reduce cost of road construction. On the McCleary Experimental Forest in a 50- to 53-year-old site II stand, the right-of-way yielded 121 M board feet per mile. Its value, $1,210, was 25 percent of the total road cost. In a 37-year-old stand on the Voight Creek Experimental Forest, right-of-way recovery yielded 42 M board feet per mile, with a value of $335, which represented 7 percent of road cost.

Proper road spacing depends on the skidding equipment to be used, unless topography is limiting. Roads spaced approximately ¼ mile apart will result in a maximum skidding distance of 660 feet, efficient for tractor skidding, but extreme for horses (*2, 27, 74*).

One mile of road under this pattern of spacing will serve 160 acres. On the McCleary Experimental Forest, where an adjacent county road was used and skidding distances ranged up to 1,000 feet for limited areas, 1 mile of road serves 175 acres (*71*). On the Voight Creek Experimental Forest, where skidding distances are mostly under 600 feet and extra mileage was needed for connecting roads, 1 mile of road serves 125 acres. On the H. J. Andrews Experimental Forest the rate is 1 mile of road per 123 acres (*44*); on the Roaring River Tree Farm, 1 mile per 142 acres.[12] An average of 140 acres should be considered reasonable for areas easily accessible to public roads, if no sizable areas unsuited for thinning are included. If considerable access road construction is necessary or stands to be thinned contain nonoperable areas, an average of 1 mile per 100 acres would be a better estimate.[13]

One mile of 35-foot road per 140 acres occupies about 3 percent of the forest area. In older stands especially, some temporary loss in growth may be expected through exposure of border trees. Since road clearing also has the effect of thinning, however, later increased growth should compensate for some of this loss. Crowns and possibly roots encroach on the road so that not all of the road area is out of production. One estimate places this encroachment at 4½ feet on each side of the road (*44*). However, trees spaced 20 x 20 feet (109 trees per acre)—a reasonable estimate for rotation-age trees—presumably use space extending 10 feet from their trunks. Hence, one might estimate that only the center 15 feet of a 35-foot road is permanently out of production. For the 140-acre per mile road pattern, about 1½ percent of the total forest area would fall in this category.

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[12] Data furnished by Verne D. Bronson of Tree Farm Management Service to Roy R. Silen, in letter dated Jan. 7, 1955.

[13] Jeffers, Nelson. Data quoted in panel discussion: "Do cuts in immature stands pay?" (Portland Chapter, Columbia River Sec., SAF, Feb. 13, 1956.)

Equipment

Light, mobile, inexpensive equipment is best adapted to thinning young stands on gentle topography. Thinning cannot bear the large, fixed costs of the heavy equipment commonly used for clear cutting. Success of thinning depends more on specialized individual effort rather than on the large-scale production efforts of typical logging operations. Trees are small, production per acre is low, and mass production techniques are usually not possible. Under such conditions, equipment used for conventional logging cannot be used to full capacity and fixed charges become prohibitive. Yet, it is common to find thinning jobs overmechanized and overcapitalized.

A light chain saw, a good horse, a small powerlift loader, and a dual-axle truck are usually the essential items of equipment. In stands more than 60–70 years old, containing larger timber, a small tractor may be better suited to skidding than horses. Steeper areas may be thinned with specialized high lead yarders and skyline systems, which are, however, much more expensive and require careful planning for efficient use.

More complete discussion of equipment will be found in a later section on extraction.

Crew Organization

Small, flexible crews are most efficient for commercial thinning. Operations on experimental forests quickly demonstrated that contracting the work to small crews was most satisfactory, often effecting savings up to 30 percent below company crew costs. Contract crews are paid on a piece rate basis with scale in cords or M board feet, or in number of poles or piling, providing the basis for payment.

Time required for the various operations in thinning provides a basis for crew organization. On a typical thinning job, 3.80 man-hours are required to fell, buck, skid, and load 100 cubic feet of wood (table 8). Allocation to the various operations is—

	Percent
Felling and bucking	34
Skidding	50
Loading	16
	100

Thus, material felled and bucked in 1 hour requires 1.5 man-hours to skid and 0.5 man-hour to load. Crews should be organized on the basis of experience data such as these. Hauling requirements, which depend largely on distance to market, are determined separately.

In older stands where board-foot scale is appropriate, felling, bucking, skidding, and loading were found to require 5.88 man-hours per thousand board feet (table 8). Percentage allocation of time to these operations was found to be about the same as for cubic feet.

Averages shown in table 8 are believed to be reasonably accurate. However, every thinning job is different and the forester should develop his own figures as a basis for crew organization where separate tasks are assigned to each man. Such data are indispensable in planning how expensive equipment (tractors or portable loaders, for example) may be kept fully occupied. Hauling time (not quoted above, but shown in table 8), in particular, must be determined for each job since it depends on the size of load hauled and travel time required.

TABLE 8.—*Man-hour requirements for the various operations in the extraction process* [1]

PRODUCTION TIME PER HUNDRED CUBIC FEET

Project	Stand age	Felling, bucking	Skidding	Loading	Hauling	Miscellaneous [2]	Total
	Years	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*	*Man-hours*
Voight Creek	40	2.43	3.20	(3)	(3)	(3)	(3)
Hemlock	50	1.05	1.78	0.71	0.64	0.44	4.62
Cowichan Lake	50	1.91	2.49	.59	(3)	.50	(3)
McCleary	55	.83	1.01	.46	.42	.44	3.16
Hood Canal	65	.93	1.09	.47	.26	.26	3.01
Big Creek	70	.61	1.84	.79	.65	.52	4.41
Average		1.29	1.90	.60	.49	.43	[4] 4.71

PRODUCTION TIME PER THOUSAND BOARD FEET

Project	Stand age	Felling, bucking	Skidding	Loading	Hauling	Miscellaneous [2]	Total
Cowichan Lake	50	3.68	4.79	1.14	(3)	0.96	(3)
McCleary	55	1.48	1.80	.82	0.75	.79	5.64
Hood Canal	65	1.61	1.88	.81	.45	.44	5.19
Big Creek	70	1.05	3.14	1.35	1.11	.89	7.54
Average		1.95	2.90	1.03	.77	.77	[4] 7.42

[1] See table 17 (appendix) for pertinent descriptive information regarding these examples of commercial thinning.
[2] Includes time spent for supervision and bookkeeping.
[3] Data not available.
[4] Sum of the averages for each operation.

Extraction

Felling and Bucking

The small power saw has been found as useful for felling and bucking thinnings as for more conventional logging (fig. 33). Many makes of dependable small power saws are available; they have helped to make commercial thinning economical, and have the advantage of all mechanical equipment; i.e., appeal to present-day labor. Light saws with an 18-inch bar and of about 3½ horsepower are well adapted to thinning.

Felling, the first step in extraction, is frequently complicated by trees hanging up. This is especially true in young, dense stands being thinned for the first time. These trees must be pulled down, a time-consuming operation. Where hang-ups are a problem, trees should be felled toward the most favorable openings in the crown canopy,

FIGURE 23.—The small power saw is efficient for felling and bucking thinnings. It has done much to make commercial thinnings feasible.

regardless of skidding requirements. Felling may sometimes be aided by pushing trees with an 8-foot pike pole.

In older stands with larger trees and in second and later thinnings, the problem of hang-ups is not so acute, and more attention may be given to felling the trees toward the skid trail to favor later skidding. This is most important for large trees. Where whole trees or long logs are skidded, directional felling not only facilitates skidding but helps to reduce skidding damage to residual trees.

Limbing is necessary only in tops of trees; lower dead limbs break off easily during felling and skidding. Trees from young stands and rough dominants in older stands normally require more limbing. In the typical operation, however, little limbing is required.

Bucking time, of course, depends on the product being harvested; more time is required for short products such as pulpwood than for tree-length or long log products. If more than one kind of product is to be extracted from the same tree, the bucker must be familiar with product specifications and able to judge the most efficient use for each tree. Normally, such refinement is not required.

Felling and bucking require about 1.29 man-hours per hundred cubic feet or 1.95 man-hours per thousand board feet (table 8)—approximately one-third of the time spent in extraction, excluding hauling. Time required per unit volume is largely dependent on tree size and, to a lesser extent, on the product being extracted. Studies allocating costs to size of tree are not available. One time study related to log size showed that production increased almost in a straight line from 53.6 cubic feet per man-hour for 7-inch logs to 111.2 cubic feet for 14-inch logs (*74*). A similar relationship probably exists for trees.

Skidding

Skidding consumes the most time in thinning, requiring about one-half of total extraction time, exclusive of hauling (table 8). Skidding is also a major cost element in conventional logging, but skidding costs are more apt to get out of line in thinning, largely because of the tendency to use equipment unsuited to the job. The operation must be planned carefully and checked frequently to insure maximum efficiency.

Commercial thinning is characterized by the small size of material produced and the small volume cut per acre, which makes it difficult to bunch and secure a full load at each turn. Much time may also be required for skidroad construction. Thus, production is limited more by the character of the cutting than by the equipment used for skidding.

Economical thinning, therefore, requires light, flexible, low-cost skidding machines. Machinery too powerful for the job cannot produce enough additional volume to compensate for higher costs.

For thinning products less than 10 cubic feet, horses are most satisfactory for skidding, provided that the terrain is favorable and skidding distances are less than 600 feet (*73*) (fig. 34). Well-trained, light horses, handled by a skilled teamster, give an excellent account of themselves under such conditions. Light (1,500 lb.) horses are preferred because of their ability to get around in the woods, though heavier horses may be able to pull more.

"Favorable terrain," in general, means absence of adverse grades and only limited areas of steep favorable slopes. Although horses may get around on steep slopes more quickly and safely than tractors, they are incapable of handling an economical load under such circumstances. Some foresters recommend that horse skidding be confined to areas with slopes not greater than 25 percent (*27*). Steeper areas have been operated in eastern Washington, and a commercial sale in a 75-year-old stand on the Olympic National Forest was thinned with horses where slopes up to 40 percent occurred on back lines.

Effect of skidding distance and size of product on the productivity of horse skidding is shown in table 9. The time study (*74*) from which this table was derived shows that skidding output falls below 30 cubic feet per man-hour when logs smaller than 8 inches are skidded 200 feet or more. At 800 feet, only logs larger than 13 inches may be

TABLE 9.—*Hourly production for horse skidding of 8-foot logs, by skidding distance and log diameter*[1]

Log diameter (inches)	Skidding distance in feet							
	100	200	300	400	500	600	700	800
	cu. ft.	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*	*cu. ft.*
7	32	26	23	20	18	16	14	13
8	41	33	29	26	22	20	18	16
9	51	41	37	32	28	25	22	20
10	62	50	45	39	34	30	27	24
11	74	55	53	46	40	36	32	29
12	82	65	55	48	41	36	32	29
13	91	69	58	49	42	36	32	29
14	105	80	67	57	48	42	37	33

[1] Adapted from tables 1, 2, and 3 of "Cost of thinning young Douglas-fir," by Worthington and Shaw (*74*). Line through the table delineates combinations of size and distance for which production is less than 30 cu. ft. per hour.

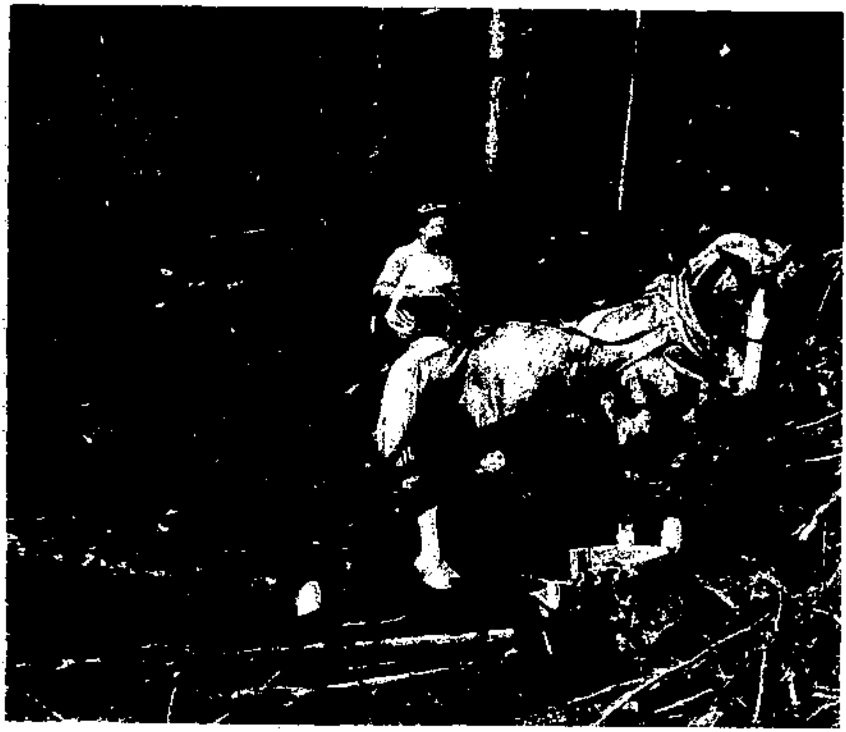

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FIGURE 34.—On favorable terrain where skidding distance is less than 600 feet, horses are most efficient for skidding products containing less than 10 cubic feet, and may be most efficient for products up to 30 or 35 cubic feet.

skidded with comparable efficiency. In general, skidding distances beyond 600 feet are not economical for horses, though it is apparent from the table that size of trees cut and, of course, cost per hour and value of product control the maximum distance for any particular job.

Despite the proved success of horses, tractors are more commonly used for skidding (fig. 35). For one thing, tractor operators are more readily available than teamsters: tractors more available than horses. For another, many commercial thinning areas include conditions unfavorable to horse skidding; for example, adverse grades, long skidding distances, and logs too large to be handled by horses.

Tractors are able to maneuver and work on adverse grades better than horses, though their use may also be limited by steep slopes, favorable or unfavorable. In general, slopes over 40 percent are considered too steep for tractor skidding.

Tractors can generally be used to skid longer distances than horses. Time studies, however, are not available to relate output to tree or log size and distance skidded. It is generally believed that small tractors, recommended for thinning, can skid up to 1,000 feet economically.

Size of material to be skidded is undoubtedly the most important element, not only in choosing between horses and tractors, but also in choosing the right tractor. As previously explained, horses are most efficient for products containing less than 10 cubic feet. For products

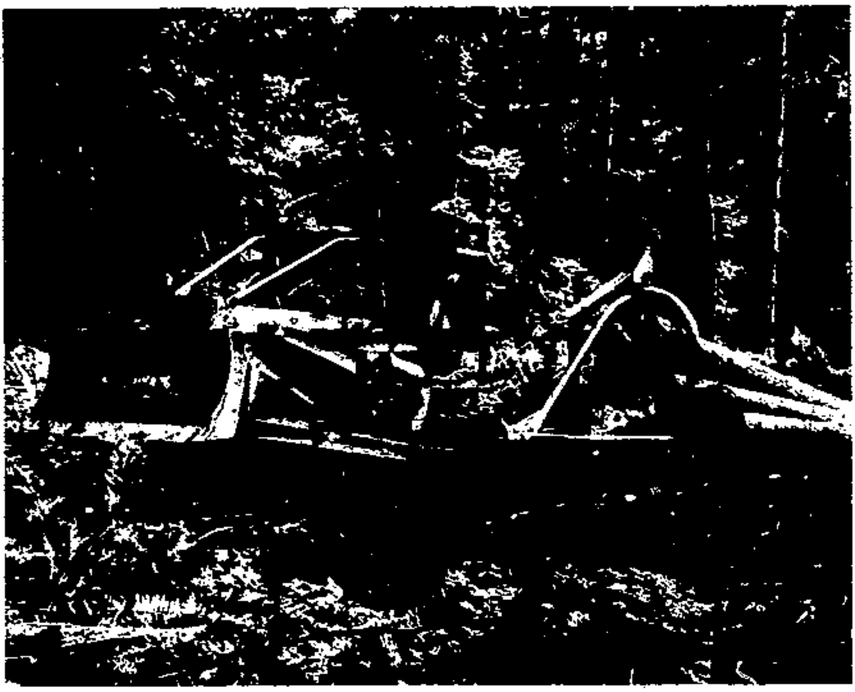

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FIGURE 35.—Small tractors are commonly used for skidding thinning products larger than can be handled economically by horses.

larger than 30 to 35 cubic feet, there is little doubt that only tractors are practicable. For sizes in between, either horses or tractors may be used, the choice depending on other factors.

Small crawler tractors (30 drawbar hp.) are most satisfactory. Rubber-tired tractors work well except in wet, boggy situations, but do not have the flexibility of crawler tractors nor the extra power often needed.

In planning a tractor operation, the most important thing to remember is that tractors are expensive and involve a high fixed cost per hour whether they are working or not. If they are not worked to capacity, idle time may easily make an otherwise good thinning job uneconomical. Over a period of years, the authors have observed that most thinning operations are overequipped.

Where skidding distances are long, a combination of horses and tractors may often be used to advantage (*3*). Horses skid the area near landings. Farther back, they skid to a main skid road where they bunch the logs for a tractor; the tractor, in turn, operates only on the main skid road. To use a horse-tractor combination effectively, production from the various types of equipment must be carefully coordinated. Often good coordination is difficult to achieve and the thinning job fails. The axiom should be "keep it simple."

Huge acreages of forest, otherwise suitable for commercial thinning, occupy ground too steep for skidding by either horses or tractors. Substantial progress has been made in developing techniques and equipment suitable for thinning such areas. For example, on the Cascade Head Experimental Forest steep (up to 60 percent) slopes below rocked roads were successfully skidded by a modified high lead system, using a $\frac{4}{10}$-yard shovel mounted on a halftrack (*6*). This machine was also used for loading. Maximum yarding distance was 300 feet.

Skyline systems, notably the Wyssen system (*38*), may also be perfected for use in commercial thinning of steep ground in the Douglas-fir region. In any event, we can be sure that future improvements in equipment and methods will make it possible to thin much land currently passed by as too steep.

The question of skidding whole trees, or long logs versus short logs, involves two factors: cost, and damage to residual stand. Unfortunately, only general observations can be made on the problem. Whether trees are bucked in the woods or on the landing is often a matter of preference, particularly among horse skinners. With tractors, tree-length or long-log skidding has proved more economical (*64*). Theoretically, damage to residual trees should be less when logs are bucked at the stump; however, this relationship is not easy to demonstrate in the woods. Presumably, stand conditions and attitude and interest of the tractor operator are more important than length of product skidded. A careful operator, particularly in second and later thinnings or in fairly open stands, except on steep slopes, can skid long logs or trees without causing significantly greater damage than when skidding shorter material.

Skidding damage includes rubbing off bark near base of standing trees, and damage to root systems. The seriousness of root damage, both as to extent and longtime effect on the tree, is not known for Douglas-fir.

Horses do the least damage and are frequently used for skidding for this reason alone. Where tractors are used, the narrower the machine, the better. This is added reason for using the smallest tractor capable of doing the job. Bulldozers should be permitted only where they are essential for opening up skidroads. Crawler-type arches should be used for skidding only where the tractor operates entirely on established skidroads.

Although trees are much less easily damaged in the dormant season when the bark is tight, the difference does not justify restricting thinning to the dormant season (*57*).

That the skill and interest of the operator largely control amount of damage, almost to the total exclusion of other influences, has been commonly observed. Although the effect of damage, particularly to roots, has not as yet been adequately evaluated, Douglas-fir appears to be remarkably resistant to decay entering from wounds. This is probably so because of an abundant flow of pitch that covers exposed wood. Certainly every attempt should be made to minimize damage but. for the reasons given, threat of damage alone is not a justifiable reason for not thinning.

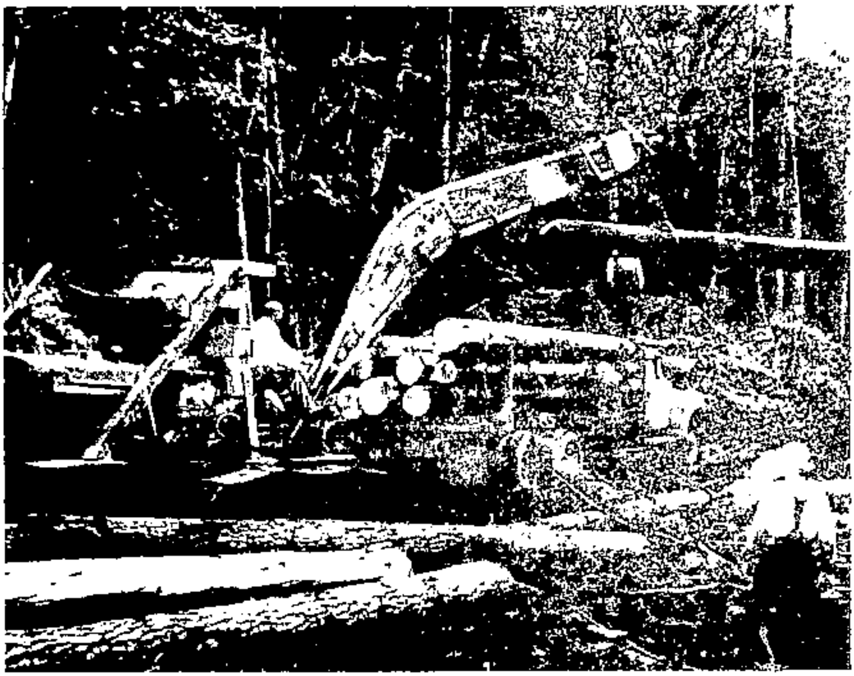
Loading

If done efficiently, loading may be expected to take about 16 percent of cubic-foot extraction time, exclusive of hauling and miscellaneous time (table 8). Efficient loading requires fast, mobile equipment. With mobile equipment, loading can be performed at any convenient point along the woods road; large fixed landings are unnecessary, and skidding is simplified.

For large products, a tractor or truck-mounted loader is most satisfactory (fig. 36). Such a loader, however, is expensive and cautions against idle time must be heeded. Where a truck-mounted loader is used, it may have to serve two or more skidding units. Usually logs can be bunched along a road for later loading, permitting the loading machine to be used to full advantage. A "hot" skidding and loading operation is not recommended, because too much time is lost from poor coordination; also, breakdown of the skidder, loader, or truck will tie up other operations.

For small products, the forklift loader is the best available equipment (fig. 37). This machine can handle a certain volume or weight and it makes little difference whether the fixed volume is in one large piece or several small ones. Thus, small diameter sticks may be loaded nearly as fast as much larger sticks. Usually the truckdriver operates the loader with minor assistance from the skidder. From 3 to 5 cords are easily loaded out in less than an hour with such an arrangement. Forklifts are commonly used for 8-foot pulpwood and for small-diameter logs up to 16 feet long.

Fixed loading devices, such as gin poles. A-frames. or rollways, are not satisfactory. Their lack of mobility is objectionable for either



[illegible] truck-mounted loader [illegible] product [illegible] good [illegible]

[illegible]

Hauling

[illegible]

[illegible]

[illegible]

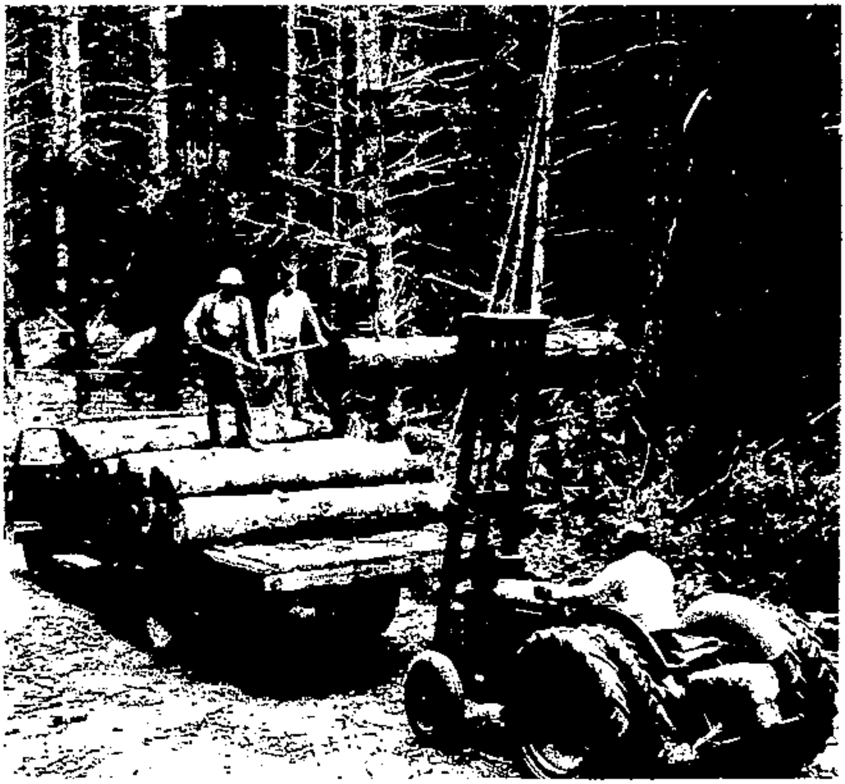


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FIGURE 37. Inexpensive forklift loaders are most satisfactory for loading pulpwood or small logs.

leaving the thinning crews to concentrate on getting products to roadside, the major bottleneck.

Summary of Extraction Process

In commercial thinning of Douglas-fir, the extraction process may logically be divided into two categories: (1) felling, bucking, and skidding; (2) loading and hauling. Felling, bucking, and skidding require "woodsmen," a special kind of laborer. Loading and hauling may be done by labor that frequently would not tackle the strictly woods part. Capital investment is low for felling and bucking, and also for skidding if horses are used; it is comparatively high for loading and hauling, especially if truck mounted loaders are required.

For large-scale, commercial thinning the forester should consider dividing the work along the following lines: Felling, bucking, and skidding may be contracted to small crews charged with delivering specified products to the roadside. A company might take delivery

FIGURE 38.—Large [illegible] trucks are best for hauling thinning products up to 16 feet long.

[illegible] is to have a crew, equipped with a suitable mobile loader and truck, follow behind several thinning crews (7). Or, as one [illegible], the loading and hauling might be contracted separately.

Products From Thinning

Size of trees cut largely determines what products can be made from commercial thinnings. Generally speaking, the larger the tree, the wider the variety of salable products. Major products in the Puget Sound area are listed in table 10. A much wider variety may occasionally be marketed (67).

Products used in the round usually have a limited market and are subject to wide fluctuation of demand. Products to be remanufactured are normally more in demand and present a better opportunity for profitable production and sale.[illegible]

[illegible] In first thinnings, remnants of a previous stand, such as an occasional standing old-growth tree, salvable peeler logs, and cedar suitable for stakes, shingles, [illegible] or fence posts are frequently removed. Strictly speaking, such products are not from the stand being thinned and, therefore, will not be considered here.

The forester should normally have a marketing agreement of some sort and complete knowledge of product specification before marking and cutting are begun (*61*).

Products vary considerably in sale value per cubic foot (table 10). Poles and piling are relatively high-value products. Specifications, however, are exacting and the market fluctuates widely. Pulpwood is just the reverse; it has comparatively low value, specifications are easily met by a high proportion of trees removed in a typical thinning, and markets, if they exist at all, are relatively stable.

TABLE 10.—*Specifications and 1957 sale value in the Puget Sound area of common products from commercial thinning*

Product	Minimum tree d.b.h.	Product specifications		Unit	Unit price	Average sale value per cu. ft.
		Minimum diameter	Usual length			
	Inches	*Inches*	*Feet*		*Dollars*	*Dollars*
Fenceposts	4	3	6–8	piece	[1] 0.20	0.308
Fuelwood	5	4	2–8	cord	10.50	.127
Pulpwood	5	4	4–8	cord	16.00	.198
Mine props	6	4	6–17	M lin. ft	16.20	.186
Car stakes	7	5	9–12	piece	[2] .45	.227
Saw logs, No. 3	8	6	8–32	M bd. ft	37.50	.195
Smelter poles	8	6	25	ton	8.55	.231
Utility poles	10	5	30–60	lin. ft	[3] .25	.464
Piling	12	6	40–100	lin. ft	[4] .40	.465
Saw logs, No. 2	16	12	12–32	M bd. ft	47.50	.294
Peeler logs	18	14	4½–18	M bd. ft	55.00	.356

[1] 7-foot post.
[2] 12-foot stake.
[3] Class 3 and 4 poles.
[4] 75-foot pile.

Principal products from thinnings at the Voight Creek Experimental Forest from 1952–54 were 8-foot Douglas-fir pulpwood, 45 percent by volume; and 8- to 16-foot Douglas-fir and alder saw logs, 55 percent (fig. 39). If special orders had been available, car stakes, smelter poles, mine props, and a few utility poles could have been cut from this 40-year-old, site III stand. Thinnings in 1954 from a 50-year-old site II stand on the McCleary Experimental Forest included 16- to 32-foot saw logs, 59 percent; 9- to 18-foot peeler logs, 22 percent; and 8-foot alder pulpwood, 19 percent. This thinning could have produced a few utility poles and piling (70-foot maximum). Thinning in a 70-year-old stand on the Sechelt Tree Farm near Vancouver, British Columbia, produced saw logs, 78 percent; pulpwood, 16 percent; piling, 5 percent; and poles, 1 percent (*75*).

Although these examples indicate considerable diversity of markets, frequently only saw logs can be readily sold (*28, 39, 57*). Persistent and opportunistic study of markets sometimes uncovers possibilities

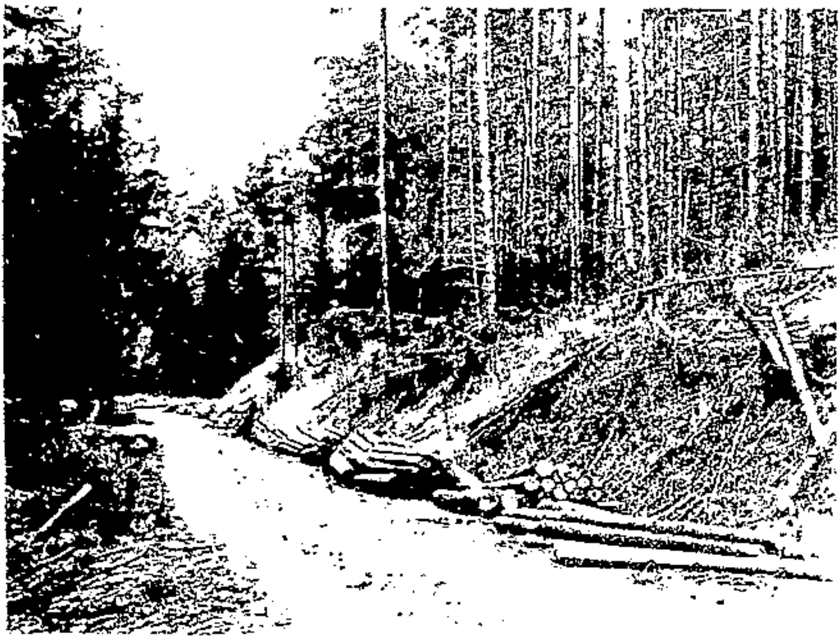

FIGURE 29.—Logs, bolts, pulpwood, and [illegible] 40 [illegible] site III [illegible] Forest.

[illegible] of poles and piling, high-value products [illegible] trees [illegible] years old and over [illegible].

FINANCIAL ASPECTS

Financial aspects of commercial thinning are an important and integral part of the larger problem of financial aspects of intensive management of Douglas-fir. Full discussion would require more complete information than is available now on costs of management, including protection, taxes, insurance, administration, etc. Many items properly in the field of economics are required, such as interest rates and distribution of various costs. These factors would have to be considered with silvicultural information on growth rates and yields to finally set valuations. Management decisions regarding rotations, levels of growing stock, cutting budgets, etc., would be based partly on valuations so established, and partly on other considerations.

It is beyond the scope of this publication to discuss fully the financial aspects of commercial thinning, involving as they do almost the whole field of forest valuation. Various features of thinnings are presented in the following sections to help the forester integrate commercial thinning into the overall management plans of intensively managed forests.

ROAD COSTS

Commercial thinning, pursued energetically, requires a more intensive road system than exists on most properties. Cost of constructing needed roads has frequently been given as a major reason for not thinning (72). This section will give some examples of investments required in roads and preferred methods of charging costs to thinnings.

On favorable topography, roads satisfactory for thinning and also, with little added expense, suitable for final harvest cost from $4,000 to $8,000 per mile during the period of 1948-53 (table 11).

Roads on experimental forests listed in table 11 were built to specifications briefly outlined on page 61. Costs of constructing the grades varied little in these areas of gentle to moderate topography, averaging $3,078 per mile.

Cost of surfacing these all-weather roads varied more widely. On the Hood Canal and Voight Creek Experimental Forests, gravel was readily available on or near the forests, and the sandy to gravelly soils encountered required a minimum of ballast. On the Hemlock Experimental Forest, gravel had to be hauled a considerable distance, and heavy applications were necessary because the soil is clayey. Conditions on the McCleary Experimental Forest were in between these extremes.

Annual road charge per acre of thinned area can be calculated as shown in table 11. Value of stumpage removed from the right-of-way is used to defray part of the initial road costs. Although there are other ways of accounting for this revenue, this scheme is simplest and most direct. Subtracting the value of right-of-way timber leaves a net cost per mile representing capital investment in the road system.

Roads must be built for final timber harvest; therefore, the only added costs of constructing them early in the rotation are interest on investment and cost of maintenance until rotation end. If these two items are charged against thinning, the original road cost can be appropriately charged against timber cut in the final harvest (72).[15]

On the experimental forests, annual charge per acre for road costs varies from $1.61 to $4.46 (table 11). High costs on the Hemlock Experimental Forest stem partly from high net cost of road, and partly from the low acreage served by each mile of road. High initial road cost is due to expensive surfacing; low efficiency (acres served per mile), to irregular boundaries of the area thinned and restricted ownership.

Road cost is one expense of thinning that is strictly fixed per acre, and hence fluctuates per unit output, depending on volume cut per acre. However, the effect on extraction costs will be small in any case.

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[15] The road system will obviously have value to the second and succeeding rotations. Hence, only the original cost less a salvage value (value to the next rotation) need be charged to the final cut.

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TABLE 11.—*Road costs on experimental forest thinning operations,*[1] *1948–53*

Forest	Topography	Stand age	Gravel per mile	Cost per mile			Stumpage value per mile	Net cost per mile	Annual charge per mile			Area served per mile	Annual charge per acre
				Grade	Surface	Total			Interest[2]	Maintenance[3]	Total		
		Years	*Yards*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Acres*	*Dollars*
Hemlock[4]	Gentle	50	2,500	3,080	5,110	8,190	1,561	6,629	331	115	446	100	4.46
Hood Canal	do	65	1,000	3,095	1,244	4,339	961	3,378	169	80	249	131	1.90
McCleary	Mod	55	1,300	2,850	1,980	4,830	1,210	3,620	181	100	281	175	1.61
Voight Creek	do	40	1,200	3,286	1,500	4,786	335	4,451	223	75	298	125	2.38
Average		52	1,475	3,078	2,458	5,536	1,017	4,519	226	92	318	133	2.39

[1] Costs are for construction of 16-foot roads with a 3-foot allowance for ditches, where necessary, and a 5-foot strip cleared beyond actual construction.
[2] Interest at 5 percent.
[3] Estimated.
[4] Western hemlock forest type.

In theory, not all annual charges need be assessed to thinning since roads have other values, notably fire control (*71*). Apportioning road costs to the many possible uses is a matter of judgment and owner policy. For simplicity, in the valuation discussions in this section, annual road cost is charged entirely to thinning.

Where a long-term capital investment in roads is possible, the recommended scheme of cost accounting results in an annual charge that is believed to be reasonable and easily sustained by a commercial thinning operation. Six years of experience on the McCleary Experimental Forest showed that in this 55- to 60-year-old stand, revenue from salvaged mortality alone amounted to $1.05 per acre annually (*71*), which is 65 percent of the annual charge calculated in table 11.

EXTRACTION COSTS

Extraction costs are the major element influencing success of commercial thinning. Many of the factors affecting extraction costs were introduced in the section Application of Thinning. In the following sections, equipment costs and experience data are presented as practical examples of thinning costs.

Equipment Costs

The importance of choosing equipment adapted to commercial thinning cannot be overemphasized. The tendency to use overpowered machinery that cannot be operated at full productive capacity results in a more costly operation for two reasons:

1. Production is not proportional to the operating cost. Thus, an overly large tractor costing $8 per hour to operate (including driver) frequently cannot produce twice as much on a thinning job as a tractor costing $4 per hour.

2. Fixed costs (depreciation, insurance, interest, and taxes), which go on even while the machine is idle, are much higher for the more expensive equipment. Idle time occurs frequently in thinning and cannot always be avoided.

Fixed and variable costs for typical equipment used in commercial thinning are given in table 12. The problem of balancing equipment with the job is apparent from this table. For example, a 45–55-hp. tractor costs $4.07 per hour to run, or $7.18 with an operator at $2.75 per hour and an allowance of $0.36 for chokers and wire rope. A horse costs $2.60, including a teamster at $2.20. On jobs where either may be used, tractor production must be 2¾ times that attainable with a horse if the tractor is to prove economical. There are doubtless many operations where a tractor would not attain this production. Furthermore, if a tractor of this size is idle one-fourth of the time, cost per hour while it is producing is increased nearly 11 percent to $7.96 because of fixed charges of $2.34 per hour. In contrast, fixed charges for the horse are only $0.12 per hour, which would increase total cost only 1½ percent to $2.64 per hour under similar circumstances. If idle time is unavoidable, as it frequently is in commercial thinning, the tractor must outproduce the horse 3 to 1.

TABLE 12.—*Cost of owning and operating representative equipment used for commercial thinning* [1]

Operation	Equipment	Initial cost	Life expectancy [2]	Lifetime use [2]	Cost per hour		
					Fixed [3]	Variable [4]	Total
		Dollars	*Years*	*Hours*	*Dollars*	*Dollars*	*Dollars*
Felling and bucking	Power saw	250– 300	2	[5] 3, 200	0. 19	0. 27	0. 46
Skidding	Horse	150– 200	4	6, 400	. 12	. 28	. 40
	4-wheel tractor	7, 000– 8, 000	5	9, 000	. 73	. 50	1. 23
	Wheel farm tractor [6]	2, 000– 3, 000	3	3, 000	1. 04	. 92	1. 96
	Crawler tractors:[7]						
	25 hp	5, 000– 6, 000	5	5, 000	. 87	. 62	1. 49
	33–45 hp	10, 000–11, 000	5	9, 000	1. 85	1. 24	3. 09
	45–55 hp	13, 000–14, 000	5	9, 000	2. 34	1. 73	4. 07
	70–80 hp	19, 000–20, 000	5	9, 000	3. 37	2. 51	5. 88
Loading	Tractor forklift	3, 000– 4, 000	6	6, 000	. 85	. 35	1. 20
	Truck loader	20, 000–21, 000	9	18, 000	1. 43	1. 61	3. 04
	Shovel loader:						
	4/10-yard	8, 000– 9, 000	5	8, 000	1. 06	1. 33	2. 39
	½-yard	25, 000–30, 000	9	18, 000	2. 10	2. 56	4. 66
Hauling	Truck:						
	Single axle	4, 000– 4, 500	5	9, 000	. 75	1. 61	2. 36
	Dual axle	7, 500– 8, 000	5	9, 000	1. 27	1. 97	3. 24
	Truck and trailer	9, 500–10, 000	5	9, 000	1. 49	2. 23	3. 72
	Short-log truck and short-log trailer	23, 000–	5	12, 500	2. 90	1. 93	4. 83

[1] Data furnished by manufacturers or equipment operators.

[2] Used for calculating fixed costs. Interest and taxes, for example, are annual charges, which must be spread over the hours of normal use.

[3] Fixed costs are the costs of ownership, including depreciation, interest, insurance, and taxes. For the horse, it also includes maintenance rations. These costs are incurred whether the equipment is being used or not.

[4] Variable costs are costs that are incurred only when the equipment is being used, including fuel, grease, oil, and repairs; for the horse it includes extra feed, shoes, harness, veterinary bills, and miscellaneous costs. Operator wages are not included.

[5] 8 hours per day for 200 days per year. Fixed costs, and maintenance and repair charges are computed on this basis, the hours being equivalent to felling and bucking man-hours. Actual saw-hours would be something less.

[6] Southeastern U.S. conditions, as reported by B. C. Cobb, "Skidding with rubber-tired wheel tractors in the Tennessee Valley." T.V.A. Forestry Invest. Tech. Note 26, Jan. 1957.

[7] Drawbar horsepower classes.

This analysis is presented not to discourage mechanization of commercial thinning, but to point out factors that must be considered in planning. As pointed out in the section on the extraction process, the tendency to think in terms of clearcut-logging techniques is frequently detrimental to thinning. Actually, more mechanization is probably needed, but development must start with a viewpoint referenced to the specific needs of commercial thinning.

Foresters planning a commercial thinning should assemble all available cost and production data before deciding on equipment to be used. Detailed costs of owning and operating machinery can usually be obtained from equipment manufacturers. Unfortunately, however, there is frequently no substitute for operating experience.

Cost of owning a horse is known fairly closely from experience on experimental forests (*73*) (table 13). The average cost per hour on four thinnings made at various times during the years 1949 to 1956 was $0.40, made up of $0.12 fixed costs and $0.28 variable costs. Feed is by far the biggest cost item in horseownership, making up 69 percent of the total.

Case History Costs

Cost summaries for experimental commercial thinnings conducted from 1948 to 1956 are presented in table 14. These data were collected from operations for which reasonably complete and accurate costs are available. Not all examples are from successful commercial thinnings; that is, not all returned the costs of extraction. Some were not operated with maximum efficiency, partly due to unwise choice of

TABLE 13.—*Estimated cost of owning and using a horse for thinning young stands in western Washington* [1]

Item	Annual cost		
	Fixed	Variable	Total
	Dollars	*Dollars*	*Dollars*
Feed	130.75	305.09	435.84
Harness and equipment		64.05	64.05
Shoeing		36.64	36.64
Veterinary service		21.58	21.58
Shelter	19.40		19.40
Depreciation of horse [2]	26.40		26.40
Taxes, insurance, and interest	13.75		13.75
Miscellaneous		16.25	16.25
Total	190.30	443.61	633.91
Cost per horse-hour [3]	.119	.277	.396

[1] Source: "Skidding with horses to thin young stands in western Washington" (*73*).
[2] Working life, 4 years; initial cost, $100 to $175, less salvage of $25.
[3] Based on 1,600 hours' use annually.

TABLE 14.—*Examples of the cost of the various operations in the extraction process* [1]

COST PER 100 CUBIC FEET

Project	Stand age	Felling, bucking	Skidding	Loading	Hauling	Miscellaneous [2]	Total	Total per cord [3]
	Years	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Voight Creek	40	5.11	6.78	[4]	[4]	[4]	[4]	[4]
Hemlock	50	2.86	4.38	2.55	4.67	2.15	16.61	13.79
Cowichan Lake	50	4.15	6.20	[5] 1.52	[4]	2.00	[4]	[4]
McCleary	55	2.45	[6] 4.42	[6] 1.93	1.66	2.21	12.67	10.52
Hood Canal	65	3.00	[6] 4.09	[6] 2.05	1.67	3.14	13.95	11.58
Big Creek	70	1.98	5.63	2.81	3.24	3.38	17.04	14.14
Average		3.26	5.25	2.17	2.81	2.57	[9] 16.06	13.33
Percent of total		20	33	14	17	16	100	

COST PER M BOARD FEET (SCRIBNER RULE)

Project	Stand age	Felling, bucking	Skidding	Loading	Hauling	Miscellaneous [2]	Total	Total per cord [3]
	Years	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	
Cowichan Lake	50	7.98	11.91	[5] 2.92	[4]	3.85	[4]	
McCleary	55	4.38	7.89	3.44	2.97	3.94	22.62	
Hood Canal	65	5.17	7.06	3.53	2.88	5.42	24.06	
Big Creek	70	3.38	9.62	4.81	5.54	5.77	29.12	
Mt. Walker	75	7.52	21.60	2.44	4.09	[7] 8.88	44.53	
Fall Creek	90	6.75	7.30	[8] 2.10	[8] 2.63	7.70	26.48	
Wind River	110	4.18	[6] 5.81	[6] 2.25	6.10	[7] 12.81	31.15	
Average		5.62	10.17	3.07	4.03	6.91	[9] 29.80	
Percent of total		19	34	10	14	23	100	

[1] See appendix, table 17, for pertinent descriptive information concerning these examples of commercial thinning.
[2] Payroll taxes; supervision, bookkeeping, and office expense.
[3] 83 cubic feet per cord.
[4] Data not available.
[5] Decking along roadside.
[6] Skidding and loading reported together; breakdown estimated.
[7] Also includes equipment depreciation, more properly part of skidding, loading, and hauling costs.
[8] Loading and hauling reported together; breakdown estimated.
[9] Sum of the averages of each operation.

machinery and partly to mismanagement. Nevertheless, costs for all jobs are included to give a realistic cross section.

Costs and production data in cubic feet are given for stands from 40 to 70 years old. The board-foot data are from stands ranging from 55 to 100 years; younger stands are excluded because board-foot measures are unrealistic for small material removed from such stands.

Averages compare favorably with costs for clear cutting similar stands. In the older stands, logging cost averaged $29.80 per M for saw logs delivered to the mill. For younger stands the cost was $13.33 per cord (83 cubic feet), although much of this material, too, was cut and sold as saw logs. Apparently, material so small that it could be sold only for pulpwood would be somewhat more expensive to produce.

Skidding is the most expensive operation, accounting for approximately one-third of the total cost. Felling and bucking is next, making up about one-fifth of the total. Though not reflected in the averages, felling and bucking in young stands is more expensive than in older. The top cost in the range—$5.11 per 100 cubic feet—occurred in a first thinning in a 40-year-old stand where hang-ups were common. Hang-ups increase skidding cost because the time required to pull the trees down is charged to skidding.

Cost of loading is 14 percent of the total cubic-foot cost, but only 10 percent of board-foot cost. This difference results in part from the difficulty of finding a suitable means of loading small material in the earlier years of the experience record.

Hauling cost is 17 percent of the total by cubic feet and 14 percent by board feet. Averages, however, are not very meaningful as cost is largely dependent on distance hauled. Hauling distance varied from 5 to 25 miles in the examples given.

Miscellaneous costs include charges for supervision, bookkeeping, and office expenses. In two examples, both part of the board-foot cost data, miscellaneous costs include machine depreciation, which in other instances is included in the extraction process to which it applies.

Both first and repeat thinning costs are included in table 14. Insufficient data are available to determine just how much cheaper second and succeeding thinnings are than first. It is estimated, however, that felling costs for second thinnings should be 10 to 20 percent less than for first thinnings, at least in young stands where hang-ups are a problem. Skidding costs, likewise, should be 10 to 20 percent less after the skid roads have been located and cleared out in the first thinning.

To obtain total costs, the road charges as previously outlined and the forester's costs for layout, marking, and sale administration must be added to the extraction costs.

RETURNS

Stands in which commercial thinning is practiced are more valuable because of (1) increased income resulting from greater yields or more valuable yields, or both; (2) income throughout rotation, which profoundly affects interest costs; and (3) higher return on the investment in growing stock resulting from reduction in growing stock without comparable reduction of increment. For the small owner there is also the possibility of remunerative self-employment in thinning, frequently an important consideration, although it may not actually affect the stand's monetary value.

Complete discussion of valuation concepts and techniques required to compare the value of managed versus unmanaged stands is beyond the scope of this bulletin. However, in the sections that follow, immediate returns from thinning based on experience data, effect of thinning on stand value, and labor returns will be discussed.

Conversion Returns

"Conversion return" as used in forest valuation (*10, p. 411*) is the immediate return from a commercial thinning; i.e., the money left from the sale of products after paying direct costs of extraction, including an appropriate road charge. Conversion return is available to pay the profit and risk of logging and stumpage. Although stumpage, in the conventional sense, may be determined for commercial thinning, the negative value resulting in many cases is misleading and discourages the application of commercial thinning. Preferably, only direct extraction costs and the annual road cost should be charged to thinning, and any margin, however small, should be regarded as either profit or stumpage.

As previously emphasized, conversion return from commercial thinning depends mostly on the age of the stand being thinned. Size of trees that may be cut controls value of harvestable products and cost of extraction; for a given site, size, in turn, depends largely on age.

In young stands conversion return may be nil, but thinning may still be highly desirable because of the possibility of substantial silvicultural benefits that will be reflected later in increased returns. In older stands conversion return may be substantial but silvicultural benefit very small. In either case, commercial thinning should be considered financially desirable.

Frequently, salvage of remnants of an original stand contributes substantially to immediate returns from first thinnings. This opportunity should not be overlooked as a means of making earlier thinnings possible.

Conversion returns (before deduction of road charges) for several pilot scale thinning examples are shown in table 15. These are the same examples for which extraction costs were presented in table 14. Clearly, not all trials were financially successful. This was due more to costs that were out of line than to abnormally low product prices. The variation indicates that experience with commercial thinning is of the utmost importance in assuring a profitable operation. Stable conversion returns and stumpage values are not easily determined for this reason.

Product prices vary widely from year to year and from place to place, and are strongly influenced by local supply and demand. For these reasons, foresters embarking upon a commercial thinning program should investigate markets closely. Typical prices prevailing in the Puget Sound area in the summer of 1957 are given in table 10.

Comparison with cost figures in table 14 give another estimate of possible immediate returns.

In general, small diameter products are also low-value products (table 10). Small products are also the most expensive to produce. Yet silvicultural benefits are most pronounced when thinning is begun early and only small products can be cut. This points up the necessity for energetically pursuing or creating new, small-product markets, and for learning how to extract these products most effectively. Otherwise, full advantage cannot be taken of silvicultural benefits that will assure maximum deferred return, and at the same time provide positive conversion return.

TABLE 15.—*Examples of typical returns in commercial thinning*

Project [1]	Stand age	Immediate return [2] per—		
		100 cu. ft.	1,000 bd. ft.	Acre
	Years	*Dollars*	*Dollars*	*Dollars*
Voight Creek	40	3. 14		17. 19
Hemlock	50	4. 57		30. 28
McCleary	55	7. 00	12. 51	55. 36
Hood Canal	65	5. 64	9. 71	42. 62
Big Creek	70	6. 06	10. 38	76. 00
Mount Walker	75		−6. 58	−28. 51
Fall Creek	90		11. 33	103. 60
Wind River	110		13. 80	98. 72

[1] See appendix, table 17 for pertinent descriptive information concerning these examples.

[2] Sale price of primary products at point of delivery (except Voight Creek, where value at roadside is used) less extraction costs, but before deduction of road charge. An appropriate annual per-acre road charge multiplied by the number of years between thinnings should be deducted from the per-acre return shown in the last column for "conversion return" as defined in the text.

Valuation

Thinning, wisely done, results in a more valuable reserve stand—values that are recovered in later thinnings or final harvest. Commercial thinning does not yet have adequate experience data from which to accurately predict the long time effects of sound thinning practices. Nor can values be even approximately foretold. Estimates and predictions must be made, however, in order to have some idea of the financial aspects of management.

Estimates made thus far on the value of continuously thinned stands consistently indicate a financial advantage for thinning (*20*, *72*). As an example of probable values, we have used the same site III stand previously used to illustrate total yields (p. 51). Resultant yields and values for a thinned and an unthinned stand are presented in table 16. According to this forecast, 27.5 M board feet would be removed in seven thinnings at 10-year intervals prior to age 100. Undoubtedly the thinning would have to be started not later than age 30 to produce a stand averaging 21.5 inches in d.b.h. at 100 years. Actually, trees smaller than 12 inches would have to be cut in addition to larger trees. No value is given to these smaller trees, however, since they do not contribute to board-foot volume. Values given are conversion return values discussed in a previous section—the income available to pay for stumpage, profit, and risk. Values assumed range from $5 per M for material cut between ages 25 and 35 to $20 per M for material cut after age 85. Trees cut at final harvest are assumed to be worth $22 per M, $2 more than the smaller, lower quality trees in the unthinned stand. Admittedly these are generalized values, but they conform fairly well to experience, as shown in table 16.

TABLE 16.—*Illustration of the valuation of 1 acre of thinned and unthinned stands on site III*

Item	Age	Volume [1]	Value per M bd. ft.	Total value		Net value [3] at age 100
				Gross	Net [2]	
	Years	*M bd. ft.*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Thinned stand						
Thinnings	25–35	1. 0	5. 00	5	4	62
	35–45	3. 5	7. 50	26	23	242
	45–55	5. 5	10. 00	55	48	341
	55–65	5. 5	12. 50	69	60	288
	65–75	4. 5	15. 00	68	60	195
	75–85	4. 0	17. 50	70	61	134
	85–95	3. 5	20. 00	70	61	90
Total thinnings		27. 5		363	317	1, 352
Final harvest	100	47. 7	22. 00	1, 049	918	918
Total yield		75. 2		1, 412	1, 235	2, 270
Less annual charges [4]					20	248
Net income					1, 215	2, 022
Unthinned stand						
Final harvest	100	62. 8	20. 00	1, 256	1, 099	1, 256
Less annual charges [4]					20	248
Net income					1, 079	1, 008

[1] Yield forecast described on p. 41.
[2] Gross value less 12½ percent yield tax.
[3] Interest at 4 percent.
[4] Annual cost of 20 cents per acre includes reforestation and ad valorem tax, 5 cents; fire patrol tax, 7 cents; administration, risk, etc., 8 cents.

Total value of the thinnings before taxes is $363, an average of $13.20 per M. The final crop is worth $1,049, making the total income from the 75.2 M board feet harvested from the thinned stand $1,412. After payment of yield taxes and annual charges of 20 cents per acre for ad valorem taxes, fire patrol tax, and administration, the income is $1,215.

In contrast, the unthinned stand with normal yield table volume of 62.8 M board feet at 100 years is worth \$1,256 at \$20 per M, or \$1,079 after taxes and administration charges.

Difference in income between the thinned and unthinned stands, \$156 per acre before taxes or \$136 after, may be ascribed to the silvicultural benefits of thinning. Part of the higher income in the thinned stand results from increased yield and part from increased value per M of final harvest trees, a reflection of their higher quality. As discussed on page 41, the increased yield of 12.4 M board feet is a result of transferring, by thinning, 2,660 cubic feet of wood that dies or ends up in small trees in the normal forest to harvested trees larger than 12 inches. This 2,660 cubic feet includes 900 cubic feet normally dying in 12-inch and larger trees, 1,110 cubic feet dying in 11-inch and smaller trees, and 650 cubic feet in live trees less than 12 inches, normally present in the 100-year-old forest.

The incomes obtained prior to rotation age earn interest to the end of the rotation, either by being invested elsewhere or by being used to pay current costs that otherwise would have to be accumulated to the end of the rotation. These early incomes are tremendously valuable and directly help to make intensive thinning a profitable practice. In the example given, income from thinnings accumulated at 4 percent is worth \$1,352 at the end of the rotation. If this thinning income is added to the final harvest income after deduction of the accumulated charges, the thinned stand is worth twice as much as the unthinned.

Another aspect of the valuation problem is return on the capital investment. This aspect is important because forest industry characteristically is very highly capitalized. Interest on capital represents a large part of the cost of forestry. A forester wishing to earn a high rate of interest on his capital must seek forms of cultivation that require small amounts of growing stock in relation to income yield (*21, p. 29*). Thinning affords a major avenue for attaining this objective.

Again, no sound data are available to properly appraise the effects of a thinning program on the interest on capital investment. From the example given in table 16, however, we may calculate that an acre of land with an established stand not yet 1 year old and costing \$30 will earn 4.4 percent compound interest on the original investment and money required for annual charges if held to 100 years and thinned as prescribed. If not thinned, the \$30 and investment in annual charges will earn interest at the rate of 3.5 percent. With interest at 4 percent, the thinned stand is worth \$40 per acre and the unthinned \$20 per acre at time of establishment.

The authors recognize that this discussion of valuation is based on a theoretical example with inadequate supporting data. However, the example is believed to be highly conservative; many experienced foresters would use more optimistic values.

Labor Return

The forest owner may frequently find profitable employment in doing his own thinning. For farmers, rural residents, and people liking outdoor work this woods employment can be an attractive return from thinning, in addition to the values just discussed. If alternative sources of employment are not available, or are low paying, such a forest owner may find it worth while to thin his stand though he gets only a reasonable wage and no stumpage or profit for his efforts. In this way he may be able to thin a stand not otherwise suitable for commercial thinning and thereby greatly improve his chance of increased later returns resulting from silvicultural benefits.

Table 8, page 65, shows that an average of 3.91 man-hours is required to extract a cord of wood in thinnings from young stands (83 percent of the time per 100 cu. ft.). Thus, the owner-worker may expect to add, at $2 an hour, $7.82 per cord to his income from stumpage.

Felling, bucking, and skidding take 68 percent of total extraction time, or 2.66 hours per cord. These jobs may be undertaken by a small forest owner since the equipment needed is easily acquired and operated. If horses are used for skidding, the capital outlay required is comparatively small. At $2 per hour these jobs represent $5.32 per cord.

In a year, one man working 200 days could expect to produce about 400 cords of wood if he did all the work connected with extraction, or 600 cords if he did only the felling, bucking, and skidding. His labor would yield him a little over $3,000 in either case.

A first cut of 6 to 10 cords per acre on 100 acres would easily keep one man busy for a full year in just felling, bucking, and skidding. Assuming $3 per cord for stumpage, profit, and risk, an owner-laborer would have a gross income of about $5,000 for his year's work.

The owner-worker is in excellent position to take advantage of specialized markets, and to salvage irregular mortality. In addition, he will likely develop a keener interest in his forest, which in turn will help ensure proper care and application of other desirable silvicultural practices such as pruning and stand improvement.

SUMMARY

Commercial thinning—thinning that pays its way—has tremendous potentialities in the Douglas-fir type in the Douglas-fir subregion, possibly adding as much as 3½ million cords, or 1¾ billion board feet, to the region's sustained-yield capacity. Although not yet widely practiced, extensive trials have shown that in accessible stands near favorable markets, thinning will not only substantially increase usable production of the forest but will also return an immediate profit.

The essence of good thinning practice, however, is not only to realize a present profit, but also to leave the stand in a condition that will enhance future returns—in short, the thinning must be silviculturally sound. This bulletin therefore devotes considerable space to the theory of thinning with special reference to silvical characteristics of Douglas-fir. A thorough understanding of this aspect is necessary for development of the sound judgment required to apply thinning to best advantage.

Douglas-fir is an intolerant species. Stagnation is almost nonexistent, occurring, if at all, only on the very poorest sites. However,

even on better sites, stocking is frequently so dense that, without thinning, crowns become greatly shortened. As a result, diameter growth is reduced far below optimum.

In younger stands—less than about 70 years—this condition may be remedied by thinning, which releases chosen trees and stimulates their growth. The more rapid diameter growth affects management by greatly improving growth-growing stock relations.

In older stands, as well as younger, thinnings that liquidate the investment in slow growing, nonproductive trees are valuable because mortality is salvaged or forestalled and growth efficiency of the remaining stand increased.

A thinning to be commercially successful requires a rather specialized labor supply, accessible stands on favorable topography, and suitable markets. At the present stage of development, commercial thinning is a marginal operation, particularly if applied to young stands where it can do the most good in the long run. As such, it requires careful organization and attention to details. The most successful jobs are those that are kept small and are operated with simple, inexpensive equipment.

Type of equipment should be governed by the stand thinned and the products removed. Horses have been found most efficient for skidding small products, and tractors for large products, with considerable overlapping where either may be used, depending on factors other than tree size. Highly mobile loaders are required. They must be inexpensive, unless the thinning can be organized to permit their continuous use, with resultant high production. Trucks, likewise, need to be utilized at or near capacity to keep high fixed charges at a minimum per unit volume.

Small, flexible, contract crews are best for commercial thinning. Proper crew organization can do much toward holding costs at a reasonable level.

Recommended thinning follows no classical silvicultural method. Because only salable trees are removed in commercial thinning, the lower limit of merchantability will first of all determine the kind of thinning. Secondly, the stand itself—whether or not released trees will respond with increased growth—exercises control. If stands are thinned as soon as the largest trees reach commercial size, a selection thinning will be feasible, provided that the stand is young and responsive. In stands of medium age, crown thinning is desirable and may be practiced if the trees available for cutting are of merchantable size. In old stands, only a low thinning is silviculturally desirable, and the possibilities for commercial thinning depend on the marketability of trees in the suppressed and intermediate crown classes. Marking guides are presented that will provide for such a sequence of thinning methods.

Desirable volume to remove—or to reserve—cannot be categorically specified because the kind of stand to be thinned exercises so much control, and also because adequate experience data have not been accumulated. In general, a much lower level of growing stock may be maintained in continuously thinned stands than in unthinned.

Frequency of thinning in young stands should be related to the capacity of tree crowns to absorb new room. In general, thinnings should be made every 3 to 5 years. In older stands the interval can be lengthened, but it should be short enough to permit maximum salvage of mortality. First thinnings are ordinarily heavier than second and later thinnings.

In the absence of trials extending over long periods, long-term financial effects of thinning are virtually unknown. Reasonable hypotheses of what thinning should accomplish combined with what little experience data are available, however, are used to project yields and values. These projections indicate real financial advantages from thinning, in addition to increased total yields. Cost experience shows that well-conducted thinning operations can also be a source of immediate income to the forest owner.

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APPENDIX

NOTE: Italic numbers in parentheses in footnotes to the tables on the following pages refer to source material listed on page 124.

The 20 tables presented should be helpful to anyone managing young-growth Douglas-fir timber. Other than compilation of tables 17 and 30 and the specifications for forest products, no original work is involved, although some revisions have been made.

Most of the tables are self-explanatory, but the application of several may require clarification. Tables 24–26 shortcut tree-volume estimation through elimination of the height variable, and should prove useful where tree height determination is not practicable. Table 27 gives cubic volume of tree segments lying between several minimum top diameter limits now commonly observed. It should facilitate estimation of additional production through improved utilization practice. Table 29 illustrates the large differences that often accrue between long and short logs scaled by the Scribner rule. Table 33 gives gross and net yields, and mortality in cubic feet and board feet of stands by site classes. Gross figures give a closer approximation of commercial yields, where thinning is consistently practiced, than do net figures.

The number, and title, of the 20 tables are as follows:

Table 17.—*Pertinent data concerning thinning projects used to illustrate man-hour requirements, costs, and returns in tables 8, 14, and 15*

Project and location	Stand age	Site class	Date of thinning	Area thinned	Products	Skidding medium	Board-foot volume removed: Total	Board-foot volume removed: Per acre	Cubic-foot volume removed: Total	Cubic-foot volume removed: Per acre	Percent of volume removed	D.b.h. cut trees: Average	D.b.h. cut trees: Minimum	Remarks
	Years			*Acres*			*M bd. ft.*	*M bd. ft.*	*M cu. ft.*	*Cu. ft.*		*Inches*	*Inches*	
Voight Creek Expt. Forest, Pierce County, Wash.	40	III	1951–57	175	Saw logs, pulpwood, poles, etc.	Horse			93	250–1,800	9–39	8.8–13.2	6	10 separate jobs.
Hemlock Expt. Forest, Grays Harbor County, Wash.	50	III	1955–56	50	Pulpwood, saw logs (8 ft.).	do			33	660	8	10.0	5	Western hemlock forest type; 2 separate jobs.
Cowichan Lake Expt. Forest, Vancouver Island, British Columbia.	50	II	1951–52	50	Saw logs	Horses	698	14.0	134	2,684	39	10.2	7	
McCleary Expt. Forest, Grays Harbor County, Wash.	55	II	1951–55	200	Saw logs (16–32 feet), pulpwood.	Tractor	885	2.5–6.0			11	15.7	9	5 separate jobs; pulpwood all alder.
Hood Canal Expt. Forest, Kitsap County, Wash.	65	III	1953	100	Saw logs	do	439	4.4			10	15.5	11	
Big Creek, Snoqualmie National Forest, Lewis County, Wash.	70	II	1950–51	90	do	Horses, tractor.	659	7.3			[illegible]	13.8	11	
Mt. Walker, Olympic National Forest, Jefferson County, Wash.	75	III	1949–51	83	do	do	370	4.3			16	13.5	10	Small trees marked for poles were utilized as saw logs.
Fall Creek, Willamette National Forest, Lane County, Oreg.	90	III	1948–49	69	do	Tractor	631	9.1			19	16.1	12	
Wind River Expt. Forest, Gifford Pinchot National Forest, Skamania County, Wash.	110	III	1951–53	113	do	do	768	6.8			12	19.4	10	40 acres was a second thinning.

TABLE 18.—*Board-foot contents of logs 8 to 32 feet long*

SCRIBNER RULE [1]

Top d.i.b. (inches)	Length of log in feet												
	8	10	12	14	16	18	20	22	24	26	28	30	32
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
6	6	8	9	11	12	14	16	17	19	20	22	23	25
7	10	13	16	18	21	23	26	28	31	34	36	39	41
8	15	19	23	27	31	34	38	42	46	50	53	57	61
9	21	26	31	37	42	47	52	58	63	68	73	79	84
10	28	34	41	48	55	62	69	76	82	89	96	103	110
11	35	43	52	61	70	78	87	96	104	113	122	130	139
12	43	54	64	75	86	96	107	118	129	139	150	161	172
13	52	65	78	91	104	116	129	142	155	168	181	194	207
14	61	77	92	107	123	138	154	169	184	200	215	230	246
15	72	90	108	126	144	162	180	198	216	234	252	270	288
16	83	104	125	145	166	187	208	229	249	270	291	312	332
17	95	119	143	167	190	214	238	262	285	309	333	357	381
18	108	135	162	189	216	243	270	297	324	351	378	405	432
19	122	152	182	213	243	274	304	334	365	395	426	456	486
20	136	170	204	238	272	306	340	374	408	442	476	510	544
21	151	189	227	265	302	340	378	416	454	491	529	567	605
22	167	209	251	293	334	376	418	460	502	543	585	627	669
23	184	230	276	322	368	414	460	506	552	598	644	690	736
24	202	252	302	353	403	453	504	554	605	655	705	756	806

INTERNATIONAL RULE (¼-INCH KERF)[2]

6	8	10	13	16	19	23	27	31	36	41	46	52	58
7	12	15	19	24	28	33	38	44	50	57	64	71	79
8	17	22	27	33	39	45	52	60	67	76	84	94	103
9	22	29	36	43	51	59	68	77	87	97	108	119	131
10	29	38	46	56	65	75	86	97	109	121	134	148	162
11	36	46	57	68	80	92	105	119	133	148	163	179	195
12	44	56	69	83	97	112	127	143	160	177	195	214	233
13	53	68	83	99	115	133	151	169	188	208	229	251	273
14	63	80	98	117	136	156	176	198	220	243	267	291	316
15	73	93	114	135	157	180	204	229	254	280	307	335	363
16	84	108	131	156	181	207	234	262	290	320	350	381	413
17	96	122	149	177	206	235	265	296	328	361	395	430	466
18	109	139	169	200	232	265	299	334	369	406	444	483	522
19	123	156	190	225	260	297	334	373	413	454	495	538	581
20	137	174	211	250	290	331	372	415	458	504	549	596	644
21	153	194	235	278	321	366	412	459	506	556	606	658	710
22	168	214	259	306	354	404	453	505	557	611	665	722	779
23	185	235	285	336	388	442	497	553	610	669	728	789	851
24	203	257	311	368	424	483	542	604	665	729	793	859	926

[1] Source: Table 2, *The Formula Scribner Log Rule (A9)*. Formula, 16 ft. log: $V=0.79D^2-2D-4$,

[2] Formula for 4-foot section: $0.905(0.22D^2-0.71D)$. Taper allowance ½ inch per 4 lineal feet.

TABLE 19.—*Cubic volume of young-growth Douglas-fir trees by diameter and total height* [1]

D.b.h. (inches)	Total height of tree in feet														
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
6	1.9	2.7	3.4	4.1	4.8	5.6	------	------	------	------	------	------	------	------	------
7	3.0	4.0	5.1	6.0	7.1	8.3	------	------	------	------	------	------	------	------	------
8	3.1	5.4	6.8	8.0	9.5	11.1	12.1	13.2	14.6	16.0	------	------	------	------	------
9	5.3	7.1	8.7	10.4	12.3	14.1	15.4	16.9	18.7	20.4	------	------	------	------	------
10	6.6	8.7	10.6	12.9	15.1	17.2	18.8	20.7	22.9	24.8	27.3	------	------	------	------
11	8.1	10.7	13.0	15.7	18.2	20.5	22.8	25.0	27.9	30.2	33.0	------	------	------	------
12	9.7	12.6	15.5	18.6	21.3	24.3	26.6	29.4	32.9	35.7	38.7	42.2	46.0	------	------
13	11.2	14.7	18.0	21.7	24.9	28.5	31.4	34.7	38.3	41.8	45.2	49.3	53.6	------	------
14	12.8	16.8	20.6	24.8	28.6	32.8	36.3	40.0	43.6	48.0	51.8	56.4	61.2	65.8	70.0
15	------	19.2	23.5	28.1	32.7	37.8	41.5	45.6	49.4	54.5	58.6	64.1	69.4	74.4	79.7

16	--	21.6	26.5	31.5	36.8	41.9	46.7	51.2	55.2	61.0	65.5	71.8	77.7	83.0	89.4
17	--	--	29.6	35.3	41.0	46.5	51.9	57.2	61.4	67.5	72.7	79.9	86.8	92.5	99.7
18	--	--	32.8	39.2	45.2	51.2	57.1	63.3	67.7	74	80	88	96	102	110
19	--	--	36.1	43.1	49.7	56.2	62.5	69.2	74.1	81	88	96	105	112	121
20	--	--	39.5	47.0	54.2	61.2	67.9	75.1	80.6	88	96	105	114	123	133
21	--	--	43.2	50.9	58.8	66.4	73.6	81.0	87.3	96	104	113	123	133	143
22	--	--	47.0	54.8	63.5	71.6	79.3	86.9	94	103	112	121	133	144	154
23	--	--	--	59.1	68.3	76.7	85.1	92.5	100	110	119	129	141	153	165
24	--	--	--	63.5	73.2	81.9	91.0	98.2	107	117	126	137	150	163	177
25	--	--	--	--	--	87.3	97	105	114	124	134	145	160	174	188
26	--	--	--	--	--	92.8	103	112	121	131	142	154	170	185	200
27	--	--	--	--	--	--	108	119	128	139	150	163	179	195	212
28	--	--	--	--	--	--	113	126	136	147	159	172	189	206	224
29	--	--	--	--	--	--	120	132	143	154	167	181	199	217	236
30	--	--	--	--	--	--	128	139	150	161	175	190	209	228	248

[1] Source: Table 5, *Volume Tables for Pacific Northwest Trees (a compilation)* (*A4*). Volumes are stem volumes, exclusive of bark and limb, between stump and 4-inch top d.i.b. Stump height equal to d.b.h. with a maximum of 24 inches.

TABLE 20.—*Board-foot volume of young-growth Douglas-fir trees by diameter and total height (International ¼-inch kerf; 16-foot logs* [1]*)*

D.b.h. (inches)	Total height of tree in feet														
	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
8	13	17	25	33	40	50	57	67	75	------	------	------	------	------	------
9	16	24	35	44	54	69	80	93	104	115	------	------	------	------	------
10	------	31	44	57	72	88	103	119	134	151	167	------	------	------	------
11	------	40	53	70	90	109	128	147	169	189	209	------	------	------	------
12	------	48	67	87	108	131	153	176	203	230	255	284	------	------	------
13	------	57	80	101	128	157	183	212	240	269	300	334	372	------	------
14	------	------	92	119	148	180	214	245	277	310	348	386	432	472	------
15	------	------	------	138	169	207	242	280	316	352	395	437	490	533	------
16	------	------	------	157	191	233	272	314	354	395	444	491	551	596	------
17	------	------	------	177	213	260	303	348	394	441	493	548	611	662	734
18	------	------	------	------	237	289	334	383	435	486	546	605	673	732	806
19	------	------	------	------	259	314	365	419	475	529	594	662	733	799	879
20	------	------	------	------	------	340	398	456	519	578	647	720	796	874	959
21	------	------	------	------	------	------	432	495	561	625	699	779	862	950	1,040
22	------	------	------	------	------	------	468	535	605	674	752	839	928	1,028	1,123
23	------	------	------	------	------	------	504	574	649	720	805	900	995	1,102	1,206
24	------	------	------	------	------	------	540	614	693	769	861	961	1,063	1,181	1,291
25	------	------	------	------	------	------	577	656	738	819	915	1,024	1,135	1,257	1,377
26	------	------	------	------	------	------	616	699	784	871	971	1,090	1,207	1,338	1,463
27	------	------	------	------	------	------	657	744	833	924	1,031	1,157	1,283	1,420	1,553
28	------	------	------	------	------	------	------	789	883	981	1,093	1,224	1,361	1,503	1,648
29	------	------	------	------	------	------	------	------	938	1,040	1,157	1,294	1,443	1,590	1,744
30	------	------	------	------	------	------	------	------	991	1,098	1,221	1,364	1,526	1,673	1,839

[1] Source: Table 10, *Volume Tables for Pacific Northwest Trees (a compilation) (A4)*. Volumes are gross and exclude (1) top above 6 inches d.i.b., (2) a 1.5-foot stump, and (3) a 0.3-foot trimming allowance for each 16-foot log.

TABLE 21.—*Board-foot volume of young-growth Douglas-fir trees by diameter and total height (Scribner rule; 16-foot logs)*[1]

D.b.h. (inches)	Total height of tree in feet												
	50	60	70	80	90	100	110	120	130	140	150	160	170
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
10	23	28	33	37	41	44	---	---	---	---	---	---	---
11	30	43	55	63	69	73	---	---	---	---	---	---	---
12	32	50	69	87	105	124	140	155	176	196	225	---	---
13	39	61	83	107	130	150	170	190	212	238	270	---	---
14	47	74	101	129	155	175	201	225	252	282	318	354	---
15	---	88	118	148	180	207	233	262	290	324	364	410	---
16	---	102	136	170	205	235	265	296	330	368	410	466	---
17	---	115	154	193	230	263	296	331	370	412	460	522	584
18	---	---	174	215	257	294	329	367	410	460	510	580	640
19	---	---	192	239	283	325	363	403	450	508	564	640	710
20	---	---	213	262	311	355	397	440	494	558	618	694	774
21	---	---	---	285	338	388	438	480	538	608	676	754	844
22	---	---	---	309	367	420	470	520	584	658	732	820	914
23	---	---	---	---	397	455	507	562	630	708	788	882	986
24	---	---	---	---	426	489	545	607	676	758	848	950	1,058
25	---	---	---	---	458	524	584	648	724	811	909	1,018	1,134
26	---	---	---	---	492	562	626	692	770	866	971	1,088	1,210
27	---	---	---	---	524	598	666	728	821	920	1,034	1,158	1,287
28	---	---	---	---	---	638	708	782	870	975	1,096	1,230	1,368
29	---	---	---	---	---	674	750	828	920	1,032	1,162	1,304	1,450
30	---	---	---	---	---	712	792	876	972	1,088	1,228	1,379	1,536

[1] Source: Table 11, *Volume Tables for Pacific Northwest Trees (a compilation)* (*A4*). Volumes are gross, and exclude (1) top above 8 inches d.i.b., (2) a 2-foot stump, and (3) a 0.3-foot trim allowance for each 16-foot log.

TABLE 22.—*Board-foot volume*[1] *of young-growth Douglas-fir trees by form class,*[2] *diameter, and log length (Scribner rule)*

Form class and d.b.h. (inches)	Number of 16-foot logs								
	1	2	3	4	5	6	7	8	9
Form Class 76:	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
12	40	70	110						
14	60	90	140	190					
16	90	120	180	240	310				
18		150	230	310	380				
20		180	270	370	460	560			
22			330	450	570	680			
24			410	550	690	830			
26			490	620	830	1,000			
28				780	980	1,180	1,380	1,570	1,770
30				910	1,140	1,370	1,600	1,830	2,060
Form Class 80:									
10	30								
12	50	80	120						
14	70	100	160	210	260				
16	100	130	200	270	340				
18		160	250	340	420				
20		200	300	410	510	620			
22			380	510	640	770			
24			460	620	780	930			
26			550	740	930	1,120	1,300	1,490	1,680
28				870	1,090	1,320	1,540	1,760	1,980
30				1,020	1,270	1,530	1,780	2,040	2,300
Form Class 84:									
10	30								
12	60	90	130	170					
14	80	110	170	230	290				

16	110	140	220	290	370	------	------	------	------
18	------	180	270	360	460	550	------	------	------
20	------	220	340	460	570	690	------	------	------
22	------	------	420	570	710	860	------	------	------
24	------	------	510	690	860	1,050	1,220	1,400	1,570
26	------	------	610	820	1,030	1,240	1,450	1,660	1,860
28	------	------	------	970	1,210	1,460	1,710	1,950	2,200
30	------	------	------	1,130	1,410	1,700	1,990	2,270	2,560

[1] Source: Tables for estimating board-foot volume of trees in 16-foot logs (*A2*). Table shows gross volumes to a top diameter that is 50 percent of the scaling diameter of the butt 16-foot log, but not less than 8 inches. Values for 10-inch trees have been added.

[2] Form class is percentage ratio between the diameter inside bark at top of first log and diameter outside bark at breast height of tree.

TABLE 23.—*Cord volume of young-growth Douglas-fir trees by diameter and total height* [1]

D.b.h. (inches)	Total height of tree in feet												
	30	40	50	60	70	80	90	100	110	120	130	140	150
	Cords	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*
6	0.024	0.034	0.042	0.051	0.060	0.070	------	------	------	------	------	------	------
8	.052	.068	.085	.100	.119	.139	0.151	------	------	------	------	------	------
10	.081	.107	.131	.159	.186	.212	.232	0.259	0.286	0.310	------	------	------
12	.120	.156	.191	.229	.263	.300	.328	.363	.406	.441	------	------	------
14	.156	.205	.251	.302	.353	.405	.448	.494	.538	.593	0.640	0.696	------
16	------	.263	.323	.384	.449	.511	.570	.624	.673	.744	.799	.876	0.948
18	------	------	.400	.478	.551	.624	.696	.772	.826	.902	.976	1.070	1.171
20	------	------	.482	.573	.661	.746	.828	.916	.983	1.073	1.171	1.280	1.390
22	------	------	.566	.660	.765	.863	.955	1.047	1.133	1.241	1.349	1.458	1.602
24	------	------	------	.756	.871	.975	1.083	1.169	1.274	1.393	1.500	1.631	1.786

[1] Source: Table 26, *Volume Tables for Pacific Northwest Trees (a compilation)* (*A4*). Volumes are stem volumes including bark between stump and a 4-inch top d.i.b. Stump height equal to d.b.h. Cordwood assumed to be cut in 8-foot lengths.

Table 24.—*Cubic-foot volumes of young-growth Douglas-fir trees by d.b.h. and stand age for site classes II, III, and IV* [1]

Site class II (S.I. 170 feet)

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Cu. ft.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
6	3.9	4.6	4.9	5.0	------	------	------	------
7	6.2	7.3	7.8	8.1	------	------	------	------
8	9.2	10.5	11.3	11.7	------	------	------	------
9	12.5	14.4	15.4	16.0	------	------	------	------
10	16.4	18.8	20.2	21.0	21.4	21.6	------	------
11	20.6	23.8	25.6	26.8	27.4	27.7	------	------
12	25.2	29.4	31.5	33.2	34.0	34.7	------	------
13	30.2	35.4	38.0	40.0	41.4	42.3	------	------
14	35.7	42.0	45.1	47.3	49.2	50.3	------	------
15	41.6	49.2	52.7	55.0	57.3	58.8	------	------
16	48.0	56.7	60.6	63.6	66.1	68.0	68.7	68.8
17	54.6	64.7	69.0	72.7	75.4	77.8	79.0	79.6
18	61.5	72.8	77.7	82.3	85.5	88.4	90.1	91.0
19	68.5	80.7	86.7	92.5	96.2	100.1	101.8	102.7
20	75.6	89.6	96.1	102.8	107.4	112.0	114.0	115.0
21	82.6	98.4	106.0	113.5	118.9	124.1	126.2	127.7
22	90.0	107.7	116.0	124.5	130.5	136.3	138.7	140.7
23	------	117.3	126.1	135.7	142.0	148.7	151.1	154.0
24	------	127.0	136.5	146.8	154.1	161.1	164.3	167.6
25	------	137.0	147.0	158.8	167.0	174.4	178.0	181.3
26	------	146.8	158.6	171.1	180.2	188.1	192.2	195.9
27	------	------	170.2	184.0	194.0	202.1	207.0	211.4
28	------	------	182.4	197.4	207.8	216.7	222.2	228.0
29	------	------	195.1	210.8	221.8	231.2	238.5	245.0
30	------	------	207.8	224.9	236.3	246.6	255.2	262.4
Site class III (S.I. 140 feet)								
6	3.6	4.5	4.6	4.7	------	------	------	------
7	5.8	7.1	7.3	7.4	7.5	------	------	------
8	8.3	10.1	10.5	10.8	11.1	------	------	------
9	11.4	13.4	14.0	14.4	14.8	------	------	------
10	15.0	17.3	18.0	18.7	19.3	------	------	------
11	18.7	21.7	22.7	23.6	24.5	------	------	------
12	22.7	26.4	27.8	28.9	30.0	31.0	31.6	------
13	27.1	31.9	33.4	34.8	36.0	37.4	38.0	------
14	32.2	37.9	39.5	41.4	43.2	44.8	45.5	45.6
15	37.6	44.1	46.0	48.3	50.6	52.4	53.3	53.4
16	43.5	50.8	52.9	55.8	58.4	60.5	61.7	61.9
17	------	57.4	60.0	63.5	66.4	68.9	69.8	70.2
18	------	64.4	67.6	71.7	74.9	77.6	78.8	79.4
19	------	71.2	75.3	80.0	83.7	87.0	88.1	88.9
20	------	78.4	83.5	88.8	92.9	96.7	98.4	99.2
21	------	------	91.9	97.9	102.4	106.7	108.6	109.8
22	------	------	100.4	107.2	112.1	117.0	119.3	120.7
23	------	------	109.3	116.1	122.0	127.5	130.2	132.0
24	------	------	118.4	125.8	132.0	138.1	141.2	143.2
25	------	------	------	135.5	142.2	149.0	152.4	154.8
26	------	------	------	145.5	153.1	160.5	164.4	167.2
27	------	------	------	155.8	164.0	172.1	176.7	179.8
28	------	------	------	166.2	175.2	183.8	189.0	192.4
29	------	------	------	------	187.0	196.1	201.4	205.2
30	------	------	------	------	199.5	208.6	214.7	218.2

See footnote at end of table.

TABLE 24.—*Cubic-foot volumes of young-growth Douglas-fir trees by d.b.h. and stand age for site classes II, III, and IV* [1]—Continued

Site class IV (S.I. 110 feet)

D.b.h. (Inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
6	3.4	3.8	4.0	4.1	4.2	4.3		
7	5.4	6.1	6.3	6.5	6.7	6.8		
8	7.8	8.8	9.1	9.3	9.6	9.8	10.0	10.1
9	10.8	12.0	12.3	12.6	12.9	13.2	13.5	13.6
10	14.1	15.6	16.1	16.4	16.8	17.2	17.5	17.8
11		19.6	20.2	20.8	21.3	21.7	22.0	22.4
12		23.7	24.7	25.6	26.2	26.6	27.1	27.6
13		28.4	29.6	30.8	31.7	32.1	32.6	33.3
14		33.2	34.9	36.7	37.4	37.9	38.5	39.3
15		38.1	40.4	42.8	43.5	44.1	45.0	45.7
16			47.2	49.4	50.2	50.8	51.8	52.5
17			54.1	56.4	57.2	57.9	59.0	59.8
18			61.2	63.3	64.3	65.1	66.4	67.3
19			68.1	70.2	71.4	72.5	73.9	75.0
20			75.1	77.3	78.5	79.8	81.4	82.8
21				84.5	86.1	87.5	89.4	91.0
22				92.0	94.0	95.8	97.8	99.5
23				99.7	102.0	104.3	106.5	108.3
24				107.4	110.0	112.6	115.3	117.1
25						120.4	123.4	125.5
26						128.9	132.2	134.4
27								144.2
28								155.4
29								
30								

[1] Source: Prepared from table 5, *Volume Tables for Pacific Northwest Trees* (*A4*), using appropriate d.b.h., age, and site class from *Height Curves for Even-aged Stands of Douglas-fir* (*A8*). Interpolated volumes curved by d.b.h. and age. Volumes are stem volumes, exclusive of bark and limbs, between stump and 4-inch top d.i.b. Stump height equal to d.b.h. with a maximum of 24 inches.

Table 25.—*Board-foot volumes of young-growth Douglas-fir trees by d.b.h. and stand age for site classes II, III, and IV (International rule ¼-inch kerf)* [1]

Site class II (S.I. 170 feet)

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
8	39	50	54	56	-------	-------	-------	-------
9	60	77	83	86	87	88	-------	-------
10	83	103	115	124	127	130	-------	-------
11	110	137	152	163	167	170	-------	-------
12	140	173	193	207	215	220	227	-------
13	173	214	238	255	265	272	280	-------
14	206	261	286	306	318	330	338	-------
15	244	309	338	362	378	393	397	399
16	282	360	396	423	443	460	465	468
17	325	411	451	490	510	535	545	549
18	369	470	511	560	585	610	624	630
19	412	528	577	630	659	691	700	712
20	460	590	647	702	740	779	790	805
21	511	655	720	780	822	867	883	900
22	561	723	795	851	910	958	980	1,000
23	-------	794	870	947	1,000	1,057	1,080	1,104
24	-------	863	950	1,033	1,095	1,156	1,189	1,211
25	-------	940	1,035	1,130	1,195	1,260	1,300	1,320
26	-------	1,019	1,120	1,224	1,294	1,362	1,408	1,434
27	-------	-------	1,109	1,324	1,398	1,472	1,523	1,557
28	-------	-------	1,301	1,429	1,505	1,590	1,641	1,680
29	-------	-------	1,398	1,531	1,620	1,710	1,761	1,810
30	-------	-------	1,490	1,640	1,730	1,839	1,880	1,940

Site class III (S.I. 140 feet)

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
8	34	42	46	49	51	51	-------	-------
9	50	63	68	73	79	80	-------	-------
10	69	90	96	102	109	112	-------	-------
11	90	120	129	137	143	150	149	150
12	115	152	162	172	182	190	194	195
13	143	188	200	211	226	235	240	240
14	174	226	242	258	273	285	289	293
15	208	267	288	306	320	337	341	348
16	245	308	336	354	372	392	400	409
17	-------	350	385	407	428	450	460	470
18	-------	397	435	463	489	512	535	536
19	-------	441	488	521	550	580	595	602
20	-------	491	542	585	619	650	668	680
21	-------	-------	600	650	690	726	742	759
22	-------	-------	659	717	760	800	820	837

See footnote at end of table.

TABLE 25.—*Board-foot volumes of young-growth Douglas-fir trees by d.b.h. and stand age for site classes II, III, and IV (International rule ¼-inch kerf)*[1]—Continued

Site class III (S.I. 140 feet)—Continued

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
23			717	789	836	880	900	916
24			776	860	912	962	980	1,002
25				932	996	1,050	1,070	1,096
26				1,008	1,080	1,138	1,160	1,190
27				1,087	1,162	1,228	1,260	1,283
28				1,166	1,250	1,320	1,360	1,383
29					1,340	1,412	1,467	1,488
30					1,435	1,510	1,570	1,595

Site class IV (S.I. 110 feet)

D.b.h. (inches)	(Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
8	32	36	38	39	41	42	43	43
9	46	53	57	61	62	63	64	65
10	65	74	80	87	90	91	92	94
11		99	105	113	119	121	122	124
12		124	134	142	150	153	157	160
13		154	170	180	188	190	196	200
14		186	204	217	224	228	235	240
15		220	241	257	264	270	277	281
16			280	300	306	310	320	329
17			321	345	353	360	370	380
18			384	390	400	407	419	430
19			408	439	450	457	470	482
20			454	487	499	510	525	540
21				538	551	566	482	598
22				590	605	620	640	652
23				640	660	678	698	712
24				692	715	735	760	775
25						797	820	839
26						856	884	900
27								967
28								1,032
29								
30								

[1] Source: Prepared from table 10, *Volume Tables for Pacific Northwest Trees* (*A4*), using heights for appropriate d.b.h., age, and site class from *Height Curves for Even-Aged Stands of Douglas-fir* (*A8*). Interpolated volumes curved by d.b.h. and age. Volumes are gross and exclude (1) top above 6 inches d.i.b., (2) a 1.5-foot stump, and (3) a 0.3-foot trim allowance for each 16-foot log.

556100°—60——8

TABLE 26.—*Board-foot volumes of young-growth Douglas-fir trees by d.b.h. and stand age for site classes II, III, and IV (Scribner rule)* [1]

Site class II (S.I. 170 feet)

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
12	93	123	134	143	147	148	150	------
13	120	137	160	172	178	183	188	------
14	150	193	208	223	234	240	246	------
15	181	231	251	270	282	291	298	------
16	213	272	298	318	332	345	355	360
17	248	314	345	370	388	402	413	418
18	283	359	395	425	447	466	477	484
19	320	404	449	485	509	533	546	554
20	359	456	504	546	576	606	618	630
21	------	508	563	610	646	680	697	710
22	------	562	624	680	720	760	778	797
23	------	619	687	751	799	843	864	888
24	------	677	753	823	880	930	957	981
25	------	------	820	900	966	1,021	1,052	1,078
26	------	------	892	977	1,053	1,114	1,151	1,178
27	------	------	968	1,066	1,148	1,212	1,250	1,288
28	------	------	1,047	1,160	1,246	1,316	1,358	1,401
29	------	------	1,130	1,256	1,349	1,420	1,469	1,521
30	------	------	1,214	1,355	1,452	1,534	1,586	1,642

Site class III (S.I. 140 feet)

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
12	76	101	111	120	127	132	134	------
13	100	131	141	150	160	168	172	------
14	126	163	174	185	198	208	212	213
15	153	197	211	226	241	250	254	256
16	180	232	250	273	284	296	299	303
17	------	268	290	310	328	344	349	354
18	------	304	329	352	372	393	401	406
19	------	342	374	396	422	446	458	463
20	------	380	419	446	477	502	516	524
21	------	------	467	498	533	564	578	588
22	------	------	517	553	594	628	640	652
23	------	------	568	610	656	693	708	721
24	------	------	615	670	720	761	776	794
25	------	------	------	732	787	832	853	871
26	------	------	------	800	856	909	930	950
27	------	------	------	867	925	990	1,012	1,048
28	------	------	------	935	1,000	1,067	1,096	1,136
29	------	------	------	------	1,078	1,150	1,186	1,219
30	------	------	------	------	1,163	1,234	1,274	1,310

See footnote at end of table.

Table 26.—*Board-foot volumes of young-growth Douglas-fir trees by d.b.h. and stand age for site classes II, III, and IV (Scribner rule)*[1]—Continued

Site class IV (S.I. 110 feet)

D.b.h. (inches)	Stand age (years)							
	30	40	50	60	70	80	90	100
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
12	-------	83	88	93	98	102	105	107
13	-------	107	116	123	128	132	135	138
14	-------	133	147	155	160	165	169	172
15	-------	-------	178	190	194	199	201	208
16	-------	-------	210	223	230	235	240	245
17	-------	-------	246	260	267	273	280	285
18	-------	-------	281	297	304	312	319	327
19	-------	-------	319	336	344	353	361	369
20	-------	-------	354	376	386	396	403	411
21	-------	-------	-------	416	427	438	449	460
22	-------	-------	-------	460	471	481	497	508
23	-------	-------	-------	501	517	529	546	558
24	-------	-------	-------	545	564	577	595	608
25	-------	-------	-------	-------	-------	624	647	660
26	-------	-------	-------	-------	-------	678	700	714
27	-------	-------	-------	-------	-------	-------	-------	770
28	-------	-------	-------	-------	-------	-------	-------	830
29	-------	-------	-------	-------	-------	-------	-------	-------
30	-------	-------	-------	-------	-------	-------	-------	-------

[1] Source: Prepared from table 11, *Volume Tables for Pacific Northwest Trees* (*A4*), using heights for appropriate d.b.h., age, and site class from *Height Curves for Even-aged Stands of Douglas-fir* (*A8*). Interpolated volumes curved by d.b.h. and age. Volumes are gross and exclude (1) top above 8 inches d.i.b., (2) a 2-foot stump, and (3) a 0.3-foot trim allowance for each 16-foot log.

TABLE 27.—*Cubic-foot contents of Douglas-fir trees between specified top diameters by d.b.h. of tree* [1]

Trees 10 and 12 inches d.b.h. (by total tree height)

Top diameter limits and d.b.h. (inches)	Total height in feet							
	50	60	70	80	90	100	110	120
Between 4- and 8-inch top:	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
10	4. 6	5. 5	6. 5	8. 1	9. 5	11. 3	13. 0	16. 8
12		4. 3	4. 9	5. 8	7. 5	8. 0	8. 7	12. 4
Between 6- and 8-inch top:								
10	3. 1	3. 9	4. 6	6. 0	7. 1	8. 8	9. 8	13. 2
12		2. 9	3. 3	4. 1	5. 5	5. 9	6. 6	10. 2
Between 4- and 6-inch top:								
10	1. 4	1. 5	1. 9	2. 2	2. 5	2. 8	3. 3	4. 1
12		1. 2	1. 5	1. 6	2. 0	2. 2	2. 3	2. 8

Trees 14 inches d.b.h. and larger (all heights)

D.b.h. (inches)	Between top diameters (inches)		
	4–8	6–8	4–6
	Cubic feet	*Cubic feet*	*Cubic feet*
14	6. 0	4. 0	2. 0
16	5. 2	3. 7	1. 5
18	4. 8	3. 4	1. 4
20	4. 6	3. 3	1. 3
22	4. 4	3. 0	1. 4
24	4. 1	2. 9	1. 2
26	4. 0	2. 7	1. 3
28	3. 8	2. 5	1. 1
30	3. 6	2. 3	1. 3

[1] Source: Adapted from tables 5 and 6, *Volume Tables for Pacific Northwest Trees (a compilation)* (*A4*).

TABLE 28.—*Volume equivalents for a stacked cord of 8-foot Douglas-fir pulpwood by average bolt diameter* [1]

Middiameter of average bolt (i.b.) (inches)	Bolts	Solid wood	Bark	Scale Scribner rule [2]	Board feet per cubic foot
	Number	*Cu. ft.*	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*
8	28. 8	81	11	365	4. 5
9	23. 0	81	11	400	4. 9
10	18. 5	82	10	430	5. 3
11	15. 5	82	10	460	5. 6
12	13. 0	82	10	490	6. 0
13	11. 2	83	10	520	6. 3
14	9. 8	84	10	545	6. 5
15	8. 6	85	10	570	6. 7
16	7. 7	86	10	590	6. 8
17	6. 9	88	11	610	7. 0
18	6. 3	89	11	625	7. 0
19	5. 7	90	11	640	7. 1
20	5. 2	91	12	650	7. 1

[1] Source: *Contents of a Cord of Eight-Foot Pulpwood (A15).* Based on 65 truckloads as scaled at 8 pulpmills and 3 sawmills in western Washington.

[2] Gross scale with no trim allowance; no scale for bolts under 6 inches.

TABLE 29.—*Percentage increase in scaled volume when long logs are bucked and scaled as 2 short logs* [1]

Diameter (inches)	1 inch in 7 feet taper and a log length before bucking of—			1 inch in 8 feet taper and a log length before bucking of—		
	28 feet	32 feet	36 feet	28 feet	32 feet	36 feet
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6	73	84	100	64	72	82
7	53	63	68	39	54	55
8	42	48	52	36	41	45
9	34	39	45	29	33	38
10	28	33	37	25	28	31
11	25	29	32	21	24	27
12	22	25	28	19	22	24
13	19	23	25	17	19	22
14	18	20	23	15	18	20
15	16	19	21	14	16	19
16	15	18	20	13	15	17
17	14	16	18	12	14	16
18	13	15	17	11	13	15
19	12	14	16	11	12	14
20	12	13	15	10	11	13
21	11	13	14	10	11	12
22	10	12	13	9	10	12
23	10	11	13	8	10	11
24	9	11	12	8	9	10

Diameter (inches)	1 inch in 9 feet taper and a log length before bucking of—			1 inch in 10 feet taper and a log length before bucking of—		
	28 feet	32 feet	36 feet	28 feet	32 feet	36 feet
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6	55	60	71	45	52	64
7	34	49	49	36	41	49
8	32	34	39	28	31	35
9	26	29	34	23	26	30
10	22	24	27	20	22	25
11	18	22	24	16	19	22
12	17	19	22	15	17	19
13	15	17	19	13	15	17
14	14	15	18	12	14	16
15	12	14	16	11	12	15
16	11	13	15	10	12	13
17	11	12	14	10	11	12
18	10	11	13	9	10	12
19	9	11	12	8	10	11
20	9	10	11	8	9	10
21	8	10	11	8	9	10
22	8	9	10	7	8	9
23	8	9	10	7	8	9
24	7	8	9	6	7	8

[1] Source: Table 2, *Long Logs or Short Logs With the Scribner Scale (A10).* Values for 6- and 7-inch diameters have been added.

Table 30.—*Board-foot/cubic-foot ratios for young-growth Douglas-fir logs* [1]

Diameter (inches)	Board feet per cubic foot when log length is—		
	8 feet	16 feet	32 feet
	Board feet	*Board feet*	*Board feet*
6	3.2	2.8	2.1
7	4.0	3.7	2.8
8	4.7	4.3	3.4
9	5.3	4.8	3.9
10	5.8	5.2	4.3
11	6.1	5.5	4.6
12	6.3	5.8	4.9
13	6.5	6.0	5.2
14	6.7	6.2	5.4
15	6.9	6.4	5.6
16	7.0	6.6	5.8
17	7.1	6.7	6.0
18	7.2	6.8	6.2
19	7.3	6.9	6.3
20	7.4	7.0	6.4
21	7.5	7.1	6.5
22	7.6	7.2	6.6
23	7.7	7.3	6.7
24	7.7	7.4	6.8

[1] Assumed taper ratio 1 inch in 8 feet. Logs scaled by Scribner rule (formula). Cubic contents by averaging log end areas. No allowance for log trim.

Table 31.—*Board-foot/cubic-foot ratios for Douglas-fir trees* [1]

D.b.h. (inches)	Board feet per cubic foot when total height in feet is—												
	50	60	70	80	90	100	110	120	130	140	150	160	170
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
10	2.9	3.2	3.3	3.4	3.5	3.5	----	----	----	----	----	----	----
12	2.9	3.7	4.3	4.7	4.9	5.1	5.2	5.3	5.4	5.6	5.8	----	----
14	3.2	3.9	4.4	4.8	5.0	5.1	5.2	5.3	5.4	5.6	5.8	6.0	----
16	----	3.9	4.4	4.8	5.0	5.1	5.2	5.3	5.4	5.6	5.8	6.0	----
18	----	----	4.4	4.8	5.0	5.1	5.2	5.3	5.4	5.6	5.8	6.0	6.1
20	----	----	4.4	4.8	5.0	5.1	5.2	5.3	5.4	5.6	5.8	6.0	6.1
22	----	----	----	4.8	5.0	5.1	5.2	5.3	5.4	5.6	5.8	6.0	6.1
24	----	----	----	----	5.0	5.2	5.3	5.4	5.5	5.7	5.9	6.0	6.2
26	----	----	----	----	5.0	5.2	5.3	5.4	5.6	5.8	5.9	6.0	6.2
28	----	----	----	----	----	5.2	5.4	5.5	5.6	5.8	5.9	6.1	6.2
30	----	----	----	----	----	5.2	5.4	5.5	5.7	5.8	6.0	6.1	6.3

[1] Source: Adapted from tables 6 and 11, *Volume Tables for Pacific Northwest Trees* (*A4*). Ratios, which have been curved, are for that portion of the stem between stump and 8-inch top.

TABLE 32.—*Weights of selected products from young-growth Douglas-fir*

	Weight per M board feet, Scribner Decimal C scale [1] *(pounds)*
Logs and piling with bark, average diameter (inches):	
14–20	12, 770
21–25	9, 194
26–30	8, 101
	Weight per M board feet, lumber tally [1] *(pounds)*
Lumber:	
Rough green, clear	3, 500
Rough green, all other grades	3, 300
Rough dry, clear, 1 to 3 inches	2, 900
Rough dry, clear, 3 inches and over	2, 700
	Weight per cord [2] *(pounds)*
Pulpwood, average middiameter of bolt (inches):	
8–9	4, 350
10–12	4, 450
13–14	4, 550
15–16	4, 650
17–19	4, 800
20	5, 000

[1] Source: *Conversion Factors for Pacific Northwest Forest Products (A8).*
[2] Source: *Contents of a Cord of Eight-Foot Pulpwood (A15).*

TABLE 33.—*Yield per acre of young-growth Douglas-fir on sites II, III, and IV* [1]

Site class and age (years)	Total height [2]	Volume: Cubic [3] net	International rule (¼-inch kerf) [4]: Gross	International rule: Mortality	International rule: Net	Scribner rule [5]: Gross	Scribner rule: Mortality	Scribner rule: Net
	Feet	*Cu. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
Site class II:								
20	44	950	1,900	0	1,900	-------	-------	-------
30	78	3,250	14,800	300	14,500	2,600	0	2,600
40	102	6,000	33,100	1,500	31,600	12,100	200	11,900
50	119	8,300	53,600	3,800	49,800	28,000	600	27,400
60	132	10,400	72,900	7,000	65,900	44,200	1,400	42,800
70	144	12,150	91,400	10,900	80,500	59,800	2,600	57,200
80	154	13,700	109,000	15,600	93,400	74,400	4,400	70,000
90	163	15,050	124,800	21,000	103,800	88,400	7,400	81,000
100	170	16,150	139,600	27,000	112,600	101,800	11,400	90,400
Site class III:								
20	37	500	200	0	200	-------	-------	-------
30	64	2,100	7,600	0	7,600	300	0	300
40	84	4,300	20,800	900	19,900	4,500	0	4,500
50	98	6,350	36,000	2,400	33,600	12,600	200	12,400
60	109	8,150	51,400	4,300	47,100	24,400	600	23,800
70	119	9,650	66,000	6,600	59,400	36,300	1,100	35,200
80	127	10,850	79,200	9,300	69,900	47,500	1,800	45,700
90	134	11,900	90,800	12,300	78,500	57,600	2,600	55,000
100	140	12,800	101,300	15,600	85,700	66,500	3,700	62,800
Site class IV:								
20	29	200	-------	-------	-------	-------	-------	-------
30	50	1,050	2,200	-------	2,200	-------	-------	-------
40	66	2,350	8,600	300	8,300	200	0	200
50	77	3,800	18,200	1,000	17,200	3,300	0	3,300
60	86	5,200	28,500	2,300	26,200	8,200	100	8,100
70	94	6,350	38,100	3,800	34,300	14,300	300	14,000
80	100	7,300	46,700	5,300	41,400	20,700	600	20,100
90	105	8,050	54,100	6,900	47,200	27,000	1,000	26,000
100	110	8,650	60,900	8,300	52,600	32,800	1,400	31,400

[1] Assembled from tables 1, 3, 4, and 22, *The Yield of Douglas-fir in the Pacific Northwest (A5)*, and tables 1c, 1d, 3c, and 3d, *Gross Yield and Mortality Tables for Fully Stocked Stands of Douglas-Fir (A11)*.

[2] Average height of dominant and codominant trees.

[3] All trees 5.0 inches d.b.h. and larger to a minimum top diameter of 4 inches. Gross and mortality figures are not available for cubic measure.

[4] All trees 6.6 inches d.b.h. and larger to a minimum top diameter of 5 inches.

[5] All trees 11.6 inches d.b.h. and larger to a minimum top diameter of 8 inches.

TABLE 34.—*Percent overrun by log diameter from young-growth Douglas-fir logs of selected lengths for 3 types of mill and 3 log scales*

Log diameter (inches)	Circular mill					
	8-foot logs [1]			16-foot logs [2]		
	Scribner Dec. C	Scribner formula	International ¼-inch kerf	Scribner Dec. C	Scribner formula	International ¼-inch kerf
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6	68	50	11	---	---	---
8	50	21	8	40	31	11
10	32	9	4	12	12	−6
12	14	2	1	9	5	−8
14	2	−1	−2	8	3	−7
16	−1	−4	−4	7	4	−4
18	−2	−4	−4	6	4	−3
20	−3	−4	−4	5	4	−2
22	−5	−3	−3	3	2	−3
24	−6	−3	−3	2	0	−5

Log diameter (inches)	Band mill			Gang mill		
	12-foot logs [3]			16-foot logs [4]		
	Scribner Dec. C	Scribner formula	International ¼-inch kerf	Scribner Dec. C	Scribner formula	International ¼-inch kerf
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
6	60	78	23	−7	57	0
8	50	30	11	14	30	5
10	67	22	9	31	24	8
12	32	17	14	34	22	9
14	21	18	11	32	20	9
16	29	22	18	28	18	9
18	23	21	16	21	17	8
20	12	16	21	---	---	---
22	12	12	8	---	---	---
24	---	---	---	---	---	---

[1] Source: Unpublished data (1951) in files of Olympia Research Center. Basis of data: 327 logs cut exclusively into 2 x 4's; 19,353 board feet surfaced, f.o.b. railroad car.

[2] Source: Worthington, Norman P. *Lumber Grade Recovery and Milling Costs (A13).* Basis of data: 332 logs cut into dimension, planks, and small timbers; 40,172 bd. ft. green chain tally.

[3] Source: Thomas, David P. *Small Band Mill Plus Small Logs Equals Increased Lumber Yield (A12).* Basis of data: 432 logs cut largely into dimension and timbers; 37,975 bd. ft. green chain tally.

[4] Source: Worthington, Norman P. *Lumber Grade Recovery From 110-Year-Old Douglas-Fir Thinnings (A14).* Basis of data: 98 logs cut into 2-inch dimension; 11,301 bd. ft. green chain tally.

TABLE 35.—*Grade recovery from young-growth Douglas-fir logs in percent of green chain tally* [1]

Log diameter (inches)	Lumber grade recovery [2]			
	Select structural [3]	No. 1	No. 2	No. 3
	Percent	*Percent*	*Percent*	*Percent*
8	24.9	67.8	5.6	1.7
9	27.3	63.3	7.7	1.7
10	29.5	59.2	9.5	1.8
11	31.3	55.5	11.2	2.0
12	32.9	52.2	12.8	3.1
13	34.3	49.3	14.2	2.2
14	35.4	46.8	15.5	2.3
15	36.4	44.7	16.3	2.6
16	37.0	42.9	17.2	2.9
17	37.2	41.8	17.8	3.2
18	37.4	40.9	18.1	3.6
19	37.2	40.3	18.5	4.0
20	36.7	40.5	18.4	4.4
21	35.8	40.8	18.6	4.8
Average	31.9	53.8	12.1	2.2

[1] Source: *Lumber Grades From Young-Growth Douglas-fir* (*A7*).
[2] Chiefly dimension. No. 1 grade is now known as Construction; No. 2, as Standard; No. 3, as Utility.
[3] Includes select merchantable.

TABLE 36.—*Single bark thickness at various heights in young-growth Douglas-fir trees*[1]

D.b.h. (inches)	Height above ground in feet			
	4.5	9.5	17.5	34.0
	Inches	*Inches*	*Inches*	*Inches*
4	0.16	0.15	0.13	0.12
5	.21	.20	.17	.15
6	.27	.25	.21	.18
7	.32	.30	.25	.22
8	.38	.35	.30	.25
9	.44	.40	.34	.28
10	.50	.46	.38	.32
11	.56	.51	.42	.35
12	.62	.56	.46	.38
13	.67	.61	.51	.41
14	.73	.66	.56	.45
15	.79	.71	.60	.48
16	.84	.76	.64	.52
17	.90	.81	.68	.55
18	.96	.86	.73	.58
19	1.02	.91	.77	.62
20	1.08	.97	.81	.65
21	1.13	1.02	.86	.68
22	1.19	1.07	.90	.72
23	1.25	1.12	.94	.75
24	1.30	1.17	.98	.78
25	1.36	1.22	1.03	.82
26	1.42	1.28	1.07	.85
27	1.49	1.33	1.11	.88
28	1.54	1.38	1.15	.92
29	1.59	1.43	1.20	.95
30	1.65	1.48	1.25	.99

[1] Source: *Bark Thickness at Several Heights in Young Douglas-fir Trees* (A6).

SPECIFICATIONS FOR THE MOST COMMON FOREST PRODUCTS PRODUCED FROM YOUNG-GROWTH DOUGLAS-FIR

Fuelwood

Wood is usually 16, 24, or 48 inches long of sound, unpeeled material. Pieces larger than 8 inches are usually split, minimum size approximately 4 inches. Normally, fuelwood is sold by the cord, containing 128 cubic feet of stacked volume.

Car stakes

Round, unpeeled, reasonably straight. Length 10–12 feet, 5½-inch minimum to an 8-inch maximum middiameter. Used in staking flatcars for transporting poles, piling, lumber, and other loose, lengthy material.

Fence posts

Round, peeled or unpeeled, straight. Length 6–8 feet, 3–6 inches diameter, although special larger sizes are sometimes specified. Usually given preservative treatment before using.

Mine props

Round, peeled or unpeeled, reasonably straight. Length 6–17 feet, 4–6 inches diameter, may be bought in random lengths to be recut later.

Smelter poles

Round, unpeeled, no limitation on straightness. Length 25 feet, minimum 8-inch butt o.b., no maximum. Used in the smelting of copper ore.

Utility poles

Poles are purchased under American Standards Association specifications.[1] Most poles are to be given later preservative treatment and must be peeled. Many buyers purchase "barkies" (unpeeled), but usually require that ASA specifications be met and that o.b. dimensions be as follows:

Length (feet)	*Minimum top circumference o.b. (inches)*	*Circumference 6 feet from butt o.b. (inches)*
30	18	28 –32
35	18	29½–34
40	25	39 –45
45	25	41 –47

Dimensions for creosoted poles, class 1–7, are length 16 to 90 feet, minimum diameter at ground line (3½ to 11 feet) 6 to 18 inches, with minimum diameter at top (i.b.) of 5 to 8½ inches. An average pole on most operations will be class 3 or 4, 45 feet long with a 12-inch butt and a 7-inch top. Rather detailed specifications on allowable defects, checks, shakes, splits, grain, knots, shape, and straightness are set out by the buyer. Full and complete specifications should be obtained from the purchaser before poles are cut.

[1] American Standard Specifications and Dimensions for Douglas-fir poles. Approved American Standards Association Mar. 14, 1941. Reaffirmed May 17, 1945.

Piling

Straight, sound, live timber free from checks, shakes, splits, or rotten knots. Twist must not exceed one-half turn in piling length. Piling intended for treatment may be bought peeled or unpeeled, but should have not less than 1-inch sapwood at the butt. Piling should be so straight that a line drawn from end to end will show pile to be at no point over one-quarter of its average diameter out of a straight line. Pieces must be cut above butt swell and show uniform taper. Ends should be square, knots trimmed, and pile finished in a workmanlike manner.

Piling should have the following limiting dimensions:

Length (feet)	Diameter at butt		Diameter at top
	Minimum (inches)	Maximum (inches)	Minimum (inches)
Under 40	14	18	10
40–50	14	18	9
50–70	14	18	8
70–90	14	18	7
Over 90	14	20	6

As in the case of poles, complete specifications should be obtained from the purchaser before cutting.

Saw logs

Saw logs are sold either woods run or by grade as specified by the log scaling and grading bureaus. The following specifications for No. 2 and No. 3 logs are condensed from rules of these bureaus.[2] (Young growth stands do not develop No. 1 grades.)

No. 2 sawmill shall be suitable for the manufacture of construction grade or better lumber in amounts not less than 65 percent of the net scaled contents, or B and Better or equivalent grade to an amount not less than 25 percent of the net scaled contents. Logs shall be not less than 12 inches in diameter, nor less than 12 feet in length plus trim, scaling at least 60 board feet. Logs having more than a certain specified slope of grain are excluded from this grade. Knots up to 2½ inches in diameter are permissible, and larger knots if the required amount of B and Better lumber may still be produced.

No. 3 sawmill shall be suitable for manufacture of Standard grade or better lumber in amounts not less than 50 percent of the net scaled contents or 33⅓ percent of the gross scaled contents. Logs shall be at least 6 inches in diameter, 12 feet in length plus trim, and scale at least 50 board feet net. Knots up to 3 inches in diameter are permissible, and larger knots only if the required lumber grades may be recovered. Logs with excessive slope of grain or excessive number of visible pitch pockets, which would exclude them from the No. 2 sawmill grade, may be included in this grade.

In many instances, restrictions on scaling content of No. 3 sawmill logs are waived by purchasers who will accept 6-inch diameter logs to minimum 12-foot lengths. Furthermore, it is common for mills cutting 2 x 4's to buy logs to an 8-foot minimum length plus trim allowance.

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[2] Source: *Official Log Scaling and Grading Rules* (*A1*).

Peeler logs

Ordinarily no No. 1 or No. 2 peeler logs can be produced from young growth Douglas-fir.

No. 3 peeler logs[3] shall be suitable for production of center core, cross core, and backs or better to an amount equal to the net scaled contents, and with not less than six annual rings to the inch. Minimum length shall be 17 feet plus trim; minimum diameter, 24 inches. Knots and/or indication shall be limited to well scattered, sound, tight knots, not to exceed 1½ inches in diameter. Miscellaneous grade defects such as pitch, pin worm holes, heart offcenter, and other deductible defects are listed. Logs of peeler quality under 17 feet in length shall be graded *Peeler blocks*. They must meet the same grade requirements as peeler logs except for length.

Suitable for peeling (SFP) grade is recognized in many localities in western Oregon and Washington as a commercial grade. These logs should have a minimum length of 17 feet plus trim, and a minimum diameter of 16–18 inches. Log surface shall be three-fourths surface clear with knots over ¾ inch confined to one quadrant. Small knots up to three-fourths of an inch are permitted. Not less than six annual rings to the inch.

Small young-growth peelers are recognized in a restricted area around Olympia and Elma, Wash. These logs are purchased in minimum lengths of 13½ feet plus trim, with minimum diameters of 12–14 inches. Scattered knots not over 1½ inches in diameter are permitted. There are no ring specifications except that extremely coarse logs are not accepted.

Anyone contemplating production of peeler logs below the No. 3 peeler grade should first make sure of his market and specifications.

Pulpwood

Pulpwood is usually bought in unpeeled 8-foot lengths measured in cords (or sometimes by weight). A few mills want 50- or 100-inch wood. Maximum diameters are usually 18 inches, minimum 4 inches. Only clear, sound wood is desired with no burned, fire-killed, or rotten wood accepted, except when special arrangements have been made prior to delivery. All timber must be trimmed closely.

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[3] Source: *Official Log Scaling and Grading Rules* (A1).

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