Stand Improvement of Douglas-fir

By

Lucien Alexander

A Thesis Presented to the Faculty of Oregon State College School of Forestry

In Partial Fulfillment of the Requirements for the Degree of Bachelor of Science

June, 1940

Approved: [Signature]
Acknowledgments.

I wish to express my appreciation to all those from whom I received a helping hand in the preparation of this thesis. In particular I wish to thank Mr. T. T. Munger, Mr. L. A. Isaac, and Mr. P. A. Bringleb of the Pacific Northwest Forest and Range Experiment Station for their kindness in making available many unpublished reports of that agency; to Professor T. J. Starker and Professor W. F. McCulloch for their suggestions and the records of experiments they made available to me; and to Professor W. Hall for his suggestions in the writing of this thesis.
Foreword

The American lumbering practices have been the actions of changing the natural resource of trees into money as quickly as possible. Little or no thought was given to growing trees for future generations, and the belief that the forests were inexhaustible prevailed. Only since the end of the virgin timber stands has become apparent have men begun to see the necessity of growing trees for the markets. When the veteran forests of the Pacific slopes are gone, the last of the naturally-supplied forests will have been used; and the time is not far distant when forest crops will be as much a part of the American economy as are farm crops at present.

The author of this thesis believes that the future of the Pacific Northwest is producing forests. What products the forests will be made to yield is a question of too great scope to answer in a paper on stand improvement. However, a goal for the forest manager to work toward is necessary. For this reason, the assumption is made that the problems of today are probably the problems of tomorrow in a modified form, and the stands of today will be utilized in the same general way as have those of the past. Nothing in these statements denies the constant change in utilization methods and standards that will come with the increases in scientific knowledge and decreases in forest supplies.
As a result of the lumbering methods of the past, much land has been left in a poorly stocked condition. To produce forests whose materials are valuable enough to withstand the freight rates to eastern markets, these understocked forests will have to be culturally treated. At the same time there are many very old stands which at the present are producing a negative amount of growth. These, too, will have to be culturally treated. This thesis is written to present as much factual material about these two problems as is available, and then to show some of the economically possible solutions.

Because of the definite set of economic and silvic facts connected with the Douglas-fir types of this region, this thesis is limited in its treatment to those types. The first part of the thesis gives a broad view of the facts that are considered important in the region from a stand improvement point of view. The second part narrows the application of the facts to specific forest types.

Most of the opinions as to advisabilities are those of the author, formed after analyzing the data found in the research for this thesis, and from the information gained from school work and personal observation.
Part I.
A PICTURE OF THE REGION.

Description of the region.

That section of North America which lies between the top of the Cascade Mountains and the Pacific Ocean and extends north from Southern Oregon almost to the southern tip of Alaska is known to foresters as the Douglas-fir Region. In the heavy coniferous stands of these forests the Douglas-fir comprises almost sixty percent of the total volume. The section of this region that lies within the United States has an area of about thirty-five million acres, of which twenty-nine million acres are classed as forest land. Found on the forest land is 546 billion board feet of timber, or about one-third of the nation's present supply. The potential timber-growing capacity on the better sites for the first one hundred years of a stand's life is exceeded only by the Redwoods of the California fog belt region.

History of man's activities.

From the forests came the materials for the first settlers' homes. All of the materials had to be hand-hewn or whipsawed at first, but in 1827 a small water-powered sawmill was established at Fort Vancouver to supply local and California demands for lumber. This was not followed by more mills until 1845, when a mill at Puget Sound was begun. The gold rush to California in '49 was the impetus for the first steam-driven mill.
After the rush was over, the growth of lumbering again stopped, and it wasn't until the railroads and ocean shipping opened the eastern markets to the region, during the '90s, that lumber production began to expand again. Up until 1850 no mill of over ten thousand board feet per day capacity had been built, but steam and transportation facilities soon gave rise to 100 thousand foot mills, and then to even larger units.²

Woods work for the early mills was all done by hand power, so none but the smallest trees were utilized. Ox teams, or "Bull teams", were soon put to work skidding the giant logs. Though these animals possessed more power than human beings, the logging was still restricted to the best of the available trees of medium and small sizes. The result of this sort of logging was a pure economic selection, and a very good stand of trees left after the operation.²

Not until the '70s did a new form of power show its use in these giant forests. Mr. Dolbeer, a redwood logger in California, adapted steam to logging machines, and the idea spread as quickly as machines were available. These power plants were developed, and new methods of use were found until, at the turn of the century, the logging had changed in form from a selection to a clear cut and removal of the trees as fast as possible.²

With this change in logging and milling came also changes in the economics and silvics of the region. Up to the advent of mass production, a logger's success was gauged by his ability to choose what trees to take and
what to leave. As steam and larger production capacity came into the industry, mass production was considered the measuring stick. None of the operators seemed to realize that many of the logs were not paying their way. The result was a flooded market, a swift destruction of many square miles of timber, and an industry that was fighting to try to come out even financially.

Just after the turn of the 1920's the tractor was introduced to the loggers of the region. Though in some places it did show benefits, even in its crude state at that time, it was not until new developments were brought in, in the late 1920's that the tractor began to be generally accepted for use. Even now a steady swing from steam to crawler tractors is going on, and new improvements in the tractor and its auxiliary machines are increasing the velocity of this swing. The new equipment combines the power of the donkey engine with the flexibility of the ox team, so that the logger can again select which trees to take, yet take them out en masse. The new sort of logging has shown loggers how to make money by leaving the negative value trees to act as seed sources, and as a result a new set of economic and silvic problems is being made.

Physical characteristics of the region.

1. Topography.

Inside of, or as part of the boundaries of the region are five mountain ranges. These have maximum elevations of from less than four thousand up to fourteen thousand feet, and a minimum elevation ranging down to sea level.28
The mountains are steep and the valleys mostly narrow. The exceptions to this rule are the Willamette River valley of Oregon and the Puget Sound area of Washington. The original cover of these flatter areas was grass, brush, and a few trees. Most of the commercial stands grew on the lower hills.

Into the two valleys run the main drainages of the region; the remaining drainages run directly into the ocean as small rivers or streams.

2. Soils.

Soils are mostly of a clay or clay loam type, with a few sands and volcanic ash soils locally. Many soils contain rock and are underlain at shallow depths by volcanic or sedimentary deposits. They are classed in the semipodzol group, but they have good structures through their entire A and B horizons. The commercial stands of trees are largely restricted to the hill residual soils that are very old.22

3. Weather.

Rain, occurring primarily in the winter, averages from 120 inches per year to less than 30 inches, with wide variation in restricted localities. High humidity characterizes the climate except for a few weeks during the summer when the humidity may drop to ten percent or less. In most of the region wet snows and freezing weather occur for limited times during the winter. Occasionally, very heavy, wet snow, or rain that freezes as it lights will fall. This is often a limiting factor in forest man-
agement. Lightning storms in the mountains of the eastern and southern portion of the region cause considerable damage during the summer months. These storms are often accompanied by heavy rains and wind, though it is very seldom that the wind velocity exceeds 30 miles per hour. Wind velocity is generally low during the rest of the year.

**Silvics of the region.**

It is a strange fact, but the associates of Douglas-fir are far more tolerant of shade than it is. In old stands it is replaced by the true firs (Abies), Sitka Spruce (Picea sitchensis), Western Hemlock (Tsuga heterophylla), Western Red-cedar (Thuja plicata), Mountain hemlock (Tsuga mertensiana), and Western White Pine (Pinus monticola). The large areas of even aged stands of pure Douglas-fir in great varieties of ages lead to the conclusion that fires, so prevalent during the summer, gave the Douglas-fir, with its ability to regenerate on mineral soil, the advantage over its associates. The fire resistance of the fir made it possible for isolated islands to live through fires and act as sources of seed for even aged stands of new growth. Judging by the extent and location of these stands, Oregon's fire history has been more severe than Washington's.9, 10, 15.

When Douglas-fir stands reach the age of two or three hundred years, the individuals begin dropping out and are replaced by the more tolerant associates who regenerate under the heavy cover of the original forest. As the last
of the fir drops out, the entire stand is taken over by an uneven aged, tolerant group of trees.\textsuperscript{15}

\textbf{Silvics of Douglas-fir.}

Douglas-fir requires at least a fifty percent open-grown canopy to regenerate.\textsuperscript{10} Seed years come at intervals of two to five years, and since about 400,000 seeds are needed to regenerate an acre of forest, at least ten good seed trees per acre are required during one of the good seed years.\textsuperscript{15, 29} Douglas-fir is not windfirm when exposed after growing in dense stands.\textsuperscript{7} This is true also where a stand is heavily logged in a selective manner.\textsuperscript{21} Decadent trees do not produce seed whose progeny are subject to decay in any greater extent than seeds of sound tree parentage.\textsuperscript{16} Other species in the typical association are more prolific in seeding habits, but they are also more exacting as to the site required for germination. They are even less windfirm than Douglas-fir.

\textbf{Present stands within the region.}

Though the Forest Resources Survey\textsuperscript{23} of the Douglas-fir region recognized thirty cover types, Mr. T. T. Munger of the Pacific Northwest Forest and Range Experiment Station divided the region into three distinct growth types. First of these is the fir type proper, which covers at least three quarters of the area of the region; second is the fog belt type, in which the principal species are Sitka Spruce and Western Hemlock; and third is the upland type, which grows on the upper slopes of the boundary
ridges of the region. Since this paper concerns the management of Douglas-fir, it will consider all of these general growth types in locations where the cover type is one of the five fir types recognized in the Resources Survey.

Of all the species within the region, Douglas-fir comprises sixty percent of the volume. Next to this in percentage of volume comes Western Hemlock with nineteen percent of the total. Silver fir, Western Red-cedar, Sitka Spruce, Noble fir, Shasta fir, Mountain Hemlock, and Ponderosa Pine make up the bulk of the other thirty-one percent of the conifers. Only four billion feet is in hardwood stands.

Of the twenty-nine million acres of forest land, over half is now in Douglas-fir, and most of the four million acres of cut over or deforested lands was in that type before the trees were removed. In this latter category (deforested lands) about one third of the area is non-restocking, and the other two-thirds has many areas so understocked that the young stands produce only about half their potential growth (about 2,300,000,000 board feet annually). A growth percent for the region of forty-two hundredths is estimated for the decade until 1942, the presence of large volumes of old growth keeping it very low. If present conditions extend into the future, the decade of 1942-52 will show an annual growth of about four billion board feet. In 1932-42 the potential annual growth equals the annual
depletion, but the actual growth is only twenty-eight percent of that amount. It is estimated that it will take until the decade of 1952-62 for the annual growth to equal half the annual depletion. These figures do not take into consideration the grade reduction from limby trees and young stands. The cause of the difference between potential and actual growth is the understocking of cut over lands. They are left without full stocking and without any possibility of attaining that degree of stocking within a reasonably short time. Often deforested waste is a better description of their actual condition.

The economics of the region.

Forest industry is the source of about two-thirds of the payroll of the Douglas-fir region. One-third of all the people are employed in these industries. These facts give an idea of the local importance of the forests.

When high speed methods mentioned previously were under way, large sums of money were invested in machines and equipment. Taxes kept mounting, and interest accumulating against the holdings of timber that were gradually decaying because of old age. Because of resulting economic pressure, the operations were necessarily as short as possible, their objective being to "cut out and get out". Counteracting this tendency has been the gradual increase in stumpage value as a result of the improvement of transportation methods and lack of old growth timber supplies. Because of decay, often a stand will be decreasing in actual volume, yet its value increment
is on the upgrade because of the lesser supply of more available timber, the migration of the logging industry, and the building of transportation systems chargeable to greater areas of timber and uses other than logging.3

In most of the old Douglas-fir stands there are many trees so decadent or malformed that even with the best of markets they could not be taken out at a profit. Other trees in the stand cannot be taken out now, but as the value of the logs increases, and as the trees grow in size many of these will become economically available. The third part of the stand is now ready and profitable to take out. The dividing line between these classes is constantly changing because of economic as well as silvical changes. Under the old, high speed system of clear cutting, everything but the worst of the negative value trees were taken. This meant that logging had to be done cheaply, so that the plus value trees could pay the way for the minus and uncertain valued ones. Under the new method of logging, costs may be much higher per thousand feet of logs, but as only the plus values are taken, there is more return in the form of profit.30 The only trouble is that the minus valued trees are left on the ground along with the uncertain valued ones, and the forest is in a degenerated condition to that extent.

Second growth forests now in the region could be divided into the same classes of values as the old growth stands, but the division point is less pronounced and the
bulk of the stand is in the uncertain group.  

Miscellaneous economic factors.

Ownership conditions are peculiar to this region alone. Half the acreage is owned by government agencies and half is held by forty thousand private individuals. With but few exceptions the private lands are in units too small to practice forestry on, and as half the private timber land is old growth, there is probably only a hope for profit from the existing stand and no thought of future forests will be a sufficient motive for land holding.

Holding land has been partially facilitated by forms of yield tax for young stands, but the property tax is still charged against the old growth in both Oregon and Washington.

Great hauling distances and high freight rates cause considerable trouble. The chief markets are the central and eastern states, to which freight rates often equal half the final sales price.

Wages paid by the forest industries of the Pacific Northwest are among the highest paid in industry in the United States.

The hope that perhaps new industries will develop to absorb much of the lower grade materials seems well founded. At present many pulp and paper mills are either running or are being planned. Box factories, excelsior plants, cellophane plants, etc. will eventually come to the region and effect a better market for the forest products.
The general problem in the second growth forests.

In order that the future products of the Pacific coast forests may compete with products of other regions for the eastern markets, the quality of the products will have to remain high. To get quality growth the tree must be free from loose knots, have uniform growth, and have wood of the correct density. Loose knots are produced by clinging, dead branches, and the number of such branches present depends upon the tolerance of the tree, the stocking of the forest, and the natural tenacity of the branches. Uniformity of growth and density of wood are both controlled by giving the tree the correct amount of freedom to grow. To summarize these statements, quality in an unregulated forest is a product of the degree of stocking. In a regulated forest, the quality in controlled by controlling the stocking and the branching habit of the trees.

Let us look at the condition of stocking in the second growth forests that now exist in the region. In a general classification of the older second growth stands, the forests are forty percent well-stocked, forty-seven percent medium-stocked, and thirteen percent from poor to no stocking of coniferous trees. This group of figures includes only the forests resulting from fire or logging prior to 1920. In a sample of the areas
logged in 1920-22, the well-stocked forests amounted
to fourteen percent of the area, the medium-stocked forests
amounted to eighteen percent of the area, and the poor-
to non-restocked sections amounted to fifty-eight percent
of the area. Ages vary in the second growth forest class,
but at the time the last report was computed (1936), the
classes varied indirectly in amount of acreage with the
age, the seventy year age class being the largest, and the
ten year age class the smallest. The area of the young
growth stands increases every year, and by the end of the
next one hundred years it will cover all of the region's
commercial forest land.

One characteristic of tree growth helps in the solu-
tion of the problem of understocking. Mr. R. McArdle
and Mr. W. H. Meyer of the Pacific Northwest Forest and
Range Experiment Station ably stated the trend of Doug-
las-fir with respect to this characteristic in the follow-
ing paragraph taken from their bulletin, "The Yield of
Douglas-fir in the Pacific Northwest."

"Although a new forest starts with many thou-
sands of small trees to the acre, only a small prop-
ortion of these survive until the stand reaches ma-
turity. At 10 years of age on a reasonably good
land there are about 900 trees to the acre, some of
them 10 to 12 feet tall and clothed to the ground with
living limbs. At 30 years of age at least one-half
of of these trees are dead, several of the survivors
are more than 12 inches in diameter and 90 feet tall,
and on all the surviving trees the branches, though
they hang on still, are dry and brittle, have been
killed by the intense shade. When the forest is 100
years old there are only about 80 living trees to
the acre, but most of them are now 2 or 3 feet in
diameter. The larger trees are nearly 200 feet
tall and have nearly attained their full height
growth; dead limbs have dropped off the trunks for
In a study on the application of yield tables to Douglas-fir, Mr. Meyer found that stands below normal at a young age approach normal density as they grow older by having a greater-than-normal percent of the trees survive. On the other hand, overstocked stands approached normal in just a reverse process, in which more than the normal number of trees died out.

Both of these statements show clearly that, despite the present stocking of the forest, about the normal stocking will be reached at some time in the future. This fact brings about the "crop tree" idea of stand improvement. (The "crop tree" plan is basically that of choosing in advance about the number of trees in the young stand that will have survived when the stand reaches the rotation age; then treating the stand to benefit those trees. By exercising this choice, no money is expended on trees that are not to be harvested. A factor of safety has to be allowed, however, because disease, insects, and other devastators often kill a few of the chosen crop trees).

We actually have a problem, not of how much stand improvement should be done, but rather of how much it will be profitable to do. Land owners have to be shown how they will benefit by the job before they will do any stand improvement work.

Pruning.

Necessity.

A tree's pruning habits control knot formation and
thus control the quality of the sawlogs that a tree produces. In well-stocked Douglas-fir stands, the limbs on the lower sixteen feet of the trunk are dead by the thirtieth year, but it took until about the eighty-fourth year for the branches to drop off a tree whose cross section was studied by Mr. L. Bransford of the Pacific Northwest Forest and Range Experiment Station. The result is a fairly small, solid knot core and a large, loose knot cylinder in the butt log. Instead of having seventy years' growth of clear wood at the end of the first century, there are but fifteen. By the eighty-fourth year, above the butt log there are five to eight more sixteen-foot logs on which the limbs are dead and producing black knots. The lumber cut from the logs of trees of this age would be predominantly common grades, while if the branches had dropped when they first died, the prominent grade would have been clear. Future plywood plants must find clear logs somewhere, and sawmills will demand the same grades. If present old growth log grade differentials in price are any indication of the future differentiation, clear butt logs will be worth from two to five times as much as the knotty butt logs. This fact should give the forest manager an estimate of the sales price differential between pruned and unpruned trees.

History.

To date, little pruning in Douglas-fir has been tried. Most forest managers do not seem to see the possible
future in the products resulting from a job which takes a present outlay of money. The Forest Service has used C.C.C. labor in a limited amount of pruning in the Mt. Hebo plantation, one of the first plantations in the region, and in a natural second growth stand near Detroit on the Willamette National Forest of Oregon.26

The Forest Service regional policy is expressed in the "Timber Management Handbook of the North Pacific Region" of this year (1940) by stating that a select crop tree pruning of about 100 trees per acre (20 by 20 foot spacing) will be used in the young forests of better site qualities. Only dead branches will be removed, and no thinning will go higher than the point at which the crowns touch, or not over one-fourth of the height of the tree. An eighteen foot log minimum for pruning is also imposed.25. In carrying out this policy, many experiments with different tools have been made.

In addition to these Forest Service experiments, a few pruning experiments have been established by the Oregon State College School of Forestry. These studies have been chiefly concerned with the effects on pruning time of the various sizes and conditions of stands and the different methods of limb cutting.

Facts concerning costs of pruning.

Pruning costs are actually labor costs. Tools are simple, rather inexpensive, and last for a large number of working hours. Wages of the region, as was stated in the beginning of the thesis, average among the highest in the United States. Consequently, when the advisability
of pruning is being considered, the required time per tree is the most important cost item.

Many sorts of tools are now available for pruning. Each has its place of best adaptability. This in turn regulates the amount of time necessary for the pruning of any one particular sort of tree. In order to find where each sort of tool is best, both the Forest Service and the School of Forestry at Oregon State College have carried on time tests, as was mentioned before. To give the reader an idea of what these studies are like, and what the probable time required for pruning is, a few results of the different tests are given here.

At Mt. Hebo the pruning was done to an eighteen-foot level. The first six to eight feet were pruned with a grub-hoe handle; the remaining ten feet with a large club or pole saw. The stand is the result of a twelve by twelve-foot spaced plantation of 1910, 1911, 1912 on site quality II and III for Douglas-fir. The number of branches average from sixty to sixty-five per tree, and the average limb diameter on codominant trees of six inches D.B.H. was one-half inch; for a fourteen-inch tree it was one inch. Dominant eight-inch trees had only seven-tenths of an inch branch diameter average, while the twenty-eight inch trees had limbs about one-half inch through. The time necessary to prune varied from four and one-half minutes for a six inch tree to twelve minutes for a twenty-eight inch tree.
The average acre took about fifteen man-hours of pruning, but almost all limbs were dead.

Another example showing the time necessary for pruning is the study of John Cross, a student of Forestry at Oregon State College, made on the McDonald Forest. This pruning was done in a poorly stocked stand which came in after being logged in 1917. Practically all branches were alive, so a saw was used. This study shows only the height to which pruning could be done in a three-minute period.

<table>
<thead>
<tr>
<th>D.B.H. (in.)</th>
<th>Height (ft.)</th>
<th>Kind of saw</th>
<th>D.B.H. (in.)</th>
<th>Height (ft.)</th>
<th>Kind of saw</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.15</td>
<td>10.0</td>
<td>Curved</td>
<td>9.55</td>
<td>6.5</td>
<td>Curved</td>
</tr>
<tr>
<td>3.13</td>
<td>10.0</td>
<td>&quot;</td>
<td>3.31</td>
<td>8.5</td>
<td>Straight</td>
</tr>
<tr>
<td>4.20</td>
<td>9.5</td>
<td>&quot;</td>
<td>4.02</td>
<td>7.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>5.05</td>
<td>10.5</td>
<td>&quot;</td>
<td>6.90</td>
<td>7.8</td>
<td>&quot;</td>
</tr>
<tr>
<td>6.30</td>
<td>8.5</td>
<td>&quot;</td>
<td>8.75</td>
<td>8.0</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

Kind of saw refers to the shape of the blade.

Mr. H. McCormack, another student at Oregon State College, found that in this same stand of trees the average diameter of the trees was 5.4 inches, and the average time required to prune the bottom eight feet of the trees with these same two kinds of saws was two and seven-tenths minutes.

Application of these facts.

These last two studies show the method by which any forest manager can go about determining how much pruning will cost per tree. Yield tables and facts about the final product will give the information on
the number of trees to prune and the length of time before a possible harvest. The probable price differential between the pruned and unpruned product will show the result of the pruning. When the manager has all of these facts, he has sufficient information to decide whether the benefits from pruning will more than make up for the cost of doing the job. Interest rates, risk, and other carrying charges vary too greatly to quote for any area, but they will have to be considered and may change the otherwise favorable decision.

**Thinnings.**

**Benefits.**

Second in importance in the quality of forest products is the uniformity of growth and the density of the wood.¹ The density of stocking regulates the growth of the individual trees, the trees in open stands growing much faster. In the normal closing of the forest canopy referred to in the introduction to this part of the thesis, the individual tree growth is slowed rather sharply at the time of the complete closure.

Another benefit of thinnings is the possible income

---

¹Thinnings in this report include what is ordinarily termed thinnings and intermediate cuttings. That is, they include the taking out of material to release the crop trees or to improve the stand at any time from the sapling to the rotation sizes.
at a time between normal cuttings and from trees that would otherwise die out and be lost to economic returns.

Much has been published about the acceleration of growth by thinnings, but it is not the rapidity of growth that should be stressed in Douglas-fir thinnings. Regulation of growth to give the most profitable product is a more economic goal. Examples of the high value products that have restrictions concerning their rate of growth are: (1) No. 1 peeler Douglas-fir logs may not have less than eight annual rings per inch; (2) No. 1 Red fir sawlogs may not have more than eight rings per inch; (3) no second growth fir piling of unusually coarse grain will be accepted.

Fast growth would defeat the purpose of management if these products are being grown. Log grades are based on the possibility of recovery of certain grades of lumber. This lumber grading in turn is based on (1) the strength, (2) the working ability of the wood, and (3) the appearance of the wood. When the speed of growth is decided, the final product will have to be outlined, at least in a general way, in order to indicate the sort of growth desired.

Regulation and choice of final crop trees is another decided advantage of thinnings. In the virgin forest, many of the crop trees chosen by nature must be long-buttoed or one or more logs left in the woods because of some physical defect. In a well regulated thinning,
these inferior trees would be the ones taken out and the more promising trees left to make up the final cutting.

Thinnings are economically one of two kinds; a source of income or an expenditure. With the present economic situation, only in cases of extremely high values of the crop product is the latter sort a good managerial practice, but the kind furnishing an income is often of as much benefit to the owner's economic condition as it is to the stand. The practice of charging compound interest against any investment creates a condition in which a quite small payment in the near future is equivalent to many times the same amount at a distant future; thus in extreme cases a thinning income may exceed the final crop income discounted to the present. This would not be so important if owners were operating their forests on a yearly income basis, but with ownership and economic conditions as they are, most people do not carry on a yearly cut sustained yield operation.

Age of thinnings.

In the choice of the age at which to begin thinning the stand, two things must be considered. These are: (1) the amount of money that will be spent on thinnings, and (2) the choice of the age at which the desired growth condition will be best secured by a thinning. Between the time that the forest is about three inches d.b.h. and the time when it is twelve inches d.b.h., the thinnings take many man-hours of work and there is no
financial return at the time of thinning. The earlier thinning is almost always an expense thinning in places where it is needed and often leaves young trees in a limby condition. Douglas-fir has a natural tendency to form dominant trees early in life, so the stand does not stagnate, though the volume growth in a thick stand may be slowed down. The older tree thinning has the disadvantage of leaving trees to compete with each other until they get large enough to form a sort of crop, and the release effect is often too sudden. The result on the economic condition of the owner, however, is much better than that of an early thinning. This latter sort of thinning is often done in such a manner as to be a pruning job also, a result of the trees falling between and among the crop trees. This is one of the reasons why the "Timber Management Handbook for the North Pacific Region" of the Forest Service specifies that thinnings will be limited to stands sixty years of age or over and to stands from which the thinnings may be utilized.25

Studies of thinnings.

Thinnings in second growth stands of Douglas-fir were some of the first experiments established at the Wind River Experimental Forest in Southern Washington. These were laid out by Mr. J. V. Hofman, then a Senior Silviculturist with the Forest Service, and consisted of two experimental plots and one check plot established in a nine-year old stand of Douglas-fir. On one of the plots
the young trees were thinned to an eight by eight foot spacing with no regard for their crown location or size. The other plot was thinned, leaving only dominant and codominant trees at as near an eight by eight foot spacing as possible. Since their establishment in 1919, the plots have been remeasured at five year intervals. These plots were not located on areas of the same site index, but the benefits of more rapid growth in thinned stands has been proved. The thinned trees, though, were completely clothed by branches until about the twenty-fifth year. The crowns did not close on the thinned plots until that age, but the unthinned plots had a completely closed crown cover at fifteen years. From this demonstration it is apparent that a pruning will have to accompany any young age class thinnings. No figures on the cost of thinning were kept.\textsuperscript{14, 27}

Unintentional thinnings have long been practiced in the older second growth stands. Many piling, sawlog, and cordwood trees have been taken out by a partial cutting in even aged forests. In order to find out if these practices could be altered enough to benefit the forest, yet still produce the desired products, the Forest Service and the Oregon State College School of Forestry have established thinning experiments in the older second growth stands found on their experimental forests. A description of a few of the most outstanding of these experiments is given here.
On the Panther Creek Block of the Wind River Experimental forest, the Pacific Northwest Forest and Range Experiment Station has established a series of thinnings in which quite varied marking rules were used. One of these plots is noted especially because it was a "logger's selection", a plot in which the purchasing logger was allowed to take the trees he chose, except that a limit on the percent of the stand to be removed was invoked. Other plots include those on which only the trees that will die before the rotation will be finished were removed; another on which a definite percent of the trees was taken. The entire thinning was handled as a regular Forest Service sale, even to the requiring of slash disposal. Since the last of the plots was established in 1939, no result on the stand of the thinning has been shown as yet, but the economic phase of what is believed to be a beneficial thinning has been proved.27

The effect of thinning old second growth stands has been shown by two series of thinning plots made by the Forest Service on the Willamette National Forest. The stand was seventy-nine years old when the thinnings were made in 1928. These plots were remeasured in 1933, and in 1938. All site qualities were III plus. Accurate statistics on growth and mortality were kept. Both high and low thinnings were tried. The first two in the series, one a low thinning and the other a check plot, showed that in the ten year period the thinned stand grew about ninety-
three hundred board feet while the unthinned grew about six hundred board feet. On a second series of two plots, thirty-one percent of the dominant trees were removed from one and the second kept as a check. The check plot grew eighty-one hundred board feet, while the thinned plot grew sixty-nine. This, however, does not show the growth percent comparison or the result of the concentration of growth on fewer stems. It does prove, though, that low thinnings hold more promise in Douglas-fir stands.27

Oregon State College has experimented with thinnings on the McDonald Forest near Corvallis, Oregon. A graduate student class established one series of three plots: one Borggreve thinning, one thinning leaving only part of the codominant and all of the dominant stand, and the third a check plot. At each remeasuring the Borggreve thinning is found to have the least volume, though the individual trees have accelerated their growth. Little effect has been shown in the growth of the residual trees on the low thinned plot.21 In each of these plots the wood taken out was sold for cordwood and the returns paid the costs of establishment.

In 1933 the School of Forestry established a stand improvement plot near the top of the main ridge in the McDonald Forest. Both students and C.C.C. men were hired to cut down the wolf trees, part of the codominant, all of the intermediate or suppressed treed, and all trees
with crooks, broken tops, and other defects. No accurate record of man-hours was kept, but the wood was hired out at so much per cord, then sold at a figure high enough to return some money to stumpage. No piling or poles were cut out of this stand, though some of the material removed would have come up to the standards set for those products. In 1937 this stand experienced one of the wet snow storms mentioned in the general picture of the region. As a result, forty-nine percent of the trees were topped, while the adjacent stand had only thirty-six percent of its tops broken. Probably the reason for the increase in top breakage is the even canopy of the thinned forest. Also, several hard wind storms have thrown numerous trees on the edge of the thinned area. No accurate figures were kept on this phase of the problem. 21

On the McDonald Forest there are also located four plots of partially logged second growth forest. This stand was logged by a local sawmill owner prior to its inclusion in the school forest, and from half to four-fifths of the original volume was removed. Two of the plots were logged in 1930, and two in 1932. Only the best trees were taken. In 1933 plots were established for observing the effect of such an operation. At the 1937 remeasuring only about one-fourth of the original residual trees were still standing, and those had most of their tops and branches broken, probably by the wet snow of the
previous winter. This sort of thinning is termed "high grading and is definitely only a benefit to the immediate economic situation of the owner. A seedling count by N. Y. A. student workers indicates that the residual stand has not acted as a sufficient seed source to regenerate the stand.21

Managerial use of thinnings.

From the facts presented, it is quite apparent that thinnings in Douglas-fir can favorably influence growth. It is also shown that if the thinnings are managed correctly and near a market, the operation may be accomplished at a profit. Whether or not the thinning is postponed until the thinnings will pay the cost is a choice of policy that is up to the managers.

Low thinnings are quite evidently the best, but even then, windfall and snow break must be guarded against. Low thinnings should be made to favor the final crop trees of the dominant and codominant classes. Enough of the codominant and dominant trees should be taken out to leave the stand growing at the correct speed and of a perfect tree composition.

The selective logging plan can and should be the one followed in making the thinning of older stands, but the cuttings should not be made on an economic selective plan. The change that is taking place in the system of logging is going to be of great benefit to the management of young forests and their thinning operations.
Actual choice of how to go about thinning to relieve the crop trees will require much consideration of the local conditions, what the crop is, and how the materials from the thinning may be marketed. No regional "rule-of-thumb" can be set up for the exact procedures.

Fire Hazard.

In many of the regions the fire problem created by the trash on the ground after a thinning is one of extreme importance. No actual studies have been made of the effect of various methods of slash disposal, but several have been tried on experimental areas. On only one of these areas was the fire hazard a problem. In the selective logging plots on the McDonald Forest, the cut was heavy, the utilization low in standard, and the slash disposal neglected. On the cordwood sales in the same forest the utilization standards were high and the fire hazard low, even without special slash disposal precautions. On the piling sales of the Wind River forest, piling and burning were prescribed in the sale contract, but the Forest Service gave the operator some C.C.C. labor to help in accomplishing the desired result. 21, 27

After the slash disposal problem is solved, the fire hazard in these thinned plots will be less than formerly because of the lack of dead and suppressed trees, and the lack of limbs on the lower trunk of the residuals.
Liberation
From Old Growth Douglas-fir.

Necessity.

After the great fires that swept the early forests, and after the present partial cut of old growth stands, a more or less distorted forest is created. The old residuals, the parent trees, jut far above the younger trees that fill in the barren areas. Usually these old trees are of very low quality, or they are too scattered to log. The "wolf tree" result holds back the growth of the young forest and cuts down the earning capacity of the stand.

In the future, liberation of second growth from the old growth will be more important, because the old growth, even of inferior quality, is becoming more valuable, since much selective logging is being done at present and more will be done in the future. The reason is that forest products' prices will raise enough when the old growth is completely gone to warrant the extra expenditure for eliminating the absolutely unmerchantable trees, as well as make it profitable to cut out the bulk of the old growth overstory.

Economics of liberation.

Whether or not the liberation will pay is one of the most variable of the facts relating to the economics of stand improvement. In order to determine whether it
would pay to cut out the overtopping trees, the merchantability of the trees, and their effect on the production of new forests must be determined. In many instances in the past, the young forest has been destroyed in order to get saw logs from the larger trees. On the other hand, some of the stands were left intact because the residuals of the veteran stand would not even be suitable for cordwood. Merchantability includes not only what product may be made from the trees, but what it will cost to make and deliver the products to a market, and how much the product will sell for on the market.

What effect will the larger trees' elimination have on the younger stand? In many instances the big trees will in falling knock down more trees than their removal will benefit. In other cases the elimination of a wolf tree will make up to a tenth of an acre more forest-producing land available, and the young trees adjacent to the wolf tree will be liberated from its competition. All of these things must be considered before a job and expenditure for liberation are undertaken.

Past experimenting.

High-lead logging did not allow the logging of trees in two-storied forests without destruction of all of the stand. The West Coast Loggers Association advocated leaving these stands for future logging where but few of the overwood were present. Since the advent of tractor logging, most of the two-storied areas are logged without
excessive damage to the young forest. 19

Leaving defective seed trees and the partial cutting in Douglas-fir will tend to create more stands in need of these liberations. The mortality of the residual trees will account for most of the problem on the logged areas, as do the beetles in the residual stand after a fire.

Many instances of open grown parent trees crowding out the younger stand are present in the old burns of the Douglas-fir region. Examples of this sort of competition are easily seen in the McDonald Forest. In fact, Professor T. J. Starker supervised students who began studies to determine the best way of eradicating the overwood on part of the forest. 21 Some trees were cut for cordwood, some were poisoned, and some were girdled. Neither poisoning nor girdling create any new forest in place of the wolf trees, but they did form a fire hazard as snags. The places where the trees were removed grew brush, as well as a few trees, but there is no fire hazard; the adjacent trees were liberated, and some return was realized from the sale of the cordwood sawed from the removed trees.

Managerial use of liberations from old growth Douglas-fir.

The use of liberation varies directly as the complexity of the stand structure and the economic value of the products. Each case must be considered separately, but seldom, under present conditions, will an outlay of money be justi-
fied. Tractor logging and decreasing supplies of available old growth will make the sale of the over wood more profit-
able in the future. The increase in economic value of stands that is almost certain to result from selective logging practices and the like will make the cultural treatment of second growth forests more of a good invest-
ment than it is now generally believed to be.

Liberation

From Hardwoods.

Necessity.

After fires or logging and broadcast burning, the forest land often reverts to hardwood stands of Red Alder (Alnus rubra), Oregon Bigleaf Maple (Acer macrophyllum), and Oregon White Oak (Quercus garryana). After these trees have established themselves and formed a protective cover, Douglas-fir germinates under them. The young fir is held back in its development beyond the seedling stage by this hardwood overstory. Competition becomes very keen, especially with the Red Alder when it is growing on moist sites.

Past experimenting.

Two main groups of experiments in this sort of liber-
erating have been carried on. One is an Alder and Douglas-
fir competition plot on the Cascade Head Experimental For-
est of the Forest Service; the other is an Oregon Oak and Douglas-fir competition plot on the McDonald Forest of the
At Cascade Head Experimental Forest, two plots were established; one as a check for the other. The liberation plot had all of the Alder cut off, while the check plot was left with the Alder overtopping the Douglas-fir seedlings. As yet no results have been published, but the trend has been for much faster growth of the fir on the liberated plot. Because of the density of the Red Alder stand, the man-hours necessary for the liberation were many, but no record of the actual number is available.

Oak girdling and poisoning were tried in places on the McDonald Forest where the Douglas-fir was growing under the Oregon Oak. The forest adjacent to the liberation plots shows, by the presence of the original oak stems, that the oak trees are eventually overtopped and killed by the Douglas-fir. There the forest also shows that the trees which came up under the oaks developed into limby parents of the adjacent Douglas-fir, the parentage being either maternal or in protection.

A few of the oak cordwood sales from the McDonald forest resulted in the liberation of young Douglas-fir. In cases of this sort, a crop was taken off and another crop given a helping hand.

Managerial use of liberating from hardwoods.

Hardwoods are going to have an important place in forest management in the future. Both a short rotation and a generally high value give at least part of them
a decided advantage over the slower and not so valuable Douglas-fir. First, then, the manager must decide whether or not Douglas-fir should be grown on the lands where the competition with hardwoods is severe enough to require cultural aid. After such a decision, the economic possibilities of such a liberation would have to be considered. Many areas could better be left for the trees to fight out the battle for supremacy.

Though there is seldom a possibility of selling the product of this sort of liberation, advantage should be taken of every opportunity to do so. Otherwise the costs and results will have to be carefully weighed before the job may be done, and the present economic advisability of such an expensive operation without a helping income from the cutting is very doubtful.

Salvaging.

Use in management.

Many of the young stands of today are the result of fires that killed out old growth stands. In such stands the snags and down logs have largely rotted away, except for the cedar, which might be either Port Orford (Chamaecyparis lawsoniana) or Western Red (Thuja plicata). The wood from these two trees is very durable and very valuable. Salvaging this dry, seasoned cedar is an industry of importance in the areas of the old burns. Both Forest Service sales and private land sales have been made on the basis of the dead cedar in the area. Wherever possible, this
sort of an operation should be made to bring in an otherwise lost revenue. Since both cedars are very durable, they do not have to be sold immediately, but can be held until the price in the locality is high enough to bring in a return.

The beneficial effect of their removal for the stand is slight, amounting to a decrease in the injury to the small trees when the snags are taken down.

Other than the cedar salvage, second growth forests usually do not have salvageable materials. The trees that drop out as the stand progresses may be taken out as they die, but a thinning is better, both economically and silviculturally, because it takes them all at once and before they have a chance to do serious damage to the growth of the adjacent stand.

Fire prevention and easy suppression are affected by this sort of operation. Snag salvage and cleaning up the forest floor do much toward these two operations, and should be considered as important results of a salvage operation.

Weeding.

No record of any weeding ever having been done in Douglas-fir is available. Douglas-fir is generally pure in the reproduction stage on burned land, so there is little weeding to be done. Some weeding of brush or competing species may have been done, but no record of the job is available.
Conclusion.

The need for stand improvement work in the second growth forests of the region far exceeds the possible amount of work that can be done. The low prices that logs bring, the rough topography, the flooded local markets, all make extensive economic stand improvement but a vision of present foresters and a hope of the future ones. However, especially on farm woodlots, there are many stands that may now be profitably thinned, or which, if given inexpensive pruning now, will be ready to yield high-valued products in both thinning and crop products in the near future. These forests we can now work with. On the other hand there are the vast expanses of poorly stocked forests, the many stands of excessively limby trees that are far back from means of transportation. These we cannot touch until the value of the forest products has gained sufficiently to make the products of treatment salable. Many stands are best left alone at present, although we may be able to work with them in the future.

Perhaps in the future an integrated plan of pruning, thinning and crop production can be worked out. Some forest that is under a medium intensive management could be pruned as soon as the crowns have closed at sufficient height to make pruning practical; then a few years later the forest could be thinned and the high quality thinnings sold for piling or posts. The crop trees under such a system would have the advantage of both pruning and thinning, and the thinnings could be made more valuable by the pruning.
Pruning charges would not be as difficult for the owner to stand, because the thinnings would return him part of his money before the crop had matured.

This and many more ideas are promised in the future for second growth stands.

At present the Soil Conservation Service, the Forest Service, the Plains Shelterbelt Administration, and the Extension Service are working toward the awakening of timber owners, especially the small woodlot owners, to the possible future of an intensive forest management program.
General Problem.

Of the regional total of twenty-eight million acres of forest land, about seven million acres are covered with the two old growth Douglas-fir types of forest cover recognized by the Resources Survey of the Forest Service. The large old growth type has a total area of a little over three and a half million acres, while the small old growth has about three and three-tenths million acres. On these areas the distinction between the three economic types of trees as described in the third paragraph of the section entitled "Economics of the Region," in part I of this thesis, is very pronounced, especially in those stands located in the more remote places.

The selective system of logging that appears to be coming into use in the Douglas-fir region will have two effects on the old growth stands: (1) it will speed up their conversion into potential growing stands; (2) it will leave on the ground many trees that will never be of a positive conversion value. Besides these negative-valued trees, the system also leaves many trees that will eventually become of positive value. These trees are usually left standing in the selective logging unit, differing from the old clear-cut system of falling or knocking all of the trees down. The stand improvement problem will consist of ridding the land of as many of
the undesirable, negative value trees as possible, yet leaving the future valuable trees in a growing condition. This is actually the same problem as is the liberation of second growth forest from the old growth and is treated under that heading.

As the Douglas-fir forests become overmature, two changes take place; (1) the Douglas-fir forests become excessively rotten; and (2) the more tolerant trees of the climax type begin to replace the Douglas-fir veterans. Other factors being the same, this reacts economically in a reduced value for the Douglas-fir trees and a replacement of many of those trees by a less valuable species.

Rot in these old growth Douglas-fir trees is often twenty to fifty percent of the gross volume, and sometimes may be even as high as ninety percent. The suppressed trees in the forest of Silver fir, Hemlock, and White Pine that replace the Douglas-fir sometimes are rotted their entire length before they are six inches in diameter. On some of the poorer site qualities, the replacement type is very nearly completely cull because of rot, wind shake, pitch seam, or other defect. Stands in this condition are producing only watershed protection.

The problem of ridding partially cut areas of the negative-valued trees, and the problem of changing the decadent stands into producing stands make up the stand improvement problem in old growth Douglas-fir types. Both phases of the problem consist of destroying negative values in the
form of rotten, cull, or valueless species, so that growing stands may take their places.

Economics of the problem.

Probably the first question that will occur to the forest managers in relation to this stand improvement problem is "What is a negative value tree, and what is an uncertain value?" The question resolves itself into a problem of predicting future utilization practices and products. Also the factor of the location of the stand in relation to the markets influences the dividing line. The division is up to the manager of each local tract to predict after taking into consideration his costs and what the group with which he works believes to be the future of the timber industry. There are, however, always those trees which are so rotten or so defective that it will be impossible under any probable utilization standard to use them, and this sort of tree should be the one worked with first.

The cost of conversion of the stand to a growing condition will be more than a charge of killing the trees. It will have to include the resulting increase in fire protection costs, the decrease in watershed protection for a period of time, and other direct effects of the killing of part of the stand. The largest single charge will be the cost of working with the trees to kill them, so that cost will be one of the first factors to be considered.
The cost and method used will have to be modified to fit the other cost items as well as the economic policy of the forest-growing agency.

Experiments with the problem.

The realization of the importance of this problem did not come until a very recent date. In 1937 the Pacific Northwest Forest and Range Experiment Station established a series of plots in a very defective Douglas-fir stand on the Wind River Experimental Forest. They established four series of plots, each of which was treated by a different system, and all cost figures were recorded. The stand was composed of Western Hemlock, Douglas-fir, Noble fir, Amabilis fir, Western White Pine, and Western Red-cedar. The job was done to eliminate the defective trees, not to eliminate any one species. The Western Hemlock formed the bulk of the volume, so it formed the bulk of the eliminated trees.

A few facts concerning these plots are given in the following table:

<table>
<thead>
<tr>
<th>Plot</th>
<th>Site</th>
<th>Elevation</th>
<th>Slope</th>
<th>Def. trees</th>
<th>System used for Elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>V</td>
<td>2000</td>
<td>0 - 10</td>
<td>71</td>
<td>Clearcut</td>
</tr>
<tr>
<td>B</td>
<td>IV</td>
<td>1950</td>
<td>5 - 20</td>
<td>42</td>
<td>Cutting defective trees only</td>
</tr>
<tr>
<td>C</td>
<td>IV</td>
<td>1750</td>
<td>0 - 5</td>
<td>21</td>
<td>Girdling defective trees only</td>
</tr>
<tr>
<td>D</td>
<td>IV</td>
<td>1850</td>
<td>0 - 5</td>
<td>36</td>
<td>Cutting and girdling defective trees only</td>
</tr>
</tbody>
</table>
(Note: A poisoning plot was established in 1938. It was found to cost $3.90 per acre to eliminate all trees, using sodium arsenate and a tree poisoning tool. No results have been forthcoming as yet.)

The girdled trees were still alive a year later, but a few were dead in the spring of the second year. Cone crops on the girdled trees were no different from the cone crops on the normal stand.

In many places, the cost of about nine dollars ($9.00) per acre for planting would have to be included in these costs. The residuals in the partially killed stands would act as seed sources for those plots.27

Most private owners feel that too many more pressing problems exist for them to give attention to this detailed situation of the old growth stands. The selective logging operators have as yet given the problem of leaving their logged lands in the best of condition very little consideration.

Managerial application.

Under the present conditions and economic situations, for any manager to spend three to forty-two dollars to change an acre of forest land from a non-producing to a producing forest would be almost financial ruination. Too
much land that will require only a five or six dollar planting to begin production is available. However, if an agency makes a practice of selective logging, it could have a part of the poorer residual trees eliminated by logging practices, such as using the trees for a break in the fall of the bigger trees, and pushing the trees over with a caterpillar tractor. If some such method were used, careful control over all logging would be essential, or too many uncertain-valued trees would be included in the destruction.

Fire, the worst enemy of any forest operator, is a limiting factor in any system of management. Originally, it was the force in the woods that changed the stands to a growing condition. Now that man has taken over that job, fire must be kept out. In poisoning, girdling, or cutting the old trees, a fire hazard is created. The extent of this fire hazard is at present the controlling factor in the change of but a few stands, the cost of killing the trees being the major trouble. The Forest Service limits its killing of trees to two hemlocks per acre in cases where the hemlock cannot be sold, largely because of the fire protection phase of the problem. 25

In cases of stands that contain enough merchantable volume to log, even selectively, the best way of handling the conversion is to log the stand. On some of the government-owned land the cost of road building and other improvements can be charged to fire protection, thus placing much of the small old growth forests in their possession in a more economically available class.
Controlled fires may have a place in the future conversion, but at present our lack of information and ability to control the fires make the use of that agency very dangerous, and hence not recommendable.
Appendix
Fig. I
These two pictures show the limby character of the young Douglas-fir trees. Both are in closed forests, but the limbs are clinging.

Fig. II
The ages of these two stands are twenty years and fifty years respectively.
Fig. III
An example of competition between old growth and second growth Douglas-fir. The old growth was left when the area was logged, and has served as seed trees. Now it is competing with the young trees. The trees pictured here have since been removed for cordwood.

Fig. IV.
Another form of old growth competition with young stands. This tree is a veteran of many fires which used to keep the Willamette Valley nearly bare of forest growth.
Fig. V
A scene in one of the experimental thinnings on the McDonald Forest. Note the slash and limby nature of the trees in the adjacent un-thinned stand.

... 

Fig. VI
A group of eighty-year old trees left after an economic logging. Note the number of broken tree trunks and the clear length of the close-grown trees.
Fig. VII

The result of opening the stand by thinning. Sign reads: "Stand Improvement Plots." (McDonald Forest).

Fig. VIII

A scene in the Tillamook burn. This is an example of the large fires that have swept the region from time to time. Note the ton-and-a-half truck at the left of the camp fire.
Selective logging plots on the McDonald Forest. Plot A is in the group of trees in the center of the picture.


15. Munger, T. T.  

16. Munger, T. T.  

17. Munger, T. T.  

18. Munger, T. T.  


20. Portland Chamber of Commerce.  

Unpublished Research Notes of the Oregon State College School of Forestry.


Index

Acknowledgements ........................................ 1
Foreword .................................................. 11

Part I

A General picture of the Region ..................... 1

Part II

Stand Improvement in Second Growth
Forests .................................................. 11

Part III

Stand Improvement in Old Growth
Douglas-fir ............................................. 37

Appendix .................................................. 44
Literature Cited ......................................... 49