The Application of Silviculture

to Douglas Fir

of the Pacific Slope

by

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INTRODUCTION

That portion of the United States commonly known as the Douglas fir region lies between the Pacific Ocean and the summit of the Cascade Range in western Oregon and Washington from British Columbia approximately to the California line. Here Douglas fir reaches its best development, not only in size and quality of the individual trees, but in the density and rapid growth of its stands.

Serious fires, probably caused by lightning and Indians, have wrought havoc in the virgin forest from time immemorial. The forest when destroyed has usually been replaced by a "second growth" forest of young timber. There is then, in this region, timber of many ages.

This region contains a little over 546 billion board-feet of timber, almost equally divided between public and private ownership and constituting roughly one-third of the Nation's total saw timber supply.

Table I

VOLUME OF SAW TIMBER IN THE DOUGLAS FIR REGION, BY OWNERSHIP CLASSES (3)

	Western Oregon	Western Washington	Total
	Million feet b.m.	Million feet b.m.	Million feet b.m.
Private.........	137,043	123,678	260,721
National Forest..	112,599	88,488	201,087
Other public and. Indian.......	51,151	33,089	84,240
Total........	300,793	245,255	546,048

Of the original 28,000,000 acres of forest area approximately 7 million acres have been stripped of their original forest, and about 200,000 acres are being added to the cutover area annually.

The forests of this region have been the backbone of industrial development from the days of the pioneer settlers to the present time and today are still the mainstay of industry and trade, furnishing income to numerous business enterprizes, taxes to the public, freight revenue to railroads and shipping concerns, and employment to thousands of wage earners.

According to the Washington State Planning Council (30), approximately 500,000 people out of a total of 1,563,396 in 1930 in the state of Washington depended directly or indirectly upon the forest industries for a livelihood, while the Forest Service estimates that 300,000 people in Oregon out of a total population of 954,786 in 1930 depended directly or indirectly on the forest industries of this state for a livelihood.

The Douglas fir region is of great economic importance to the United states because of its present great supply of virgin timber, its large annual contribution of useful lumber products, and its great possibilities for continuous production of superior forest crops in large quantities from lands suited to this purpose alone.

The maintenance of a productive forest resource and of inherent and related capital values is one of the most important problems that the lumbermen and foresters of this region must solve. If the lands of this region are to be lastingly productive and the support of a prosperous people, the industries and communities must be established on a permanent basis with continuous supplies of high-quality raw materials.

It is the purpose of this thesis to study the silvical requirements of Douglas fir and determine the best silvicultural practices, economically feasible, to maintain productivity in the Douglas fir region.

This thesis is not based on original research. It has been obtained for the most part from extensive reading of manuscripts, reports, papers, and bulletins prepared by men with years of experience in the field of forestry in this region.

A brief history and description of the region will be followed by an account of the ecological basis for silvicultural practice, the economic basis for silvicultural practice, and finally the recommended procedures to be followed in this region.

Although there are many other species besides Douglas fir in the region it would be inadvisable to go into the silvicultural aspects of each one, because the time and space consumed would necessarily be too great. However, these species will be considered wherever they affect the silvicultural management of Douglas fir.

HISTORY OF THE REGION

Early Lumbering:

The first sawmill in the region was a small, water driven one set up near Fort Vancouver by Dr. John McLaughlin, Chief Factor of Hudson's Bay Company. This mill had a capacity of 3,000 feet of lumber per day.

Soon the Americans added further operations in the Willamette Valley, on the Columbia river, and at Olympia, Seattle, and other points on Puget Sound. The gold rush of 1849 gave the first modest boom to the industry. Before this, rough lumber sold generally at \$20 to \$ 30 per thousand feet board measure at the mills. By November of 1849 the price soared to \$50, and in March 1850 to \$100. However, the following year it dropped back to \$30 and even to \$10 before the end of the decade.

An added impetus to the development of the industry was the extension of transcontinental railroads into the West. Expansion started with furnishing materials for the Union Pacific in California and the building of the Northern Pacific to Puget Sound. The final milestone in this development was the opening of the Panama Canal, which gave the West Coast the markets of the Atlantic Seaboard.

This expansion of markets caused a gradual improvement in the mechanics of lumbering, and the trend was toward larger and larger operations. After 1850 steam driven sawmills were introduced into the region, and a few years later plants producing 100,000 board feet per day were common. Prior to this time the sawmills were water driven and produced generally from 2,000 to 10,000 board feet per day.

The progress in the woods kept pace with progress in the mills. Hand labor was replaced by oxen, oxen by horses and mules, and finally the steam donkeys and railroad operations began to put in an appearance. These donkeys grew in size, speed, and power, and the railroads were increased in length to follow the receding timberline.

Washington has led the region in lumbering expansion and since 1905 has led the United States in lumber production with the exception of the year 1914. Although cutting in Oregon has not been so extensive, this state has been one of the leaders for a number of years.

Relation of Early Lumbering to Practice of Silviculture:

The early logger practiced a form of economic selection. He selected only those trees that were prime for lumber and which would yield a net profit when put on the market. All the rest he left standing in the woods. This very often left the forest in a good producing condition.

The advent of power yarding ushered in the clear cutting system. Practically all merchantable timber was removed in the first cut, and the few remaining trees were destroyed by the yarding. This type of logging also introduced a high degree of fire hazard. The establishment of reproduction was very uncertain under these conditions and large denuded areas resulted. Much of the cutover lands have been burned over three or four times, killing whatever reproduction that had established itself.

The failure of these methods to maintain productivity is clearly shown by a survey of private lands, logged from 1920 to 1923, in 15 counties of western Oregon and western Washington (3). They showed the following degree of restocking:

Well stocked.	12 per cent
Medium stocked.	17 per cent
Poorly stocked.	29 per cent
Nonstocked.	42 per cent

Clearcutting is the most common method of lumbering used today in this region although some operators are beginning to change over to a form of selective logging with tractor equipment.

CLIMATE AND SOILS OF THE REGION

The climate of this region is exceptionally favorable for coniferous growth. The growing season is usually long and free from extremes of heat or cold, except at the higher elevations in the mountains. The average temperature during the growing season is about 56° F. The annual precipitation varies from 20 inches to over 100 inches, with an average over most of the region of 40 to 60 inches. From June to September there is little rain anywhere in the region.

The region is composed of rugged mountains and broad fertile valleys. The soils of wide variety consist of sterile gravels, sands, heavy clays, loose friable loams, volcanic ash, and almost every possible combination of these individual classes. Generally clays and loams are found on the mountains, while the loams and gravels are found in the valleys. However, it is difficult to make a hard and fast line of distinction because the soil classes are often intermingled to a great extent.

Effects of Climate and Soil on Douglas Fir:

Light:

The Douglas fir is very exacting in its light requirements. This inability of Douglas fir to thrive in diffused light makes it incapable of forming an understory. Although this is a disadvantage to the tree in retaining its position in the forest, it is an advantage from the commercial standpoint in that this inability to withstand shade results in early pruning of the branches, with a comparatively clear, straight bole being produced in early life.

Temperature:

The length of the growing season in this region is variable, and the seedlings have apparently not become adapted to the variability. Sometimes late spring or early fall frosts cause injury to young growth. The actual killing of young growth by frost is not common, but the extensive death of seedlings as a result of frost heaving sometimes occurs.

The Douglas fir seedlings are often killed on hot, exposed slopes through injury to the cambium ring at the surface of the ground. Hofmann (9) says, "A temperature of 144° F. at the surface of the soil kills the cambium and causes girdling of the seedlings."

Douglas fir is affected by a form of winter injury known as parch blight. During the winter months a sudden change from a period of rainy and cloudy weather with moderate temperature and westerly winds to cold, clear weather accompanied by dry easterly winds will turn the foliage on the Douglas firs reddish brown, giving the trees a scorched appearance. The trees, however, rarely suffer serious effects and by the end of the next growing season, at the latest, signs of the injury have practically disappeared.

Moisture:

The successful establishment and growth of young Douglas firs is largely controlled by moisutre.

Hofmann (9) says that the ability of Douglas fir to extend its root system six or eight inches during the early part of the first growing season is an important factor in perpetuating the species.

Severe damage to young stands sometimes results from ice storms, known locally as "silver thaws" or by wet snow storms. The heavy snow and ice sticks to the foliage, and the overloaded tops break off. This makes for crooked and deformed trunks, as well as making an entry port for fungi.

Wind:

The average annual wind velocity of the region varies from 5 to 15 miles per hour, with several stations recording maximum velocities from 40 to 60 miles per hour and over. Occasional bad storms take their toll of trees. The worst storm of this kind in recent years occured on the Olympic

Peninsula in Washington in 1921. The recorder showed a wind velocity of 140 miles per hour before it was finally destroyed. This storm blew down a strip of timber 50 miles long and 15 to 20 miles wide.

The prevailing winds of the summer are from the north and northwest while those of the winter are from the south and southwest. Occasional dry east winds during the summer cause high temperatures and low humidity.

ECOLOGICAL BASIS FOR PRACTICE OF SILVICULTURE

<u>Character of the Forest:</u> (Munger (23) recognizes 3 types.)

In the valleys of Puget Sound, Willamette River Basins, on the mountains of the Coast Ranges, and on the foothills and lower slopes of the Cascade Range where Douglas fir comprises 60 per cent or more of the timber volume, it is classed as the Douglas fir type proper. The associates of the Douglas fir in this type are western hemlock (Tsuga heterophylla), silver fir (Abies amabilis), noble fir (Abies nobilis), lowland white fir (Abies grandis), western white pine (Pinus monticola), and many other less important species.

The fog belt type on the humid western slopes of the Olympic Mountains and Coast Ranges is comprised chiefly of Sitka spruce and western hemlock, although Douglas fir is usually present. Western red cedar and Port Orford cedar (Chamaecyparis lawsoniana) are also valuable components of this type.

The upper slope types of the Olympic, Cascade, and

Siskiyou Mountains are composed largely of species other than Douglas fir. Some of these are silver fir, noble fir, mountain hemlock (Tsuga mertensiana), western hemlock, western white pine, Alaska cedar (Chamaecyparis nootkatensis), lodgepole pine (Pinus contorta), Alpine fir (Abies lasiocarpa), and others.

For the most part this paper will be concerned with the Douglas fir type proper.

Stand Regeneration and Development:

Seed:

Bountiful seed crops in Douglas fir occur at irregular intervals, usually two or three times per decade. Sometimes a fair crop follows a heavy crop and other times hardly any seed is produced following a heavy seed year. Hofmann (9) says,

> "The average mature Douglas fir tree produces about 40,000 seed per crop. A wide variation in seed production is due to age, size, and health of the tree, density of the stand, soil, latitude, and altitude. Each of these factors influence seed production, although the direct effect of each individual factor can not be definitely stated."

The largest crop of cones is found on medium-aged, rather large trees, in open stands and in warm localities. However, cones collected in cool localities are more free from insect attacks than those in warm localities. Young trees yield very good cones.

The age of the tree has apparently no effect on the germination per cent of its seeds.

Insects and rodents destroy large quantities of

Douglas fir seed. In years of light crops the insect Negastigmus spermotrophus concentrates its attacks and often causes failure of crops in some sections. Mice, chipmunks, and squirrels relish the seeds which are their chief source of food over large areas.

Munger and Morris (26) brought out some interesting facts concerning Douglas fir seed. In a series of planting experiments they found:

1. Seed trees of different ages are equally good parents as far as growth of progeny is concerned.

2. The quality of the site where the parent grows does not affect the inherent vigor of the progeny.

3. Seed trees grown in very dense and very open stands produce equally vigorous progeny.

4. The differences in quantity of precipitation between dry and wet localities in western Oregon and western Washington probably are not great enough to cause the development of Douglas fir strains demanding either wet or dry sites.

5. Trees derived from parents infected with red ring rot have grown just as well as those from sound, healthy parents, and at about 20 years of age show no signs of poor health or declining vigor.

6. It is not safe to use seed from a warm coastal belt for planting in the high mountain climate of Oregon and Washington, and some stock derived from high altitudes grows poorly at low altitudes. However, trees derived from

certain localities at relatively low altitudes have done well at high altitudes.

7. No parent characteristics were observed to have affected significantly the viability of the seed. The largest cones and seed were found on the young trees and on the most vigorous branches of any given tree.

On National Forest timber sales single seed trees, two per acre, have done some reseeding, but they are by no means adequate for successful regeneration. Studies of the Wind River Northwest Experiment Station (14) indicate that 75 per cent of these trees are lost within 10 years after logging, and that those not destroyed by logging or slash burning, either windfall or die from exposure, insect injury, or decay. A very good assurance of an adequate seed supply is a nearby block of uncut timber.

In a series of experiments with seed traps, a box kite, and pilot balloon Isaac (12) discovered the following facts concerning the dissemination of Douglas fir seed:

The abundance of the crop, the height of release, the wind velocity, and the tree species all have a definite bearing on the distance and density of seed distribution.

In the shorter woodlot type of trees (trees approximately 75 years old and 150 feet high) the bulk of the seed falls within 100 feet of the edge of the timber, but from a heavy crop sound seed in goodly numbers (8,000) per acre can be expected 900 feet from the edge of the timber.

Although a record of seed fall from typical virgin Douglas fir (225 years old and 210 feet high) was obtained for a light seed crop only, a comparison of dissemination of the two types indicates that the seed from the tall trees will be carried twice as far as that of the wood-lot type.

The kite and balloon tests indicated that the increase in distance of dissemination is more than directly proportional to the increase in height of release.

Many early writers believed that the seed of Douglas fir remained viable for a number of years on the forest floor. However, more recent studies indicate rather definitely that seed not consumed by birds and rodents either germinates or decays within one year after it falls.

Growth of Seedlings:

An abundant and continuous seed supply is a necessity because of the probable annual loss of the young seedlings. Studies (14) wherein environmental factors were measured show that from 66 to 95 per cent of the annual seedling crop is lost from one cause or another. The principal causes of seedling loss on the areas studied in the order of their importance are: heat injury to the stem (sun scald), drought, rodents, frost, insect injury, and competition from other vegetation. Some mortality may be due to a combination of the above causes, and in some years any of these may be responsible for the loss of the major portion of the season's seedling crop.

Heat injury sometimes starts when the surface soil (upper eighth inch) attains a temperature of about 123° F. if the seedlings are less than a week old, and death may follow if this temperature is continued long enough. However, as the seedlings grow older they become more resistant, and sometimes survive temperatures as high as 150° F. Drought losses are serious and would probably be the most certain to occur annually if they did not come along during the periodic dry spell of midsummer after most seedings have been killed off by other causes. Rodents, especially the white footed mice, are often a problem, and in one instance they consumed practically the entire season's crop of newly germinated seedlings on sample plots. Late spring frosts were found to kill tender seedlings by freezing, with injury starting at air temperatures of 30° F. or lower. Late fall and winter frosts will cause seedling loss by heaving. Some losses on the area studied were due to the strawberry weevil and cut worm. Some seedlings were choked out by surrounding vegetation.

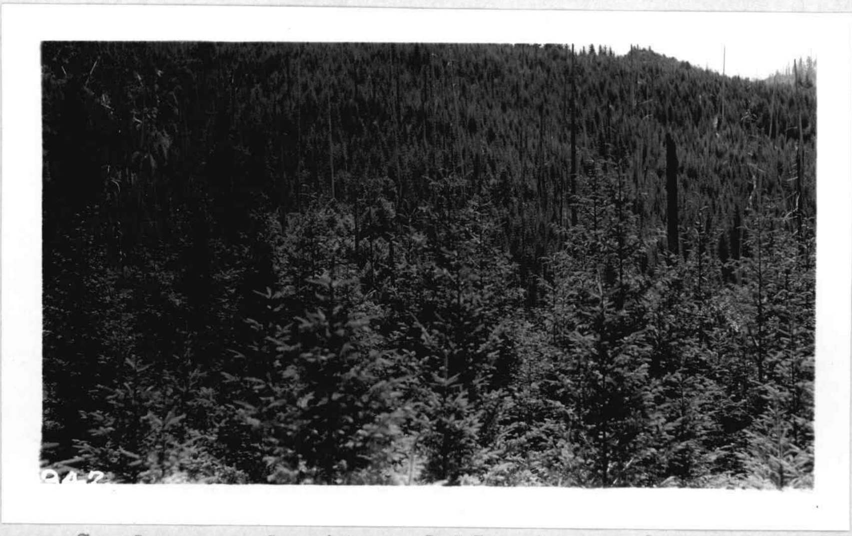
Shade is important not only to keep the soil surface cool in the day time but to keep it warm at night as well. During the summer months of five successive years the maximum soil temperatures on a fully exposed surface averaged 49 per cent higher than the air, and 29 per cent higher under a brush cover, while under virgin timber they were practically the same as the air. While too much shade may be as detrimental as no shade, some shade may prevent great seedling loss by moderating surface temperatures. Shade likewise influences evaporation from the soil and tends to retard transpiration.

"Dead shade" or the shade of logs, stumps, and debris is more favorable to seedling growth than the shade of weeds and brush because it provides the same protection against evaporation, sun, and frost but does not compete with the seedling for moisture and plant food.

For the first few years in the life of a seedling vegetative cover, if not too dense, is helpful because of indirect benefits resulting from its shade. However, when the cover is well established the presence of this competing vegetation appreciably retards seedling growth and also prevents new seedlings from coming in.

Douglas fir after a few weeks is very demanding of light, and plants that have much shade do not thrive. Each year after logging the cover of vegetation becomes denser so that after ten years the ground is matted with dried vegetation and in summer the weeds and shrubs often make a head-high jungle with open spots few and far between. Seed has little chance to find a germinating bed in such an area. Likewise the tiny seedlings are hard put to survive the competition of a continuous cover of six foot plants. Therefore areas which are not seeded rather soon after cutting have a diminishing chance of ever becoming restocked with Douglas fir, even with a constant seed supply.

However, when the trees get a head start on the weeds



Good reproduction following a burn in Douglas fir.

Scattered reproduction following a burn in the Douglas fir region. (Note the hazardous snags which make fire control difficult.)

and shrubs or are able to find plenty of light in spite of this competition, they make vigorous growth and after the first three years begin to shoot up at the rate of a foot, then a foot and a half and even two feet a year, and by the time they are eight or ten years old they are past the danger of being smothered by lack of light. Now the Douglas firs start competing with each other.

Growth Characteristics of the Forest:

The density of the young growth affects its development during its early life and has an influence throughout the life of the stand.

The seedlings of Douglas fir produce more rapid height growth during early life than do any of their associates. Sometimes the height growth during the first few years is small as a result of early or late frosts, and a bushy type of seedling is formed. However, once the leader is formed, the height growth is very rapid.

Although Douglas fir in dense stands is definitely retarded in growth, it does not stagnate. Dominant trees are numerous and natural thinning takes place rapidly during the first 2 or 3 decades. Some stands start as dense as 50,000 to 60,000 seedlings per acre and diminish to 20,000 at 20 years. However, the average stands are not so dense, usually containing 2,000 to 10,000 seedlings to the acre during the first 15 years. The thinnings continue rapidly after 20 years, and at 35 years the average acre of Douglas fir contains about 500 trees. At 50 or 60 years this number becomes 250 trees per acre, and 75 to 100 trees to the acre at 100 years.

In a scattered stand growth is much more rapid during the early stages, but the lateral branches grow to larger size and persist on the trees, producing inferior lumber. In the dense stands of young growth the lateral branches die while small, and after they fall the trunk remains clean throughout the life of the tree and produces clear lumber. Hofmann (9) says that it is important that the stand is started with at least sufficient density to insure clearing of the trunk in the early life of the tree. He says that at least 800 trees per acre are desireable, and even a greater density is not a serious hinderance to the development of the young trees.

Insects and Decay:

Young Douglas fir is very little affected by diseases and insects. The Douglas fir bark beetle (Dendroctonus pseudotsugae) is very common in fallen trees but so far has not caused important losses in living timber. An aphid (Chermes cooleyi) inhabits the needles but is relatively harmless. The western hemlock looper (Ellopis fervidaria) periodically becomes epidemic and destroys considerable merchantable material in some localities before it subsides. The needle-case fungus (Rhabdocline pseudotsugae) may cause defoliation during seasons favorable for its development. The honey fungus (Armillaria mellea) occasionally attacks and kills seedlings and saplings.

Boyce (2) found the ring scale fungus (Trametes pini) responsible for 80.8 per cent in boardfoot volume of the total loss by decay; brown trunk rot caused by the quinine fungus (Fomes laricis) accounted for 8.6 per cent; red-brown butt rot caused by the velvet top fungus (Polyporus schweinitzii) accounted for 6.2 per cent; yellow brown top rot caused by the rose colored conk (Fomes roseus) was responsible for 4.1 per cent; pitted sap rot caused by the purple fungus (Polystictus abietinus) 0.1 per cent; spongy sap rot caused by the conifer root fungus (Fomes annosus) 0.1 per cent and unknown rots 0.1 per cent.

Boyce (2) says that scars are of minor importance as entry ports for decay because red ring rot invariably enters through dead-branch stubs or knots. Of the scars, those resulting from fires are the most important, because red-brown butt rot commonly enters through fire scars. This decay not only attacks the heart-wood of the butt log but also predisposes trees to windfall.

Actual loss through decay sometimes appears in individual trees rather early in the life of the stand.

The Effect of Slash Burning on Site:

The thickness of the duff layer in the Douglas fir region averages about 1.5 inches. In a study (15) of a typical Douglas fir soil at Wind River, analysis showed that the duff on the average acre, estimated to total 32 tons, contained approximately 28 tons of organic matter, 594 pounds of nitrogen, 76 pounds of phosphorus, 555 pounds of calcium, and 121 pounds of potassium. The duff has still further significance because of its influence upon the soil's moisture holding capacity and upon soil-reaction.

Disposal of slash is required by the laws of Oregon and Washington. Figures compiled by McArdle and Isaac (15) in 1934 showed that the quantity of slash left on the average acre after logging was 24,000 cubic feet, and this included 15,000 cubic feet of small branches, twigs, chips, bark, and slabs. A light slash fire consumes about 90 per cent of the branch wood and takes about 10 per cent of the larger slash material. Although this reduces the fire hazard, it also destroys a protective soil covering and future source of soil organic matter.

A heavy slash fire results in almost complete destruction of the duff layer. In an area studied by Isaac (15) the following results were noticed:

> "(1) A loss per acre of 25 tons (89 per cent) of the organic matter contained in the duff; (2) a change in duff reaction from a highly acid condition (ph 4.95) to an alkaline condition (ph 7.6); (3) the escape of approximately 435 pounds of nitrogen per acre; (4) an increase in the supply of plant nutrients available in the surface soil. This resulted from deposition at the surface, in a highly soluble form, of a part of the nutrients present in the duff, which in the absence of fire would probably have become available gradually, over a long period of years. Serious subsequent loss by leaching appeared probable; and (5) an indicated loss of a considerable part of the mineral nutrients contained in the duff, presumably carried off in smoke."

The action of such a fire on the surface zone of the mineral soil causes some dehydration of secondary minerals, colloidal breakdown, change from a favorable to an unfavorable structure, and reduction of moisture holding capacity to a point at which seedling survival is very seriously affected.

Also the blackening of the surface soil greatly increases its heat absorption capacity and can cause its temperature to rise high enough to kill tree seedlings at times when the surface temperature of adjacent unburned, natural colored soil remains so low that no injury is caused.

This greater than normal quantity of plant food available following the slash fire may have an undesireable effect on Douglas fir regeneration. The first year seedlings tend to develop luxuriant crowns and small shallow root systems, which do not fit them for withstanding the annual summer drought. Unburned soil conditions, in which normal quantities of plant food are made available gradually during the regeneration period seem to be more favorable to Douglas fir reproduction. For this reason and because of the adverse after affects of fire on surface soil temperature and soil moisture, Isaac (15) concludes that the harmful effects of the ordinary slash fire more than outweight any beneficial effects it may have on the productivity of Douglas fir forest soil. He also indicates that the harm done is roughly proportional to the completeness with which the fire consumes the duff and the organic matter in the surface soil.

The main reason for slash disposal by burning is to reduce the fire menace of the vast amount of dry litter that there may be less chance of accidental fires latter. However, in this region even the most thorough burning fails to consume all the inflammable trash that is on the ground, and areas burned by a good slash fire have been known to reburn the same year.

After the first slash fire, various weeds--usually those not found in the virgin forest--take possession of the ground and create a vegetative cover, which dies and dries up year after year adding greatly to the inflammability and to the danger of subsequent fires. Prominent among these weeds are fireweed, hawkweed, pearly everlasting, bracken fern, and thistle. If the area is not reburned these plants after five years or so give place to bushes such as hazel, alder, salmonberry, vine maple, and elderberry, and to tree saplings. This decrease in annual plants and increase in shade producing and less combustible brush, reduces the inflammability of the area.

<u>Grazing Use of Cutover Lands:</u>

Ingram (10) shows the possibility of reducing the fire hazard on logged off and burned over Douglas fir lands by sheep grazing. It has been pointed out that many weeds follow a slash fire on Douglas fir land. Sheep graze a high percentage of the foliage of many of these plants. In addition they trample down much of the uneaten vegetation, break up a considerable part of the dry material on the ground, and work it partly into the soil where it can not burn so readily and where it is more apt to absorb moisture.

In studies made by Ingram (11) from 1925-1927, grazing by sheep was found to cause a decrease in most palatable plants, although the grasses and sedges tended to increase under grazing. However, the bracken fern increased under grazing and decreased under protection from grazing. The experiments had not been carried on long enough to determine the cumulative effect on conifer seedlings, but the evidence obtained seemed to indicate that moderate grazing use is not seriously inimical to forest regeneration and is more than compensated by the protection that it affords through reduction in fire hazard.

In a follow-up of Ingram's work Reid, McArdle, and Pickford (29) in 1938 found that on areas of double and delayed burns the initial increase in fire hazard was counteracted by the rapid encroachment of the bracken fern. However, on an area of single burn the substitution of shrubs for weeds has resulted in permanent reduction of fire hazard and considerably improved conditions for reforestation.

The results of their research indicate that cutover Douglas fir lands similar to the ones studied and treated in the same manner will have ample forage from 3 to 7 years following burning, but the supply dwindles thereafter, and the potential duration of grazing on such lands is probably 11 to 15 years.

ECONOMIC BASIS FOR SILVICULTURAL PRACTICE

Many of the stands of this region are silviculturally mature or overmature but are not economically mature. Since they are far from market, expensive to log, cannot be utilized closely, and must enter a surfeited and competitive market, they yield only a slender return. However, the carrying charges on this timber are so great that the owners are compelled to liquidate their investments. Being on a liquidation basis the owners wanted to cut at the same time every tree that would appear to yield a salable board.

To widen the margin between production costs and returns the lumbermen have directed their attention chiefly toward lowering production costs. To do this highly organized engineering technique and a great deal of expensive machinery has been employed, which, in turn, involves high-speed, mass production methods.

The exploitation of the forests by this means has not yielded high returns in all cases. Tracts of excellent mature timber have been liquidated without recovery of the capital investment plus carrying charges. Only the most desireable bodies of timber are salable, only the best species have a positive stumpage value, and even with these the margin of profit is too low to permit close utilization.

Brandstrom (3), in extensive studies, has proved that logging can be done to better advantage with more flexible types of logging machinery and with a consequent lowering of costs.

Utilization:

Logging in this region is accompanied by an excessive waste of lower grade materials. Hodgson (6), in 1926, found that timber of cordwood size and larger abandoned annually in West Coast logging operations amounted to more than 3 billion feet log scale. Many loggers are leaving a substantial per cent of their number 3 Douglas fir logs in the woods. The amount of waste is usually related to the extent of overproduction and operating losses. The great distance that separates the industry from the larger industrial markets of the United States where low grade lumber is chiefly consumed, makes it impossible for the operator to make a profit on the poorer grades.

There is a ray of hope, however, that Douglas fir logging waste can someday be converted into pulp at a reasonable cost. Douglas fir is being pulped on a commercial scale by the sulfate and soda processes. However, the markets for unbleached pulp are limited, and there has been much research carried on to develop pulping processes whereby Douglas fir can economically be converted into bleached pulp or paper with extensive markets. The Forest Products Laboratory has been able to produce a bleachable pulp by the sulfate and sulfite methods, but it does not yet seem practical to use Douglas fir for bleached pulp in competition with such easily bleached woods as spruce, hemlock, and the balsam firs. However, with progress being made along these lines it seems reasonable to believe that there will be a place in industry for the enormous quantities of Douglas fir logging wastes that are now unused.

<u>Economics of Clear Cutting Versus Selection:</u>

In any overmature forest there is generally a good range in tree size and in tree quality and often tree species. Some trees will have a conversion value of plus $5.00 per thousand feet while adjoining trees have a conversion value of minus $5.00 per thousand. Clear cutting practice implies logging negative value stumpage along with the positive. Therefore potential profit from the valuable trees is penalized by logging small or low quality trees at a loss. Selective cutting permits logging only the single trees or groups of trees that have a positive value.

Where large and small trees are intermingled, the unit volume cost of falling, bucking, hauling, loading, and milling the small trees is considerably greater than for the large ones. The manufacturing cost per item is therefore greater under clear cutting than under selective cutting of the larger trees.

Progressive improvements in mobile equipment have developed means for logging selectively in dense stands of large trees.

A selection system makes more of the tract accessible to logging at any one time than does a clear cutting system. The operator therefore is in a better position to take

Light and movable equipment of this type has made selective cutting possible in the Douglas fir region.

advantage of changes in market demands and prices. Under the clear cutting system the operator is rather closely restricted to cutting and forcing on the market everything and anything that lies in front of his fallers.

In a selective cutting the capital investment would be refunded from profits more rapidly than through clear cutting. Since the biggest and best trees are taken first a higher percentage of value rather than volume is taken out during the initial cut. The larger the profits of the first few years, the quicker the capital will be retrieved and the lighter the interest and taxes to be cut in the later cycles.

Munger (25) cites an example of one very large property where there was a rather unusually wide spread from tree to tree in present realization values. It was found that by practicing economic selective cutting the capital investment could be retrieved in nine years, leaving an abundant reserve of growing stock. However, under a clear cutting system it would not be retrieved for 24 years, leaving the land in a poor condition, while the entire stand would be exhausted in 30 years of this treatment. The same tract showed a present stumpage value of $2,000,000 greater with a selective cut than with a clear cut. He advocates logging with tractors and combining these with small sledded or gasoline donkeys, or skyline swings to meet changes in topography and weather.

Even under a clear cut system it is more profitable to log the merchantable timber in three separate operations. In one study Brandstrom (3) found the total costs under the flexible method to be $4.10 per thousand board feet while the costs under the old donkey method were $6.20. This method also causes less breakage since the trees are not all felled at the same time.

This system will not work on all areas, and there may be some stands where it is entirely impractical. However, when it can be used it has decided advantages over the old methods.

Costs of Protection:

The following costs have been estimated for fire protection of the Douglas fir forests during logging (23).

1. Fire warden or chief.--Averages 3.5 cents per thousand of entire year's cut.

2. Fireman, watchman, speeder patrols, etc.-- 10 cents per thousand for summer months or 3 cents per thousand over the entire year.

3. Clearing and sprinkling around donkey setting.-- 0.5 cent per thousand during the summer, or 0.25 cent per thousand over the entire year.

4. Water system (having water in quantity quickly available under pressure on hazardous areas). This cost will vary from operation to operation. A charge of 2.5 cents per thousand of the entire year's cut should cover it.

5. More careful burning of slash--$1.00 per acre or

2.5 cents per thousand logged.

6. Felling snags.--Extremely variable, averages about 8 cents per thousand logged.

7. Proper burning of right-of-ways.--2 cents per thousand of the entire year's cut.

This is a total of 22 cents per each thousand board feet cut. Munger (23) recommends an increased expenditure of one cent per acre for general cooperative forest protection for lands already assessed.

Costs of Securing Reproduction:

If proper cutting technique is used, natural seeding should take place, and reproduction should come in in abundance. In selective timber management there would probably be plenty of trees left to furnish seed although a little planting to control species might be needed. In clear cutting operations the delayed cutting of blocks of timber would not increase logging costs to any great extent.

Leaving sound seed trees is not advisable in this region because of the high mortality of such trees. If 10 or 12 per acre were left, the investment might run up to $30.00 per acre and above. Planting in this region costs between $9.50 and $12.00 per acre when 1-1 stock is used with an 8 by 8 spacing.

Yield of Douglas Fir:

By intensive forest practice, under present standards of utilization, the commercial forest lands of this region could be made to yield continuously 8.2 billion board feet of saw logs per year. This would approximately equal the

TABLE III

Yield table for Douglas fir on fully stocked acre, trees 12 inches in diameter and larger (17)

YIELD IN BOARD FEET, SCRIBNER RULE

Age (years)	SITE CLASS V Site index 90	SITE CLASS IV Site index 110	SITE CLASS III Site index 140	SITE CLASS II Site index 170	SITE CLASS I Site index 200
30.......	0	0	300	2,600	8,000
40.......	0	200	4,500	11,900	24,400
50.......	200	3,300	12,400	27,400	44,100
60.......	2,600	8,100	23,800	42,800	62,000
70.......	5,300	14,000	35,200	57,200	78,200
80.......	8,600	20,100	45,700	70,000	92,500
90.......	12,000	26,000	55,000	81,000	104,800
100......	15,400	31,400	62,800	90,400	115,100
110......	18,900	36,300	69,400	98,300	123,700
120......	21,800	40,700	75,000	105,100	131,100
130......	24,600	44,700	80,000	111,000	137,700
140......	27,200	48,300	84,500	116,300	143,500
150......	29,600	51,600	88,600	121,200	148,700
160......	31,900	54,600	92,400	125,700	153,500

TABLE II

Yield table for Douglas fir on fully stocked acre, trees 12 inches in diameter and larger (17)

YIELD IN CUBIC FEET

Age (years)	SITE CLASS V	SITE CLASS IV	SITE CLASS III	SITE CLASS II	SITE CLASS I
	Site index 90	Site index 110	Site index 140	Site index 170	Site index 200
20.......	0	0	0	0	140
30.......	0	0	150	730	1,850
40.......	0	190	1,190	2,960	5,650
50.......	170	850	3,100	6,300	9,290
60.......	680	1,990	5,650	9,400	12,050
70.......	1,360	3,400	8,000	11,820	14,330
80.......	2,110	4,800	9,940	13,720	16,230
90.......	2,980	6,100	11,430	15,230	17,850
100......	3,690	7,170	12,620	16,410	19,140
110......	4,500	8,050	13,530	17,430	20,200
120......	5,150	8,760	14,300	18,270	21,090
130......	5,720	9,360	14,920	18,960	21,840
140......	6,190	9,860	15,450	19,580	22,520
150......	6,600	10,300	15,910	20,130	23,170
160......	6,950	10,700	16,340	20,650	23,760

average annual depletion in the past.

Table (II) and (III) show the normal yield in cubic feet and board feet for the Douglas fir region.

Meyer (19) found the best yields on north and east slopes, with the highest volumes on approximately 40 per cent slopes. On strip surveys in 83 individual tracts he found that second growth stands of Douglas fir, not including the major openings and gaps, were slightly better than 80 per cent of the normal yield table values.

From present available data it has been determined that young understocked stands between 40 and 80 years approach normality at the rate of 4 per cent each decade.

Intensive forestry should be practiced first on sites of best quality. On a basis of saw log productivity one site II acre is equal to 4 site IV acres while one site I acre is equal to 22 site V acres.

The commercial forest lands of this region average site class III.

THE PRACTICE OF SILVICULTURE

Cutting Methods:

There are three main cutting methods that have been advocated at different times for this region; namely, seed tree, selection, and clear cutting. The selection system has been shown to be the best from a financial standpoint and, if properly applied, will be the best from a silvicultural standpoint, However, local conditions will sometimes dictate that one of the other systems or modifications of all three should be used.

The different cutting methods are discussed separately.

Clear Cutting:

Clear cutting has been practiced quite extensively in this region and usually with very little thought toward securing a future crop. There are, however, various ways to provide for a seed supply under this system. These are staggering settings, reserving strips along creeks and across valleys, leaving single defective trees, leaving long corners or islands of timber, leaving nonmerchantable timber on upper slopes and leaving any patches of immature timber.

In the staggered setting methods, the settings are scattered or staggered so that blocks of uncut timber will be interspersed with the logged areas and remain uncut long enough to reseed the logged land and give it time to pass its most critical period of inflammability. The settings cut clear should not exceed half a mile in width so that the standing timber on either side will surely reseed the intervening blocks. Fire control and slash disposal are made safer by this method because of the size of the clear cut areas.

By reserving strips of timber along creeks, across valleys, and along ridges, a maximum of seeding with a minimum of outlay can be accomplished. These strips would serve as fire breaks as well as sources of seed, since a strip of green timber, particularly on wet ground along a creek, is a decided fire barrier and a material aid in controlling slash or accidental fires. The strips should be wide enough to withstand the inroads of winfall. The strips do not have to be continuous but can be broken as required by logging, character of topography, or character of timber. Where a long, narrow valley is to be logged, transverse uncut strips of considerable width are desireable to bulkhead the watersheds against fire sweeping from one end to the other. If the strips contain many trees of seed producing age they should be effective up to a quarter of a mile. If the strips are narrow, however, they should be placed correspondingly closer.

In many tracts of timber in this region, particularly where the contour is broken or hilly, there are patches of timber that are not profitable to log because of inaccessibility or low quality or a combination of these factors. Whenever the stand and topography suggest the practicability and profit of leaving uncut long corners or islands of timber here and there, the operator should carefully determine in advance of line construction what patches should be left. Then these patches should be protected as much as possible from damage by logging equipment.

Where nonmerchantable timber is left on the upper slopes, great care must be taken during slash disposal to

Wherever patches of immature timber occur, logging lines should be kept out of them, and care should be used in slash burning to keep the fire from running through them.

The result of a clearcut and broadcast burn. Since no adequate means of securing reproduction has been provided, the area will be years in restocking.

prevent it from being scorched and burned. This makes it necessary to fire the slash at the top first and work progressively toward the bottom.

Throughout the Douglas fir forests there are occasional patches of young timber on old burns, old homestead clearings, or logging works. This immature timber is a potential source of seed for the surrounding country. A conscious effort should be made to spare these islands of young timber. Logging lines should be kept from running through them, and cutting should be planned so as to fall and log away from the edges of such patches.

Not all of these methods will be practical on all operations. However, if the operator studies the conditions at hand and uses the method or combination of methods that is best adapted to the topography, timber, and logging equipment the seed supply should be assured.

Seed Tree Cutting:

Certain portions of the Douglas fir region can be regenerated by seed tree cuttings. In many stands there are numerous low value or cull trees. Although they have little or no conversion value because of heart rot, they have good crowns and bear seed of as good quality as that from sound trees.

Trees with full crowns and plenty of foliage should be selected. These trees should be given special attention to protect them from being killed when the slash is burned. This may be done by clearing slash away from them in some cases and firing slash so as to burn away from them.

Single seed trees should not be left within 250 feet or so of railroad tracks, landings, or the guy lines of spar trees. These trees are particularly subject to windfall just over the brow of a hill, on a moist bottom, and where the trees are tall and slender with short, high crowns. They are very subject to logging and fire injury in narrow or steepsided canyons.

The number of seed trees to be left would depend upon their character and the conditions peculiar to the area. It was formerly believed that two trees per acre were sufficient to restock the area. However, more recent studies indicate that up to 10 or 12 trees per acre should be left. Isaac (14) says, "Single seed trees at the rate of approximately two per acre on National Forest timber sales have been found to do some reseeding, but they are by no means adequate."

Because of the high value of merchantable, mature trees and their low survival as seed trees, it would not be financially feasible to leave them.

The single seed tree method is not recommended except where the defective trees are so numerous that a sufficient seed source will assure restocking; where there is a fair chance that the trees will survive fire and withstand wind; where logging will not be seriously inconvenienced by these trees or these trees seriously injured in the logging process; and where other methods of breaking the area into compartments are not possible.

Selective Timber Cutting:

It has been pointed out that the forests of the Douglas fir region include a large number of species. The majority of them being shade enduring form stands of great density. Douglas fir definitely demands open space for regeneration, but once established it develops into extremely dense stands, both pure and mixed. Its inability to regenerate in the stand is largely due to the invasion by an understory of the more shade enduring species before the upper crown cover has opened enough to permit regeneration of Douglas fir. Owing to the wide distribution of Douglas fir many authorities believe it would be good policy in handling the remaining merchantable stands to encourage where feasible the perpetuation of the mixed forest as better fitted to meet the industrial requirements of the region than a pure Douglas fir forest. The mixed forest is generally recognized as the safest from insects and disease.

Under a selective form of cutting, using the flexible operating methods that are now available, selection for economic reasons results in removal of trees both singly and in small groups. These methods if slightly regularized for silvicultural reasons will lead to a silvicultural system wherein regeneration occurs in small groups while the remainder of the stand is not intentionally under regeneration but is subject to stand management for many successive cutting cylces. Kirkland and Brandstrom (16) believe that the clear cut spots will regenerate densely to the desired mixed conifer forest. At the age of 40 to 60 years, wherever there is a market for pulpwood, post, pole, or saw logs, cutting for stand management purposes in these groups can be started, using the same roads on which adjacent old timber is being taken out at short intervals. Such early cutting usually can not be practiced in present large areas of second growth stands because of the low-value products which can not stand the cost of forest improvements constructed for their special benefit. Under the selection form of cutting these improvements are paid for and maintained by the high-quality large timber that is continuously being produced.

Silviculture in order to be practical must be on an economic basis. Selective type of management is the most satisfactory from a financial standpoint. Crawler tractors, fairlead arches, bulldozers, and tractor-mounted drum units combined where necessary with skyline swinging make practical tools for intensive selection by individual trees and by small groups. They also bring important savings through reduction on timber breakage and logging costs.

The advantages of this system are most easily seen in connection with large, well stocked properties with a long time timber supply. In such a forest Kirkland and Brandstrom (16) recommend starting with the best and handiest logging shows for an initial removal of only a small portion of the stand, generally 15 to 25 per cent by volume, partly by individual tree selection and partly by small group selection from one to 10 acres, according to the character of the stand. This would liquidate quickly the financially most overmature portion of the realizable timber capital. In most cases the timber taken out in this first cut would consist for the most part of decadent old growth timber of high stumpage conversion value, together with salvage of merchantable windfalls or other dead and rapidly deteriorating timber.

To carry out this plan a rapid extension of the local road system would be necessary. The savings affected through the hastened liquidation of only a small portion of the stand will pay for this road system.

A permanent system of this kind would give convenient and quick access to all parts of the operating area. This will be of major importance from a fire protection standpoint. This system will permit light return cuts to be made one after another. The cutting operations should sweep back and forth, touching lightly in some places, not at all in others, and clear cutting small patches where necessary, always aiming at removing that portion of the stand which at any given time is most urgently in need of removal. Thus logging can always be kept attuned to the market, and fire-killed, bug-killed, windthrown, or otherwise damaged merchantable timber can be salvaged before serious deterioration sets in.

As the selective timber management program is carried on the net productivity of the forest should gradually increase. Mortality losses in merchantable timber will be practically stopped as soon as windfalls and defective old growth trees are removed, and the remaining timber placed under intensive management. Growth of this remaining merchantable timber should thereafter offset a large part of the cut, thereby extending the life of the timber supply. Further progress should be made as young timber responds to release cutting, and new growth comes in to take the place of the slow growing old timber that has been removed.

Highly favorable conditions will exist for regeneration, survival, and management of new growth, because this method, unlike extensive clear cutting, will provide an abundant seed supply, will better retain the forest climate with its naturally moist growing conditions and relative safety from fire. In densely stocked patches of second growth thinnings would begin at the ages of 40 to 60 years, and this treatment would be repeated at short intervals over a long period before liquidation and regeneration cuttings again took place.

<u>Slash Disposal:</u>

It has been pointed out that slash burning is not beneficial to the soil, and sometimes only results in a temporary reduction of the hazard. However, if the slash is not burned it constitutes a very high fire hazard for 10 to 15 years.

Large accumulations of slash, resulting from the logging of Douglas fir.

A fairly light slash following logging in the Douglas fir.

Broadcast burning has been the common practice in this region. However, more and more judgment is being used in determining what areas to burn and the methods to be used in burning. The state of Oregon maintains a force of inspectors who inspect cutover areas and make recommendations as to the proper form of disposal. Wherever the hazard is not too great they give the operators extensions or releases. Also on National Forest timber sales, the slash is left whenever the right conditions exist.

In determining what areas to burn due allowance must be made for local influencing factors. The selection is largely dependent on the density of the stand, nature of the ground cover, closeness of utilization, and natural fire hazard of the surrounding country. Haefner (5), of the Forest Service states,

> "As a general rule occasional slash areas seem safe to leave when: (1) The debris of logs and broken timber is light or does not exceed 5 or 6 m.b.f. of logs over 6 inches in diameter at the small end, per acre; (2) the brush cover on on the logged area is scattering; (3) the slash area is surrounded by green timber or burned-over areas to serve as a fire break; (4) the area is away from railroads, highways, and other avenues of human travel; (5) the area can be patrolled during the peak of the fire season if necessary."

Wherever there are large accumulations of slash or high likelihood of fire starting, the slash should be burned as a protective measure.

If slash disposal is required, prompt burning is necessary. It will be readily seen that if slash is left one or two seasons, any seed on the area will be germinated and the little seedlings will surely be killed by a fire. This retards reproduction just that much longer.

Much has been said about the proper season to burn. There seem to be arguments on both sides. Spring slash fires consume less of the humus and duff than do fall fires. Spring burning is risky unless the operator is willing to put out every smoldering fire before the dry season if the late spring rains fail to do so. Also, a spring-burned area is subject to higher soil temperatures than one burned in the fall. Fall burning is advantageous in that it does no damage to seed disseminated during late fall and winter.

There are difficulties and disadvantages in burning at any time of the year, and the operator must compare them all from every angle and for each particular set of conditions. Munger (23) recommends a "burn as you go" policy, burning small areas of fresh slash as fast as they accumulate, using both the spring and fall and even the winter season, as circumstances may allow.

It would probably be unwise to recommend any one form of slash burning for the region as a whole. Each cutover differs from every other one, and each has its own particular situations to contend with. On sites of high hazard slash should probably be burned completely. In order to obtain maximum reduction of the fire hazard, the operator should carefully plan his burning so as to (1) get an effective clean up of debris, (2) keep fire out of adjacent stands of uncut timber, (3) protect any young growth left on the areas, (4) keep the slash fire from re-burning areas already logged and burned.

Necessary Steps in Broadcast Burning:

1. The area to be burned should be laid off with reference to topography, cover, and natural fire breaks, so that the fire may be held to the area.

2. The dryness of the slash and surrounding country should be determined, and both should be right before a fire is started. It is just as undesireable to burn slash that is too wet as it is to burn slash that is dangerously dry.

3. A forecast of the weather should be made and the relative humidity noted. Haefner (5) cites several cases where slash was fired just before a rain storm making a mop up of the area unnecessary.

4. The time of day or night should be chosen with regard to humidity, local air currents, etc. Burning should never be started in the morning unless a rainstorm is setting in.

5. All equipment and a reserve crew should be held in readiness to fight the fire if necessary.

6. The fires should be started so the force of the conflagration may work toward the center of the area to be burned. The fire should be started on the uphill side before the downhill side, and first on the leeward side, on the flanks next, and lastly on the windward side.

7. Slashings should be fired so as to protect standing

patches of young growth.

8. Fires should be watched and confined to the lines set.

9. A competent patrol should be organized to mop up and watch the area until smoldering fires are out.

Other Methods of Burning:

Any modifications of broadcast burning such as strip or spot burning have some advantages over broadcast burning. In certain parts of the region where slopes are steep a large proportion of the slash is dragged down to the bottom of the draws. If strips were burned along the base of these slopes most of the slash could be disposed of, leaving the bulk of the cutover land unburned and in better condition for regeneration.

Hazard Reduction:

A great part of the immediate fire hazard is removed when the slash is burned. However, there are other measures necessary to make physical conditions unfavorable to fire.

Snags are great hindrance to fire control because they catch fire easily and scatter sparks far and wide. The state law in Oregon requires the felling of snags except in old burns where part of the snags must be fallen in places designated by the State Forester. The Forest Service also requires the felling of snags on its timber sale areas. Munger (23) says,

> "It should be a minimum requirement that prior to the first slash burning season following logging all snags over 15 feet high and within

150 feet of railroad tracks or of donkey-engine settings should be felled, as well as all snags over 15 feet high and 20 inches in diameter anywhere on the area."

Most operators who have practiced snag felling prefer to fall snags concurrently with green timber. Some of the snags have a value for donkey fuel, and a few have a log value that helps offset the cost of falling.

Right-of-way clearing for principal railroad or truck roads results in large accumulations of highly hazardous inflammable debris immediately adjacent to the roadways. If this material is disposed of, fires will be less likely to start, and those that do start can be corralled more easily and at less expense. This debris can usually be removed by spot burning, which should be handled as carefully as larger slash fires. Generally it should not be necessary to clear more than about 10 feet from the edge of the road. These cleared areas also serve as excellent fire lines through the area.

Prevention and Control of Fire:

The growing of continuous crops of timber in the Douglas fir region is primarily contingent upon the control of fire. It is useless to spend time and money to obtain reproduction if fire is allowed to run over the area from time to time.

The states of Oregon and Washington have recognized the importance of fire prevention and have many laws dealing with this subject. The Forest Service also has strict regulations that must be followed on their timber sales.

An excellent stand of Douglas fir reproduction.

The result of fire in a young stand of Douglas fir. The area is now a "snag patch" of no value and a constant hazard to surrounding timber. Adequate protection must be established on all holdings.

Most logging fires start from one of the following causes: sparks from steam, oil, and gas equipment, live coals from ash pans, sanding flues and dumping ashes in hazardous places, sparks from brake shoes, blasting fuses, smoker's discards, lunch fires, block and line frictions, and operation during dangerous weather.

Many of these causes can be eliminated by the proper equipment or by proper education of the workmen. However, each operation should have complete fire plans drawn up, with men divided into crews with good leaders, proper fire fighting equipment at strategic locations, and an adequate system of fire detection and communication. The relative humidity should be watched closely. As a general rule when a humidity of 40 per cent is expected, patrolmen should be stationed along lines at corner blocks, sprinkling around donkeys should be done oftener and a track patrol should be at full efficiency. At a humidity of 35 per cent extreme precautions should be taken, and the entire operation should be suspended at 30 per cent.

Improving the Quality of the Young Stand:

The size of knots and duration of branches in the young stand are greatly influenced by the degree of stocking of the stand. In the dense stands the side branches die and drop off while they and tree trunks are still of small diameter, and trees grown under these conditions produce a maximum amount of clear lumber. In many second growth stands the trees are not close enough together to

Young stands of Douglas fir, 60 to 70 years old.

A limby Douglas fir. This type of tree has little value and should be eliminated from future stands by proper spacing.

accomplish this result and the natrual stand should be supplemented by planting to obtain the necessary stocking. Trees from well stocked stands also have better form and taper than trees from sparsely stocked areas.

Uniformity of growth is desireable in second growth stands since the comparatively small size of the trees makes it impracticable to cut separate pieces from the portions of the log containing wood of different quality as is now done in the manufacture of lumber from the large virgin trees.

In the present second growth stands of Douglas fir there is a tendency toward a rather abrupt change to slower growth and heavier wood as the trees become larger and the growing space more completely occupied. Uniformity of growth in these stands can hardly be expected without recourse to thinnings, and even in well stocked stands after the lateral branches have disappeared from the lower parts of the tree stems, the removal of some of the trees is very desireable. Then too, larger timber of higher quality can be grown on a shorter rotation if thinnings are practiced.

Allowing trees of low quality timber to grow is likely to cause an increasing liability. There is little demand for lumber cut from such trees, and if left uncut they continue to occupy land that should be devoted to the growing of better trees.

If the highest quality of ultimate product is desired, it is probably best not to thin too early. In some thinning experiments with young Douglas fir seedlings and saplings near Wind River, Meyer (20) found that although the diameter growth was greatly accelerated in the thinned plots, trees of the thinned stands were decidely limby with limbs almost to the ground. Thinning had no noticeable effect on height growth. It would appear from these findings that it might be better to wait until natural pruning had accomplished its purpose before thinning.

Control of Grazing:

If cutover lands have been kept from reburning, moderate grazing of sheep may be a benefit in reducing inflammable weeds. If grazing is permitted the following rules should be observed.

1. The sheep should be handled in such a way as to prevent overgrazing and trampling of the seedlings.

2. Grazing should be deferred for one season on those portions of the area where heavy germination is taking place.

3. Grazing should only be permitted on those areas where the number of seedlings is so great that an increased loss would not result in understocking.

Under a selective form of management, there would probably be few áreas large enough to make grazing a profitable venture.

Control of Disease and Insects:

Since red ring rot, the principal rot of Douglas fir, is for the most part a disease of old growth timber the principal methods of control lie in salvaging infected timber or cutting on shorter rotation. The selective cutting system that has been described is ideal for removing decadent trees. It has been pointed out that all of the area will be easily accessible and under constant attention.

The hemlock looper has been successfully controlled by airplane dusting with calcium arsenite, and this can be resorted to in case of severe outbreaks of this insect.

Planting the Failed Areas:

If the proper cutting methods are followed, reproduction should come in swiftly in the majority of cases. However, this is not always the case, and planting should be resorted to. Planting, is however, an expensive operation and is not recommended as a general practice for this region.

It is best to defer planting until it is apparent that an area will not reseed naturally, and one can not be sure that an area will not reseed until a seed year or two has passed (except in the case of repeated burns) and a careful scrutiny of the ground has been made.

It is better to plant nursery-grown trees than to seed directly because sufficient seed is not likely to escape the birds and rodents unless an extravagant quantity is used. Planting of wild stock is not recommended, because this stock does not stand transplanting as well as nursery-grown trees, and the cost of collecting is prohibitive.

The Forest Service has used 1-1 stock and 2-0 stock for planting on the National Forests. One authority recommends fall-sown one-year-old stock.

The planting in this region should take place in March and April, although earlier planting is possible at the lower elevations. Excellent results can be obtained by one man equipped with a grub hoe or mattock. Although an 8 by 8 foot spacing is recommended, more attention should be given to finding each tree a favorable location than to maintaining a precise spacing. Wherever possible the trees should be planted on the shady side of logs and stumps.

SUMMARY

Douglas fir grows rapidly and attains its largest size in western Oregon and Washington.

The vast forests of this region are of great economic importance to the people of the Pacific Northwest and to the United States as a whole. Therefore they should be handled in a manner that will allow them to perpetuate themselves and maintain productivity.

Douglas fir restocks itself naturally if the forest is properly handled. An abundant and continuous seed supply is a necessity because of the annual loss of young seedlings. The best source of seed is a nearby block of timber.

Insects and decay are not serious problems in young stands, although some of the overmature forests have extensive decay.

Slash burning temporarily reduces the fire hazard but affects survival of seedlings through deterioration of site. However, areas of high hazard should be burned to keep fires from starting at inopportune times. Great care should be used in burning, and the situation should be studied carefully to determine the proper methods.

Because of the high-speed donkey methods of logging clear cutting has been practiced extensively in this region. Areas cut in this manner have not always restocked successfully. Proper reproduction can be secured, however, by keeping the size of the clear cut areas small and keeping fires from running over these areas.

The seed tree method of cutting is not recommended except in cases where a great many nonmerchantable trees are on the area.

The advent of tractors and truck logging gives great promise to the selection type of cutting. It has been shown that it is more economical than the old clear cut method. Favorable conditions will be created for successful regeneration and management, because an over abundant seed supply will be provided, the natural forest climate will be maintained, and permanent roads, a permanent logging organization and intensive fire protection will be provided for. Any timber that is deteriorating on the forest due to wind, insects, fire, or decay can be immediately salvaged under this system. Slash disposal could be left in many cases. Thinning of the growing stock would be possible in this method because of the extensive road system.

A selective form of cut will also best promote the aesthetic and protective values of the forest. Although these are hard to evaluate in dollars and cents the operator of today can not afford to overlook them if he wants the support and cooperation of the public.

Selective cutting, however, is not claimed to be a "cure-all" for silvicultural practice in this region. Many problems will have to be solved. The intolerance of Douglas fir may cause a too rapid transition to the more shade loving species; if the canopy is materially broken, serious windfall may result, and the reserved trees may be damaged by felling part of the stand.

Under any cutting method, adequate fire protection must be provided. Snags should be disposed of and right-of-ways cleared.

With intensive forest practice, and with present standards of utilization, the commercial forest land of this region could be made to yield continuously 8.2 billion board feet of saw logs per year which would approximately equal the average annual depletion in the past.

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