SENIOR THESIS

COMMERCIAL FORESTRY IN THE DOUGLAS FIR REGION

Presented April 10, 1934 by Joe O. Lammi

PREFACE

The vast area of devastated land in the Pacific Northwest has always been a subject of interest to the writer. It was proximity of these lands to his home and early life that first emphasized to him the need for forestry and influenced him to take up forestry for his life work.

The interest has remained, and it was only fitting and proper that he should choose this subject for his graduation thesis, and in this way attempt to bring together, briefly, in readable form, all the available facts touching on this problem.

The writer hopes that this brief presentation, although, perhaps, incomplete and sketchy in spots, will serve to emphasize to the reader that good forestry, timber cropping instead of timber mining, is desirable, possible, and profitable.

Corvallis, Oregon April, 1934 Joe O. Lammi

COMMERCIAL FORESTRY IN THE DOUGLAS FIR REGION

Past Practices, Present Policies, and Future Possibilities in Forestry by the Private Timber Operators of This Region

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Those of us who have had close contact with the logging camps of the Douglas fir country have carried away lasting impressions. As youngsters we were thrilled by the husky cry of the faller, "Tim-br-r-r," the echoes of which were drowned out by the thunderous crash of a giant yellow fir. How well we remember the crunch, crunch of the loggers' spiked boots as they headed down the tracks toward camp with swinging stride, their once-white woolen underwear giving off odoriferous fumes of yellow fir pitch and Scandinavian sweat. As we grew older this romantic (or is it poetic?) side of logging was overshadowed by the realization that logging resulted in the complete and rapid destruction of the wonderful forest. In a few years the surrounding timber had been completely logged-off, the camps had retreated farther back into the mountains, and finally had suspended operations altogether. We inquired as to the cause of this devastation and were told it was caused by the

greed of Eastern lumbermen who didn't realize the wholesale destruction they were causing in our forests, or, if they did realize it, they didn't give a darn! Was this the cause of the denudation of our Douglas fir forests? What happens to the logged-off lands in years to come? Is timber-mining with us to stay? What can be done to keep our forests from becoming extensive bracken-fern fields?-----These are a few of the questions we shall attempt to answer in this brief survey.

The forest problem of the United States is essentially a problem of private forestry. It is estimated by the Forest Service (28) that one-half of all the commercial forest land in the United States, or 270,000,000 acres, is owned by private timber operators, and, in addition, about 200,000,000 acres is in smaller tracts, farm woodlots, etc., so that the commercial forest land in private ownership in the United States comprises about 80-90 percent of the total. Statistics (23) show that the private forests produce 97% of our total yield of lumber and other forest products, represent an investment of ten billions of dollars, furnish employment to 1,300,000 people and support for 10,000,000 more in normal times. These figures show the importance of our private forests; the following statistics show the <u>problem</u> represented. Of the 400,000,000 acres, more or less, of forest land in private ownership some degree of forest management to assure new timber growth is practiced on less than 25,000,000 acres; less than four percent of approximately 9,900,000 acres cut over annually is logged with any regard for future production of timber (27); more than 800,000 acres of private forest land

is added annually to the area already devastated, totaling over 83,000,000 acres; and, although the United States was originally one of the greatest forest areas of the world, the available timber has dwindled until at present it is necessary to import considerable quantities of forest products, especially paper, wood pulp, and pulpwood.

The above facts paint rather a dark picture of the conditions in American forestry as practiced on private timber lands. Does this situation prevail in the private forests of the Pacific Coast? Some facts have been gathered by public and private agencies that will answer this question.

The Pacific Coast has the most favorable conditions for forest growth of any region in the world. Exploitation has not progressed to the extent it has in the eastern part of the United States and at present nearly one-half of the total volume of merchantable timber of the nation is found in the Pacific Coast and Northern Rocky Mountain States. Forest Service statistics (28) show that in the Pacific Coast region 28 million acres are under industrial ownership, the greater part of which is saw timber stand. In the Douglas fir region the investment value of the timber is well over a half billion dollars. The region produces a great deal more forest products than it can consume and many eastern states and foreign nations depend on the Pacific Coast for their timber supplies. The extent of this production over consumption is illustrated by the following figures, thousand board feet, for the year 1928 (28).

State	Production	Consumption
Oregon	4,371,924	1,044,709
Washington	7,305,277	1,703,867

The Pacific Coast produces one-third of the nation's lumber. It produces large timbers, wide clear boards, veneers, and similar material difficult to produce elsewhere. In spite of the importance of this region for timber production present logging practice results in only 60 percent reforestation (1), as shown by the following transect study made in the Douglas fir region:

Non-stocked 40% of the area
Poorly-stocked 30% of the area
Medium-stocked 15% of the area
Well-stocked 15% of the area

It is significant to note that sustained yield as a policy has been adopted by only four Pacific Coast concerns, with a total area under such practice of 209,400 acres. Nine concerns, with a total area of 1,224,050 acres (28), are attempting to prolong the productivity of their lands by practicing selective logging and intensive protection of reproduction from logging damage.

A typical scene in the Douglas Fir Region
a quarter century after logging

It is significant that even the most rudimentary forestry is practiced on less than a million and a half acres out of a total of 28 millions in industrial ownership. Commercial forestry on the Pacific Coast is yet in its early infancy!

What are the reasons for this lack of interest in forestry on the part of our loggers? Foresters, loggers, and timberland owners agree that some or all of the following factors have an important bearing on the lack of private forestry practice, providing for permanently productive timberlands:

1-Uncertainty of future market for products, and adequate returns from the timberlands.

2-Risk in carrying the investment, due to fire, insects, and disease.

3-Excessive taxation burden.

4-Lack of finances to carry on forestry practices with no immediate returns.

5-Ignorance of timberland owners about the possibilities in forestry.

It is believed that these are the outstanding deterrents to private forestry, although other factors of considerable importance could also be listed. Private capital has not been attracted to forestry because the returns did not, apparently, justify the investment. In this connection it is interesting to note that the Forest Service (28) recently made the assertion that adequate fire protection and other measures of forest perpetuation could have been assured by the expenditure of the sum spent in the over-development of operating facilities on the Pacific Coast. That statement, probably a true

one, does not, however, alleviate the situation.

What can be done to make private forestry an attractive investment? Many remedies for the ills of private forestry have been proposed and, in some cases, tried. Our rabid foresters have even gone so far as to attempt to force private timber operators to practice forestry (witness the N.R.A.), but the old adage "you can lead a horse to water but you can't make him drink" still seems to hold true. Private forest owners must be shown that forestry pays before they will take a serious interest in practicing forestry. Representatives of the timber industry have repeatedly declared that private operators must receive substantial government aid and cooperation in meeting their forestry problems, and that such cooperation would be of mutual benefit; one forester (6) says that "a government investment in aiding private forest industries would result in greater returns than the investment in the Panama Canal." Government aid to private forestry could take the following forms:

1-Creation of a Federal Forestry Board, with representatives of private and public interests, to act in an advisory capacity, dealing particularly with problems of forest management.

2-Cooperative fire protection, intensified, probably along lines now followed. This will reduce the risk to all timber owners.

3-Research in silviculture, forest utilization, forest management, and related fields to greater extent than practiced now, and making this information available to all for-

est owners. Education of private owners will increase their interest in forestry.

4-Incorporating into National Forests of tax-delinquent cut-over lands to reduce the burden on the local government and bring these lands into productive condition.

5-Creation of a Federal Loan Fund, similar to the farm loans, to aid financially weak concerns.

In addition to the above federal aids to forestry the states must revise their forest taxation systems, as needed, to prevent undue burdens on timberlands.

The above steps will decrease the effect of most of the deterrents to private forestry or entirely remove them, but the uncertainty of future returns is still present. Perhaps the only way to assure fair returns from forest products is to develop some scheme of production control or stabilization. The lumber code may be a step in this direction, time will prove whether it is a workable and effective one.

From the above discussion one would gather that forestry is impossible without government aid or subsidy. If private forestry cannot stand on its own feet why not eliminate it in favor of public forest ownership? This, of course, is a debatable question and, since we are mainly interested in the problems of the private forest owner, should not be entered into here. It will be of interest, however, to discuss briefly the possibilities in private forest management under the present economic set-up.

In his 1933 report (27), the United States Forester makes the following statement:

"the trend in private forest land ownership is toward progressive deterioration in the character of the forest, in the value of the stand, in replacement through growth, and in the productive capacity of the property. Much of our private forest land, also, is already publicly owned due to tax delinquency or is passing into public ownership."

From that it appears that private forest-land ownership is rapidly becoming a thing of the past. IS private forest ownership a thing of the past? The Forest Service (28) in a recent estimate states that 22.5%, or 6,300,00 acres, of the commercial timber land on the Pacific Coast will remain in private ownership even under present economic conditions. Factors tending to promote continued private forest ownership are: increased stability of the lumber industry due to better utilization developing from a greater variety of lumber products, better merchandising, and greater development of markets for products; progressively decreasing fire risk, improved taxation schemes, and the development of the country resulting in decreasing interest rates.

Since the private owner is apparently doomed to remain in the timber production business what are his chances for making it pay? Let us look back and see what the lumber business has produced in the way of profits in past years. Records of the West Coast Lumbermens' Association (7) from the year 1919 to the year 1928 show four years of gain with average profits ranging from 77 cents to $2.93 per thousand and six years of losses ranging from 18 cents to $2.15 per thousand. During this term, of course, some operators showed constant profits whereas others show losses, the averages being as above shown. Apparently, as a whole, the lumber

business has not been very lucrative. Statistics (7) also show that in the period from 1909 to 1930 the total lumber consumption in the United States has reduced one-fifth and the per capita consumption one-third. The lumberman will continue to meet this situation, with increasing numbers of wood substitutes, etc., coming into the market, and competition of Southern pine products in the Eastern lumber market, also, will continue due to their proximity and lower cost of production. Intensive forestry practice will also incur additional expenses to the operator. Among the expenses to be considered are: taxes, carrying charges, protection, silvicultural practice, stand betterment, and planting.

If the above facts are true how can the operator hope to make forestry pay? The value of intensive forestry practice is illustrated by the following Forest Service (28) figures: cost to the operator on the Pacific Coast of intensive forestry is estimated to be 65 cents per acre per year, the returns from intensive forestry, however, are estimated to be $3.60 per thousand board feet per acre as opposed to $1.18 for extensive forestry, under similar conditions. The returns to the operator are more than tripled!

The industrial timber holdings on the Pacific Coast are located on the best sites of any in the region for production and marketing of the timber. It is stated (24) that the yields in the Douglas fir stands of the Pacific Northwest are the greatest of any in the northern hemisphere! Douglas fir stands, at the maximum capacity, increase in volume at

the rate of four percent per year, or more than twice that of the best Northern European forests. Timber owners may well think about this fact! Germany (31), with less rapid-growing forests and a smaller per capita wood consumption than the United States, finds it profitable to practice intensive and most expensive forest management on nearly as great a percentage of her land area as that under forest cover in the United States, and Germany's forestry is becoming more profitable as management technique improves.

Other facts tending to make forestry more profitable may also be mentioned. In past years the Douglas fir logger left one-third of the volume of the standing timber as waste in the woods, and one-fifth of the sawlogs was wasted in manufacturing. The development of better equipment and new types of forest products reduces and eliminates this great waste. New developments in selective logging and utilization of most valuable timber will increase returns.

As a concrete illustration of what can be done in setting up sustained yield in Douglas fir we shall borrow a theoretical management plan from a recent Forest Service publication (28).

A forest area of 20,000 to 100,000 acres will be small enough for easy management and will be sufficiently large to allow the practice of sustained yield. One-half of this area can be cut-over land without hindering the setting up of perpetual production.

A mature stand of Douglas fir should be clear-cut when setting up sustained yield, and, according to the report, 5 to 15 percent of the area in each cutting cycle will be clear-cut. The lower diameters in a mature Douglas fir stand are commonly hemlock, and, upon release from the competition of the mature trees, will quickly respond with increased growth, often amounting to 400-800 board feet per acre per year. The first cut in this stand can then be made in about 20 years, taking off about 20,000 board feet per acre. The returns of

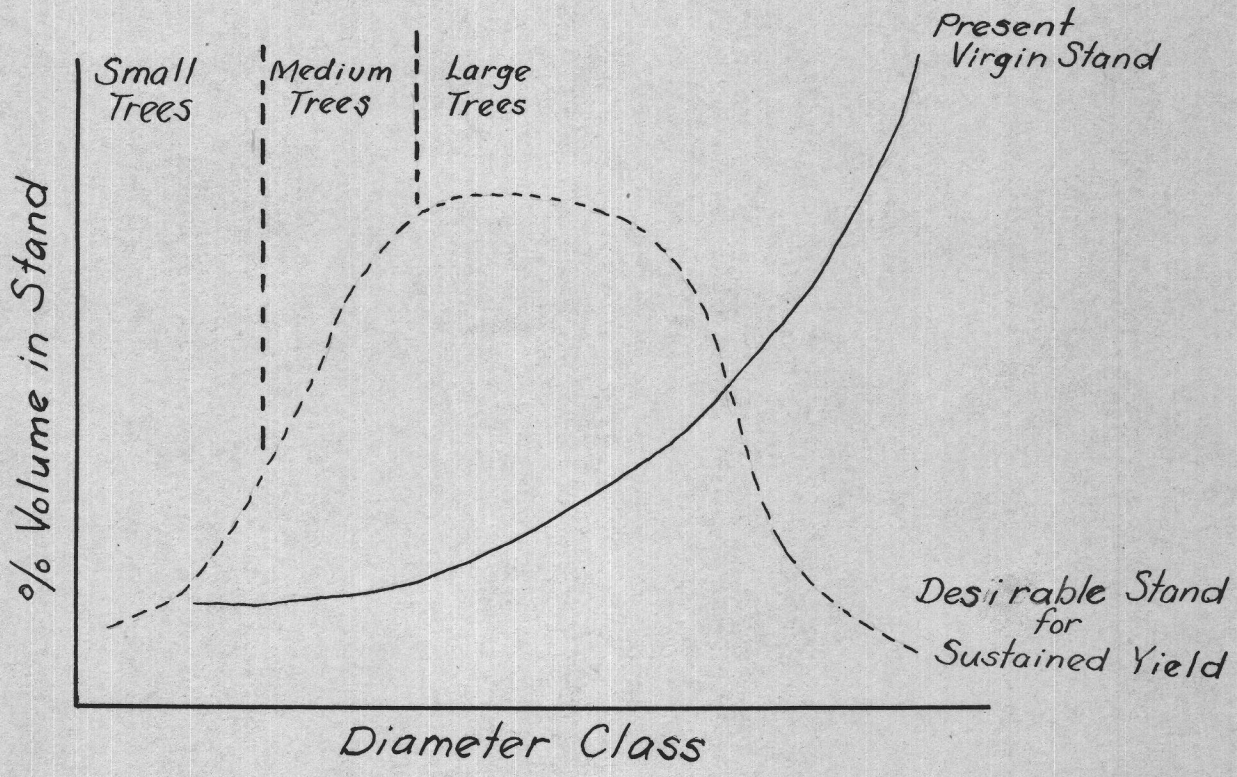
this cut will apply to permanent improvements and a partial on total liquidation of the mature stand.

After the first cut the sustained yield growing stock remains, and will produce about 500 board feet per acre per year. Soon afterward the second cut is begun, taking off 30,000 board feet per acre, or more, varying with local growing conditions. The estimated cost for the administration, protection, and taxes will amount to about $1.00 per thousand board feet.

A mixed Douglas fir-hemlock stand may be thinned for pulpwood in 30 to 40 years. An early cut of the timber will produce poles, ties, posts, and similar material and longer rotations will produce larger timbers and sawlogs.

During all this time the land is never idle and logging operations are never in danger of being shut down from lack of timber.

The relationship between sustained yield forests and present virgin stands is graphically illustrated by the following chart (28):



Enthusiastic foresters and public-spirited citizens are prone to discuss sustained yield forest management in the light of benefits to posterity. Undue emphasis of this may lead to such emphatic, tobacco-juice lubricated, comments as this, made by a Minnesota lumberman: "Posterity! Posterity! What the hell has posterity ever done for me?" (18) Most of our practical lumbermen are undoubtedly more interested in the profits they can receive from the practice of sustained yield management, and it is hoped that our discussion has shown profits to be possible. It is well, however, to point out at this time some of the indirect benefits of permanent timber cropping. The benefits of perpetual forest crops may be summarized as follows:

1-Forests become permanent resources, and will furnish continued timber supplies, employment, and benefit to the people.

2-Nearby communities are stabilized, unhealthy "boom" towns will be prevented. A permanent industry will result in permanent communities which will be of great benefit to the people of those communities. Stable communities provide greater social and economic opportunities through the churches, schools, public libraries, hospitals, places of entertainment, stores, etc. Furthermore, nearby farmers will be assured of permanent markets for their products.

3-Indirect and other benefits to the community and the nation will include: preservation of constant water supplies, prevention of floods, increased opportunities for recreation, prevention of losses on taxes due to devastated lands, a less

costly lumber supply of the future, a permanent lumber supply available in emergencies, prevention of overproduction of forest products since sudden liquidation of vast timber stores is unnecessary.

Private timber owners may well ask themselves: "is not sustained yield forest management worthwhile?" Private operators, communities, the state, and the nation will all benefit from timber cropping. Isn't it reasonable to hope that forest management will be practiced on more than one million acres out of a total of twenty eight million on the Pacific Coast?

Logged-off----brush reproduction

What is the present condition of the cut-over lands in the Douglas fir region? Timber mining resulted in vast areas of denuded lands which apparently produce nothing but fireweed and bracken fern years after being logged. Research (16) (17) on Douglas fir reproduction has brought out facts that may show the reasons for the lack of a new forest cover on these lands. Clear-cutting of the forest with the sudden exposure of the soil to the elements has been found to have the

A spot of good Douglas fir reproduction

And a spot of poor

following effect:

1-The temperature of the air and of the soil is increased.

2-The rate of evaporation from the soil is increased.

3-The rate of transpiration of the plants on these areas is increased.

4-The temperature and moisture fluctuations on bare areas prove very injurious to seedlings.

5-The practice of broadcast burning of the slash leaves a bare, charcoal-covered area which is more subject to overheating than other areas, with a fatal effect on young tree seedlings.

Studies (16) have further shown that south and west exposures and poor soils have the poorest reproduction. Plants starting on these sites are the most subject to death from exposure, drought, and competition of more hardy vegetation. The intense heat of direct sunlight (plant leaves die at temperatures between 104--122 degrees F.) and the drying effect of the warm prevailing westerly winds result in conditions discouraging to tree seedling growth. Douglas fir reproduction, in nearly all cases, is more abundant on the north and east slopes where the heating and drying of the soil is less severe.(14)

Regardless of the fact that clear-cutting tends to bring about conditions unfavorable to Douglas fir reproduction it is generally agreed that no other system has yet proved as applicable to this type of stand. Forest research (17) has shown, however, that the controlling factor in Douglas fir reproduction is soil moisture and that clear-cut areas have

the lowest percent of soil moisture, as an average for the year, of any method of handling the stands. Studies (17) made between the years 1919-1924 show that the selection and shelterwood systems of handling Douglas fir stands result in thrice the amount of reproduction found on clear-cut areas. Although this study also shows that only six percent of the Douglas fir seedlings survive after the first year, and 50% of these die within the next three years, the shelterwood area shows the most vigorous growth of the surviving seedlings and is to be highly recommended for this species. Timber owners, however, may well proceed with caution in adopting any new schemes for handling Douglas fir stands. Other foresters have come out with statements in support of our old clear cutting method (1), of group selection (28), and of various modifications of these. Further research on this subject is necessary, and cutting systems will undoubtedly vary with individual stands and local conditions.

The Douglas fir stands of Southwestern Washington have been logged-off by the clear-cutting method, and no provision was made for future forest growth. A survey of the extensive logged-off areas shows anything but a pleasant picture from a forestry viewpoint. A typical area was selected in Cowlitz County, Washington, on which operations were abandoned over a decade ago. The Douglas fir had been clean-cut but the less valuable hemlock had been left, to be broken-up in the logging operations or to survive. Part of the hemlock had survived and is reseeding the surrounding area to this species. Douglas fir appears in some spots but is too scat-

tered to form a valuable stand. In the areas of best reproduction, the sheltered valleys and coves, Douglas fir occurred in very open, limby stands, estimated at less than 150 trees to the acre. Such a stand is valuable only as a source of seed in future years. It is significant that reproduction occurred in the sheltered valleys and seemed to prefer mineral soil, such as along old skidways. Reproduction also preferred the north and east slopes, and was absent altogether on the exposed southerly aspects. Bracken fern was very abundant and dry, a great fire hazard. The old railroad grades were supporting a vigorously growing and dense stand of alder (Alnus oregona). In the areas of scattered reproduction, both alder and Douglas fir, rodents were abundant, and numerous young trees were girdled, limbed, and destroyed by these pests.

Over three decades after logging----
View from a farmhouse

When conditions like the above prevail several decades are necessary to produce a new forest cover on the land. Planting may be necessary on these areas but is expensive,

therefore it would be desirable to handle the stands with an eye to future yields, particularly in the matter of slash disposal. If the Cowlitz County loggers had practiced better fire control and kept fires off the cut-over lands perhaps a new forest would now occupy the bracken-fern fields. Slash fires destroy the seed that may have been dropped by the trees that were removed, and recurring slash fires destroy all seedlings that may have subsequently started.

Natural reproduction is in nearly all cases preferable to reproduction by artificial means such as planting, and the aim of all timber owners should be to secure a new forest by natural means when the old forest is cut off. Instances where artificial regeneration may be used are summarized as follows (26):

1-In very old stands where the Douglas fir is too old to bear seed and where the undergrowth is of undesirable species.

2-In stands where the leaving of seed trees is impossible due to danger from windthrow, etc.

3-In stands where trees are of high merchantable value.

4-Where a great danger from erosion or brush competition exists and where immediate forest cover is necessary, as on a city watershed.

If past logging practices have resulted in denuded lands what are the present operators doing to better the situation? Although forest devastation still goes merrily on in some regions it is encouraging to note that as a whole the lumbermen are showing greater interest in good forestry practice.

In the Southern States (11), although state forestry legislation is in many cases lacking, the loggers are showing considerable interest in forest growing. The operators are practicing close utilization of their timber, organized fire prevention, special methods of slash disposal, good forest management with diameter limit cutting aimed at a reasonable cut with future timber production, and some operators go so far as to carry on research in the management of their forest lands to attain maximum production.

In the Idaho White Pine Region operators are practicing forestry to a great extent. One of its largest operators, the Clearwater Timber Company (12), is finding good silviculture profitable. Horse and tractor logging, diameter limit cutting, leaving an average of 97 trees per acre below the 11 inch diameter limit, and adequate fire protection are all practiced and found desirable. The Clearwater Timber Company plans to log these areas again in about 35 years.

In California the redwood operators proudly point to the fact (30) that they are planting twenty trees for every one they remove. They have found that the yield from the second growth forests exceeds that of the virgin stands. Although, according to recent reports, the redwood reforestation and fire protection program has been seriously curtailed during the depression the attitude of the lumbermen is at least encouraging.

We have previously pointed out that private forestry on the Pacific Coast is still a matter of the future. It can be reasonably expected, however, that this will not be

the too distant future. One of our largest operators (21) has made the statement that "the large and permanent lumber companies of the Douglas Fir Region desire to conserve the great forests which are their heritage and their responsibility." Such a statement is significant, regardless of the fact that some of our foresters (4) warn us to take these statements "with a grain of salt" for, they say, "this hullaboo is inspired by selfish motives, real estate development, protection from lawsuits, development of the esthetic beauty of their lands, and similar reasons far removed from timber production."

In the United States as a whole the industries have spent $2,500,000 on forest research of which 90% was research in forest products, mainly dealing with pulp and paper. Industrial research has taken the form of investigations in pulp and paper, wood preservatives, fire-proofing of wood, and other problems of wood utilization. Lumbermen have also taken an active interest in research along the following lines: amount and condition of reproduction on their logged-off lands, value of the lands for purposes other than timber production, selective logging, seed certification of the forest tree seeds sold by them, and others.

In the Douglas fir region many individual lumbermen are doing work along forestry lines. Considerable publicity has been given such forestry-minded operators as the Crown Willamette Paper Company and the Long-Bell Lumber Company. The timber cropping plans of these companies can well be taken as examples of what constitutes desirable industrial forestry

planning. It is to be regretted that the economic depression has forced serious curtailment of these plans. The Crown Willamette Company has operated its own nurseries in West Linn, Oregon, and carried on extensive planting operations with plans for placing its forests on sustaine yield. Other companies interested in forestry to a lesser degree include (23) Booth-Kelly Lumber Company, Hammond Lumber Company, Weyerhaeuser Timber Company, St. Paul and Tacoma Lumber Company, and many companies of the Gray's Harbor Region including Polson Logging Company, Donovan-Corkery Timber Company, Simpson Logging Company, Shaefer Brothers Logging Company, Northwestern Lumber Company, Clemmons Logging Company, and others.

As an example of what lumbermen can do in the way of industrial forestry we shall briefly consider the work of the Long-Bell Lumber Company in Longview and Ryderwood, Washington (13).

The original plans of the company called for the restocking of its cut-over lands by means of natural reproduction as much as possible and artificial regeneration of the rest. The logging operations were planned with this in mind and experiments with modified logging methods, such as "spot" logging, were tried. It was found that one-half to two-thirds of the area cut-over each year had to be planted because natural reproduction was difficult to secure due to the lack of seed in the very old timber and the large denuded area produced annually, making seeding from the surrounding timber impossible.

The planting program called for mixed stands and species that could be thinned at an early age and utilized for pulp.

Reforestation was to keep up with denudation, but, of course, a year or two behind. The company has tried the following forest tree species: Port Orford cedar, redwood, Douglas fir, western hemlock, Sitka spruce, western red cedar. To decrease fire risk the planted areas were divided into compartments by planting firebreaks and railroad grades with alder and some other broadleaf species such as willow, cottonwood, and cascara. The alder is said to act as an effective fire break, and, due to its rapid growth, it can be utilized at an early age at considerable value. The company has also cooperated with the State of Washington (29) in the operations of lookout towers to protect its land.

The company collects forest tree seed in the nearby region, and has experimented with seed collected in different forest regions. The forest nurseries, located in Ryderwood near the logging operations, have an annual output of two million trees when operating at full capacity, and are constructed according to modern plans, having such innovations as electrically heated seed-beds, etc. At present (1934), due to financial difficulties, the company has been forced to abandon its planting program and the nurseries are leased to private nurserymen.

Planting is done with 1-1 stock for the most part, and since operations began in 1926 the plans have been to plant acreages as follows: 1926, production started in nurseries; 1927, 400 acres of cut-over lands planted with own and imported stock; 1928, about 1600 acres planted; 1929, 2550 acres planted; and the 1930 plans called for the planting of 3000-4000 acres. Since 1930 no forest tree planting has been done

except for about 100 acres planted for rabbit poisoning research. Apparently the worthy forestry program has been abandoned for an indefinite time.

The Long-Bell Lumber Company had an extensive and ambitious forestry program that could well be copied by other companies, but financial difficulties have forced retrenchment. Perhaps in the future plans such as these can be carried to successful conclusion,--when that day arrives, of course, our private forestry problems will be a thing of the past. Under the lumber code our Douglas fir loggers will "leave their lands in condition for regrowth." How this is to be accomplished and how far the loggers will go to accomplish it is a matter of conjecture.

Private forestry is struggling under great difficulties at the present time. Unless changes are made in our economic set-up we will probably continue to see forest devastation, the continued growth in our bracken fern areas, and retrenchment in the forestry plans of our lumber companies. Foresters hope that the spiked boots of the Scandinavians can continue to crunch in logging camps that will continue to operate as long as civilized man uses wood. The ideal of sustained yield of our forests is basically sound and we should strive to overcome the difficulties which prevent its extensive application.

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