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(SUPPLEMENT)

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# GROWTH after partial cutting of PONDEROSA PINE on PERMANENT SAMPLE PLOTS in EASTERN OREGON

BY EDWIN L. MOWAT



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U. S. DEPT. OF AGRICULTURE · FOREST SERVICE

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## INTRODUCTION

The purpose of this supplement to Research Paper 44 is to describe in further detail each of the seven series of ponderosa pine methods-of-cutting study plots that are summarized together in the research paper. This supplementary report describes for each area the site, the timber stand, and methods of cutting tested; gives data on board-foot growth and mortality for the earlier years as well as most recent period of measurement; and discusses these results as related to stand conditions and cutting methods.

This is the first complete published report on any of these studies. Hence it seems desirable to make available this more detailed information for reference by foresters in eastern Oregon or others who may be interested in specific areas. Reading some of these more complete reports may also give aid toward a more thorough understanding of the factors affecting growth and mortality and the background of the conclusions and suggested ideas on application given in the research paper. If still further detail is desired, anyone interested may borrow the unpublished office reports listed at the end of the supplement, page 27.

Since cross-reference is made to several figures and tables, the series numbers of such in this supplement are a continuation of those in the research paper.

## WHITMAN NATIONAL FOREST PLOTS 1-3[1]

The Whitman methods-of-cutting plots are the oldest ponderosa pine plots in Oregon and Washington. These three 15-acre plots were established in 1913 on the Eccles sale area near the Blue Mountain Ranger Station by T. J. Starker and others. Plot 3 was cut in 1914 according to the prevailing Forest Service practice of that time; 82 percent of the merchantable volume was removed (fig. 1). Plot 2 was a somewhat lighter cut removing 70 percent, largely in the form of a group selection which made large openings in the stand. On plot 1 a lighter selection cut removed 62 percent of stand volume, taking overmature, defective, and less vigorous trees.

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1/ These plots are in the Blue Mountain Ranger District, the administration of which was recently switched from the Wallowa-Whitman to the Malheur National Forest. However, since they are so familiarly known as the Whitman plots, that name is retained in this report. This also avoids confusion with Malheur plots 1-3.

Growth of reserve stand has not been too encouraging over the full 36-year period of measurement. Net annual growth[2] has averaged only 7, 35, and 59 board feet per acre on the three plots (table 4). Even gross increment has not been as good as on some areas, but the chief trouble has been loss of trees from windfall and bark beetles. The plots may be subject to higher than average loss, as they are situated on a low broad ridgetop with a shallow rocky soil over lava bedrock. Windfall losses during the first 5-year period were especially heavy because of a severe storm in September 1914; average annual loss for this period was 128 board feet per acre; average annual loss for the entire 36-year period was 23 board feet. Losses from insects have continued throughout (averaging 22 board feet per acre annually), but have been heaviest on plot 1 where more mature trees were reserved, least on plot 3.

Apparently there has been a progressive deterioration over the years of many trees that must have been thrifty at time of cutting, with consequent development of high-risk characteristics and bark beetle kill. The cause is not known; some ascribe it to inability to cope with increasing competition from dense reproduction stands which were released by removal of overstory trees (fig. 1). Root rot may be a factor; this has not been studied. Many ponderosa pine stands in the region, especially those on marginal sites, suffered deterioration and heavy insect attack during the dry years of the 1930's. This may have affected the reserved trees here, too.

This is the only set of plots that provides much indication of trend of growth with time after cutting. Since mortality on small plots may be erratic, gross increment of sawtimber trees is taken as the best rough gage of that trend. Gross increment of plot 1 (with largest reserve) has continued at a fairly even rate over five periods of measurement, while rates for plots 2 and 3 have progressively increased. This tends to confirm the showing by Briegleb (1) that good growth is maintained up to 40 years or more. Studies in the Southwest (9) and the Northern Rocky Mountains (10) have indicated a falling off in growth rate after 10 to 20 years. However, the maintenance of accelerated growth here could be discounted to some degree because of the probable but unmeasured influence of more favorable climate in the last decade.

The Whitman plots have also given us the most complete record we have on quantity and development of reproduction. Seedlings were abundant, although inconspicuous and patchy in distribution, at time of logging, averaging from 7,912 pines per acre on plot 1 to 4,776 per acre on plot 3. Up to 1939, 42 percent of these were still living.

New seedlings appeared in large numbers, especially in 1914 and 1915; up to 1939 cumulative numbers of subsequent seedlings were from 10,720 per acre

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[2] For definitions of terms and units, see page 22 of Research Paper 44.

Table 4.--Summary of statistics for ponderosa pine methods-of-cutting plots 1, 2, and 3, Whitman National Forest (per-acre basis)

| Plot No. | Area | Year cut | Number of years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 1 | 15 | 1914 | 36 | 62 | Light selection |
| 2 | 15 | 1914 | 36 | 70 | Group selection |
| 3 | 15 | 1914 | 36 | 82 | Current R-6 or heavy selection |

| Plot No. | Original volume | Cut volume | Residual stand (1914) | | | | Volume at beginning of recent period (1939) | Volume at end of recent period (1950) |
|---|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees[1] | Average d.b.h.[1] | Percentage of other species | | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. | Bd.ft. |
| 1 | 29,070 | 17,904 | 11,166 | 16.8 | 22.7 | 1.6 | 10,753 | 11,439 |
| 2 | 23,594 | 16,397 | 7,197 | 11.6 | 21.9 | 1.6 | 7,652 | 8,519 |
| 3 | 27,283 | 22,460 | 4,823 | 10.4 | 19.9 | 5.3 | 5,912 | 6,902 |

| Plot No. | Periodic annual increment and mortality | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | First 25 years after cutting | | | | | Latest 11 years | | | | | Net increment for entire period |
| | Gross increment of reserve | In-growth | Mortality | Total net increment | Net growth | Gross increment of reserve | In-growth | Mortality | Total net increment | Net growth | |
| | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent | Bd.ft. |
| 1 | 74 | 5 | 96 | -17 | -0.2 | 86 | 4 | 27 | 63 | 0.6 | 7 |
| 2 | 58 | 10 | 51 | 17 | .2 | 78 | 10 | 9 | 79 | 1.0 | 35 |
| 3 | 69 | 8 | 33 | 44 | .9 | 86 | 6 | 2 | 90 | 1.5 | 59 |

[1] Number of trees and average d.b.h. are of sawtimber trees only; i.e., those 11.1 inches d.b.h. and larger.

on plot 1 to 4,728 on plot 3. Average survival of these new seedlings to 1939 was, however, only 9 percent. In spite of these apparently large average numbers, there are still some openings that have not restocked.

Selected advance pine seedlings (those present at time of logging) have grown from an average of 1.9 feet tall to 21.6 feet tall in 36 years (fig. 1). Young trees of western larch and lodgepole pine have grown a little faster than ponderosa pine.

There are differences in numbers, survival, and height growth of seedlings between plots, but for the most part they can not be ascribed to particular method of cutting. However, in terms of reproduction which had reached the pole stage (4 to 10 inches d.b.h.) by 1950, the heavier cut plots seem to show an advantage due to greater release from overstory competition. Number of such trees per acre averaged: plot 1, 192; plot 2, 224; and plot 3, 392. These numbers are in inverse relation to the total numbers of seedlings per acre previously cited.

Ingrowth, which is board-foot volume of trees entering the minimum sawtimber size (11.1 inches d.b.h. in this study), has contributed from 2 to 12 board feet per acre per year to total growth through the five periods of measurement. Differences between plots have no significance. This source of increment should increase very rapidly within the next 20 years as great numbers of poles will be reaching minimum sawtimber size.

Differences in cutting methods on the three plots are largely in degree of cut, although particular mode of marking had some effect upon nature and distribution of reserve and hence upon growth. Plot 3, cut to the heaviest degree by Forest Service standard selection and having the lowest reserve volume, made the highest net growth over the 36 years. Even its gross increment was equal to that on plot 1, which had more than twice as much initial reserve volume. Number and volume of thrifty immature trees was relatively low on all plots, but particularly low on plot 1, where the additional reserve volume was largely in slow-growing overmature and less-vigorous mature trees.

Gross increment of plot 2, group selection, averaged a little lower than either of the other two; one-fourth of its reserve volume was in overmature trees in 1939, and many individual trees grew poorly because of their clumpwise distribution. In the spaces between groups, young trees should have a better chance to develop rapidly, but such a trend is not strongly evident in the record of the pole stand to date. For the latest 11-year period, total gross increment was practically the same on the three plots.

The relatively slow growth rates on plots with heavier reserve volumes may be partly compensated by somewhat higher average quality; also by greater opportunity for an early second cut of large trees. Thus in 1950, the board-foot volume in trees over 24 inches d.b.h. was about 8,000 per acre on plot 1, 6,000 on plot 2, and 4,000 on plot 3.

## JOHN DAY EXPERIMENTAL FOREST PLOTS 1-3

The first study started on the newly created John Day Experimental Forest was the establishment in 1936 of three sample plots to measure growth and development of typical reserve stands on the western half of the forest. This area had all been cutover between 1918 and 1926 under prevailing Forest Service marking practice of the time, a heavy selection cut in which an average of about 80 percent of volume was removed. The percentage of cut actually varied from 68 percent on plot 1 to 86 percent on plot 3 (table 5). These differences reflect variations in volume, composition, and structure of original stand such as might be expected in any broad area, and possibly also slight differences in marking practice from 1920 to 1923. The three plots lie in three different sections, but all are on southerly aspects and thus represent ponderosa pine type rather than the mixed-species type found on northerly aspects.

Reliable growth data are available only for the 13-year period 1936-49, although rough figures on original and cut volumes, as given in table 5, were derived from stump measurements and sample increment borings. Net annual growth averaged 58, 91, and 83 board feet per acre on the three individual plots, or 81 board feet for the group. This is a fairly good rate for such heavy selection cuttings. It may be credited to the comparatively high proportion of young reserve trees (Keen age class 2), low rate of mortality for ponderosa pine, and high ingrowth rate. Other species (Douglas-fir, white fir, and western larch) also grew fairly well and contributed 19 percent of total gross increment.

Gross annual increment of pine sawtimber trees on the three plots averaged 61, 68, and 68 board feet per acre--a narrow spread compared to that of total net increment. These rates show little relation to volume of pine reserve--the lowest reserve was on plot 3 but it grew as much as the heaviest reserve on plot 2. The stand on plot 3 contained more full-crowned vigorous trees (Keen class 2A and 3A), and reserve trees were more uniformly spaced over the area than on plot 2. Plot 1 also had a rather poor (clumpwise) distribution of sawtimber trees. Small differences in site quality between these three widely separated plots may also have affected growth.

Ponderosa pine suffered an average loss of 7 board feet per acre per year while Douglas-fir was losing 9 board feet. Cutting had removed all old and decadent pine trees but this was not true of Douglas-fir. Heaviest volume loss of Douglas-fir was in a few old trees on plot 1. Insects, wind, and lightning were responsible for 42, 36, and 21 percent, respectively, of all pine losses. Insects caused 88 percent of the Douglas-fir volume loss.

No measurements of reproduction or of pole stand below 11.1 inches d.b.h. were made, but in general the plots are fairly well stocked with small poles and saplings. A large wave of ingrowth may be expected when these trees begin reaching board-foot size, but that will be several decades hence.

Table 5.--Summary of statistics for ponderosa pine methods-of-cutting plots 1, 2, and 3, John Day Experimental Forest (per-acre basis)

| Plot No. | Area | Year cut | Number years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 1 | 10 | 1923 | [1]13 | 68 | Current R-6 selection |
| 2 | 20 | 1922 | [1]13 | 77 | Current R-6 selection |
| 3 | 10 | 1920 | [1]13 | 86 | Current R-6 selection |

| Plot No. | Original volume | Cut volume | Residual stand (1920-23) | | | | Volume at beginning of recent period | Volume at end of recent period |
|---|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees[2] | Average d.b.h.[2] | Percentage of other species | | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. | Bd.ft. |
| 1 | 15,057 | 10,282 | 4,775 | 17.6 | 18.9 | 37.2 | 5,457 | 6,215 |
| 2 | 18,806 | 14,573 | 4,233 | 17.1 | 19.1 | 29.5 | 5,374 | 6,550 |
| 3 | 18,213 | 15,726 | 2,487 | 11.6 | 18.6 | 18.8 | 3,690 | 4,778 |

| Plot No. | Periodic annual increment and mortality, latest 13 years | | | | |
|---|---|---|---|---|---|
| | Gross increment reserve | Ingrowth | Mortality | Total net increment | Net growth |
| | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent |
| 1 | 74 | 10 | 26 | 58 | 1.1 |
| 2 | 88 | 19 | 16 | 91 | 1.7 |
| 3 | 75 | 15 | 7 | 83 | 2.3 |

[1] Plots not established until 1936 (see text).

[2] As of 1936, beginning of recent period.

## MALHEUR NATIONAL FOREST PLOTS 1-5

Somewhat comparable series of permanent sample plots to study variations of selection cutting practice were established on the Malheur, Rogue River, and Deschutes National Forests during the period 1926 to 1930. Most of these were under a study plan prepared by R. H. Westveld (1928), and nearly all were selected, surveyed. and mapped by him. Marking was usually done by a "marking board" or committee of forest officers. Several plots were not logged until some years later.

Malheur plot 1 was established in 1927 and cut in 1930. The other four Malheur plots were established in 1930 and cut in 1934. Although site quality of all of these plots falls within the range of poor to good site IV, they vary considerably in topographic position and original stand volume and makeup as well as in method or degree of cut. Plot 1 lies on a comparatively dry flat bench above Shirttail Creek. Plots 2, 3, and 4 are on or near a broad ridgetop, 400 to 500 feet higher in elevation and about 1-1/2 miles to the north. Plot 5, another half mile to the north, includes part of the valley bottom and lower slope of Damon Creek, where moisture supply is better. Plots 4 and 5 are on northerly aspects which are favorable to Douglas-fir--in 1948, poles of this species outnumbered those of ponderosa pine, although Douglas-fir comprised only about 2 percent of the volume of the original stand.

Plot 1 is a sample of the then current heavy selection cutting which took "...all trees above 18 inches d.b.h. except about 50 percent of Keen class 3A trees," constituting the long-crowned thrifty mature type. The original stand here was predominantly mature and overmature so that comparatively few trees were left under this cutting practice.

Marking policy on plot 3 was similar to that on plot 1, a standard Forest Service selection leaving most trees under 18 inches and the best immature or thrifty mature trees larger than that. Results were far different from those on plot 1, however, because the original stand (fig. 2) here consisted predominantly of immature trees (Keen age class 2). Thus the residual stand contained two and a half times as many sawtimber trees, with about 2,000 board feet per acre greater volume than on plot 1 (table 6).

Plot 2, adjacent to plot 3, also had many immature trees in the original and reserve stands (fig. 5), but under the "bull pine-yellow pine selection" marking applied here a heavier volume was retained, including more mature trees. Some young as well as older trees were cut within groups to favor thrifty younger trees.

Original stand on plot 4 consisted of a more typical mixture of age classes and a fairly heavy volume per acre. The "light selection" cutting here aimed to remove the most mature trees and also those of high risk. Ninety percent of the reserve volume was in mature and a few overmature trees.

Table 6.--Summary of statistics for ponderosa pine methods-of-cutting plots 1, 2, 3, 4, and 5, Malheur National Forest (per-acre basis)

| Plot No. | Area | Year cut | Number of years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 5 | 10.0 | 1934 | 13 | 56 | Economic selection |
| 4 | 10.0 | 1934 | 13 | 59 | Light selection |
| 2 | 10.0 | 1934 | 13 | 62 | Bull pine-yellow pine selection |
| 3 | 5.0 | 1934 | 13 | 68 | Standard selection |
| 1 | 9.2 | 1930 | 18 | 76 | Current R-6 selection |

| Plot No. | Original volume | Cut volume | Residual stand (1930-34) | | | | Volume at beginning of recent period | Volume at end of recent period |
|---|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees | Average d.b.h. | Percentage of other species | | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. | Bd.ft. |
| 5 | 31,468 | 17,699 | 14,413 | 18.4 | 24.1 | 4.5 | 15,543 | 16,751 |
| 4 | 27,300 | 16,049 | 11,252 | 17.6 | 23.4 | 1.6 | 12,656 | 13,880 |
| 2 | 24,876 | 15,422 | 9,454 | 22.6 | 20.2 | 0 | 10,541 | 12,205 |
| 3 | 22,105 | 14,910 | 7,196 | 25.0 | 18.2 | 1.7 | 8,513 | 10,274 |
| 1 | 21,363 | 16,332 | 5,031 | 9.9 | 21.2 | 0 | 5,788 | 6,124 |

| Plot No. | Periodic annual increment and mortality | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | First 5 years after cutting[1] | | | | | Latest 8 years | | | | | Net increment for entire period |
| | Gross increment of reserve | Ingrowth | Mortality | Total net increment | Net growth | Gross increment of reserve | Ingrowth | Mortality | Total net increment | Net growth | |
| | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent | Bd.ft. |
| 5 | 258 | 8 | 125 | 141 | 1.0 | 190 | 10 | 49 | 151 | 1.0 | 147 |
| 4 | 158 | 2 | 37 | 133 | 1.2 | 180 | 5 | 28 | 157 | 1.2 | 148 |
| 2 | 145 | 6 | 16 | 135 | 1.4 | 202 | 9 | 3 | 208 | 2.0 | 180 |
| 3 | 186 | 18 | 15 | 189 | 2.6 | 196 | 24 | 0 | 220 | 2.6 | 208 |
| 1 | 88 | 2 | 12 | 78 | 1.4 | 86 | 6 | 44 | 48 | .8 | 65 |

[1] For plot 1, these data are for first 10 years after cutting.

Figure 5.--The stand on this portion of Malheur plot 2, as seen before cutting, is comprised of a typical mixture of age classes--overmature in the center, thrifty mature on the right, and immature on the left. Low weeds and grasses form the light ground cover. A relatively light (62 percent) selective cutting which favored younger trees was applied here, removing the trees indicated by white lines.

Plot 5 had the heaviest original volume of the five plots, so that although percentage cut (56 percent) was only a little lighter than on plot 4, the reserve volume was substantially greater (table 6). This plot also had an appreciable percentage of Douglas-fir volume (1,074 board feet per acre). The "economic selection" cutting aimed to remove overmature high-value trees, as well as some leaners and other high-risk trees. Relatively few immature trees were available for reserve (fig. 5), so that proportion of pine volume in mature and overmature classes (96 percent) was even higher than on plot 4.

As might be expected with such a variety of site and stand conditions and cuttings, growth varied widely. For the full period since cutting, net annual increment ranged from 65 board feet per acre on plot 1 to 208 on plot 3 (table 6). For the latest 8-year period, the corresponding range is from 48 to 220 board feet. These rates represent growth percents of 0.8 and 2.6, respectively. The difference in these two similarly cut plots is due mainly to character of reserve stand, as described above. High ingrowth on plot 3 (from the many immature trees just growing to sawtimber size) and high mortality among the older trees on plot 1 contributed to this difference. Except for plot 1, which with lowest reserve fell well below others, gross growth shows little relation to volume of reserve. Plots 2, 3, 4, and 5 grew from 180 to 202 board feet per acre per year, gross rates that are above average for the region. The lower reserve volumes on plots 2 and 3 were more than compensated by vigor of the large number of younger trees. Heavier mortality among the older trees on plots 4 and 5 cut down their net increment in relation to that of plots 2 and 3.

Mortality has been light on plots 2 and 3, averaging only 7 board feet per acre per year since cutting. In comparison, plot 1 lost 27 board feet; plot 4, 31 board feet; and plot 5, 78 board feet. Of total volume killed on all plots, 60 percent was charged to bark beetles, 27 percent to windfall, 8 percent to lightning, and 5 percent to slash fires. Bark beetle killing occurred on all plots, but was heaviest on plots 1 and 5. As usual, the older and lower vigor trees were more subject to insect attack. Windfall damage was practically all on plot 5; the high loss here may be related more to particular topographic location and soil type than to method of cutting.

Four of these plots (2 to 5) provide a measure of growth of the designated reserve portion of the stand during a 5-year period prior to logging, which may be compared with growth of the same trees after logging. Gross increment of sawtimber trees practically doubled in the 5-year period after logging on plots 2 and 3, where younger trees predominated. On plots 4 and 5 only a small increase of gross increment occurred, partly because of heavier reserve stand and perhaps also because the older trees here were less capable of quick response to release.

## MALHEUR NATIONAL FOREST PLOTS 8A AND 8B

The purpose of Malheur plot 8 is similar to that of other plots in that it was designed to measure the effect of methods of cutting upon growth and mortality. But the scope and layout are far different, for this "plot" really consists of 395 small (0.4-acre) growth plots and a continuous 4-chain-wide mortality strip along 49 miles of sample lines, distributed through a cutting area of some 35,000 acres. Location of the area is the broad band of timber on the gentle slopes and ridges surrounding the flat open floor of Bear Valley near Seneca, Oreg.

Methods of cutting were two variations of the maturity selection system, for convenience called value marking (plot 8A) and thrift marking (plot 8B). The maturity selection system provides for the cutting of trees which are biologically and financially most mature. In value marking, a requirement that each tree yield the operator a margin of at least $2.50 per thousand feet (1936 prices) was followed rather strictly, except for a 10-percent volume allowance for salvage of decadent trees. Under thrift marking, trees to cut and leave were defined on the basis of Keen class and diameter, with the object of cutting the more mature, high-risk, and least thrifty trees. Under both rules, cutting was limited principally to trees 22 inches d.b.h. and larger. The cuttings have been called 40-percent selection, but according to sample plot data, removal averaged 29 percent of original pine volume in the value marking area and 32 percent in the thrift marking area (table 7).

Established in 1938, the plots were remeasured 10 years later, and mortality surveys were repeated at 1- to 3-year intervals up to 1948. In this summary, it is possible to present only a few selected statistics from the mass of information obtained in such an extensive study. The subplots and strips, representing cross sections of the entire area, included north-slope fir–larch types, lodgepole pine, young ponderosa pine, and several minor types. Old growth or "large"

Table 7.--Summary of statistics for ponderosa pine methods-of-cutting plots 8A and 8B, Malheur National Forest (per-acre basis)[1]

| Plot No. | Area | Year cut | Number of years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 8A[2] | 70.4 | 1938 | 10 | 29 | Maturity selection (value) |
| 8B[2] | 87.6 | 1938 | 10 | 32 | Maturity selection (thrift) |

| Plot No. | Original volume | Cut volume | Residual stand (1938) | | | | Volume at end of recent period (1948) |
|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees | Average d.b.h. | Percentage of other species | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. |
| 8A | 15,781 | 4,062 | 11,719 | 20.9 | 21.6 | 13.0 | 12,133 |
| 8B | 18,998 | 5,134 | 13,864 | 20.4 | 22.9 | 14.7 | 14,546 |

| Plot No. | Periodic annual increment and mortality | | | | |
|---|---|---|---|---|---|
| | Gross increment reserve | Latest 10 years = entire period | | | |
| | | Ingrowth | Mortality | Total net increment | Net growth |
| | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent |
| 8A | 99 | 14 | 74 | 39 | 0.3 |
| 8B | 116 | 11 | 62 | 65 | .5 |

[1] Stand and growth data are for old-growth ponderosa pine type (P-4) only.

[2] Malheur plot 8 consists of 395 subplots, 0.4 acre each, at 10-chain intervals along 49 miles of line; mortality measured on 1,561 acres of strip sample. The plots and portions of strips in "value marking" area are designated plot 8A; those in "thrift marking" area, plot 8B.

ponderosa pine type (P-4) occupied 72 percent of the sample area, however, and since this type is most similar to that on other permanent plots, the figures given in table 7 and the discussion (except as noted later) apply to this type only.

Original stand volumes on plots 8A and 8B averaged lower than on most other study areas, partly because this was a general cross section rather than chosen plots in well-stocked stands. But because of the light cut, reserve volumes were comparatively heavy (table 7). Percentages of minor species, which were not cut at all in logging, are also appreciable; this is characteristic of much of the Blue Mountain territory. Only 6 to 7 percent of reserve pine volume was in the immature classes (Keen age 1 and 2), but the thrifty mature classes (Keen 3A and 3B) were well represented (52 percent on plot 8A, value marking; 62 percent on plot 8B, thrift marking).

Gross annual growth of sawtimber trees averaged 99 board feet per acre under value marking compared with 116 board feet under thrift marking. With ingrowth added, rates were 113 and 127 board feet. For ponderosa pine alone, these respective rates were 85 and 90 board feet. Gross growth for thrift marking thus appears to be slightly superior, but the difference is not statistically significant.

Mortality was generally high during the 10-year period. Value marking lost 59 board feet per acre per year of ponderosa pine, 15 board feet of other species. Under thrift marking, loss rate of ponderosa pine was appreciably lower at 47 board feet; other species, 15 board feet, the same as for value marking. The pine loss rate for thrift marking was consistently low from year to year, indicating that there was a real benefit from this variation of marking. In terms of percentage of initial reserve volume, the pine loss rate was 0.58 percent in the value marking area, 0.39 percent in thrift marking. Corresponding rates for other species were 0.74 and 1.02 percent. An independent study of pine mortality over the same period in this area by the Forest Insect Research Division of the Station showed but slightly lower average loss rates and a similar advantage for thrift marking.

Bark beetles were the principal cause of tree killing, accounting for 84 percent of total volume loss of ponderosa pine, or 76 percent for all species.[3/] Wind was second in importance, causing 12 percent of pine loss, and 15 percent of that for other species. Lightning was responsible for 2-1/2 percent of total loss. Dwarfmistletoe in Douglas-fir was charged with 5 percent of the loss for that species. "Unknown" cause was recorded for 6 percent of total volume loss; this was mostly in larch and white fir. Miscellaneous other causes were responsible for the remaining 1-1/2 percent.

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[3/] Mortality figures cited in this and the following paragraph are for all timber types and both forms of marking combined.

Insect-caused loss was high for the first 2 years, then generally tapered down, but with a temporary resurgence in 1943-45. Windfall losses were also moderately high (11 board feet per acre per year) for the first 2 years, trending generally downward except for 1948, when an unusual storm caused a loss rate of 42 board feet per acre for that year. Nearly one-half of this volume loss was in species other than ponderosa pine, however.

This study provides some of the most extensive historical growth and mortality data for other species yet obtained in the pine region. It emphasizes the high growth capacity of Douglas-fir and white fir in this territory. Thus, compared with 0.80 for ponderosa pine, average gross percentage growth rate for Douglas-fir was 1.28 percent; for white fir, 2.94. Part of this advantage, especially for white fir, is associated with smaller tree size, but even allowing for this, the growth rates are generally higher than for pine. Western larch grew at a lower rate than any other species, 0.64 percent, but since with a few exceptions larch trees in this area were in poor condition as a result of an old attack by defoliators, this figure may not be a fair indication of the real potential of the species.

Thrift marking resulted in substantially better net annual increment than value marking--65 compared with 39 board feet, respectively. For ponderosa pine alone, corresponding rates were only 43 and 26 board feet. Thus neither of the two variations of marking produced results that are particularly favorable to this system of cutting--gross growth was only fair and mortality too high. One of the contributing factors was the 22-inch diameter limit, which left many very slow-growing and high-risk trees in the stand. Closely related to this was the failure to do any cutting primarily for release or spacing purposes.

## ROGUE RIVER NATIONAL FOREST PLOTS 1-6

Rogue River plots 1 to 4, similar to Malheur plots 2 to 5 and Deschutes plots 1 to 4, are comparatively small (9.1 to 10 acres each) and represent typical well-stocked stands cut by various modifications of the Forest Service tree selection method. They were established and cut in 1927. Plot 6 had been cut 3 years earlier, but may be considered in the same series. Plot 5 is in the form of a strip 4 chains wide and 125 chains long, and was cut 2 years later. But since it is near the other plots and also represented prevailing cutting practice, it too may be treated in the same series.

Location of these plots is the gently eastward sloping plateau just east of Crater Lake National Park, at elevations of from 4,850 to 5,150 feet. Soil is a deep, coarse pumice.

Original stand was nearly pure ponderosa pine, with a small percentage of lodgepole pine in a few spots. It must have been rather uniformly well stocked, as original volume averaged the highest of any of the study areas (table 8). It also contained a better than average proportion of immature and thrifty mature trees, but comparatively few poles, saplings, and seedlings. Ground cover was

Table 8.--Summary of statistics for ponderosa pine methods-of-cutting plots 1, 2, 3, 4, 5, and 6, Rogue River National Forest (per-acre basis)

| Plot No. | Area | Year cut | Number of years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 2 | 9.1 | 1927 | 20 | 66 | Bull pine-yellow pine selection |
| 5 | 50.0 | 1929 | 20 | 74 | Current R-6 selection |
| 1 | 10.0 | 1927 | 20 | 76 | Current R-6 and bull pine thinning |
| 4 | 10.0 | 1927 | 20 | 83 | Current R-6 selection |
| 3 | 9.1 | 1927 | 20 | 84 | Seed-tree cutting |
| 6 | 10.0 | 1924 | 25 | 69 | Current R-6 selection |

| Plot No. | Original volume | Cut volume | Residual stand (1924-29) | | | | Volume at beginning of recent period | Volume at end of recent period |
|---|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees | Average d.b.h. | Percentage of other species | | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. | Bd.ft. |
| 2 | 33,928 | 22,529 | 11,399 | 18.5 | 22.2 | 0.4 | 12,571 | 13,848 |
| 5 | 31,496 | 23,269 | 8,227 | 15.8 | 21.1 | .8 | 9,291 | 10,991 |
| 1 | 34,602 | 26,210 | 8,392 | 13.0 | 23.1 | .3 | 9,729 | 11,628 |
| 4 | 30,958 | 25,553 | 5,405 | 10.2 | 21.6 | .2 | 6,153 | 7,724 |
| 3 | 30,863 | 26,085 | 4,778 | 7.9 | 22.2 | 0 | 4,884 | 6,179 |
| 6 | 22,398 | 15,378 | 7,020 | 14.7 | 21.1 | 0 | 9,142 | 10,728 |

| Plot No. | Periodic annual increment and mortality | | | | | | | | | | Net increment for entire period |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | First 10 years after cutting[1] | | | | | Latest 10 years | | | | | |
| | Gross increment of reserve | Ingrowth | Mortality | Total net increment | Net growth | Gross increment of reserve | Ingrowth | Mortality | Total net increment | Net growth | |
| | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent | Bd.ft. | Bd.ft. | Bd.ft. | Bd.ft. | Percent | Bd.ft. |
| 2 | 112 | 5 | 7 | 111 | 1.0 | 153 | 13 | 38 | 128 | 1.0 | 119 |
| 5 | 114 | 8 | 12 | 110 | 1.3 | 170 | 16 | 21 | 165 | 1.7 | 138 |
| 1 | 111 | 11 | 0 | 122 | 1.5 | 182 | 8 | 0 | 190 | 2.0 | 156 |
| 4 | 88 | 6 | 20 | 74 | 1.4 | 140 | 18 | 1 | 157 | 2.6 | 116 |
| 3 | 75 | 4 | 70 | 9 | .2 | 121 | 8 | 0 | 129 | 2.6 | 69 |
| 6 | 119 | 11 | 12 | 118 | 1.7 | 155 | 15 | 11 | 159 | 1.7 | 134 |

[1] For plot 6, these data are for the first 15 years after cutting.

principally bitterbrush, except on plot 6, which is at a slightly higher elevation than the others and supported a considerable amount of snowbrush.

Three plots, numbers 4, 5, and 6, represent Region 6 Forest Service selection marking practice of that time. Trees removed were nearly all of the overmature and the majority of the mature ponderosa pine, leaving only the best dominant and codominant mature trees and all of the immature or "bull" pines excepting those diseased or deformed. Because of differences in original stand and perhaps in interpretation of marking policy by different markers from 1924 to 1929, the cuts ranged from 69 to 83 percent, and left volumes of 5,400 to 8,200 board feet per acre (table 8).

Plot 2, having the lowest percentage cut and highest reserve volume, represented "bull pine–yellow pine selection," which deviated from standard marking chiefly in the leaving of a considerable number of "line" trees in the mature class. It retained the best dominant, codominant, and intermediate mature trees, and probably all immature trees.

Plot 1 was a combination of "bull pine thinning" and standard Forest Service selection. A thinning from below was made in the groups of immature pines of merchantable size. The reserve stand consisted of all dominant and a few codominant "bull" pines, and a few of the thriftiest mature trees. Original volume here was highest of the six plots, but percentage cut and volume reserved were close to the averages for plot 5, cut by standard selection.

On plot 3, a "seed-tree cutting," only the immature trees and a minimum number of larger diameter mature trees were left for restocking. The object was to secure a maximum growth rate (of individual trees) with a small investment for restocking. The percentage cut (84 percent) was the heaviest and the reserve stand the lightest, in this series. Evidently the original stand here did not contain as many immature trees as on other plots. (Parenthetically, neither this "seed-tree cutting" nor any of the other methods tested on this area resulted in satisfactory restocking in 20 years (fig. 4). This feature is discussed further in the chapter on reproduction in the general section of Research Paper 44, page 16.)

The three plots, numbers 4, 5, and 6, cut according to prevailing regional practice, yielded about the same net increments during the recent period (157, 165, and 159 board feet, respectively). Plot 4, with lowest reserve of the three, grew less in gross volume, but luckily suffered very little mortality. Plot 5, with high reserve, made the best gross growth, but also had more loss than the other two. For the earlier period and the full time since logging, plot 4 grew least in both gross and net terms; plots 5 and 6, at fairly similar rates. Plot 6 seems to be falling behind plot 5 in board-foot growth, but it has a heavier understory of poles which will eventually boost its growth rate as they reach sawtimber size.

Plot 2, with the heaviest volume of growing stock, grew at a gross rate which was only about average for the group, and in the recent period suffered mortality which reduced its net rate to the lowest of the group. Compared with standard selection practice (plots 4-6), the additional growing stock here was mostly in the older age classes. Distribution of reserve was groupwise, with comparatively little release within groups. The crowded, older trees grew slowly and those of low vigor were subject to insect attack, the chief cause of mortality. The plot was unfortunate in losing two large trees by lightning strike within the last period.

Plot 1 made the best net growth in both periods (table 8). Although its superior growth may partly be credited to more favorable structure of reserve stand, the "bull pine thinning" was also beneficial in removing trees of low vigor and slow growth and in giving some release to trees in crowded groups. No deaths of sawtimber trees occurred here during the 20 years after logging--a result which may be due in part to the thrifty character of these well-spaced reserve trees, in part probably to good fortune on this particular 10 acres.

Plot 3, the "seed-tree cutting," lost several large-crowned class 3A trees by windthrow soon after logging, the volume of which almost offset gross growth for the first 10-year period. The remaining trees, most of which were well released by cutting (fig. 4), grew rapidly so that the percentage rate for sawtimber trees only (2.6 percent) was the highest of the group during the recent period. Individual good growth could not fully compensate for low volume of growing stock, however, and gross growth in board feet was lowest of the series.

Mortality since logging has been comparatively low in general on this set of plots, averaging only 16 board feet per acre per year for all plots. Heavy windfall, mostly on plot 3, was the predominating loss during the first period after logging. In the recent decade, 61 percent of total volume loss was caused by insects, 29 percent by wind, and 10 percent by lightning. Most of the wind damage in this period was on the 50-acre plot 5.

Plot 5 was one of the few in this study that was extensive enough to be subdivided to see how stand and growth varied within the stand. Data for subplots, each 10 chains by 4 chains, show reserve stand in 1939 ranging from 5,625 to 14,376 board feet per acre, and gross annual sawtimber increment, from 104 to 232 board feet per acre during the subsequent 10 years. Lowest and highest reserves correspond with these low and high yields, but between the extremes the correlation is not close. Stand structure and distribution on the ground (groupwise or not) are also important determinants of increment, as was emphasized above in the comparison of plots 1 and 2. Structure and distribution of reserve stand vary from acre to acre, even in an area all cut under one marking rule.

## DESCHUTES NATIONAL FOREST PLOTS 1-7

Deschutes plots 1, 2, 3, 4, and 6 were established in 1927 and 1929 but were not logged until 1937. Each is a square 10-acre plot. Plot 5, in the form of two strips, each 1/2 mile long and 4 chains wide, was cut in 1929. Plot 7, an 8-acre rectangle, was cut in 1927.

Plots 1 to 6 are distinctive in that they are located close to the edge of the "high desert," where the growing season is short and moisture supply is near the minimum for maintenance of ponderosa pine forest. In the dry cycle ending about 1938, the forest lost ground to the sagebrush desert along this fringe. On these plots many trees died during the bark beetle epidemic that accompanied this drought, and others were so reduced in vigor that they had not fully recovered even by 1947. The plots lie on flat to slightly rolling land at an elevation of about 4,750 feet. Soil is chiefly fine pumice sand. Site is on the borderline between IV and V. The timber stand is pure ponderosa pine (fig. 6) except in the shallow draws and other spots where a few lodgepole pines are found. Advance reproduction is relatively sparse, except in certain small areas.

Plot 7 is at about the same elevation as 1-6, but is located about 15 miles to the west, well within the ponderosa pine zone. It probably receives more precipitation than the other plots and site is slightly better. It lies on a gentle westerly slope between two comparatively recent flows of lava. The pumice soil is similar to but possibly shallower than that on plots 1-6. Because of the better site and also because many of the beetle-susceptible trees had been cut, this plot experienced less loss between 1927 and 1937 than the others. With a recognition of these differences, the plot may still be compared in the same series with plots 1-6.

Figure 6.--Reserve stand 10 years after partial cutting at east end of Deschutes plot 5. Typical of plots 1-6, with somewhat patchy distribution of reserve trees and occasional groups of advance reproduction, interspersed with small openings occupied by bitterbrush, sagebrush, and grass, principally Idaho fescue, which also form the ground cover under the timber.

Plots 4, 5, and 7 were marked according to the prevailing Forest Service selection system, which here removed from 67 to 74 percent of the sawtimber volume, leaving a stand of from 5,000 to 7,000 board feet per acre (table 9). This system marked for cutting practically all overmature trees, most of the mature trees, and suppressed or diseased young trees of sawtimber size. The reserve thus consisted of most of the immature trees ("bull pines") and the thriftiest trees of the mature class (fig. 6).

Plot 2 was marked for "bull pine-yellow pine selection" which apparently differed from "standard" Forest Service selection chiefly in the leaving of more trees in the mature class and even a few of the best overmature trees. Volume left was similar to that on plots 5 and 7, but greater than on nearby plot 4 where original stand volume was relatively low.

Cutting on plot 1 was designated as a "seed-tree cutting," which left for reserve only the immature trees and occasional dominant mature trees where needed for seed. However, as applied here the cutting differed in effect but little from standard selection on nearby plot 4--percentage cut, volume left, and structure of reserve stand were similar on the two plots. Therefore, it was not what one would picture as a typical seed-tree cutting.

Cutting on plot 3 was the heaviest of all the study plots, removing 96 percent of the original volume and leaving a stand of only 764 board feet per acre. It was planned to cut all trees down to a 14-inch diameter limit (essentially a clear cutting of all merchantable trees), but a few larger trees with rapid taper were left. Plot 3 represents about the minimum of seed source requirements under the Oregon State law.

Plot 6 represented "value selection." Trees marked for cutting included most of the overmature class and the clearest individuals of the mature class; that is, the trees of highest quality with the idea of a light cut and short cutting cycle. It was the lightest cut of this series (47 percent) and left a reserve volume of nearly 10,000 board feet per acre.

These plots probably do not now represent the various marking ideas in very pure form. Losses were very high during the period 1927-41. On plots 1-4 and 6, marking preceded cutting by 8 to 10 years, and a number of marked trees, mostly small trees of lower crown classes, were never cut.

The story of increment on these plots is largely one of net loss. In the prelogging period up to 1937 on plots 1-4 and 6, loss chiefly from drought and beetle kill averaged 374 board feet per acre per year. It is significant that 94 percent of this loss was in trees which had been marked for cutting. On plots 5 and 7, this period was mostly after logging, and loss rate, mainly from windfall, was 139 and 78 board feet, respectively. Gross increment was low on all plots during this period--many trees showed no measurable diameter growth (bark sloughing compensated for very slow wood growth).

Table 9.--Summary of statistics for ponderosa pine methods-of-cutting plots 1, 2, 3, 4, 5, 6, and 7, Deschutes National Forest (per-acre basis)

| Plot No. | Area | Year cut | Number of years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 6 | 10 | 1937 | 11 | 47 | Value selection |
| 2 | 10 | 1937 | 11 | 63 | Bull pine-yellow pine selection |
| 1 | 10 | 1937 | 11 | 66 | Seed-tree cutting |
| 4 | 10 | 1937 | 11 | 67 | Current R-6 selection |
| 3 | 10 | 1937 | 11 | 96 | 14-inch diameter limit |
| 5 | 32 | 1929 | 18 | 68 | Current R-6 selection |
| 7 | 8 | 1927 | 21 | 74 | Current R-6 selection |

| Plot No. | Original volume | Cut volume | Residual stand | | | | Volume at beginning of recent period | Volume at end of recent period |
|---|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees | Average d.b.h. | Percentage of other species | | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. | Bd.ft. |
| 6 | 18,780 | 8,895 | 9,885 | 16.3 | 23.6 | 0 | 8,633 | 8,537 |
| 2 | 20,015 | 12,720 | 7,295 | 14.2 | 22.2 | 0 | 5,076 | 5,295 |
| 1 | 15,519 | 10,250 | 5,269 | 14.6 | 19.7 | 0 | 4,408 | 4,516 |
| 4 | 15,081 | 10,050 | 5,031 | 11.8 | 20.8 | 0 | 2,963 | 3,241 |
| 3 | 20,806 | 20,042 | 764 | 4.9 | 15.7 | 0 | 740 | 906 |
| 5 | 20,894 | 14,154 | 6,740 | 19.7 | 19.0 | 1.2 | 5,695 | 6,337 |
| 7 | 25,960 | 19,101 | 6,865 | 16.5 | 19.5 | .3 | 6,818 | 7,672 |

| Plot No. | Periodic annual increment and mortality | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | First 5 years after cutting[1] | | | | | Latest 6 years[2] | | | | | Net increment for entire period |
| | Gross increment of reserve | Ingrowth | Mortality | Total net increment | Net growth | Gross increment of reserve | Ingrowth | Mortality | Total net increment | Net growth | |
| | Bd.ft. | | | | Percent | Bd.ft. | | | | Percent | Bd.ft. |
| 6 | 30 | 4 | 295 | -261 | -2.6 | 47 | 2 | 65 | -16 | -0.2 | -127 |
| 2 | 52 | 0 | 490 | -438 | -6.0 | 62 | 5 | 30 | 37 | .7 | -182 |
| 1 | 14 | 1 | 189 | -174 | -3.4 | 43 | 1 | 26 | 18 | .4 | -70 |
| 4 | 15 | 2 | 431 | -414 | -8.2 | 45 | 3 | 2 | 46 | 1.6 | -165 |
| 3 | 9 | 1 | 16 | -6 | -.8 | 25 | 3 | 0 | 28 | 3.8 | 11 |
| 5 | 22 | 7 | 139 | -110 | -1.6 | 77 | 10 | 7 | 80 | 1.4 | -25 |
| 7 | 63 | 4 | 78 | -11 | -.2 | 137 | 4 | 56 | 85 | 1.2 | 35 |

1/ For plots 5 and 7, these data are for the first 10 to 11 years after cutting.
2/ For plots 5 and 7, these data are for the latest 8 to 10 years.

In the first period after logging, all plots showed net losses, ranging from 6 board feet per acre per year on plot 3 to 438 on plot 2 (table 9). For this period the main cause of loss was windfall, particularly on those plots nearer the desert edge. Insect-caused loss continued at an appreciable rate, however, averaging for all plots 35 board feet per acre per year. Most trees were still growing very slowly and showed but little release effect. Average diameter growth of all reserve trees was at the rate of only 0.3 inch per decade on plots 1-6. Trees on plot 7 grew slightly better, averaging 0.7 inch per decade. Average gross volume increment of all plots was 32 board feet per acre per year.

In the second measurement period after logging, growth improved and mortality dropped off to a more normal rate. Diameter increment was at an average rate of 1.0 inch per decade on plots 1-6 and 1.4 inches on plot 7. Gross volume growth, averaging 63 board feet per acre per year, was about double the rate for the preceding period. Volume loss from mortality averaged 31 board feet per acre per year. Of this, 34 percent was charged to wind, 31 percent to lightning, and 29 percent to insects. Every plot except number 6 made a net gain in increment in this period, but only on plots 3 and 7 was it sufficient to offset earlier net losses (table 9).

Growth comparisons between plots are somewhat obscured by heavy early mortality, which was not closely related to cutting method. Perhaps the latest period of measurement provides the best basis for comparisons.

In this period, gross growth on the three "standard" selection plots 4, 5, and 7 varied from 48 to 141 board feet per acre per year (table 9). Low growth on plot 4 was partly due to depleted growing stock from earlier mortality. High growth on plot 7 is associated in part with better site. Gross growth on plot 5, 87 board feet, maybe a fair average.

Plot 2, with "bull pine-yellow pine selection," was next lower in order of gross growth, but windfall loss, which is more or less accidental in occurrence, reduced its net rate to only 37 board feet. Reserve stand had fewer immature trees and more overmature trees than plot 5.

Plot 1 grew about the same as plot 4; comparatively low growing stock and clumpwise distribution appeared to be responsible for its low growth rate.

Plot 3, the "14-inch diameter limit cut," grew fairly well considering that it had a growing stock of only 740 board feet per acre in 1941. No trees died in the latest period, and net increment averaged 28 board feet per acre per year. Even the smaller crowned mature trees made fair growth after this heavy cutting.

Plot 6, representing "value selection," showed gross increment below average and the highest mortality rate, resulting in a net loss of 16 board feet per acre per year. A number of low-vigor overmature and mature trees left here as reserve made practically no gross growth, and several fell prey to bark beetles.

## PRINGLE FALLS EXPERIMENTAL FOREST PLOTS 30-36

Seven plots to demonstrate and study the results of various intensities of cutting were established on the Pringle Falls Experimental Forest in 1936. This is the largest intensive test of this nature made in this region. The gross area of plots ranges from 57 to 97 acres each and totals 506 acres in a solid block. (Growth was measured on an average of 27 acres of each plot.) Intensities of cut were 20-, 40-, 60-, and 80-percent volume removal. For each degree of cut, except 80 percent, two contrasting policies in marking were applied: a "thrift" marking and a "value" marking. The 80-percent cut was the prevailing Forest Service standard selection, essentially a "thrift" marking.

This is the only set of plots on which all ponderosa pine trees were fully classified by the Keen system before cutting, and on which all such trees over 15 inches d.b.h. were log graded and valued. Each plot was "paper marked" by both thrift and value methods; that is, on the listing of individual trees, each was designated for cut or leave by the alternate method as well as by the marking policy actually used on the plot. Thus, comparisons of values of reserve stand and calculated growth potential could be made on each plot as well as between plots. In this brief summary it is not possible to present all these comparisons and explore the full possibilities that the great mass of data for these plots provides. Emphasis will therefore be upon increment and mortality on the portions of plots measured for actual growth after logging.

The plots are on nearly level land at an elevation of about 4,300 feet. Soil is a loamy, coarse pumice sand, usually from 2 to 5 feet deep overlying brown stony loam or in some spots lava bedrock. Site is a medium IV. The original stand varied from 27,662 board feet per acre on plot 31 to 16,809 on plot 36 (table 10). The stand was typical of ponderosa pine timber in central Oregon, being characterized by a predominance of mature and overmature trees. Of the volume in trees 15 inches d.b.h. and larger, 70 percent was overmature (Keen class 4), and 24 percent mature (Keen class 3). Lodgepole pine, the only other species, occurred chiefly in the understory as scattered trees or clumps but occasionally in larger patches with little or no ponderosa (fig. 7). Of the reserve stand board-foot volume, proportion of lodgepole pine varied from 3 percent on plot 30 to 40 percent on plot 36. Most of the area was well stocked with advance reproduction of seedling and sapling size (fig. 7). Reproduction was largely ponderosa pine except in limited areas where lodgepole pine prevailed.

The methods of cutting may be defined further. On all plots, dying trees, apparently including most of those we would now designate as high risk, were cut. Value marking, which was practically the same as maturity selection, was based on office computation from tree class and log grade records of the net stumpage value of each numbered tree and its estimated growth and mortality rates. From these figures, the net cost of holding a tree in the woods at 3 percent interest (or the return from holding a faster growing tree above 3 percent interest) was

Table 10.--Summary of statistics for ponderosa pine methods-of-cutting plots 30, 31, 32, 33, 34, 35, and 36, Pringle Falls Experimental Forest[1] (per-acre basis)

| Plot No. | Area | Year cut | Number of years of record | Percentage of original volume cut | Method of cutting |
|---|---|---|---|---|---|
| | Acres | | | | |
| 30 | 27.2 | 1937 | 11 | 24 | 20-percent thrift selection |
| 33 | 28.2 | 1937 | 11 | 22 | 20-percent value selection |
| 35 | 24.4 | 1937 | 11 | 40 | 40-percent thrift selection |
| 34 | 26.5 | 1937 | 11 | 41 | 40-percent value selection |
| 31 | 24.6 | 1937 | 11 | 57 | 60-percent thrift selection |
| 32 | 28.0 | 1937 | 11 | 66 | 60-percent value selection |
| 36 | 29.9 | 1937 | 11 | 72 | 80-percent Forest Service selection |

| Plot No. | Original volume | Cut volume | Residual stand (1937) | | | | Volume at end of recent period (1947) |
|---|---|---|---|---|---|---|---|
| | | | Volume | Number trees | Average d.b.h. | Percentage of other species | |
| | Bd.ft. | Bd.ft. | Bd.ft. | | Inches | | Bd.ft. |
| 30 | 23,119 | 5,632 | 17,487 | 23.0 | 23.2 | 3.0 | 18,719 |
| 33 | 22,796 | 4,985 | 17,811 | 23.3 | 23.2 | 5.0 | 19,440 |
| 35 | 21,481 | 8,626 | 12,855 | 22.8 | 20.8 | 8.2 | 13,893 |
| 34 | 20,856 | 8,512 | 12,344 | 23.2 | 22.5 | 12.3 | 13,246 |
| 31 | 27,662 | 15,824 | 11,838 | 22.5 | 20.2 | 8.3 | 12,963 |
| 32 | 19,647 | 13,010 | 6,637 | 19.5 | 17.4 | 25.5 | 7,257 |
| 36 | 16,809 | 12,025 | 4,783 | 16.1 | 16.8 | 40.5 | 5,248 |

| Plot No. | Annual increment and mortality--entire period (11 years) after logging[2] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gross increment of reserve | | Ingrowth | | Mortality | | Total net increment | | | Net growth | | |
| | Ponderosa pine | Lodgepole pine | Ponderosa pine | Lodgepole pine | Ponderosa pine | Lodgepole pine | Ponderosa pine | Lodgepole pine | Both species | Ponderosa pine | Lodgepole pine | Both species |
| | Bd.ft. | | | | | | | | | Percent | | |
| 30 | 89 | 8 | 6 | 21 | 9 | 3 | 86 | 26 | 112 | 0.5 | 4.9 | 0.6 |
| 33 | 93 | 10 | 7 | 22 | 3 | 8 | 97 | 24 | 121 | .6 | 2.8 | .7 |
| 35 | 89 | 8 | 7 | 17 | 13 | 14 | 83 | 11 | 94 | .7 | 1.0 | .7 |
| 34 | 62 | 12 | 4 | 17 | 0 | 13 | 66 | 16 | 82 | .6 | 1.1 | .7 |
| 31 | 83 | 12 | 7 | 23 | 4 | 19 | 86 | 16 | 102 | .8 | 1.7 | .9 |
| 32 | 46 | 16 | 5 | 25 | 11 | 25 | 40 | 16 | 56 | .8 | .9 | .8 |
| 36 | 41 | 15 | 5 | 18 | 2 | 35 | 44 | -2 | 42 | 1.5 | -.1 | .9 |

[1] Gross areas of Pringle Falls plots 30-36 were from 57.1 to 97.2 acres each; this table shows volume, growth, and mortality on sample areas as listed; mortality also measured on full area.

[2] For explanation of inclusion of lodgepole pine, see pages 21 and 24.


Figure 7.--A, Virgin ponderosa pine with lodgepole pine understory (background) on Pringle Falls plot 34. Sparse ground cover of bitterbrush and suppressed pine seedlings.

B, The same view 2 years after a 40-percent value cut removed two large mature trees. The central reserve tree, showing high-risk characters--many dying branches in crown--was of too low value to cut under the regular marking rule, but should have been taken under the salvage clause.

C, The same view 12 years later. The central tree has died, with a loss of 1,600 board feet of low-quality wood. Remaining reserve trees are thrifty. Reproduction in foreground is developing slowly.

computed.[4] Tree records were then arranged in order from those costing most to those returning the best net, and a number chosen from the top of the list to equal the desired percentage cut. These trees were then marked in the stand.

Thrift marking aimed to remove trees of highest insect susceptibility and those of poorest vigor and growth, leaving trees which would contribute most to the health and increment of the forest. Although the marker had a background knowledge from the stand-structure analysis of about what classes of trees would have to be chosen for a given percentage of cut, the marking was done in the usual manner by on-the-ground inspection of each tree. These two marking policies thus differed in certain details from the value and thrift marking on Malheur plots 8A and 8B.

The marking guides were developed for ponderosa pine trees 15 inches d.b.h. and larger, and the percentages to be cut were originally calculated for this part of the stand only. Lodgepole pine was not marked initially, but most trees considered suitable for crossties were cut by a portable mill immediately after the ponderosa pine sawtimber cutting. Percentages of cut for lodgepole alone ranged from 37 to 60 percent of original volume on the seven plots, and had no relation to percentage of ponderosa pine cut. It is for these reasons, plus the fact that statistics for the portion of each plot used for growth measurement differ by various amounts from those for the full plot, that the actual percentages cut shown in table 10 are not exactly at the even 20-percent intervals designated.

Gross growth of the reserve stand varied from 56 board feet per acre per year on plot 36 to 103 board feet on plot 33. For ponderosa pine only, these figures are 41 and 93 board feet, respectively. Thus, the lowest growth was on the 80-percent cutting and the highest on the 20-percent cutting, as might be expected. For plots 30-35, thrift cuttings averaged 96 board feet; value cuttings, 80 board feet. However, between the extremes the relation to degree of cut or to reserve volume is erratic, and for the 20-percent cutting the value selection plot yielded better growth than thrift selection. Differences in growth potential at the start and unexplained variations could account for the deviations in gross growth from average or expected relationships.

Dahms, in a detailed study of data for these plots, found that there was a strong correlation between Briegleb's predicted growth for the entire stand before cutting and actual growth of the reserve stand following cutting. On the basis of

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[4] For more detailed explanation of these computations, with examples, see the unpublished reports on Pringle Falls plots 30-36 listed at end of supplement, or "Recent Developments in Pine Silviculture," by Thornton T. Munger and Philip A. Briegleb, Northwest Sci. 16: 40-45. 1942.

this regression, he computed the following adjusted gross growth figures for ponderosa pine, which are believed to make fair allowance for differences in potential of original growing stock:

| | Cutting method | Adjusted growth | |
|---|---|---|---|
| | | (bd. ft.) | (rank) |
| Plot No.: | | | |
| 30 | 20-percent thrift | 74 | 3 |
| 33 | 20-percent value | 91 | 1 |
| 35 | 40-percent thrift | 88 | 2 |
| 34 | 40-percent value | 61 | 6 |
| 31 | 60-percent thrift | 64 | 4 |
| 32 | 60-percent value | 58 | 7 |
| 36 | 80-percent Forest Service selection | 64 | 5 |

It appears that the inferences may still hold that there is some overall advantage for thrift over value marking and that adjusted growth trends downward as percentage of cut increases. However, the exceptions to these trends make such general conclusions rather insecure.

Failure of growth to be more strongly correlated with percentage cut or reserve stand volume was in part due to the high proportion of older age classes in this stand. Overmature (Keen class 4) trees usually contribute little to gross growth and sometimes show a net loss. The poorer vigor mature trees also grow very slowly. Here, cutting of any proportion of volume up to 60 percent removed chiefly these older, low-vigor trees. Heavier reduction of growing stock was also partly compensated by greater release of reserve trees, but this trend was not very strong in this first period after cutting.

Of the total growth of initial reserve stand, lodgepole pine contributed from 8 to 16 board feet per acre per year, somewhat in proportion to the volume of this species rather than any relation to degree of cutting of ponderosa pine.

Ingrowth added from 21 to 30 board feet per acre per year to the gross volume (table 10). This had little relation to method of cutting, although over a longer period the heavier cut plots should gain more rapidly from this source. A large share of this ingrowth volume (17 to 25 board feet) was lodgepole pine, of which there were many trees just under 11.1 inches d.b.h. in the stand.

Mortality of ponderosa pine ranged from 0 to 13 board feet per acre per year in the tagged-tree portions of the seven plots. The larger sample of mortality obtained from surveys of the entire area shows a range of from 6 to 15 board feet, or a general weighted average of 9.6 board feet per acre per year.

Bark beetles caused about two-thirds of the board-foot loss. The remainder was charged to wind, lightning, logging damage, and unknown causes, in that order of magnitude. During the same period, annual losses on a nearby 320-acre virgin forest plot averaged 50 board feet per acre. Thus all of the cuttings, by removal of high-risk trees, were effective in greatly reducing mortality, particularly that caused by bark beetles (5).

Loss rate showed no consistent relation to degree of cut, indicating that most of the high-risk trees had been removed even in the lighter cuts. Mortality caused by insects alone averaged 5.4 board feet per acre per year on the thrift cuttings and 8.8 board feet on the value cuttings. This loss rate was consistently lower for thrift marking, suggesting that at least a small advantage resulted from a more critical effort to eliminate insect-susceptible trees (fig. 7). Mortality from other causes occurred erratically with no relation to either intensity or type of cutting. The plots were checked for deaths at 1- to 3-year intervals during the 11-year growth period. Although there was some year-to-year variation, the identity of losses for single years was not too certain, and no significant trend through the period is evident.

Lodgepole pine mortality averaged 15.4 board feet per acre per year. Loss rate by plots was from 3 to 35 board feet per acre per year (or from 4 to 31 board feet per full plot survey), varying with the volume of this species in the initial reserve. No consistent relation to intensity or type of cutting is apparent. Since the cutting of lodgepole was largely "logger's selection" of trees of suitable size and form for crossties, there was no special effort to remove dying or defective trees. Logging damage was also heavy, probably because of the understory position of lodgepole. Thus many trees died within the first few years after cutting, after which loss rate dropped off somewhat. Volume of lodgepole pine killed by bark beetles was relatively lower (56 percent) and that charged to wind, logging, unknown cause, and disease each a little higher than for ponderosa pine.

Net increment (unadjusted) of ponderosa pine only ranged from 40 board feet per acre per year on plot 32 (60-percent value selection) to 97 on plot 33 (20-percent value selection). Lodgepole pine on plot 36, though comprising 40 percent of the reserve volume, made no net growth. On other plots it showed net gains of from 11 to 26 board feet per acre per year--an appreciable proportion of total growth. Inclusion of lodgepole pine in stand increment figures may either weaken or exaggerate true differences related to method of cutting, and yet the increment of this species is an integral part of the growth picture for any plot so cannot be neglected. For both species together net increment rate was lowest, 42 board feet per acre per year, on plot 36 (80-percent Forest Service selection) and highest, 121 board feet, on plot 33. As with gross increment, net increment on the Pringle Falls plots averaged better for thrift- than for value-marked plots, and shows a downward trend with decreasing volume of reserve, but these relations are not without exception.

## UNPUBLISHED STUDY REPORTS

(Copy of each on file in office of Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.; also at Bend Research Center, Bend, Oreg.; and, for most plots, in the office of the forest supervisor of the national forest where located.)

### General

Working Plan for Methods of Cutting Study in Western Yellow Pine (Permanent Sample Plot Phase), R. H. Westveld, March 6, 1928.

### Whitman National Forest Plots 1-3

Establishment Report, T. J. Starker, November 20, 1913.
Progress Reports:
- T. J. Starker, June 17, 1916.
- T. J. Starker, December 12, 1916.
- N. L. Cary, March 12, 1919.
- E. L. Kolbe, 1929.
- B. L. Rasmussen, April 29, 1936.
- D. F. McKay, April 21, 1941.
- W. G. Dahms and E. L. Mowat, March 31, 1954.

### John Day Experimental Forest Plots 1-3

Working Plan: E. L. Kolbe, June 24, 1936.
Establishment Memorandum: W. H. Beeman, March 16, 1937.
Establishment and Progress Report: E. L. Mowat and W. G. Dahms, December 20, 1951.

### Malheur National Forest Plots 1-5

Establishment Report: W. H. Beeman, April 23, 1936.
Progress Reports:
- T. Kachin and T. T. Munger, September 1, 1942.
- W. G. Dahms, March 16, 1955.

### Malheur National Forest Plot 8

Working Plan: E. L. Kolbe, May 26, 1938.
Establishment Report: D. F. McKay, January 31, 1940.
Progress Reports:
- W. G. Morris, March 15, 1944.
- E. L. Mowat, March 21, 1955.

Report on Losses, Silvies W. C.: J. M. Whiteside, November 1, 1946.

Rogue River National Forest Plots 1-4

Establishment Reports: R. H. Westveld, June 18-September 10, 1928.
Progress Reports:
M. E. Becker and D. F. McKay, April 24, 1941.
E. L. Mowat, January 13, 1956.

Rogue River National Forest Plot 5

Progress Report: D. F. McKay, April 10, 1942.

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Establishment Report: E. J. Hanzlik and L. P. Brown, April 8, 1925.
Progress Report: D. F. McKay, February 26, 1942.

Deschutes National Forest Plots 1-4, 6

Establishment Reports (Plots 1-4): R. H. Westveld, June 18-September 10, 1928.
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W. G. Dahms and E. L. Mowat, April 21, 1955.

Deschutes National Forest Plot 5

Progress Reports:
D. F. McKay, March 5, 1942.
W. G. Dahms, May 6, 1955.

Deschutes National Forest Plot 7

Establishment Report: R. H. Westveld, February 1928.
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W. G. Dahms, May 11, 1950.

Pringle Falls Experimental Forest Plots 30-36

Working Plan: E. L. Kolbe and A. J. F. Brandstrom, June 22, 1936.
Timber Sale Report: A. J. F. Brandstrom and E. L. Kolbe, March 9, 1937.
Establishment Report: D. F. McKay, May 9, 1940.
Report on Tree Classification and Evaluation--Pringle Falls Plot 37: T. T. Munger and D. F. McKay, December 5, 1941.
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