Watershed-Management Aspects of Thinned Young Lodgepole Pine Stands

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THE CENTRAL SECTION of the Rocky Mountains within Colorado and Wyoming is an important water-yielding area. Stream flow which originates in the mountains supplies water for irrigation, power generation, and domestic use. The actual source of most of this water is located above 8,000 feet in elevation. Here snows are heavy and water yields run as high as 24 inches per year.

This same high mountain region is also one of low erosion hazard. Most of the precipitation is snow which, in melting, releases water at a rate readily absorbed by the soil. Summer rains are frequent, but usually very light. The erosion hazard is limited by the dense vegetation that clothes the mountain slopes and ridge tops; trees to elevations of about 11,000 feet, grasses and tundra vegetation on higher areas. The principal forest types are lodgepole pine and Engelmann spruce-alpine fir. Young stands of lodgepole pine are extremely dense and this density is maintained in overmature stands by the advance growth of pine or spruce and fir. The spruce-fir type has a dense cover in both the overstory and understory, the latter composed of spruce and fir reproduction and shrub growth. A complete litter cover prevails in both forest types, although it is deeper under the spruce-fir.

The combination of high water yields and low erosion hazard on the same area is fortunate. This means that the mountains, predominantly valuable for their water yields, can also be used for the commercial production of timber. The favorable combination indicates that the actual value of an area for water production may be increased by some reduction in tree canopy and an accompanying reduction in water losses from trees.

Increasing water production through forest management is the subject of a series of experiments being conducted on the Fraser Experimental Forest in north-central Colorado. One completed study, conducted on a plot basis, has shown that the harvest cutting of mature lodgepole pine does, in fact, increase the water available for stream flow (*4*). Another study is now under way that will make use of actual stream-flow measurements to test the effects of timber harvesting both on quantity and quality of water yields. The study reported here is an extension of the research on harvest cutting to include the results of thinning young stands of lodgepole pine.

Description of the Area

The Fraser Experimental Forest encompasses an area of 23,000 acres and ranges in elevation from 8,800 to nearly 13,000 feet. Annual precipitation averages about 24 inches, with the proportion of snowfall varying from two-thirds to three-quarters of the total. Snow accumulation starts in October or early November and continues without melt until late March or early April. Prolonged by heavy spring snowfall, a snow cover usually persists until late May or early June. June is a month of little precipitation, but convection rain showers become frequent in July and persist throughout the summer. In 8 years of record at the Fraser Experimental Forest at elevation of 9,000 feet, the heaviest storm produced 1.75 inches of rainfall; the second heaviest, 0.75 inches.

The present study was conducted on six blocks of 2¼ acres each located within the main valley of St. Louis Creek, the main drainage of the Experimental Forest, at an average elevation of about 9,000 feet. Logging of the original forest of lodgepole pine and spruce-fir in this valley around 1910 was followed by fire and a large area is now covered with a dense second growth of lodgepole pine. The blocks were chosen to sample a wide range of slope, aspect, and stand density. Slopes vary from 2 to 25 percent and aspects range through all cardinal directions. Stand densities varied from over 8,500 stems per acre on one block to less than 2,100 on another. Basal areas differed less; the maximum basal area being 116.3 square feet per acre; the minimum, 46.3; and the average, 89.4. Dominant trees averaged 23 feet in height.

The soils on all blocks are developed from stratified coarse-textured glacial outwash, consisting of schist, gneiss, and granite. In two blocks, a clay layer exists at depths of 16 to 24 inches; in the remaining blocks this layer was not found. Volume weights averaged 1.04 for the surface 3 inches of all blocks, but increased sharply to 1.61 at the 16-inch depth. Depth of outwash material was in excess of 48 inches throughout the study area.

Each of the six blocks was divided into three ¾-acre plots and random drawings made to determine the thinning treatment to be applied to each plot. One plot of each block was left untouched; the other two received different types of thinnings.

Silvicultural Treatments

The silvicultural thinning of second-growth lodgepole pine stands has been extensively practiced in the Rocky Mountain region and has proved beneficial to timber growth. The present experiment was specifically designed to measure the effect of such treatments on hydrologic factors related to stream flow.

Two different methods of thinning were applied to the young pine stands. One, called "single-tree thinning," consisted simply of reserving the better trees that were spaced about 8.5 feet apart over the plot. This left a total of approximately 600 trees per acre. All

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FIG. 1.—A plot thinned by the single-tree method showing the winter snow accumulation.

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FIG. 2.—A plot thinned by the crop-tree method. Arrow designates one of the crop trees.

other trees were cut (Fig. 1). The same type of thinning had been applied by the Civilian Conservation Corps over thousands of acres in the Rocky Mountain region.

The other type of thinning, designated "crop-tree," was done by cutting openings 8 feet in radius around each of 100 trees per acre. Selection of crop trees was based on their potential to develop into desirable specimens in the mature stand; secondary consideration was given to providing a uniform spacing of 21 feet. All trees outside the cleared circle surrounding each crop-tree were left standing. This method of thinning is less expensive than the single-tree since less of the original stand is removed and less time is needed for the selection of trees to be reserved. Furthermore, it leaves a pattern of forest cover which approaches that recommended by Church and others (*1, 2*) as the ideal for the maximum accumulation and storage of snow and its silvicultural value may be as great as that of the single-tree thinning. The appearance of the crop-tree plots is indicated by Fig. 2. In this type of thinning as well as the single-tree type, all trees were felled parallel to each other and large branches were lopped to reduce the depth of slash and hasten decay. Treatments were completed on all plots in the summer of 1945.

Stand densities in stems and basal area per acre were reduced by more than half their original values by both treatments (Table 1). Expressed in square-foot basal area, the percentage reductions were 51.2 for the crop-tree and 59.7 for the single-tree thinning.

Hydrologic Measurements

The hydrologic factors measured were those of snowfall, rate of snow-melt, rainfall, and soil-moisture losses. These were measured on all plots in the same manner and to the same intensity so that direct comparisons could be made of the thinning treatment effects.

Snowfall

The measurement of snowfall was divided into two parts and procedures; snow surveys and precipitation gages. This was desirable because snow-melt rarely occurs during the winter months. Snow falling during this period accumulates without loss (except by sublimation) until late March or early April. The sum of winter snowfall can be measured by snow surveys taken just prior to melt in early spring. Samples at 16 randomly located points on each ¾-acre plot comprised these surveys. Measurements were started 1 year before the thinning treatments in order to detect any plot variations in snow accumulation associated with inherent differences in aspect or elevation of the undisturbed forest stands. These data, statistically analyzed, showed no differences that would affect conclusions drawn from post-treatment data. Measurements after treatment were taken in 1947, 1948, and 1949 (Fig. 1).

Spring snowfall occurs while snow-melt is intermittently progressing. Snow on the ground at any time during this period represents the winter accumulation plus the prior spring snowfall minus the prior snow-melt. Snowfall during this period can be measured by precipitation gages. The results are then free of snow-melt effects. Standard 8-inch-diameter rain gages were used for this purpose with periodic movement to new random locations for greater sampling efficiency (*3*). One gage per plot was used in 1947 and 1948; two gages per plot in 1949 (Fig 3).

Snow-melt

Intensive study of snow-melt rates was made only in 1949; but observations made in 1947 and 1948 gave additional qualitative information. The 1949 measurements were made by means of weekly readings of the gages used to measure current snowfall and weekly

TABLE 1.—STAND DENSITIES AS AFFECTED BY THINNING TREATMENTS, ALL DATA ON A PER-ACRE BASIS

Treatment	Number of stems: Pre-treatment	Number of stems: Post-treatment	Number of stems: Percent reduction	Basal area in square feet: Pre-treatment	Basal area in square feet: Post-treatment	Basal area in square feet: Percent reduction
None	4,413	4,413	0.0	89.6	89.6	0.0
Crop-tree	4,275	2,072	51.5	88.8	43.3	51.2
Single-tree	4,025	649	83.9	89.8	36.2	59.7
Average	4,238	......	......	89.4	......	......

snow surveys to determine the snow remaining on the ground. The snow-melt occurring in any period was computed by adding current snowfall to that already accumulated at the beginning of the period and subtracting the snow remaining in storage at the end of the period.

Rainfall

Net rainfall determinations were complicated by the thick mantle of debris that covered the ground in the treated plots after the cuttings were completed; debris that obviously might intercept an important fraction of the gross rainfall. It was insufficient to measure net rainfall by standard gages placed with their orifices above the level of the slash; the fraction of rainfall intercepted by slash also had to be considered. Two cylindrical gages per plot, moved after each storm to new random locations, measured rainfall above the slash level. Rainfall under the slash was gaged by two shallow troughs equipped with screen baffles to eliminate splash. These two gages were also moved after each storm and were slipped beneath any slash that was present at the random sampling point (Fig. 4). Measurements by both methods were made in 1946 and 1947, 1 and 2 years after the thinnings.

Soil Moisture Losses

Soil-moisture losses as affected by the thinning treatments were determined by means of extensive sampling done in mid-September.

TABLE 2.—NET WINTER AND SPRING SNOWFALL, IN INCHES OF WATER, AS AFFECTED BY THINNING TREATMENTS

Year	Thinning treatments None	Crop-tree	Single tree
1947	10.38	11.49	12.34
1948	9.70	11.74	12.28
1949	10.00	11.94	12.41
Average	10.03	11.72	12.34
Thinning effect in inches of water		1.69	2.31
Thinning effect in percent		16.8	23.0

TABLE 3.—SPRING SNOW-MELT, IN INCHES OF WATER, AS AFFECTED BY THINNING TREATMENTS, RECORD OF 1 YEAR ONLY

Treatment	Total melt[1]	Treatment effect	Average melt per day
None	5.53	....	0.26
Crop-tree	7.54	2.01	0.36
Single-tree	7.88	2.35	0.38

[1]During first 21 days of melt period when snow cover was complete or nearly so.

TABLE 4.—NET SUMMER RAINFALL, IN INCHES, AS AFFECTED BY THINNING TREATMENTS MEASUREMENTS MADE ABOVE SLASH LEVEL

Year	Thining treatments None	Crop-tree	Single tree
1946	2.90	3.30	3.50
1947	4.47	5.04	5.16
Average	3.68	4.17	4.33
Thinning effect (inches)		0.49	0.65
Thinning effect (percent)		13.3	17.7

This period approximated the annual low point in soil moisture caused by the excess of evaporational and transpirational losses over summer rainfall. Sampling was done by means of a 1-inch geotome which extracted a core of soil. Samples were taken to a 48-inch depth, but were separated into segments of 0-18 inches and 18-48 inches in order to determine if the treatment effect varied between these two depths. Sixteen annual samples were taken from each plot at both depths. during the period of study.

Results

Snowfall

The thinning treatments had a marked effect on the snowfall reaching the ground within the experimental plots. Over the 3 years of the study, the average water equivalent increase in net snowfall due to the crop-tree thinning was 1.69 inches; while the increase caused by the single-tree treatment was 2.31 inches (Table 2). Artezonal comparisons indicated that these increases were real and not attributable to chance. However, the sizable difference between the effect of the crop-tree thinning and that of the single-tree could have been by chance alone.

Of the total increases in snowfall, the gains in net winter accumulation accounted for most. Crop-tree and single-tree thinning increased the winter accumulation by an average water equivalent of 1.31 inches and 1.68 inches, respectively.

Snow-melt

Observations made in 1947 and 1948 indicated that the thinning treatments produced acceleration in the rate of snow-melt. The intensive quantitative measurements of 1949 bore out this conclusion (Table 3). During the first 3 weeks of the melt period when the snow cover was still complete or nearly so,

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FIG. 3.—Gage for measuring spring snowfall located in a plot thinned by the crop-tree method.

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FIG. 4.—Cylindrical and trough gages in place on plot thinned by single-tree method.

the melt under the crop-tree thinning amounted to a total of 2.01 inches of water more than did that on the unthinned plots. The single-tree thinning increased snow-melt by a total of 2.35 inches of water in the same period. Beyond the 3-week period the snow cover became spotty (Fig. 5) with less snow area under the treated stands than under the untreated and further comparison could not be made because of the unequal snow surface areas subject to the snow-melt factors.

Rainfall

The partial removal of the forest canopy by the thinning treatments allowed more rainfall to penetrate beneath the crowns and to the level of the slash. The extent of these increases is shown in Table 4. For the 2 years of measurement, the average increase caused by the crop-tree thinning was 0.49 inches or 13.3 percent of the summer rainfall received under the untreated plots. The single-tree thinning produced an increase of 0.65 inches or 17.7 percent. Statistical tests showed these increases to be real and not due to chance.

Different results were obtained, however, from the measurements by trough gages of the rainfall penetrating the slash and actually reaching the soil surface. These measurements, taken in 1946 and 1947 when many needles still remained on the felled trees, showed no real influence of the thinning treatments. The felled trees while still holding their needles were apparently about as effective in intercepting rainfall as they were when standing.

Soil Moisture Losses

The intensive sampling of soil moisture in each of 3 years after the thinning revealed no effect by the treatments. Mid-September measurements showed no real differences between the moisture content of the soil under the treated plots and that under the untreated. Both the 0-18-inch and the 18-48-inch depth of soils showed this lack of difference in the year immediately following thinning as well as 4 years after cutting.

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FIG. 5.—Snow cover under crop-tree thinning late in spring melt period.

It is concluded from these results and the information obtained on rainfall reaching the soil surface that the losses of moisture from the soil through evaporation and transpiration were unaffected by the thinning treatments. The soil-moisture content in late summer is the total of summer rainfall on the soil, less the evaporation-transpiration losses. As shown by the trough gages, the amount of rainfall reaching the soil was similar in both the treated and untreated plots.

Summary and Discussion

This study has again demonstrated that the thinning of dense forest stands will appreciably increase the net precipitation received on the forest floor. For the particular environment and type of stand studied, the treatments applied caused an average increase of 20 percent in net snowfall and 15.5 percent in summer rainfall.

Partially offsetting these apparent watershed-management benefits were two other influences on precipitation: one was measured, the other was unmeasured and can only be discussed. The measured effect was that the felled trees intercepted an appreciable fraction of the summer rainfall; sufficient, in fact, to reduce to zero the effect of the thinnings on rainfall reaching the ground. It is probable, however, that as the slash disintegrates, the rainfall reaching the soil will increase. It is also probable that if the felled trees had been removed for utilization as poles or small posts, some immediate increase in net rainfall would have been realized.

The unmeasured effect of the treatments was that on the sublimation and evaporation losses of water from the snow. Because the thinnings allowed more wind and sunlight to reach the snow surface, they very likely increased the sublimation losses during cold weather and the evaporation losses during periods of melt. There is no known technique for accurately measuring these vaporization losses on an areal basis so the influence on them of the thinning treatments could not be evaluated. This deficiency does not weaken the conclusions regarding winter snow accumulations since the snow measured in early spring is the total snowfall less vaporization losses. The extent of these losses is unknown and probably can only be definitely established by watershed studies which measure in terms of stream flow the integration of all the hydrologic factors.

The evaporation and transpiration losses of moisture from the soil were found to be unaffected by the thinning treatments. This result is in support of the conclusion reached in the earlier study of harvest cuttings in mature lodgepole pine (*4*). In that study it was apparent that the effects of the cutting on autumn soil moisture were produced not by decreasing the soil-moisture losses but rather by increasing the rainfall reaching the soil. In the present study, the net rainfall was unaffected by the treatments and no influence was found on the soil moisture of late summer.

The measured increases in snow-melt rates could be detrimental to the stream flow from some watersheds and under some weather conditions. However, the specific situation including the opportunity for flood storage would determine the degree of harm (or benefit) in such increased melt rates. Thinnings which reduced basal area by an average 55 percent caused an additional 2.2 inches of total snow-melt in a 21-day period. Per day, this amounted to an average 0.10 inch but the maximum value on a particular day was probably well in excess of this figure.

The above are the results with regard to the treatment effects on quantity and manner of water yields. With respect to soil erosion, there has been no visible increase since the thinning operations. The soil is still stable under the present rainfall and snow-melt conditions to which the plots are subjected.

Conclusions

The thinning of dense young lodgepole pine stands is an accepted, silvicultural method of stimulating growth and shortening the rotation required for saw timber or pole production. Concerning areas such as those in the high mountains of Colorado and Wyoming where the primary value of the land lies in its high yield of quality water, the question arises as to whether these thinning operations are beneficial or harmful to water yields.

Indicative answers to these questions covering a period of 4 years following thinning operations were obtained from a study made on a typical area along the Continental Divide where the erosion hazard is low and the forest growth is dense. On experimental plots it was found that the thinning of dense young lodgepole pine stands increased net precipitation while not increasing soil-moisture losses. It is concluded that where climatic and forest conditions are similar to those studied, the thinning of dense pine stands should appreciably increase water yields A more complete and definitive answer must await watershed studies where the answer can be obtained directly in terms of stream flow, and vaporization losses from the snow surface can be more accurately accounted for. Accelerated erosion has not resulted from the thinning operations and it appears that the quality of stream flow would not suffer from similar thinnings where the climate and vegetation are such that the erosion hazard is low.

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