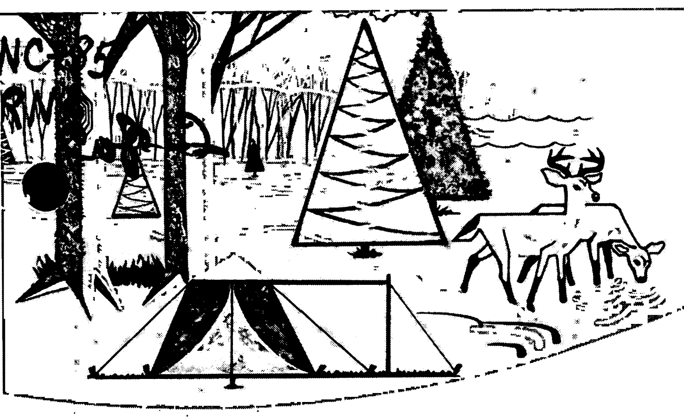

U. S. FOREST SERVICE

RESEARCH NOTE NC-85

NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE

Folwell Avenue, St. Paul, Minnesota 55101

RELATION OF SNOWPACK ACCUMULATION TO RED PINE STOCKING

ABSTRACT. — A snow accumulation study was conducted in a 33-year-old red pine plantation thinned to different stocking levels. Snowpack water content increased an average of 2 percent for each 10 square feet of basal area reduction, within the range of 60 to 180 square feet of basal area. Reducing plantation stocking from 180 to 60 square feet of basal area per acre would result in 1.4 to 1.9 inches of additional water in a winter when 6 to 8 inches of precipitation were received.

OXFORD: 111.784:228.1:174.7 *Pinus resinosa* **(774)**

Two-thirds (420,000 acres) of the forest plantations in northern Lower Michigan are either red pine (*Pinus resinosa* Ait.) or mixed red and jack pines (*Pinus banksiana* Lamb.) (Stone and Chase 1962). Many plantations are now reaching the size and stocking level where they must be thinned periodically. Present economic guidelines for thinning red pine are based on expected returns from timber (Lundgren 1965). Possible changes in value of other forest resources following thinning are usually not considered, primarily because of the lack of quantitative information about the effect of stocking level on these resources. This paper describes the results of a study designed to determine the relation between red pine density and snow accumulation, and provides some of the information necessary to incorporate the effects of thinning on water yields into management guidelines.

Methods

The study was conducted from 1967 to 1969 in a 33-year-old red pine stand, located 20 miles west of Cadillac in the northwest corner of the Lower Peninsula of Michigan. The stand is on Kalkaska and Rubicon soils with a site index potential of 70. In 1960 portions of the stand were thinned to stocking levels of 30, 60, 90, 120, and 150 square feet of basal area per acre. Additional thinning was done in 1966 to maintain the plots at their designated stocking levels. Two plots with initial stocking of 166 and 176 square feet were left unthinned. Nineteen plots were selected for snowpack measurements (fig. 1). All plots were 0.4 acre in size and were 132 feet (about 3 tree heights) across.

Some plots were thinned from below, some from above, and some by a combination of both. Others were thinned by removing every second or third row (rows were oriented north-south). However, the effects of the different thinning methods on snowpack water content were not detectable with the sampling intensity used, and in any event, appeared smaller than the effects of reduced stocking.

Snow measurements were made along a 50-foot line that crossed several tree rows near the center of each plot. Ten snow samples were taken at 5-foot intervals along the line using a Mt. Rose snow tube and scales. The 10 samples were emptied into a pail and the accumulated sample was weighed and recorded.

The winter snow accumulation period usually has at least one period of rain or snowmelt. Melt rates and snowpack water loss would be expected to be greatest in the lower density plots (Eschner and Satterlund 1963, Goodell 1959, Kittredge 1948). Because these are the same plots that have the greatest snowpack accumulation, the accelerated water loss could partially or even entirely obscure the accumulation differences. Consequently, sampling dates were

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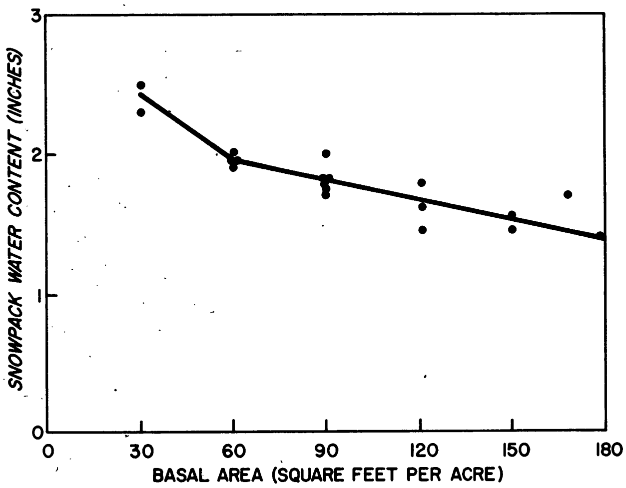

Figure 1.—Snowpack water content at different basal areas for one 32-day storm period of 2.4 inches total precipitation. Each point represents the mean water content of one plot.

selected so that periods of snowpack accumulation could be separated from periods of water loss due to midwinter snowmelt or rain. Snowpack measurements were usually made several days after every snow accumulation period (after the intercepted snow had left the crowns, but before any snowmelt water loss had occurred) and after every period of snowmelt that produced water loss from the snowpack. Thus, it was possible to separate the effect of stand density on snowpack accumulation without the confounding effect of intermittent melting. Snow accumulation periods that did not have pre- and post-snowfall measurements according to the above criteria, or that contained substantial amounts of rain or snowpack water loss, were rejected from the analysis.

Results

Eight snow accumulation periods ranging from 3 to 33 days, were selected for analysis from the three winters of record. In each period there was an obvious trend toward greater snowpack water content with lower residual stocking. A typical trend for one snowpack accumulation period is illustrated in figure 1.

Plots thinned to 30 square feet of basal area had snowpack water contents consistently higher than less heavily thinned plots. These low stocking level plots appeared as holes in the canopy, and may have accumulated more snow than they would have if the same stocking level was maintained over a large area. In fact, there was no significant difference ($p = .05$) between the snow water content caught in the 30-square-foot plots during snow accumulation periods and that caught in the nearest precipitation station located in a forest opening 4 miles south. Therefore, the snow water content in the 30-square-foot plots (mean of two plots) was used as the total precipitation for the accumulation periods analyzed.

Snowpack water content decreased at higher stocking levels for all eight accumulation periods (fig. 2).

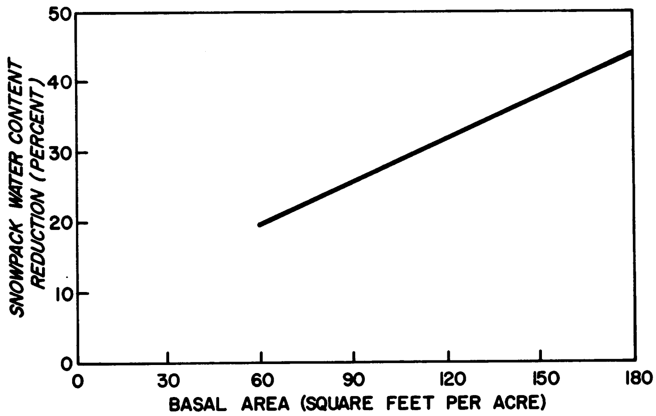

Figure 2.—Reduction in snowpack water content at different basal areas as a percentage of total precipitation. Based on mean of eight accumulation periods.

The smallest snowpack water content, which occurred at the 180-square-foot[1] stocking level, ranged from 34 to 69 percent and averaged about 44 percent of the precipitation.

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[1] *No plots were actually thinned to 180 square feet of basal area. Data for this level were obtained by extrapolating the trend lines past 176 to 180 square feet.*

The difference in snowpack water content between plots of different stocking levels increased as snowfall increased (fig. 3). The upper curve shows the difference between 0 and 180 square feet of basal area for different size storms. The lower curve provides a more useful comparison for the forest manager. It shows the difference in snowpack water content resulting from maintaining plantations at 180 square feet rather than 60 square feet. For example, the snowpack contained 0.5 inch less water in a 180-square-foot plot than in a 60-square-foot plot after 2 inches total precipitation, with an average difference for all storms of about 25 percent.

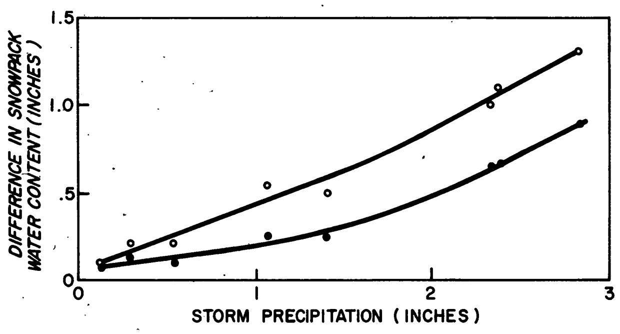

Figure 3.—Difference in snowpack water content for selected stocking-level alternatives over a range of precipitation. The upper curve shows reduction in snowpack water content from managing at 180 square feet of basal area as compared with clear cutting; the lower curve shows reduction from managing at 180 square feet as compared with 60 square feet.

Using the above data, it is possible to estimate the increase in snowpack water content for a given reduction in stocking level. Assuming that the effect of stocking on snow accumulation is linear over the range in stocking levels of 60 to 180 square feet of basal area, and that an average of 24 percent more snow is accumulated at 60 square feet than at 180 square feet, there would be a 2-percent increase in the snowpack water content for each reduction of 10 square feet of basal area between 180 and 60. The effect of basal area reduction for different accumulated snowpack water contents up to 8 inches is shown in figure 4.

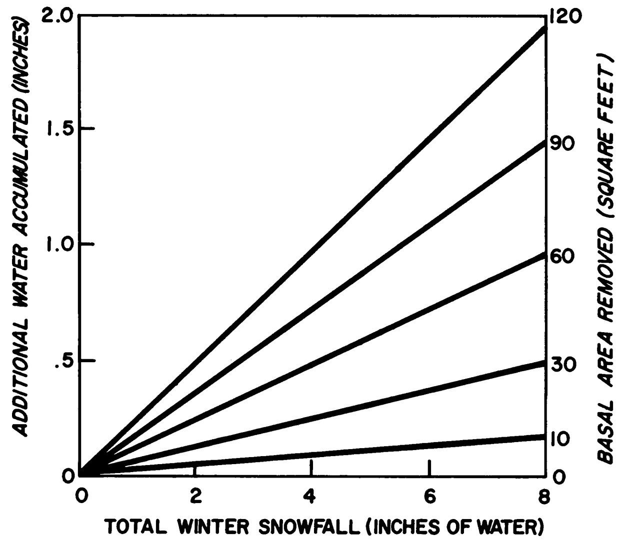

Figure 4. — Additional snowpack water accumulated for given levels of basal area reduction and given total winter snowfall. Relationshps are for a 33-year-old red pine stand with initial stocking of 180 basal area and site index 70.

Total annual precipitation in the study area averages 32 inches (U.S. Weather Bureau 1956). Eight inches, or about 25 percent, comes from December to March, mostly in the form of snow. In this area of highly permeable sands, most snowmelt infiltrates the soil to recharge the ground-water supply, with little contributing to direct surface runoff. It has been demonstrated that the amount of ground-water recharge is closely related to the water content of the snowpack under these conditions (Urie 1966). Therefore, it is reasonable to expect that the additional snowpack gained through reduced stocking will result in a proportional increase in ground-water recharge.

The "snowpack water content" data (figs. 1, 2, and 3) also include any snowpack evaporative loss that occurred during the same time periods. Snow accumulation during these periods was apparently typical over the major portion of the winter, and thus should adequately represent the net winter snow accumulation. However, the data do not cover the 2- to 4-week spring snowmelt period, when higher temperatures might have increased evaporative loss (Geiger 1965, Kittredge 1948, West 1962). Because evaporation rates would be expected to be greatest in the plots with low stocking (Kittredge 1948, West 1962) less water would be available for soil moisture recharge. The magnitude of such reduction is not known at present. Also, the differences in snowpack water content could be expected to vary with climate and stand conditions. Factors such as temperature, site, stand age, initial stand density, and previous thinnings might affect the magnitude of the snowpack differences. Therefore, the values in figure 4 should be treated as approximations of the potential water increase at this time.

It should be noted that this study dealt only with snowfall. Because only about 60 percent of the annual ground-water recharge in the study area originates from the December through March snowfall season,[2] during which some of the precipitation is rain, the effect of stand density on the quantity of rain reaching the ground is also important to the water yield picture. Although no local data are available, several interception studies throughout the world have shown that rainfall interception by conifers is at least as great as snowfall interception (Kittredge 1948, Geiger 1965, Rowe and Hendrix 1951). Also, the effect of conifer stocking on rainfall interception (Kittredge 1948) is similar in direction to the snowfall trend presented here.

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2 *Unpublished data from Dean H. Urie, U.S.D.A. Forest Service, North Central Forest Experiment Station, Cadillac, Mich.*

Literature Cited

Eschner, A. R., and Satterlund, D. R. 1963. Snow deposition and melt under different vegetative covers in central New York. U.S.D.A. Forest Serv., Res. Note NE-13, 6 p. Northeast. Forest Exp. Sta., Upper Darby, Penn.

Geiger, Rudolf. 1965. The climate near the ground. 611 p., illus. Cambridge, Mass.: Harvard Univ. Press.

Goodell, B. C. 1959. Management of forest stands in western United States to influence the flow of snow-fed streams. *In* Int. Ass. Sci. Hydrol., Hannoversch-Munden, Symp. 1: 49-58.

Kittredge, Joseph. 1948. Forest influences. 394 p., illus. New York: McGraw-Hill Book Co., Inc.

Lundgren, Allen L. 1965. Thinning red pine for high investment returns. U.S.D.A. Forest Serv., Res. Pap. LS-18, 20 p., illus. Lake States Forest Exp. Sta., St. Paul, Minn.

Rowe, P. B., and Hendrix, T. M. 1951. Interception of rain and snow by second-growth ponderosa pine. Amer. Geophys. Union Trans. 32: 903-908.

Stone, R. N., and Chase, C. D. 1962. Forest plantations in northern Lower Michigan. U.S.D.A. Forest Serv., Lake States Forest Exp. Sta., Sta. Pap. 102, 30 p., illus.

U.S. Weather Bureau. 1956. Climatic summary of the United States — supplement for 1931 through 1952, Michigan, 56 p.

Urie, Dean H. 1966. Influence of forest cover on snowpack and ground-water recharge. Groundwater 4: 5-9.

West, Allen J. 1962. Snow evaporation from a forested watershed in the central Sierra Nevada. J. Forest 60: 481-484.

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