EFFECTS OF MIXED CONIFER FOREST OPENINGS ON SNOW

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Introduction

It has been observed that small openings in forests accumulate more snow than do adjacent forest overstories (Gary and Troendle, 1982; Golding and Swanson, 1978; Hansen and Ffolliott, 1968; Rothacher, 1965). This increased snowpack, in turn, can result in water yield improvements from upstream watersheds. To better understand this phenomenon, a snow hydrology study was initiated in the mixed conifer forests of the White Mountains, located in east-central Arizona, during the winter of 1982-83. This paper reports the preliminary findings of this work.

Description of Study

An objective of the study was to evaluate the usefulness of results from an earlier snow hydrology investigation, conducted in the lower elevation ponderosa pine forests (Gopen, 1974), for describing snowpack dynamics that are associated with small openings in mixed conifer forests. Additionally, new empirical relationships were developed to characterize peak snowpack accumulation in small clearcut openings in Arizona's mixed conifer forests.

The study site was the South Fork of Thomas Creek, a 562-acre watershed in the mixed conifer forests on the Apache-Sitgreaves National Forest, approximately 25 miles south of Alpine. Timber had been harvested by patch cutting on the study site. The patches were designed to increase snowpack accumulation, although at the time of harvesting, this could only be hypothesized. A series of nine study plots were established in small clearcut openings. These openings, from one-half to two acres in size, were irregular in shape.

Two transects that intersected perpendicularly at the center of the study plot were established. Sampling points were located at 50-foot intervals along these transects. The sampling points extended a minimal distance of 150 feet into the surrounding forest overstory that surrounded the small clear cut openings.

Inches of snowpack water equivalent (WE) were measured at the sampling points with a federal snow sampler and scale throughout the winter season. However, as mentioned above, peak snowpack accumulation was of primary interest in this paper. Peak snowpack accumulation occurred in early April during the winter of 1982-83, a season of heavy snowfalls with a long snowpack accumulation period.

A forest inventory was also conducted to describe the density characteristics of the forest overstory that surrounded the small clearcut openings. Standard point sampling techniques were employed. This inventory identified seven coniferous and one deciduous tree species on the watershed, including: Douglas-fir, ponderosa pine, white fir, Engelmann and blue spruce, corkbark fir, southwestern white pine, and quaking aspen. The average basal area density of the forest overstory was nearly 125 square feet per acre.

Slope and aspect measurements were also taken to estimate potential insolation values at the sampling points (Frank and Lee, 1966).

A multiple regression derived by Gopen (1974) for southwestern ponderosa pine forests was initially used to predict the net effect of the small clearcut openings on peak snowpack WE. By definition, the net effect of an opening is obtained by computing the signed deviation between that of the measured snowpack WE of every sampling point in the transect and the average snowpack WE of the undisturbed forested condition. Summation of these deviations indicate the net effect of the opening. The analytic procedure that is followed in calculating the net effect has been explained elsewhere (Gopen, 1974; Ffolliott, 1983) and, therefore, will not be discussed here.

Gopen's empirical regression equation is:

$$Y = 117 - 0.226X_1X_2 + 0.471X_3^2 - 0.119X_4$$

where Y = net effect of opening, in inches of snowpack WE

X_1 = forest density, in square feet of basal area per acre

X_2 = average tree height, in feet

X_3 = precipitation, in inches

X_4 = average daily potential insolation values, in langleys

$r^2 = 0.561$

Once again, the above regression equation was developed from source data collected in southwestern ponderosa pine forests, not mixed conifer forests.

Results and Discussion

As shown in figure 1, the values of peak snowpack WE obtained through solutions of Gopen's regression equation did not generally agree with peak snow-

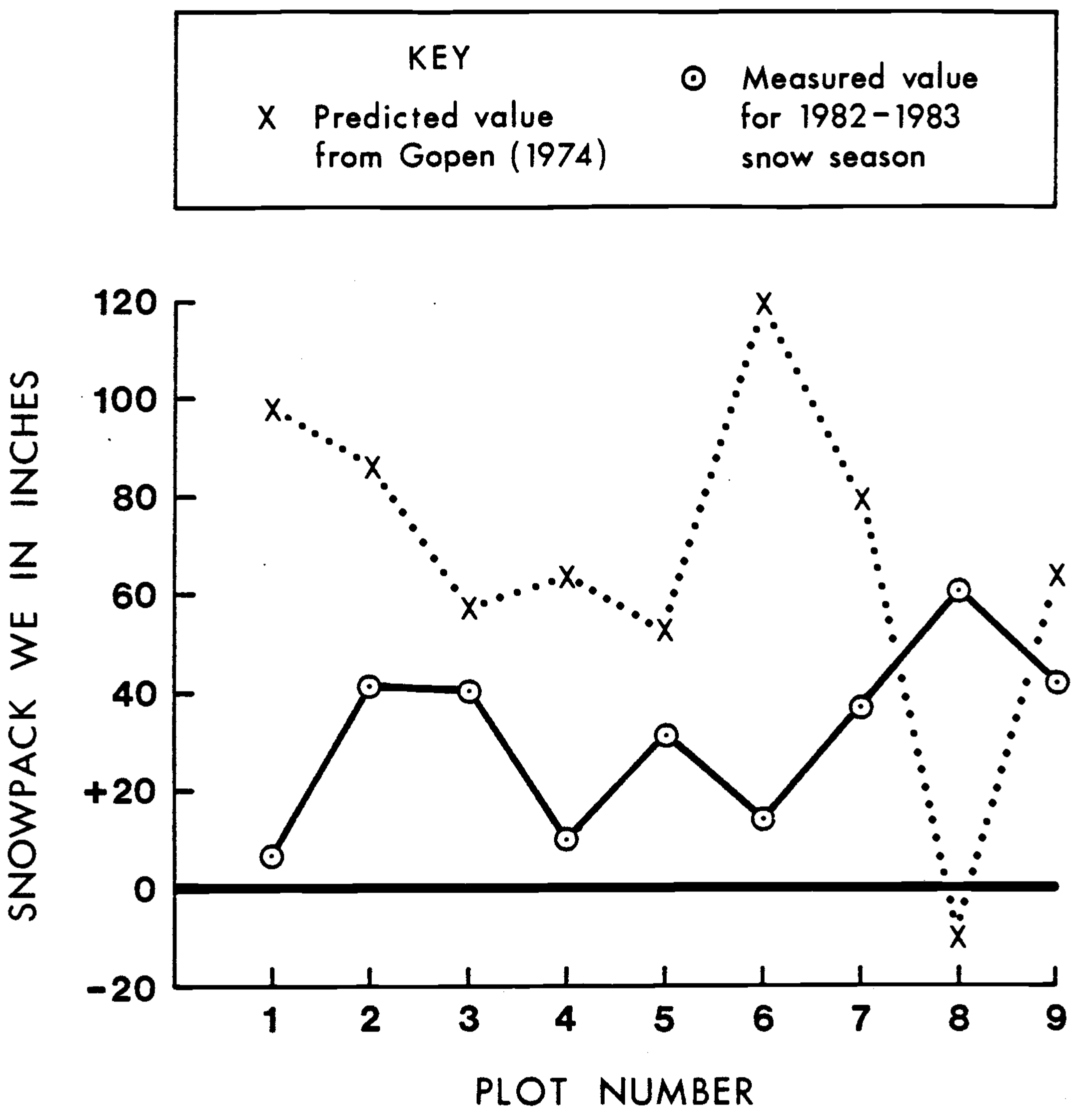

Figure 1. Comparison of peak snowpack WE values obtained from solutions of Gopen's regression equation to measurements on-site.

pack WE values that were measured on-site. Differences in the range of climatic and site conditions from which Gopen's equation was developed, and the conditions encountered in this study, are a possible reason for this result. From a visual observation of figure 1, it must be determined that Gopen's work is not directly applicable to Arizona's mixed conifer forest overstories.

Using a step-wise regression approach, new empirical relationships were derived to predict peak snowpack WE in the small clearcut openings on the South Fork of Thomas Creek. Three independent variables were regressed against the net effect variable, at the 10 percent level of significance. The independent variables were: accumulated daily potential insolation values on index dates from December 1, the approximate start of the snowpack accumulation period, to April 1, the date of peak snowpack accumulation (Frank and Lee, 1966); size of the clearcut opening, in acres; and the density of the forest overstory that surrounded the opening. Four expressions of forest density were considered, including basal area, stem density, bole area (a measure of bolewood surface area), and percent crown closure.

The results of the step-wise regression analysis are summarized as follows:

Step 1

$$Y = -144 + 0.00263X_1$$

where Y = net effect, in inches

X_1 = accumulated daily potential insolation values, in langleys

$r^2 = 0.468$

Step 2

$$Y = -163 + 0.00302X_1 + 22.1X_2$$

where X_2 = size of clearcut opening, in acres

$r^2 = 0.675$

Step 3

Inclusion of forest density variables, regardless of expression, did not significantly improve the regression equation over step 2. Therefore, the equation presented in step 2 has been assumed to be the "best" relationship.

In contrast to the situation in southwestern ponderosa pine stands, forest density (regardless of the expression) was not a significant variable in relation to peak snowpack WE in small clearcut openings in the mixed conifer forests on the South Fork of Thomas Creek. This finding was not necessarily surprising, however, since there is generally more variability in the spatial distribution of ponderosa pine forests than of mixed conifer forests. These latter forest overstories, especially on the South Fork of Thomas Creek, are relatively homogeneous in structure, even following timber harvesting.

From the results of this study, for a given value of potential insolation (which is a measure of the slope-aspect combination of a site), the size of an opening is a controlling variable in describing peak snowpack WE in the opening. Within the range of conditions studied on the South Fork of Thomas Creek, the larger the clearcut opening, the greater the accumulation of snowpack in the opening. The effects of clearcut openings in excess of two acres in size remains unknown.

Conclusions

The preliminary results of this study indicate that, in general, peak snowpack dyanmics in small openings created in Arizona's mixed conifer forests cannot be predicted from an empirical regression equation that was developed in an earlier investigation of snowpack dynamics in southwestern ponderosa pine forests. Instead, it became necessary to derive new empirical relationships for mixed conifer forests. Of the independent variables analyzed in developing these latter relationships, only potential insolation values (a measure of slope-aspect combinations) and size of the openings related to peak snowpack WE in small clearcut openings on the South Fork of Thomas Creek.

A question that remains unanswered, however, concerns the proportion of a watershed should be cleared in small openings to optimize snowpack dyanmics relative to water yield improvement from the entire area. The juxtaposition between openings and uncut forest must be determined.

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