DESCRIBING SNOWPACKS IN ARIZONA MIXED CONIFER FORESTS WITH A STORAGE-DURATION INDEX

Mark A. Warren and Peter F. Ffolliott

INTRODUCTION

The quantification of snowpacks in relation to inventory-prediction variables may be useful in the development of water yield improvement practices involving vegetation management in the mixed conifer forests in Arizona. These forests can receive 10 to 15 inches more annual precipitation than the adjacent ponderosa pine forests, with much of this additional precipitation occurring as snowfall during the winter. Therefore, while mixed conifer forests are relatively limited in extent in Arizona, the potential for water yield improvement by manipulating snow storage through vegetation management may be high.

Although previous studies in the mixed conifer and other forest types have reported empirical relationships between snowpack conditions at a point in time and various inventory-prediction variables, little work has been directed toward the dynamic evaluation of snowpack conditions over time. To provide such information for mixed conifer forests in Arizona, an exploratory study was conducted to assess the possible usefulness of a storage-duration index (Wilm 1948) in the development of vegetation management practices for water yield improvement. This index, which is synthesized for arbitrary time periods by adding together snowpack water-equivalent measurements made on successive sampling dates, is considered to be an integrated single measure of initial snow storage and subsequent snow melt. Theoretically, maximum index values are obtained with high initial storage followed by slow melt, while low initial storage followed by rapid melt provides minimum values.

DESCRIPTION OF THE STUDY

The exploratory study described herein was designed to evaluate the storage-duration index as related to inventory-prediction variables that are either readily available or easily obtained by the land manager. Specific variable selected for study were forest density, expressed by basal area, potential insolation, which is a measure of slope steepness and aspect interactions, and elevation. These variables have been shown to be important in describing snowpack conditions at a point in time in previous studies (Ffolliott and Hansen 1968, Ffolliott and Thorud 1972).

The study utilized 93 snowpack water-equivalent measurement points located on the North Fork of Thomas Creek, a 467 acre experimental watershed in east-central Arizona. These sample points were arrayed in a systematic sampling design with multiple random starts (Shiue 1960). In addition to serving as a snowpack measurement point, each sample point provided the framework to inventory and subsequently define the forest density, potential insolation, and elevation variables.

The mixed conifer forests overstory on North Fork consists of seven coniferous species and two deciduous species. The coniferous species are Douglas-fir, white fir, corkbark fir, Engelmann spruce, blue spruce, ponderosa pine, and southwestern white pine; the two deciduous species are quaking aspen and Gambel oak (Embry and Gottfried 1971).

Topography on North Fork varies, with the lower and middle portions of the watershed being quite steep. Soils are derived from basalt parent materials, and elevations range from 8,400 to 9,150 feet. Annual precipitation averages 27 inches, approximately one-third of which occurs during the snowfall season of November through April.

Snowpack water-equivalent measurements were made with a snow tube and scale at all sample points through the winter of 1973-74. However, only those measurements taken on January 12, February 16, and March 2, 1974, were used in synthesizing the storage-duration index evaluated in this study. These measurements represented the approximate times of peak seasonal snowpack accumulation, peak daily runoff, and end of snowmelt runoff.

The authors are Research Assistant and Associate Professor, School of Renewable Natural Resources, University of Arizona, Tucson, Arizona. Approved for publication as Journal Paper No.2425 of the Arizona Agricultural Experiment Station. Appreciation is extended to the USDA Forest Service for providing the study area and contributing source data.

Forest density, measured in terms of square feet of basal area per acre, was estimated by point sampling techniques employing standard forest mensurational procedures (Avery 1975). Potential insolation, expressed in gram calories/cm^2, received on an index date indicative of the snowpack water-equivalent measurement period (February 6) was obtained from slope steepness and aspect measurements at each sample point (Frank and Lee 1966). Elevation of each sample point was estimated to the nearest 25 feet by using an altimeter.

A multiple regression analysis (a = 0.10) was employed to empirically quantify the relationship between the storage-duration index and the combined effect of the selected inventory-prediction variables.

RESULTS AND DISCUSSION

The regression equation that defined the relationship between the storage-duration index and the inventory-prediction variables selected for study is presented in Table 1. It is suggested that the general usefulness of this equation is not necessarily in predicting storage-duration index values *per se*, but in identifying the sites on a watershed with desired snow storage characteristics. Such information may be gleaned through an examination of the respective signs of the regression coefficients, i.e., a positive sign indicating a direct association (as occurs with elevation) and a negative sign indicating an inverse association (as is the case with basal area and potential insolation).

Table 1.--Regression equation of storage-duration index versus forest density, potential insolation (slope steepness and aspect), and elevation.

$$Y = -16.2 - 0.00643(X_1) - 0.0158(X_2) + 0.00361(X_3)$$

$$r = 0.650$$

where Y = storage-duration index

X_1 = basal area in square feet per acre

X_2 = potential insolation on index date (February 6) in Langleys

X_3 = elevation in feet

r = multiple correlation coefficient

On the North Fork of Thomas Creek, high initial snow storage followed by slow melt was associated with low forest densities, low potential insolation values, and high elevations, as sample points exhibiting these conditions also possessed maximum storage-duration index values. Low initial snow storage followed by rapid melt was associated with high forest densities, high potential insolation values, and low elevations.

Storage-duration index values and snowpack water-equivalents at peak seasonal accumulation in the year of study on North Fork were similarly associated with forest density, potential insolation, and elevation, as evidenced by the results from this exploratory study and from a companion investigation of snowpack conditions on North Fork at various points in time (Warren 1974). This association implies that high initial snow storage under low forest densities, low potential insolation values, and high elevations is not necessarily offset by accelerated melting, but remains high throughout the snowmelt season. On the other hand, low initial snow storage correlated with high forest densities, high potential insolation values, and low elevations may not persist because of rapid melting.

Generally, the results of this exploratory study indicate possibilities for empirically identifying similar hydrologic strata on a mixed conifer forest watershed (Anderson 1967) in terms of initial snow storage and subsequent snow melt criteria. Then, once identified, water yield improvement practices designed to affect snow storage may be prescribed and implemented.

Forest density is the only inventory-prediction variable selected for study that can be manipulated by vegetation management. By decreasing forest density levels through thinning operations on high elevation sites with low potential insolation, storage-duration index values should be increased, resulting in higher initial snow storage followed by slower melt. Allowing forest density levels to increase on low elevation sites with high potential insolation would cause storage-duration index values to decrease, resulting in lower initial snow storage followed by more rapid melt.

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