SNOWPACK DYNAMICS IN ARIZONA'S ASPEN FORESTS

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INTRODUCTION

Quaking aspen (Populus tremuloides) is the most widely distributed tree species in North America (Little, 1971). In Arizona, however, aspen does not occur as extensive, continuous forest, but this species is found as isolated stands varying in size from less than 10 to several hundred acres. A large portion of these aspen stands are found in the vicinity of the White Mountains in eastern Arizona, on the lower slopes of the San Francisco Mountains near Flagstaff, and on the Kaibab Plateau north of the Grand Canyon.

Although not extensive in area, aspen forests in Arizona may be important from a hydrologic standpoint. For example, annual water yields approaching 3 to 7 inches have been estimated for many aspen stands (Ffolliott and Thorud, 1975), with much of this water originating from snow. Unfortunately, little is known of snowpack dynamics in Arizona's aspen forests.

DESCRIPTION OF THE STUDY

While investigations of relationships between snowpack dynamics and associated vegetative-physiographic characteristics in ponderosa pine (Pinus ponderosa) and mixed conifer forests have been conducted in Arizona, little information is available to describe these relations in aspen forests. The study was implemented to obtain empirical information necessary to describe snowpack accumulation and melt processes in aspen forests, and to compare these processes with those reported in ponderosa pine forests. Information collected from the first year (1978-79) of a two-year study period is reported here.

STUDY AREAS

Study areas were located in the snow zone near the San Francisco Mountains (Figure 1). Three criteria determined the acceptance of the areas: accessibility, integrity of aspen stands, and proximity of coniferous stands.

Two study areas were established 13 and 20 miles northwest of Flagstaff, along State Highway 180 on the Coconino National Forest. Each area included a relatively pure stand of aspen and a representative stand of ponderosa pine within one-third mile of the aspen stand.

The site nearer Flagstaff, Crater Lake, is situated at the base of a small volcano. The average slope is less than 5 percent; the aspect is westerly. Elevation is approximately 8,000 feet. Soils are derived from basalt and range from shallow to moderate in depth.

The second site, Kendrick Park, is adjacent to a cienaga of that name. The average slope of the aspen stand is less than 5 percent, while the average slope of the adjacent ponderosa pine stand is 7 percent. The aspect of both stands is easterly. Elevation is 7,900 feet. Soils are derived from basalt and range from shallow to deep.

FIELD PROCEDURES

Thirty sample plots were established in each of the two aspen stands, and 10 sample plots were installed in each of the two ponderosa pine stands. Individual plots consisted of a diamond-shaped cluster of five sample points within a one-fifth acre circular plot. A plot was considered the primary sampling unit and consisted of the five sample points. Sample plot locations were determined by choosing areas most representative of the stand in terms of density, age, and size class distributions (Table 1).

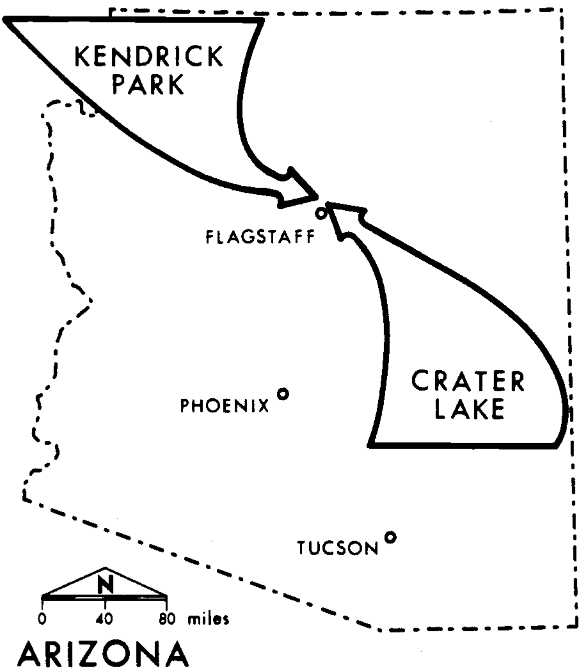

Figure 1 - Study areas in the snow zone near the San Francisco Mountains.

Table 1 - Minimum, mean and maximum values of forest density values.

Value	Forest Type					
	Aspen			Ponderosa Pine		
	Min	Mean	Max	Min	Mean	Max
Diameter inches	0.5	9.3	26.2	0.5	13.7	48.0
Basal Area sq. feet/acre	50	115	245	65	115	190
Stems number/acre	8	243	624	58	112	195
Volume cubic feet/acre	1168	2305	4665	948	1662	2959

Starting on February 18, 1979 for the Crater Lake site and on March 11, 1979 for the Kendrick Park site, snowpack measurements were taken every two to three weeks until the snowpack disappeared. Snow depth and snowpack water equivalent (WE) were measured with a Federal snow sampler.

An initial inventory of the aspen and ponderosa pine forest overstories was made in May 1979, using standard point sampling techniques (Avery, 1975). Basal area and number of stems per acre were calculated . These two widely used expressions of forest density were used as input variables in evaluating the effect of aspen forests on snowpack dynamics. Slope percent and aspect measurements were taken to compute potential direct beam solar irradiation (gram calories cm^{-2}), using tables prepared by Frank and Lee (1966).

A second inventory was made in August 1979 because a limited timber cut had removed a portion of the ponderosa pine forest overstory on the Crater Lake site. It is anticipated that the timber removal will not affect snowpack dynamics in the second year of measurements.

ANALYTIC METHODS

In addition to basic summaries of the source data, simple regression analyses were performed using peak seasonal accumulation (March 24) and a storage-duration index as dependent variables. A storage-duration index (the summation of snowpack WE measurements taken in successive surveys) is indicative of the integration of initial snowpack accumulation and subsequent melt rates (Wilm, 1948). Maximum index values are obtained with large initial accumulations followed by slow melting; while low initial accumulations followed by a rapid melting provides minimum values. The storage-duration index developed in this study was a summation of snowpack WE measurements taken on March 24, April 7, and April 28, 1979.

The independent variables used in the regression analyses were aspen basal area, total (aspen and ponderosa pine) basal area, total number of stems, and potential direct beam solar irradiation. Inverses, squares, and logarithmic expressions of the independent variables were included in the analyses.

PRELIMINARY RESULTS

The results of the snowpack measurements taken during 1978-79 are summarized in Table 2 and illustrated in Figure 2. In general, these results indicate greater snowpack accumulations under aspen than under ponderosa pine forest overstories. These differences are presumed to be due to less interception of snow in the aspen stands. Also, it is suggested that snow melt rates are higher in aspen than ponderosa pine forests, although a detailed assessment of the melting process is incomplete.

Table 2 - Snowpack water equivalent, depth, and density for Crater Lake and Kendrick Park study sites, February-April, 1979.

	CRATER LAKE						KENDRICK PARK					
DATE	Aspen			Ponderosa Pine			Aspen			Ponderosa Pine		
	WE	Depth	Density	WE	Depth	Density	WE	Depth	Density	WE	Depth	Density
	--inches--			--inches--			--inches--			--inches--		
Feb. 18	10.3	30.9	0.33	9.1	25.7	0.35	--	--	--	--	--	--
Mar. 11	10.0	28.6	0.35	8.2	23.3	0.35	9.1	26.3	0.35	6.5	17.1	0.38
Mar. 24	10.6	31.9	0.33	8.3	25.8	0.32	9.4	28.6	0.33	5.8	17.6	0.32
Apr. 7	9.0	23.6	0.38	7.9	20.6	0.38	7.3	20.3	0.36	4.0	10.1	0.39
Apr. 28	0.0	0.0	0.0	0.4	0.8	0.50	0.0	0.0	0.0	0.0	0.0	0.0

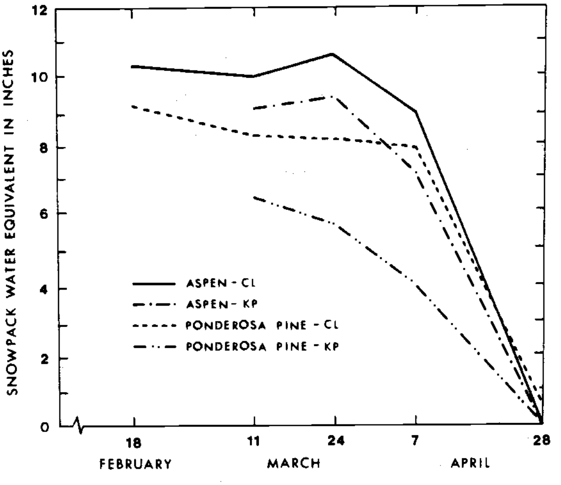

Figure 2 - Sample WE measurements taken during 1978-79.

Studies conducted elsewhere have found greater snowpack WE accumulations in aspen than in coniferous forests, again due, in part, to the relative losses attributed to snowfall interception. For example, Dunford and Niederhof (1944) reported an average of 10.9 inches of snowpack WE in aspen stands, and 8.4 inches in lodgepole pine (Pinus contorta) stands in Colorado. The general trend illustrated by these averages was consistent over a two-year study period, suggesting that aspen was more efficient in accumulating snow than was the coniferous forest type evaluated.

In New Mexico, Gary and Coltharp (1967) found a small difference in snowpack accumulation between aspen and Douglas-fir (Pseudotsuga menziesii) stands on warm sites. On cool sites, however, aspen stands accumulated 40 percent more snowpack WE at peak seasonal accumulation than did Douglas-fir stands.

With respect to snow melt rates, inconsistent results have been reported. Dunford and Niederhof (1944) found no differences in the rates of snow melt between aspen and lodgepole pine stands. In Minnesota, Weitzman and Bay (1959) reported similar snow melt patterns under aspen and red pine (Pinus resinosa) stands. In contrast to these two studies, Gary and Coltharp (1967) indicated greater rates of snowpack depletion under aspen than under Douglas-fir stands.

Regression analyses indicated that potential direct beam solar irradiation was a nonsignificant (in all transformational forms) independent variable in relation to both peak seasonal accumulation and the storage-duration index (at the 90 percent confidence level). This finding was attributed, in large part, to a lack of variation in slope and aspect among the sample plots. Regressions with independent variables involving expressions of forest density had significant forms, although none were highly correlated with snowpack WE in terms of coefficients of determination. For example, aspen basal area and total (aspen and ponderosa pine) basal area accounted for only 8 and 10 percent, respectively, of the variation in peak seasonal accumulation. Similar results were obtained using number of stems.

ANTICIPATED FUTURE ANALYSES

Following the collection of snowpack measurements in 1979-80, all source data will be collated and subjected to regression analyses to determine the relative magnitudes of vegetative-physiographic influences on the snowpack dynamics in Arizona's aspen forests.

Including the above analyses, a computer simulation model, called SNOW, will be expanded to describe impacts of alternative land management practices on snowpack dynamics in the forest ecosystems in Arizona (Ffolliott and Rasmussen, 1979). Through application of this model, land management practices designed to affect water yields from these forest ecosystems can be prescribed to achieve desired hydrologic objectives.

CONCLUSIONS

Preliminary results obtained in the first year of a two-year study on snowpack dynamics in Arizona's aspen forests indicated: (1) snowpack accumulations were greater under aspen than under ponderosa pine stands; (2) snow melt rates may be higher under aspen than under ponderosa pine stands (this finding is tentative); and (3) only forest density variables appeared useful in inventory-prediction equations. Refinement of these preliminary results will, hopefully, allow for the expansion of a computer simulation model to include snowpack dynamics in aspen forests.

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