A PRELIMINARY ASSESSMENT OF SNOWFALL INTERCEPTION IN ARIZONA PONDEROSA PINE FOREST

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INTRODUCTION

In central Arizona, which includes the Salt and Verde River Basins, the maintenance of economic stability is dependent, in part, on the availability of useable water supplies that originate as snowmelt runoff from outlying forested areas. The forested region consists primarily of nearly 3 1/2 million acres of ponderosa pine (Pinus ponderosa Laws.). Thus, knowledge of interactions between snowpack dynamics and ponderosa pine forest is prerequisite to the proper implementation of water yield improvement programs involving the snow resource. The snowfall interception phenomenon should be more fully evaluated, since it may represent a potential water loss in terms of snowmelt runoff from forested areas (Harshbarger et al., 1966).

The disposition of snow on a forest canopy during and after snowfall involves five general processes that are affected by complex relationships between the tree canopy, intercepted snow and climatic parameters. These processes include wind erosion of canopy snow, snowslide from the canopy, stemflow, vapor transport from meltwater, and vapor transport of canopy snow (Miller, 1966). The first three processes do not necessarily represent a net water loss to the snowpack, only delayed delivery. The snow removal processes can be operative separately or in combination depending on wind, air temperature, available radiation and vapor pressure of the air and canopy snow (Miller, 1966).

DESCRIPTION OF STUDY

The purpose of this study is to make a preliminary assessment and ranking of the relative significance of the five processes that may cause snow removal from ponderosa pine forest canopies.

Data were collected from a study site located seven miles south of Alpine, Arizona on the Apache National Forest. Approximately 90 percent of the tree cover is uneven-aged ponderosa pine, with Gambel oak (Quercus gambelii Nutt) and quaking aspen (Populus tremuloides Michx) minor components. The estimated site index (Meyer, 1961) is 65 feet at 100 years.

The area is gently rolling, has few slopes exceeding 15 percent (Ffolliott and Thorud, 1972), and is 8100 feet above sea level. Annual precipitation averages 27 inches, almost half of which occurs between October 1 and May 3 (Rich, 1970).

The presence of snow in the canopy of a stand of trees ranging from 25 to 60 feet in height was documented with a super 8-mm time-lapse camera. The self-contained camera is activated during daylight hours by a photoelectric cell linked to a battery power source (Patton, Scott, and Boeker, 1972). The stand of trees was photographed at five-minute intervals.

Wind speed and direction were recorded at 30 feet above the ground with a continuous recording anemometer. Relative humidity and air temperature were recorded with a hygrothermograph which, along with maximum-minimum thermometers, was located in a standard instrument shelter, four feet above ground level. Incoming short wave radiation was recorded with an Eppley 180° pyrheliometer at Alpine. An index of incoming precipitation was obtained with standard rain gages located on the study site, and with a recording rain gage located on a nearby experimental watershed.

Photographs for January 1 through 4, 1973, which represented a post snow storm period, were analyzed by means of a movie projector and dot grid. Individual frames were projected onto the grid, and a snow load index was determined for hourly intervals.

The snow load index was expressed as a ratio of forest canopy area covered with snow to the total canopy area. Specifically, the number of dots for total canopy area (N), which included any above-ground tree parts hit by a dot, were counted for a clear day with no canopy snow. Then, during periods with canopy snow, total above-ground tree parts with no snow cover (n_1) were again determined; thus, $N-n_1$, or n_2, represents an estimate of the snow present on the trees comprising the stand. The snow load index, n_2/N, was then calculated and used to characterize the accumulation and disappearance of forest canopy snow.

Peak wind velocity (mph), air temperature (°C), atmospheric vapor pressure (mb), incoming short-wave radiation (ly), and cumulative precipitation (in.) were empirically correlated with snow load index values to help identify, assess, and rank in terms of magnitude, the five mechanisms by which snow is removed from the forest canopy.

RESULTS AND DISCUSSION

A six-hour snow storm occurred prior to activation of the time-lapse camera on January 1. The storm deposited approximately 0.5 inches of snowpack water equivalent on the ground; however, the total water equivalent of snow intercepted by the forest canopy is unknown. The snow load index as defined above, was determined for hourly intervals of camera operation from January 1 through January 4.

The changes in snow load index and the climatic data obtained for the evaluation period are graphically presented in Figure 1.

The snow load index changed from 83 to 64 between 0830 and 0930 on January 1 (Figure 1), suggesting immediate changes in snow storage after cessation of the storm. During this period, temperatures were below 0°C, peak wind velocity did not exceed 12 mph, and incoming short wave radiation was less than 3 lys per hour. The primary processes affecting snow removal appeared to be wind erosion, with the possibility of some snowslide. Considering the low air temperatures and short wave radiation load during this time interval, melt may not have been quantitatively significant; likewise, the relatively low energy load in combination with a short time interval suggests that vaporization may not have been a major removal process.

The snow load index change was minimal from 0930 on January 1 through 1500 on January 2. Although some change in snow storage may have occurred, intermittent snowfall during this period (Figure 1) could have offset loss of snow from the forest canopy.

Snowslide and wind erosion appeared to be a major cause of removal of canopy snow from 1500 on January 2 to 0800 on January 3, when the snow load index changed from 73 to 56 (Figure 1).

The greatest daily change in the snow load index occurred on January 3, when the index changed from 55 to 6 (Figure 1). Large masses of snow disappeared from the trees at a constant rate between 0900 and 1400 on this date. According to Miller (1966), a constant rate of snow removal is often associated with snowslide; consequently, this process may have been dominant at this time. Peak winds on this date were 25 mph, indicating that some wind erosion may also have occurred. However, the snow had been in the trees for two days and had possibly hardened as a result of metamorphism, which may tend to make it progressively less susceptible to wind erosion.

By 1300 on January 3, all canopy snow had disappeared from the upper 35 feet of the stand depicted by photography. Some snow remained on the smaller trees in the lower canopy until the following day. This small amount of residual snow persisted for more than one-half of the day on January 4 (Figure 1); melt and, possibly, vaporization may have been occurring at this time, as air temperatures were above 0°C and short wave radiation values were high.

Overall analyses of the behavior of the snow load index during the period January 1 through 4, 1973, suggests that snow removal by snowslide and wind erosion were of major importance. Conversely, stemflow, dripping melt water, and vapor transport of melt water and canopy snow appeared to be of comparatively minor importance. This preliminary assessment and ranking of the relative significance of the processes affecting the deposition of snow on a forest canopy agrees, generally, with findings observed in Colorado subalpine forests (Hoover and Leaf, 1966) and in northern Idaho (Satterlund and Haupt, 1970). However, additional analysis will be necessary before the tentative assessment and ranking of the processes that may cause snow removal from ponderosa pine canopies can be fully documented.

The potential loss of intercepted snow by vaporization in the water budget during this study period may have been minimal, as most of the canopy snow appeared to eventually reach the forest floor. Again, similar results have been reported elsewhere (Hoover and Leaf, 1966; Satterlund and Haupt, 1970).

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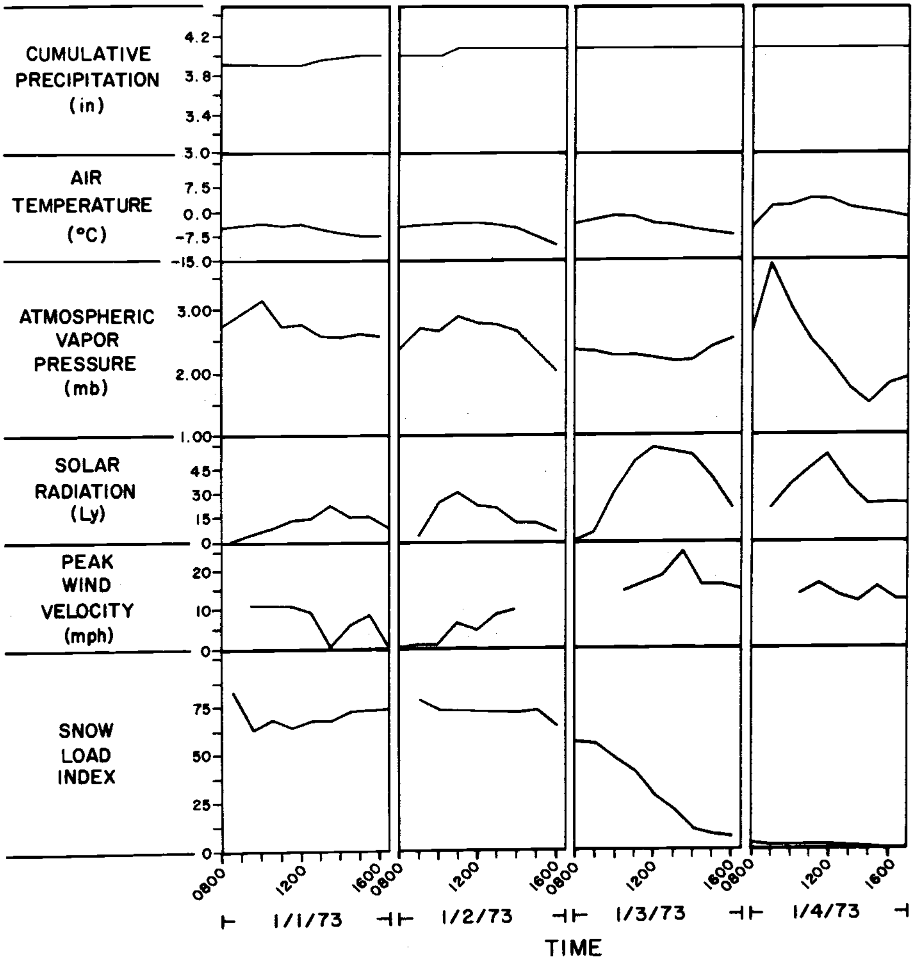

Fig. 1. Snow load index and climatic data for daylight hours of January 1 through 4, 1973.

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