A MODEL OF SNOWPACK DYNAMICS IN FOREST OPENINGS

Peter F. Ffolliott, D. Phillip Guertin, and William O. Rasmussen
School of Renewable Natural Resources, University of Arizona
Tucson, Arizona 85721

Introduction

To assist watershed management specialists and land use planners in estimating the impacts of alternative forest management practices on snowpack accumulation and melt patterns, a computer simulation model, called SNOW, has been developed to analyze snowpack dynamics in forested conditions. In structuring SNOW, three simulation options have been defined. The first option is the simulation of snowpack water equivalent (WE) before a change in forest management. The second and third simulation options are estimates of snowpack WE following either (a) reduction in forest densities through a thinning practice or (b) creation of forest openings by a clearing practice. By comparing snowpack WE prior to a forest management change with that predicted following the implementation of the change, the impact of the forest management practice on snowpack WE can be estimated.

The general formulation and application of the simulation option that estimates the impacts of creating forest openings on snowpack WE are described in this paper. Importantly, a prerequisite to the applications of this option of SNOW is that the winter snowpack accumulation period has begun, that is, a snowpack already has accumulated on the ground.

Formulation of Model

Forest openings have been shown to affect snowfall distribution patterns (Hoover and Leaf, 1967; Ffolliott and Thorud, 1974; Gary 1974). However, it is not always known whether a resultant change in snowpack WE has taken place. To help in this determination, SNOW includes a simulation option to assess the spatial and temporal effects of forest openings on a snowpack.

In essence, the effect of forest openings on snowpack WE at a point in time is dependent upon input variables that change in time and space. Variables that change in time include temperature, precipitation, and snowpack albedo; variables that change in space are forest structure, slope-aspect relationships, and dimensions of the forest openings. After a screening of possible input variables, a set of input variables was identified to simulate the effect of a forest opening on snowpack WE. Importantly, all of the selected input variables in SNOW are readily available.

Net Effect of Forest Openings

Earlier studies have reported that the effect of forest openings is insignificant at a distance of 2 to 3H (H = average height of surrounding trees) into the adjacent forest (Anderson, 1963; Hansen and Ffolliott, 1968; Ffolliott, 1983). Measurements of snowpack WE taken beyond 3H generally represent undisturbed forested conditions, that is, conditions before the creation of the forest openings. Therefore, in structuring SNOW, the net effect of forest openings has been defined and calculated as the difference between the mean snowpack WE across the openings and extending 3H, and the mean snowpack WE beyond 3H. Positive differences represent a net increase, while negative differences are a net decrease.

Time-Dependent Variables

Of the variables analyzed that change with time, only the amount of precipitation that accumulated over the interval of time between the initialization of the model and the simulation period was related to the measurement of the net effect of forest openings. Therefore, the use of this variable requires a user to initialize conditions, with precipitation accumulated from that point to the time of simulation.

Space-Dependent Variables

In terms of variables that change in space, forest density, average height of surrounding trees, potential direct-beam solar radiation, and the dimensions of the forest openings are required in the operation of SNOW.

An input of forest density is necessary to index the processes of interception of precipitation, obstruction of short-wave radiation, and re-radiation of long-wave radiation from trees onto a snowpack. Square feet of basal area per acre was selected as the expression of forest density because it is easily determined in the field, readily converted to other expressions of forest density, and numerous multi-resource forest relations have been developed with basal area as the indpendent variable.

To meet specific hydrologic objectives in terms of snowpack profiles in and adjacent to forest openings, the prescribed width of the openings commonly is defined in terms of H (Ffolliott, 1983). However, to convert this measurement to equivalent feet, knowledge of the average tree height is required. Therefore, if a forest opening is 2H in width and the surrounding trees are 65 feet in height, the opening is 130 feet wide.

Values of average potential direct-beam solar radiation (in langleys) received daily throughout a snowpack accumulation and melt season are used to index the slope-aspect combinations at a site. Once calculated, this variable does not change with time. Considering a solar day as the basic time unit at a site, potential direct-beam solar radiation can be obtained from tables with slope and aspect measurements (Frank and Lee, 1966).

The dimensions of the forest openings, both widths and lengths, are necessary to provide a spatial measure of the effects of the openings on snowpack dynamics.

Flowchart

The flow of activities that are followed in operating SNOW to simulate the effects of forest openings on snowpack WE is outlined in figure 1. Through inputs of precipitation, forest density, height of surrounding trees, potential direct beam solar radiation, and the dimensions of the forest openings, the net effect of creating the forest openings is estimated in terms of snowpack WE gained or lost.

Application of Model

To employ SNOW to predict the effects of forest openings on snowpack WE, a user responds to interactive statements and questions that structure the simulation exercise and provide the required inputs. These statements and questions are offered to the user after the forest type has been specified, a positive response has been made to a question asking whether a forest management change is being proposed, and an appropriate response has been made to the simulation option.

For purposes of illustration, the effects of forest openings 1-1/2H wide and 300 feet long, oriented with their long axis up-and-down slope, will be simulated in terms of increasing or decreasing the snowpack WE at peak seasonal accumulation, prior to the start of runoff. Such an estimate often is one of the better estimators of potential water yields from a melting snowpack in Arizona (Ffolliott and Thorud, 1972).

A ratio of openings to forested areas of 1:3 is prescribed for the hypothetical 2,500-acre watershed. The amount of precipitation accumulated in the interval between the initialization of the model, a time in the winter snowpack accumulation period, and peak seasonal accumulation is 2.4 inches. Forest density, representing the conditions prior to the forest management change, is 100 square feet of basal area. The average height of the surrounding trees is 65 feet. Average potential direct beam solar radiation received daily in the snowpack accumulation and melt season, based on an average slope of 10 percent, southeast aspect, and latitude of 34 degrees north, is 748 langleys.

In comparison to the snowpack WE simulated to represent undisturbed forested conditions, estimated to be 8.6 inches, the simulated net effect of creating the forest openings is to reduce the snowpack WE on the watershed at peak seasonal accumulation, prior to the start of runoff, by 0.08 inch. In other words, the average snowpack WE on the 2,500-acre watershed after implementation of the clearing practice to create the forest openings is estimated to be 8.52 inches. It appears that creating forest openings on the relatively "warm aspect" that characterized the hypothetical watershed will accelerate snow melt during the early winter snowpack accumulation period, with less snowpack WE in and adjacent to the openings at peak seasonal

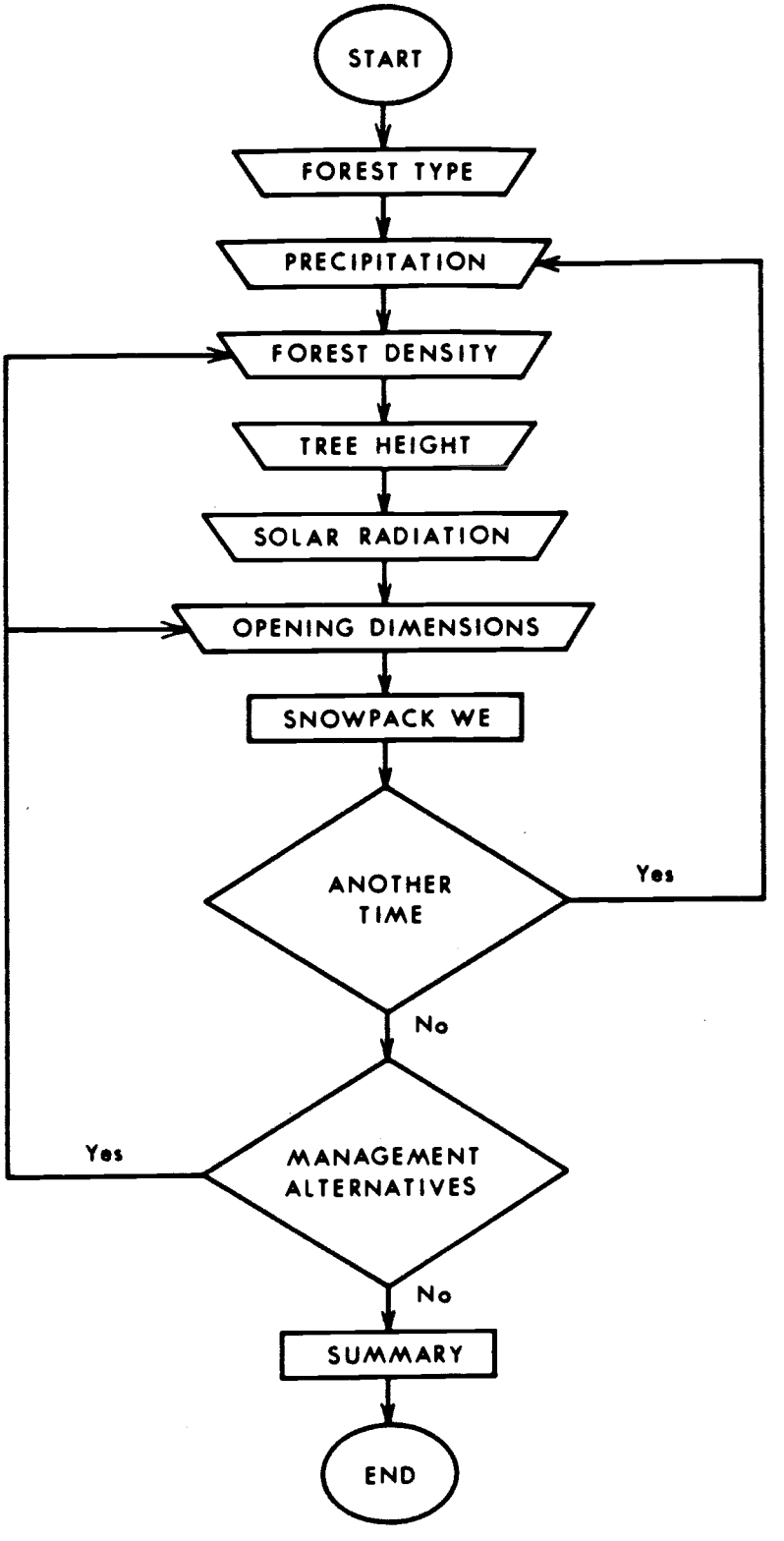

Figure 1. - Flow of activities in SNOW to estimate the effects of forest openings on snowpack WE.

accumulation, prior to runoff.

Factors not considered in SNOW must be evaluated by watershed management specialists and land use planners before the implementation of any forest management practice. However, based on the illustrative example presented herein, and assuming that an increase in snowpack WE at peak seasonal accumulation is a planning objective, implementation of an alternative forest management practice appears to be feasible.

Future Developments

To a large extent, SNOW is considered to be a "prototypical" computer simulation model. Developed from source data sets representative of selected southwestern ponderosa pine forests, further testing of the model will be undertaken to determine its applicability to a wide range of conditions encountered in these forests.

Once testing in the ponderosa pine forests has been completed, it is anticipated that the structure of SNOW will be extrapolated to the higher elevation mixed conifer forests, in which the potentials for snowpack management are likely to be greater.

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