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A Field Guide for Predicting Snow Damage to Ponderosa Pine Plantations

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ABSTRACT

Describes a procedure for predicting potential damage to ponderosa pine plantings due to weight and movement of snowpack. Provides an example of the procedure for field use and discusses management implications of planting ponderosa pine in areas with high potential for snow damage. Current area of application covers the Weiser and Payette River drainages in central Idaho.

KEYWORDS: reforestation, silviculture, forest management, tree damage, snow pressure

INTRODUCTION

For more than five decades, ponderosa pine (*Pinus ponderosa* Laws.) has been the preferred species for reforesting burned and cut-over areas in many of the warmer and drier portions of the Northern Rockies. Because of its high timber value, ease of establishment, dependable growth rates, and lower susceptibility to insects and disease, this tree is usually preferred to other species. Although researchers have reported on susceptibility to snow damage of various conifers in the Western United States (Kangur 1973; Leaphart and others 1972; Schmidt and Schmidt 1979; Watt 1951, 1960; Williams 1966), we could find no reports of damage by snowpack to ponderosa pine in the Northern Rockies. Snow damage to ponderosa pine has been reported in California (Powers and Oliver 1970) and Arizona (Ffolliott and Thompson 1976; Schubert 1971).

Most damage studies have been concerned with wet snowfalls that overload tree crowns and cause bending and deformation. Our study deals with damage caused mainly by lateral snow movement and pressure against the stem, although some damage from crown overloading may have also occurred. Recent reconnaissance of ponderosa pine plantations in west-central Idaho revealed widespread snowpack damage to pine saplings under certain site conditions. Some damage to Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) was also noted but was less widespread. Type and degree of damage varied from bent (probably temporarily) terminal stems to permanent 90 degree bends in the main stem and to entire saplings pushed into permanent, critical departures from vertical (fig. 1). Other causes of deformed trees included rodents, soil creep, and rolling rocks or debris, but these were of minor importance compared to the effects of snow.

Once deformed, the pine's height growth is reduced (Rehfeldt 1987; Williams 1966), compression wood forms on the downhill side of the stem (Panshin and others 1964), and the tree becomes increasingly vulnerable to shrub competition. In some cases, severely deformed trees are killed by the brown-felt snow mold (*Neopeckia coulteri* [PK.] Sacc.) during years with prolonged snow cover. Thus snow damage may reduce timber yield, wood quality, and plantation survival.

A recent study involved the evaluation of 45 ponderosa pine plantations in the Douglas-fir/ninebark and the grand fir/mountain maple habitat types. Prior to logging, all of these sites appear to have supported naturally established ponderosa pine in varying amounts. These two habitat types represent some of the more productive timber sites in southwestern Idaho, and a common practice was to clearcut and plant ponderosa pine. The high potential for shrub competition usually required that contour stripping or pile-and-burn site preparation be used on these sites. Slopes too steep for these treatments were often broadcast burned.

Many of the pine plantations studied exhibited snow damage. Plantations were considered as damaged if more than 10 percent of the trees were obviously deformed by snow. Snow damage occurred to 65 percent (22) of the 34 grand fir/mountain maple sites sampled, but to only 9 percent (1) of the 11 Douglas-fir/ninebark sites. Actual percentage of damaged trees ranged from close to 10 percent to virtually 100 percent.

Analyses of snow-damaged versus undamaged pine plantations revealed that certain site features were related to snow damage. These findings led to development of a procedure for predicting snow damage potential from site features easily obtained by forest managers (Megahan and Steele 1987). The purpose of this paper is to adapt the snow damage assessment procedure for field use.

The present area of application includes the Weiser and the Payette River drainages in west-central Idaho (fig. 2).

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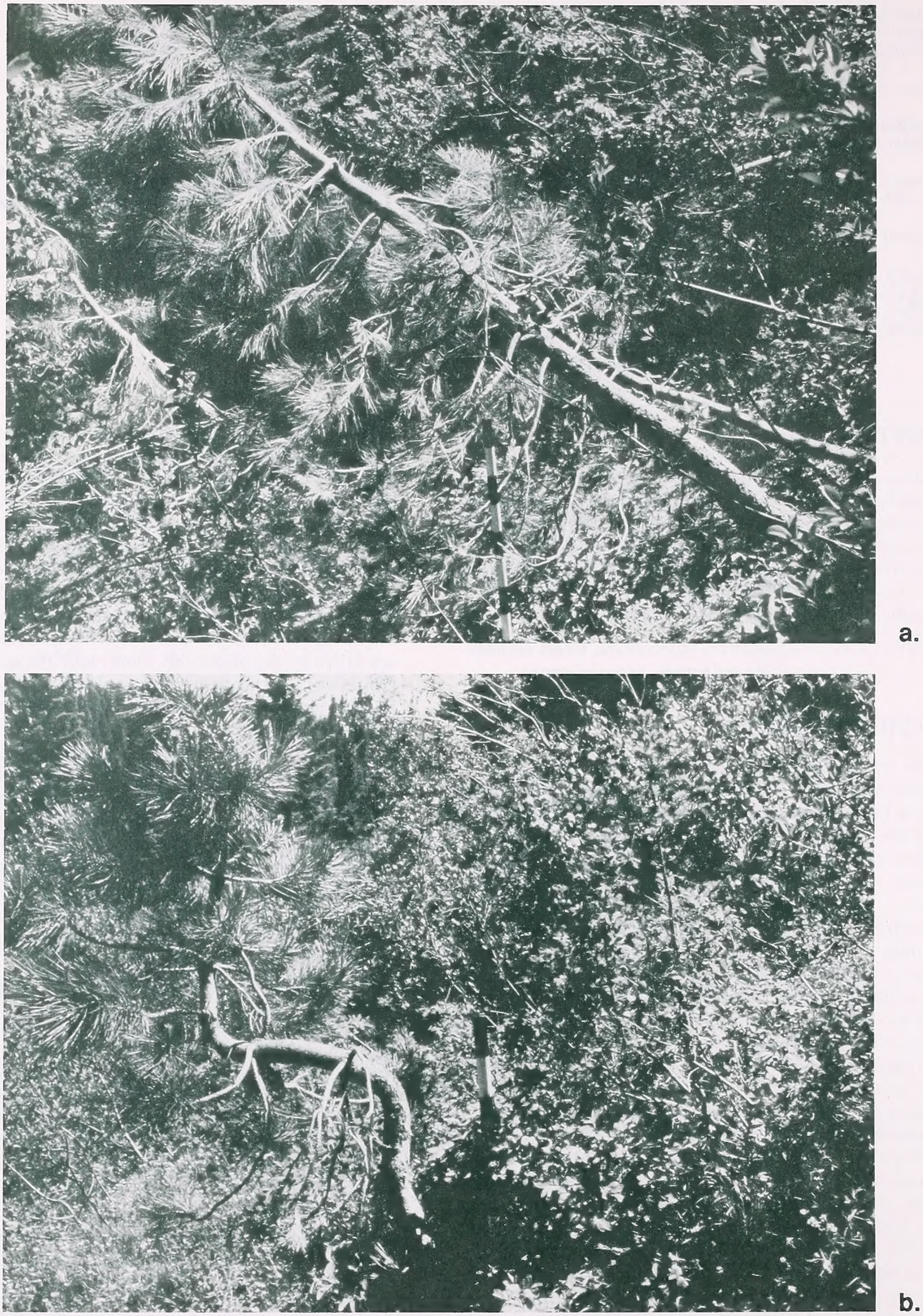

Figure 1a, b—Snow-damaged ponderosa pine.

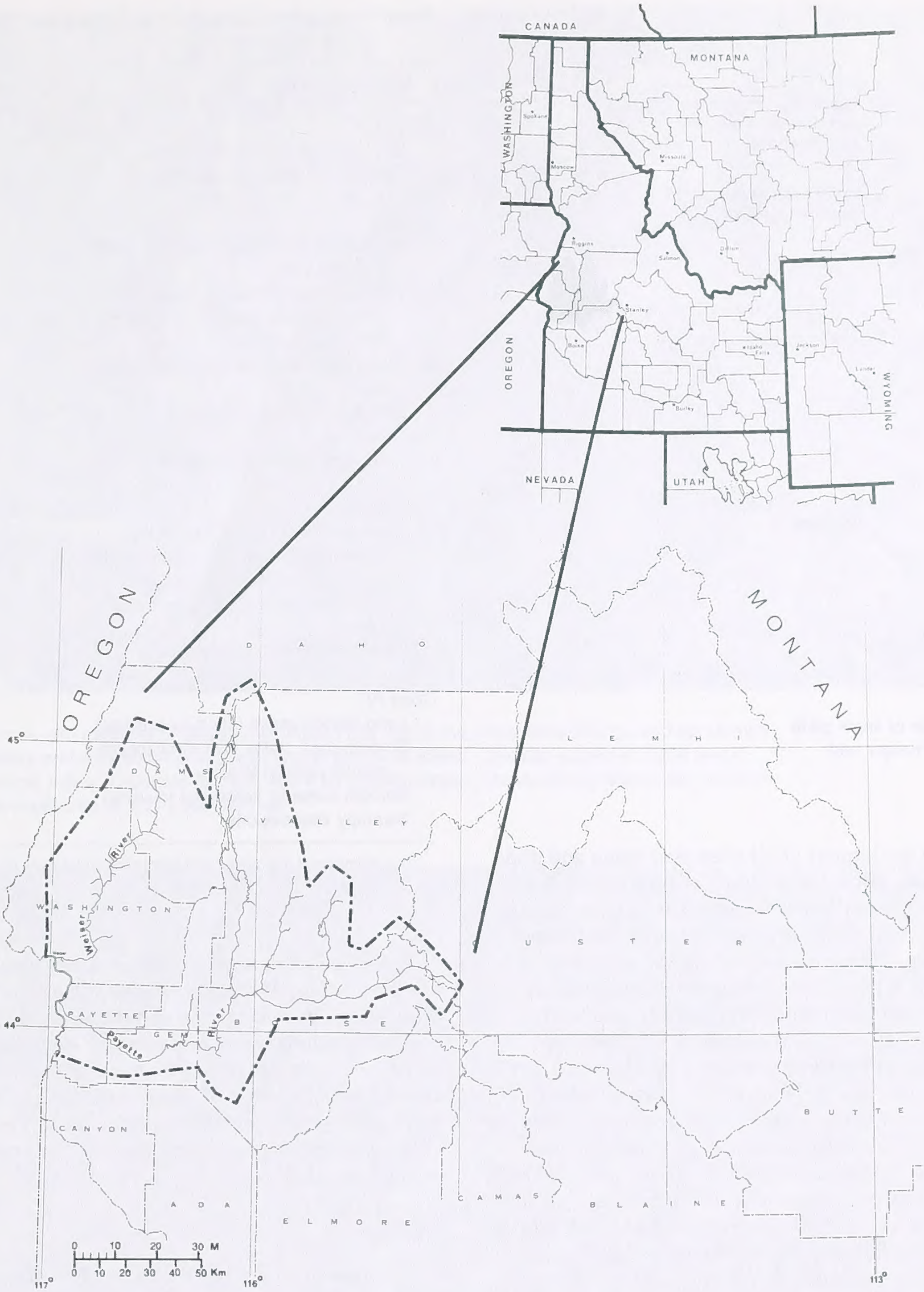

Figure 2—Area covered by the field guide to predicting snow damage.

Annual precipitation, mostly snowfall, ranges from 25 inches at the lowest elevation to 60 inches at the highest elevation. Topography is typical of that found in the Northern Rocky Mountains, with steep, dissected slopes ranging in gradient from 10 to 100 percent. Geology includes the intrusive, acid, igneous rocks of the Idaho batholith as well as the extrusive, more basic rocks of the Snake River basalts. Granitic soils are coarse textured, shallow, and poorly developed, and tend to be slightly acidic. In contrast, basaltic soils are finer textured, deeper, better developed, and more basic than the granitic soils.

PROCEDURE FOR PREDICTING SNOW DAMAGE

Snow that accumulates on the ground undergoes a change in its crystalline structure that causes a plastic deformation of the snowpack and exerts pressure on young trees. Three types of snowpack movement can occur,

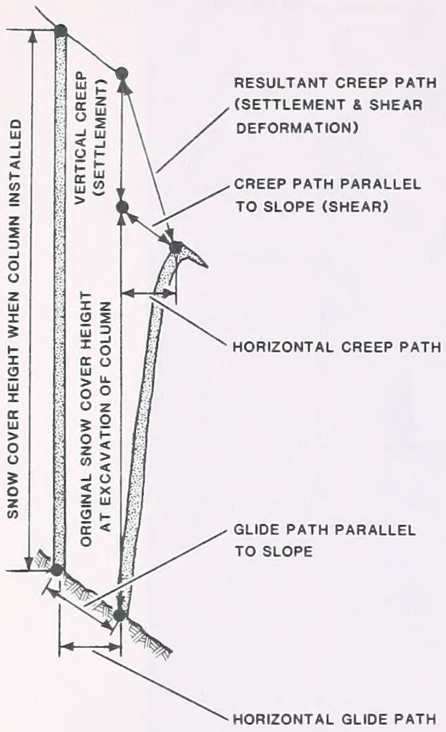

Figure 3—Example of snow glide and creep (after Frutiger and Kuster 1967).

namely vertical settlement at all sites plus creep and glide on steeper slopes. Snow creep refers to differential motion throughout the pack with more movement in upper layers than in lower layers. Glide involves the slow downslope movement of the entire snowpack along the soil-snow interface (fig. 3). Glide tends to be greater on south aspects, is directly proportional to snow depth, and is inversely proportional to slope roughness. Frutiger and Kuster (1967) documented glide movement of up to 3 feet or more on study slopes in Switzerland. Creep varies directly with snow depth, snow density, and slope gradient. Martinelli (1960) measured snow creep averaging more than 7 inches per 70 inches of snow depth on snow fields in Colorado. Frutiger and Martinelli (1966) adapted the snow pressure concept, originally presented by Haefeli (1951), to quantify the static forces caused by creep and glide in a snowpack. We used a multiple, discriminant analysis to adapt the snow pressure approach to predict snow damage hazards on ponderosa pine plantations (Megahan and Steele 1987).

In order to calculate snow pressure for each plantation, the following site data are needed:

1. Elevation in feet
2. Slope gradient in percent
3. Slope azimuth in degrees
4. Roughness (a rating based on site characteristics).

Measurement precision for the various factors should be: elevation – 100 feet; slope gradient – 5 percent; slope azimuth – 10 degrees; roughness – 0.1.

Table 1—Roughness as defined by surface features (derived from Frutiger 1962)

Surface feature	Roughness
Class I	
Big boulders (d[1] >30 cm, 12 in)	
Terrain with more or less big outcroppings of rock	1.2
Class II	
Surface covered with shrubs at least 1 m (39.4 in) tall	
Well-expressed mounds covered by grass and low shrubs; mounds must be at least 50 cm (20 in) high	
Well-pronounced livestock or game trails	
Boulders (d[1] about 10-30 cm, 4-12 in)	1.6
Class III	
Short grass (such as pinegrass) with shrubs less than 1 m (39.4 in) in height	
Small boulders (d[1] <10 cm, 4 in) intermingled with grass and shrubs	
Only a few mounds up to 50 cm (20 in) tall covered by grass and shrubs	
Grass with indistinct livestock or game trails	2.0
Class IV	
Long-bladed grass (such as bromes)	
Smooth rock plates with stratification planes parallel to slope	
Smooth scree or scree-soil mixtures	
Swampy depressions	2.6

[1] d is diameter of the blocks that determine roughness of the surface.

The calculation assumes uniform site conditions within the plantation. If there are large variations in any of the site factors, the plantation should be divided into subunits and calculations made accordingly. Roughness is determined with the use of table 1 and the photographs illustrating various levels of roughness (figs. 4-7). Interpolations can be made between roughness levels if necessary.

Snow pressure (P) is calculated as the product of three variables as follows:

$$P = D * C * G$$

where

P = snow pressure in pounds per foot of tree diameter
D = depth factor in pounds per foot of tree diameter
C = creep factor
G = glide factor.

The depth factor (D) is obtained from figure 8. Enter figure 8 at the appropriate elevation in feet and project a vertical line to the curve. At the intersection of the curve, project a horizontal line to the left to read the depth factor (see example on fig. 8). The creep factor (C) is obtained from figure 9 in a similar manner as for the depth factor on figure 8 except that the figure consists of a family of curves representing various slope gradients. In this case, the appropriate slope gradient for the site is used as the point of intersection. Interpolate between the curves if

Figure 4—An example of class I roughness (1.2) due to the many downed logs and tall stumps; boulders and rock outcroppings can create the same effect. This site occurs at 7,700 feet in elevation with a 20-degree azimuth and a 55 percent slope. These site conditions can produce snow pressures of 1,210 pounds/foot.

Figure 5—An example of class II roughness (1.6) due to the nearly complete cover of tall shrubs. This site occurs at 5,930 feet in elevation with a 240-degree azimuth and a 38 percent slope. These site conditions can produce snow pressures of about 365 pounds/foot and result in damaged pine plantations as shown.

Figure 6—An example of class III roughness (2.0) due to the scattered low shrubs and cover of short grass, sedges, and forbs. This site occurs at 5,500 feet in elevation with a 40-degree azimuth and 34 percent slope. These conditions can produce snow pressures of about 205 pounds/foot, resulting in some snow damage to pine saplings.

Figure 7—An example of class IV roughness (2.6) due to the smooth surface and extensive cover of tall grass. This site occurs at 5,050 feet in elevation with a 260-degree azimuth and a 36 percent slope. In spite of the smooth surface, the combination of these conditions can only produce snow pressures of about 160 pounds/foot, resulting in pine saplings with virtually no snow damage.

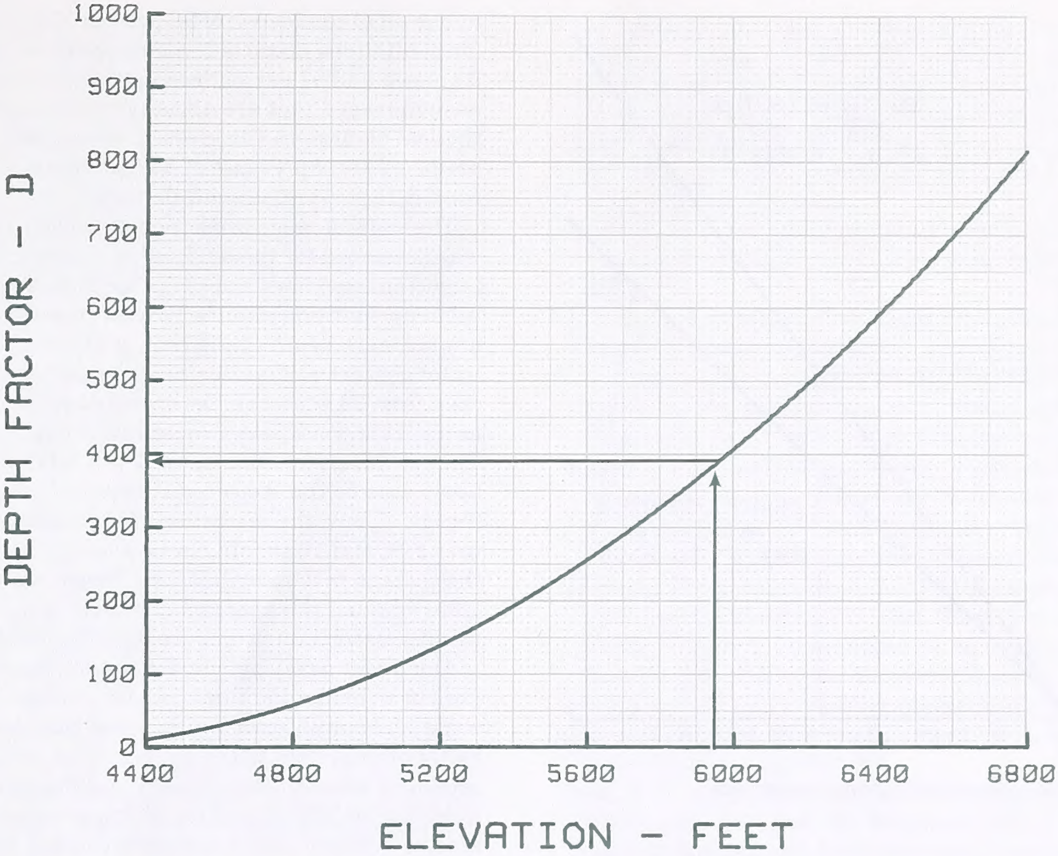

Figure 8—Depth factor as a function of elevation.

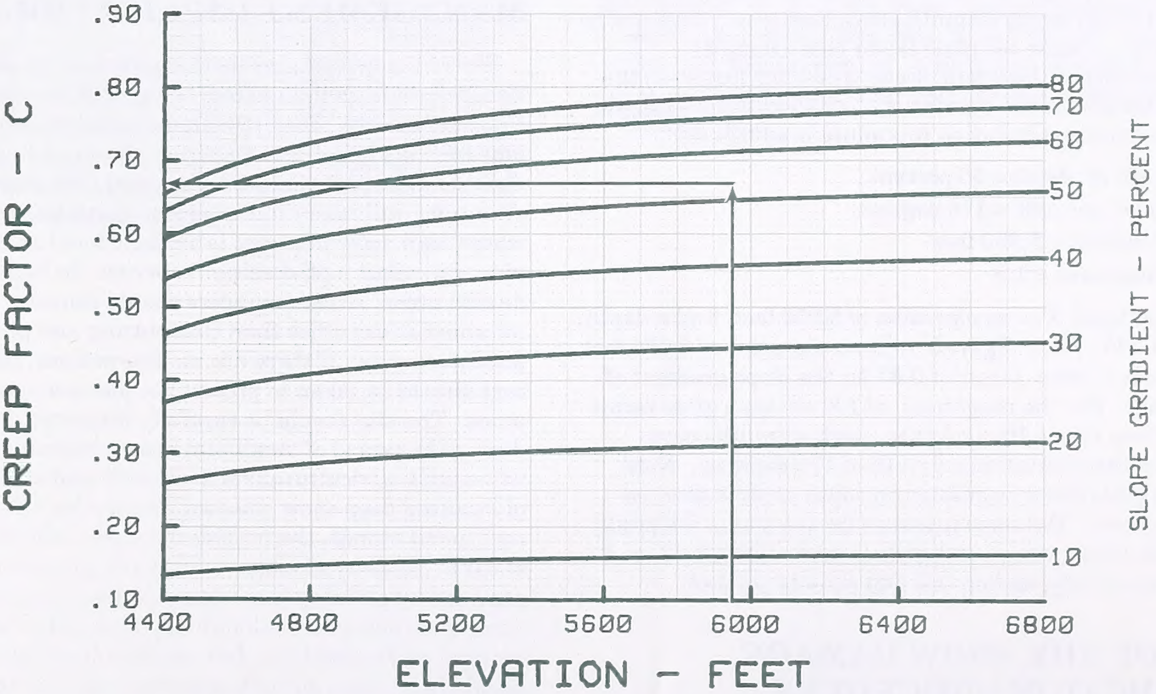

Figure 9—Creep factor as a function of elevation and slope gradient.

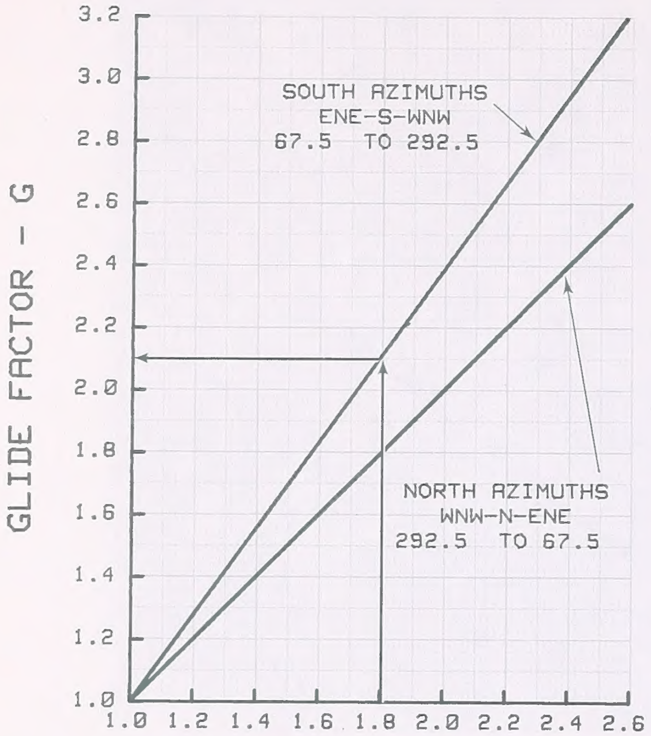

Figure 10—Glide factor as a function of roughness and azimuth.

necessary for intermediate slope gradients (see example). The final component, glide factor (*G*), is obtained from figure 10 from the slope roughness and the azimuth for the site. Enter the figure with slope roughness, project a vertical line to the correct azimuth class, then read horizontally to the left to obtain the glide factor (see example).

The product of the depth, creep, and glide factors is the snow pressure for the plantation. A hypothetical example to illustrate the calculation procedure is as follows:

Slope gradient = 53 percent
Slope azimuth = 170 degrees
Elevation = 5,950 feet
Roughness = 1.8

Entering figure 8 at an elevation of 5,950 feet, find a depth factor of 390. Enter figure 9 with an elevation of 5,950 feet and obtain a creep factor of 0.67 for the slope gradient of 53 percent. For the roughness of 1.8, obtain a glide factor of 2.10 from figure 10, using the south azimuth curve (based on the plantation azimuth of 170 degrees). Note that the glide factor is greater on south aspects than on north aspects. The snow pressure for the site is the product of the depth, creep, and glide factors of 390, 0.67, and 2.10, respectively, and equals 549 pounds per foot.

USE OF THE SNOW DAMAGE PREDICTION PROCEDURE

Megahan and Steele (1987) show that plantations are subject to damage if snow pressures are equal to or greater than 188 pounds per foot of tree diameter. The overall prediction success for this procedure averages 80 percent at a level of confidence of 95 percent (74 percent correct for plantations predicted as damaged that are actually damaged and 91 percent correct for plantations predicted as undamaged that are actually undamaged). The hypothetical plantation site given in the example above had a predicted snow pressure of 549 pounds per foot and is a candidate for serious snow damage!

The snow damage prediction procedure presented here was developed for the study area shown in figure 2. An important component of the procedure is a relationship between elevation and the 20-year average (1961-80) annual snow depth at the time of annual maximum snow water content at the site. Such a relationship was developed from 24 snow courses operated within the study area as a part of the USDA Cooperative Snow Survey network. The resulting elevation-snow depth relationship may not apply outside the Weiser and Payette River drainages (fig. 1). Thus, the prediction results obtained from figures 8, 9, and 10 should not be used for areas outside these areas without validation. Megahan and Steele (1987) discuss the approach for development of the snow damage prediction procedure for other locations.

At current development, the prediction procedure allows us to define the threshold for damage. Common sense and our observations suggest that damage is directly proportional to the amount that predicted snow pressures exceed the threshold. Additional research is needed to define the nature of this relationship as well as recovery capabilities of damaged trees in relation to seed sources. In the meantime, the snow pressure prediction procedure provides a means to "red flag" probable damage potential.

MANAGEMENT IMPLICATIONS

Where ponderosa pine has been chosen for reforestation, selecting seedlings from the proper genetic seed source is critical. Seedlings from improper seed sources may be less likely to recover from snow bending. But it should not be assumed that pine seed from appropriate elevations will result in successful plantations on sites where high snow pressure is predicted and ponderosa pine was never a predominant species. In high-snow-hazard areas, forest managers should consider silvicultural alternatives other than clearcutting and planting ponderosa pine. If there are no alternatives, then special care should be taken to protect the planted ponderosa pines. The site should be carefully inspected, including during the period of maximum snow accumulation. This will enable silviculturalists to identify and avoid planting of localized deep snow sites such as the lee side of adjacent uncut stands, the lee side of ridges, and the toe slope of cut banks or road beds. Additional protection can be provided by planting trees downhill from local obstructions that reduce downslope creep and glide, such as stumps, rocks, and logs. Intense broadcast burning should be avoided on these sites because this treatment removes logging debris and stimulates shrub development. The shrubs can then outcompete the planted pines more easily because snow damage has reduced growth rates of the young trees and the trees, in turn, spend more years within the snow damage window. Obviously, the best time to make these assessments is during preparation of the initial site prescription so that necessary mitigating measures can be included.

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