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Windthrow Around Staggered Settings in Old-growth Douglas-fir

BY
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IN THE PAST DECADE, the patchwise pattern of clear cutting known as the staggered-setting system has gained wide acceptance in the Douglas-fir forest of the Pacific Northwest. Several advantages and a few disadvantages are claimed for this cutting method in comparison with continuous clear cutting (Aufderheide, 1949). One major disadvantage of the staggered-setting system has proved to be windthrow of trees along the margins of the clear-cut units. In some areas, the damage has seriously depleted many of the settings reserved for later cutting, forcing changes in cutting plans and creating administrative problems.

This study has attempted to determine the relative importance of some of the factors which influence windthrow around clear-cut settings in the Cascade Range.

Wind Behavior in Mountains And Forests

There is a substantial literature on the behavior of wind in mountains and forests. Certain observations can be drawn from this literature which help to explain wind damage on the study area. These observations should also help forest managers in locating windfirm cutting boundaries.

1. Wind damage is often heavy on ridgetops and upper slopes. There are several reasons for the heavier damage. High ridges protrude above the general level of the terrain and are exposed to the higher wind speeds of the free air. In addition, a ridge which protrudes upward into the wind stream forms an obstruction causing vertical convergence of streamlines. As free air passes over an obstruction such as a ridge, it moves at greater speed (French, 1951). Wind damage consequently occurs in the vicinity of the crest (Smith, 1946).

Heavy wind damage in forests on ridgetops and upper slopes has been reported from many places, including the Oregon Coast Range (Ruth and Yoder, 1953); from Colorado (Alexander, 1954); from eastern Oregon by Smith and Weitknecht;[1] and from New England (Brooks, 1939).

2. If a ridge or mountain is shaped so that wind can pass around as well as over it, wind speeds will be accelerated on the shoulders of the mountain. With a west wind, for example, accelerated wind speeds

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[1]Smith, Kan., and R. H. Weitknecht. 1915. Windfall damage on cut-over areas Whitman National Forest. U. S. For. Serv., Pacif. Nthwest, For. Range Exp. Sta. Unpub. ms.

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10. Windthrow is likely to be heaviest in the first few years after cutting. The most vulnerable trees are windthrown during the first heavy storms after cutting. The remaining stand grows more windfirm with passing time (Alexander, 1954; Weidman, 1920).

11. Investigators in the Pacific Northwest have found no consistent relationship between size of clearing and amount of wind damage. Worthington (1953) observed only negligible windfall around small group clear cuts in virgin old-growth Douglas-fir, although it appeared to be severe around a large clear-cut area of 130 acres. On the other hand, Ruth and Yoder (1953) found that blowdown occurred on the lee side of openings as small as one-half acre in the Sitka spruce-western hemlock-Douglas-fir type. On eight units ranging in size from 11 to 81 acres, they found no correlation between size of clear cut and amount of blowdown.

Study Area

The H. J. Andrews Experimental Forest is located on the west slope of the Cascade Range, 50 miles east of Eugene, Oregon. It occupies the 15,000 acre drainage of Lookout Creek, a tributary of Blue River which, in turn, flows into the McKenzie River. The rough, mountainous topography and the 400-year-old stand of old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are representative of old-growth forests on the west slopes of the Cascade Range. Western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn), and Pacific silver fir (*Abies amabilis* (Dougl.) Forbes) are present in the stand as understory species. Western white pine (*Pinus monticola* Dougl.), noble fir (*Abies procera* Rehd.), and incense-cedar (Libocedrus decurrens Torr.) are present in small amounts. The drainage is triangular in shape and narrows to a point at its lower end, which opens to the west-southwest. A long, high ridge rises abruptly across the wide upper end of the drainage.

Windthrow was studied around the perimeters of eight units cut in a staggered-setting pattern on a north-northwest slope (Fig. 1). The units range in size from 24 to 66 acres and lie between elevations of 1,600 and 4,000 feet. Three of the units were cut in 1950, and the remaining five in 1951.

In general, the soils are deep clay loams, but localized areas of shallow soil underlain by rock are scattered throughout the drainage.

The climate and weather conditions are typical of the Oregon Cascade Range. The winters are mild and wet, the summers warm and dry. Annual precipitation averages 65 to 100 inches, mostly rain, at the elevations occupied by Douglas-fir. About 75 percent of the precipitation falls during November through April, saturating the soil during the period when violent storm winds are most common. The wet soils furnish poor anchorage for the trees.

Methods

A total of 885 windfalls containing an estimated 1.8 million board feet of timber

FIGURE 1. *Windthrow study units on the H. J. Andrews Experimental Forest. The camera was pointed approximately southeast.*

were studied in detail. The position of each windthrown tree along 8.9 miles of cutting line was plotted on a map (Fig. 2), and the following data were recorded: Species, diameter at breast height, direction of fall, evidence of wood rots or logging injury, and soil conditions in the root holes. Finally, the position of each tree on the cutting boundary was classified according to topographic location and the distance from the cutting edge.

Wind Behavior in the Study Area

Approximately 90 percent of the windthrown trees were blown down by winds from the southwest quadrant (Fig. 3). Most of the damaging winds in western Oregon accompany southwest storms which sweep in from the Pacific Ocean during the winter. Sixty percent of the trees on the study area were felled by the violent storm of December 4, 1951, which blew down almost 5 billion board feet of timber in the Cascade Range in Oregon (Greeley *et al.*, 1953). Other southwest storms accounted for about 30 percent, and most of the remaining 10 percent were felled by east winds which occasionally reach damaging speeds.

Patterns of windfall (Fig. 2) showed that windflow on the study area was in accordance with many of the observations of wind behavior described in the literature. Windfall was light around units in topographically sheltered locations, notably units B, C, and E, G, and I. It was heavy around middle and upper slope units that were in dangerous locations according to the observations listed earlier.

Heavy and definite patterns of windfall around the upper clear cuts showed that strong winds occurred on the upper slopes (observation 1). Lighter and more haphazard windthrow around the units on the lower slopes suggests that stormwinds are generally less violent at the base of the mountain. However, not all the topographically sheltered locations are on the lower slopes. Very little windthrow occurred around unit G on the middle slope and around unit I on the upper slope.

Unit I. This clear cut is located on a very steep, concave slope on the lee side of the mountain. Stormwinds followed down the gentle gradient from the summit to the top end of the clear cut (observation 3) and caused a moderate amount of blowdown there. Below the road, however, the windthrow stopped. Here the wind did not closely follow the slope, apparently because it was too steep, or the change in slope was too abrupt. Hence there was very little windthrow around the largest part of this unit.

Unit B. A V-shaped indentation in the downwind cutting edge on unit B funneled wind into the reserve stand at the narrow end of the opening (observation 8). The gradual constriction of the air channel between cutting edges "A" and "B" (Figs. 4 and 5) concentrated the force of the accelerating wind against trees at the apex of the funnel. The winds blew down a lane of trees and extended the end of the funnel 300 feet into the uncut timber (point "C," Fig. 4). Indentations of this kind in exposed cutting edges are obviously dangerous.

Unit H. Of all the cutting units, unit H, located on the northwest shoulder of an abrupt rise in the main ridge over which

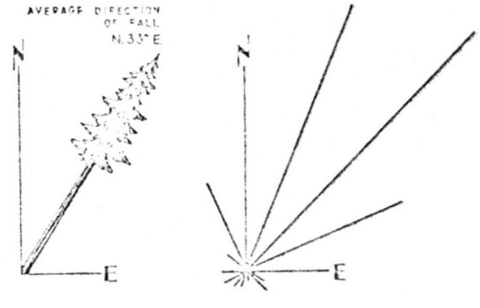

FIGURE 3. *Direction of fall for windthrown trees on the study area.*

FIGURE 6. *Storm winds blow unhindered into unit F (foreground) from the saddle on the main ridge where this picture was taken.*

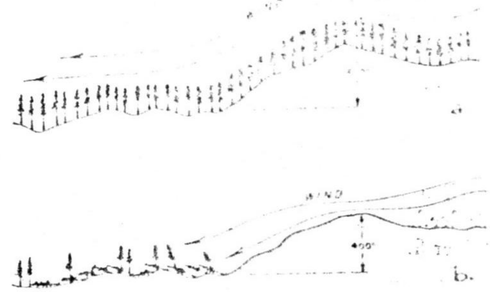

FIGURE 7. *Windflow over the ridge in unit F before cutting (a) and after cutting (b).*

the stand (Fig. 8). The deflected wind currents converged with the wind stream flowing over the crest and down the lee slope of the ridge. This further accelerated the wind speed along the north cutting edge. Where these combined winds funneled out of the unit at its northeast corner, a swath of green timber a quarter-mile long was blown down.

Penetration of windthrow into the reserve stand. Most of the windthrow around the study units occurred within 200 feet of the cutting edges. The windthrown trees were most concentrated in the first 50 feet. For each successive 50 feet away from the cutting boundary, the number diminished by about one-half (Table 1). In general, windthrow beyond the 200-foot distance was negligible and assumed a widely scattered pattern similar to that found in the virgin forest in other parts of the drainage. Average penetration of windthrow was deepest on east cutting edges where the southwest winds exerted their full force after blowing across the clear-cut area.

Blowdown beyond 200 feet from the cutting boundary occurred in only four places on the study units, all on east cutting edges. Three of the locations have already been described—funneling of wind by cutting edges in unit B, lee flow on the upper slopes in unit H, and topographic and funneling effects in unit F. The fourth location was the southeast corner of unit D, where wet soils along a creek and in a poorly drained area contributed to the heavy windthrow.

Wind escaping into or flowing out of logging road right-of-ways caused a small amount of windthrow on the edges of a few settings, but this effect seems to be relatively unimportant. The light damage was limited to about 1 chain on each side of the right-of-way on the edges of the settings. The windthrown trees were mainly of the understory species.

No attempt was made to determine amounts of windthrow along roads between the clear-cut settings. However, the windfall patterns around the study units and observation along the roads indicated that the rights-of-way were not very important in feeding the wind from clearcut to clearcut. In one place, clearing the right-of-way allowed the wind to enter a swampy area on the lee side of the road. A moderate amount of windfall occurred on this wet area.

Factors Affecting Wind Damage To the Reserve Stand

Size of clearcut. Amount of windfall showed no consistent relation to the size

TABLE 2. Windfall in relation to size of setting during the first 2-year period after cutting.[1]

Unit (1)	Size (2)	Length of cutting boundary (3)	Vol. windthrown per acre clearcut (4)	Volume per chain of cutting boundary (5)	Acre equivalent[2] (6)
	Acres	*Chains*	*Bd. ft.*	*Bd. ft.*	*Acres*
G	24	68.7	3,040	44	0.65
C	30	75.0	2,390	32	0.64
D	37	87.5	5,180	59	1.28
E	39	83.4	3,450	41	1.75
B	40	100.5	4,020	40	1.40
H	44	91.6	5,950	65	2.83
F	48	97.1	15,640	161	8.04
I	66	108.9	680	6	0.64

[1]Gross volume.
[2]Number of acres in the original stand on each unit which would be equivalent to the volume windthrown around the unit. This comparison allows for differences in stand density and size of trees.

sistance to wind than the more dense crowns of western hemlock and silver fir. Curtis (1943) found that open-crowned trees were among the most resistant to windthrow. Boyce (1929) attributed the windfirmness of western redcedar on the Olympic Peninsula to its open crown, short bole, and deep root system.

In the uncut stand, hemlock and silver fir in the understory were protected from the force of storm winds by the taller Douglas-firs. Fritzsche (1933) has pointed out that root systems developed under such conditions are not adapted to withstand drastically increased wind stresses such as those which occur on the perimeters of clear-cut settings. These trees were, therefore, very susceptible to windthrow (observation 9).

All sizes of Douglas-fir seemed equally susceptible to windthrow. The number windthrown by diameter classes was in proportion to the abundance of trees of those diameter classes in the virgin stand. The larger diameter western hemlocks also proved just as susceptible to windthrow as smaller ones.

Topographic location of cutting boundary. Windfirmness of cutting boundaries on different topographic locations was compared on the basis of number of Douglas-fir windfalls per chain of cutting boundary. Only Douglas-fir was used for this comparison because they were the largest trees and contained 77 percent of the windfall volume.

Cutting edges located parallel to the contour or along roads sustained the least windthrow (Table 4). This low rate of loss was not due to topographic location but to the fact that southwest storm winds in the study area blow parallel to cutting edges on the contour. Therefore, the trees on such boundaries were not exposed to the full force of the storm winds. As road grades on the study area are usually 7 percent or less, with maximum grades of 10 percent, cutting boundaries along roads are, in effect, vary similar to those located parallel to the contour.

Cutting boundaries at right angles to the destructive winds were more windfirm when located along ridges than when located along creeks or perpendicular to the

TABLE 4. Number of windfalls per chain of cutting boundary by species and by topographic location of cutting boundary.

Topographic location	Length of cutting boundary (chains)	Windfalls per chain							
		Douglas-fir	Western hemlock	Western redcedar	Silver fir	White pine	Noble fir	Incense cedar	All species
Along road	100.2	0.14	0.29	0.04	......	......	0.01	......	0.48
Along creek	146.1	.98	2.05	.11	0.01	0.01	......	......	3.16
Along ridge	184.5	.27	.59	.12	.06	.02	......	......	1.06
Perpendicular to contour	213.0	.29	.30	.02	.02	......	......	......	.63
Parallel to contour	64.9	.14	.42	.03	.11	......	......	0.02	.72
Outer edge of bench	4.0	......	......	.25	......	......	......	......	......

A high water table may be present on some areas only during the rainy season. During the dry summer period, when many of the cutting units are laid out, these places may be difficult to recognize. Local topography is often helpful. Shallow basins on flats or benches at the base of a slope may become saturated during the rainy season. A high water table may also be present in streambanks along shallow watercourses or the streams may overflow and saturate adjacent areas.

Skunk cabbage (*Lysichitum americanum* Hulten and St. J.) is an excellent indicator of poorly drained areas (Ruth and Yoder, 1953). Root systems of windfalls are also useful. On sites with a high water table, the root systems often have a flat, tablelike appearance on the bottom. A somewhat similar root development may also occur where rock or dense clay layers restrict root development. In either case, it would not be wise to expose such areas on the edge of a clear cut.

Decay. Root rots were by far the most important factor predisposing Douglas-fir to windthrow (Table 5). Root rots were associated with the loss of 34 percent of the windthrown Douglas-firs.

Butt rots were next in importance to root rots. Almost 20 percent of the windthrown Douglas-firs had been weakened by butt rot to the point where they were either uprooted or broken off at the base.

Polyporus schweinitzii Fr., which causes red-brown butt rot, was by far the most important fungus causing windthrow of Douglas-fir. It was responsible for one-third of the root rot and all of the butt rot in windthrown Douglas-firs. An examination was made of all stumps on a strip one-third of a chain wide inside the edges of the eight study units. Although *Polyporus schweinitzii* was found in only about 18 percent of the Douglas-fir trees in the stand, this 18 percent contributed 29 percent of the windthrown Douglas-firs.

Poria weirii Murr. was second in importance. This fungus was responsible for most of the root rot in Douglas-fir. *Poria weirii* sometimes enters and causes decay in the lower portion of the bole, but it was of little importance as a butt rot in the study area. Although it was associated with almost one-fourth of the windthrown Douglas-firs, it was found as a butt rot in only about 3 percent of the 702 Douglasyear or two after the fire. This resulted in an indiscriminate thinning of the edge of the stand and increased the exposure of the remaining trees to storm damage.

Conclusions and Application Of Results

Windthrow around staggered settings cannot be eliminated entirely, but it can be reduced. Success in a particular area will depend largely upon the judgment of the forester who lays out the settings. The results of this and other studies suggest several ways foresters can reduce wind damage around staggered settings in the Oregon Cascade Range.

Destructive winds in the Cascade Range usually come from the southwest, but east winds also cause appreciable windthrow. Settings should be designed for maximum protection from the southwest winds. However, in areas known to be subject to strong east winds, the cutting edges which will be exposed to the east winds should also be chosen with special care.

Windward cutting boundaries and boundaries located parallel to the direction of stormwinds generally suffered only light damage. Protection from wind damage need not be the governing factor in the selection of these boundaries. A normal amount of care in their selection should be sufficient.

Leeward cutting boundaries suffered the greatest windthrow losses (Fig. 2). Prevention of windthrow should be a major consideration in locating leeward cutting boundaries.

The relationship between windthrow and topographic location of cutting boundaries suggests a unit design for reduction of windfall on slopes with northwest or southeast exposures in the Cascades. The top and bottom boundaries of the clear cut should be located either along roads or parallel to the contour on benches. A somewhat less desirable location for the lower boundary would be along a main creek. The side boundaries should be located

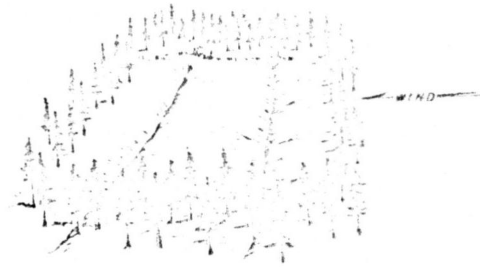

FIGURE 9. *Unit design suggested for northwest and southeast slopes in the Cascade Range.*

either on the crest or on the windward slopes near the crest of a secondary or other minor ridge (Fig. 9). Units laid out in this manner should result in a minimum of windthrow, simplify salvage of any windthrow which does occur, and eliminate the necessity for yarding salvage logs through the regenerating area. In addition, some slash burning problems are simplified (Silen, 1955).

On long, high ridges which are exposed to storm winds, cutting should start in the lee of the ridge. Clear cutting the top of a secondary ridge that obstructs the wind can indirectly cause extensive blowdown in the stand in its lee. Windthrow might be minimized by cutting successive settings "into the wind"—for example, starting two settings beyond the base of the ridge (Fig. 10). The last setting in the series should include the stand on the windward slope of the ridge. By allowing time for each clear-cut setting to restock before the next unit is cut, the new stands will decrease in height to windward, and the extent of cutting boundaries exposed to wind damage will be minimized.

Additional guides for reduction of windthrow. Following are some further suggestions that may be helpful in reduction of windthrow around staggered settings.

1. Locate cutting boundaries that are exposed to damaging winds at least 200 feet from poorly drained or shallow soils.

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