Vegetation composition on recent landslides in the Cascade Mountains of western Oregon

D. W. R. MILES

Department of Forest Engineering, Oregon State University, Corvallis, OR, U.S.A. 97331

AND

F. J. SWANSON

United States Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Corvallis, OR, U.S.A. 97331

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Shallow, rapid landslides are common events and significant causes of vegetation disturbance in the Pacific Northwest. Landslides remove surface soil and above- and below-ground biomass from steep slopes and deposit them downslope or in streams. Vegetation cover and frequency were sampled on 25 landslides aged 6–28 years in the Cascade Mountains of western Oregon. Landslides sampled were debris avalanches ranging in surface area from 36 to 1287 m^2, in elevation from 460 to 1100 m, and in slope from 40 to 173%. The landslides originated in undisturbed forests, recently harvested tracts of timber, road cuts, and road fills. Substrates within landslide areas were separated into five types and the vegetation cover was estimated for each: bedrock, 19%; secondary erosion, 25%; primary scar, 51%; secondary deposition, 57%; primary deposition, 71%. Vegetation cover averaged 51% overall and cover ranged from 7 to 88% among landslide sites. No relation between landslide age and vegetation cover was established. *Pseudotsuga menziesii* (Mirb.) Franco was the most common tree species overall and dominated all substrates except bedrock, where no single tree species occurred on more than 20% of the plots. *Rubus ursinus* Cham. & Schlecht. was the most common shrub species on all substrates. *Anaphalis margaritacea* (L.) B & H and *Trientalis latifolia* Hook. were the most common herb species on all substrates except bedrock, where annual *Epilobium* spp. were most common.

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Des glissements de terrain superficiels et rapides sont des phénoménes qui provoquent des modifications importantes de la végétation dans les Etats du Nord-ouest. Ces glissements ont pour effet de prélever la couche superficielle du sol et la biomasse au-dessus et en-dessous du sol sur des pentes escarpées et de les déposer plus bas ou même dans les ruisseaux. On a analysé la couverture de végétation et sa distribution sur 25 glissements survenus il y a 6 à 28 ans dans les monts Cascade de l'ouest de l'Oregon. Ces glissements étaient constitués de débris d'avalanches d'une superficie allant de 36 à 1287 m^2, situés à 460–1100 m d'altitude et dont la pente variait de 40 à 173%. Les glissements s'étaient produits dans des forêts intactes, des aires de coupe récentes et des emprises de routes. On a divisé en cinq types les substrats des aires de glissements et estimé la couverture végétale pour chacun d'eux: roche-mère, 19%; érosion secondaire, 25%; premier prélèvement, 51%; dépôt secondaire 57%; déposition primaire, 71%. Globalement, la couverture végétale occupait 51% du sol et variait de 7 à 88% d'un glissement à l'autre. Un n'a pu établir de lien entre l'âge du glissement et la couverture végétale. L'essence dominante était *Pseudotsuga menziesii* (Mirb.) Franco, qui se retrouvait sur tous les substrats, à l'exception de la roche-mére ou on ne retrouvait des essences que sur moins de 20% des places-échantillons. *Rubus ursinus* Cham. & Schlecht. était l'arbuste de plus fréquemment rencontré, quel que fut le substrat. *Anaphalis margaritacea* (L.) B & M et *Trientalis latifolia* Hook. étaient les herbacées les plus fréquentes sur tous les substrats, à l'exception de la roche-mère où *Epilobium* spp. dominait.

[Traduit par la revue]

Introduction

Shallow, rapid mass movements of soil, here called landslides, are common in the steep terrain of the Pacific Northwest, occurring in both undisturbed and managed forests (Swanson and Swanson 1976; Ketcheson and Froehlich 1978; Megahan *et al.* 1978). Landslides are a significant cause of vegetation disturbance (Veblen and Ashton 1978; Hupp 1983) and affect subsequent timber productivity for several decades at least (Miles *et al.* 1984).

Landslides move mineral soil, organic matter, and above- and below-ground biomass from steep slopes (Flaccus 1959; Hupp 1983) and deposit them downslope or in stream channels. The newly exposed subsoil in landslide scars holds few residual root crowns or seeds to sprout and occupy the site, but deposits of landslide debris may have some surviving crowns or seeds near the surface.

Vegetation succession after landslides is described by Flaccus (1959) in New Hampshire, Mark *et al.* (1964) in New Zealand, Veblen and Ashton (1978) in Chile, Hupp (1983) in Virginia, and Shimokawa (1984) in Japan. Smith *et al.* (1983) sampled vegetation on landslides in a *Tsuga heterophylla* (Raf.) Sarg. coastal forest in British Columbia. Little is known about the development of vegetation after landslides in the *Pseudotsuga menziesii* (Mirb.) Franco region of the Pacific Northwest.

The purpose of this study was to examine the composition of vegetation on recent landslides in the vicinity of the H. J. Andrews Experimental Forest in the western Cascade Mountains of Oregon. We examined differences in vegetation frequency and cover on landslides of varying ages and on different substrates within landslides.

Methods

The site for the study was the H. J. Andrews Experimental Forest and the adjacent upper Blue River drainage of the Willamette National Forest in the western Cascades, about 80 km east of Eugene, Oregon. The vegetation is dominated by *P. menziesii* with varying amounts of

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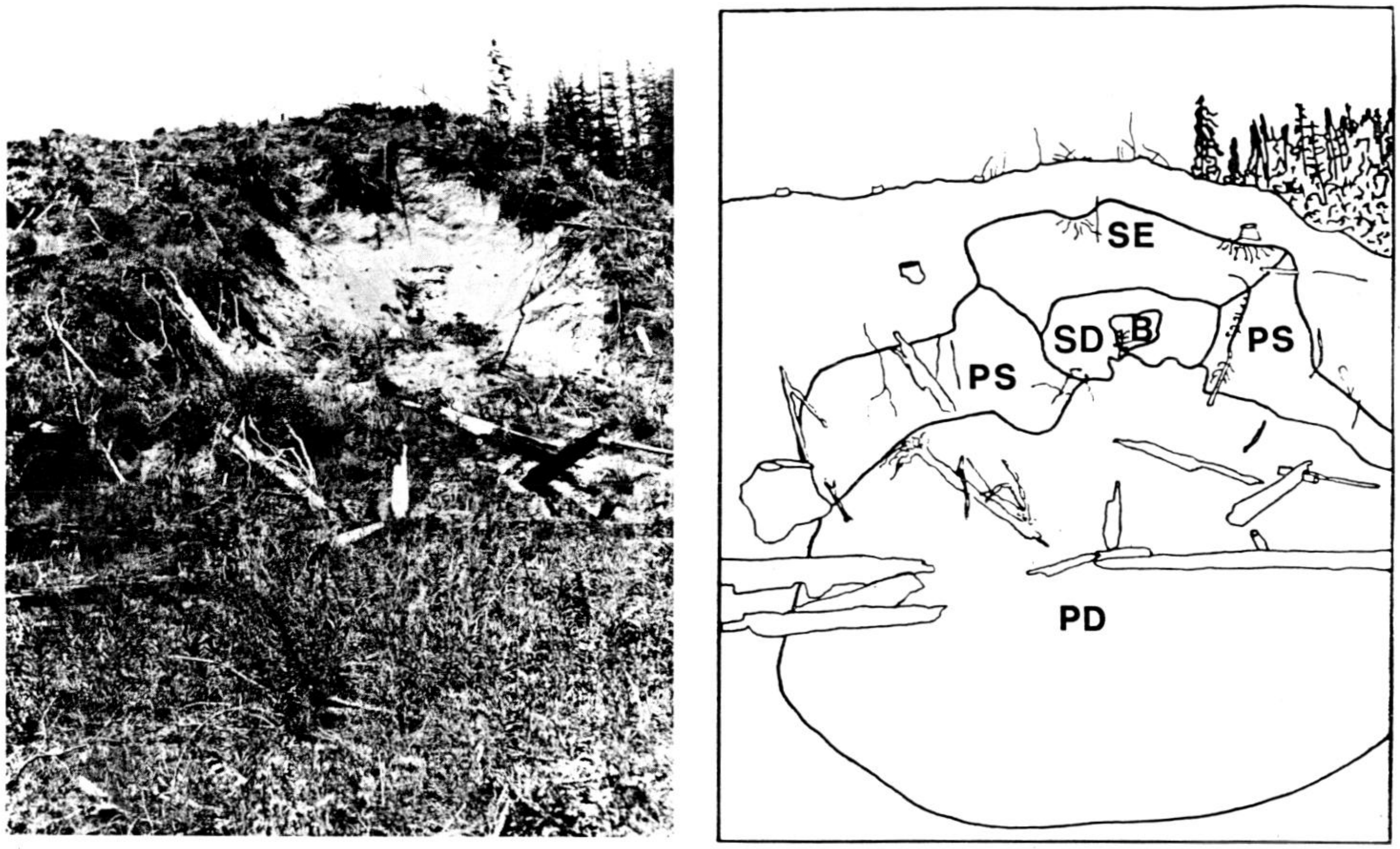

FIG. 1. Left: Photo taken in 1968 of landslide that occurred December 1964 to January 1965. Right: Location of five substrate types on a landslide in the western Oregon Cascades: B, bedrock; SE, secondary erosion; PS, primary scar; SD, secondary deposition; PD, primary deposition.

T. heterophylla and *Thuja plicata* Donn. Average annual precipitation totals approximately 2400 mm, primarily as rain, with 70% falling from November to March. Volcanoclastic rocks and lava flows dominate the geology of the area (Swanson and James 1975). Inventories of 257 landslides occurring in the 12 300 ha area since 1946 (Dyrness 1967; Swanson and Dyrness 1975; Marion 1981) provided the population from which sites were selected for sampling vegetation composition.

A random sample of 25 landslides from throughout the study area was taken from the 257 inventoried landslides. A grid system established on each of the sampled landslides was used to locate 20 circular plots of 2.27 m radius in an even distribution over the landslide surface. Where the landslide debris was deposited immediately downslope from the landslide scar, both areas were sampled; otherwise, only the scar was sampled. Where 20 plots would not fit on the landslide without overlap, the number of plots was reduced accordingly.

Ocular estimates of percentage of canopy cover were made for each plant species or genus to the nearest 5% (except for 1–5% and 99% cover), with plants less than 1% cover given a 1% value. Average canopy cover for each species was based only on the plots on which the species occurred. Total vegetation cover was also estimated for each plot. Species frequency was calculated as a percentage of the total number of plots on which the species occurred. Taxonomy and nomenclature of vascular plant species follow Hitchcock and Cronquist (1973).

Each plot was subjectively classified into one of five substrate types: bedrock, secondary erosion, primary scar, secondary deposition, and primary deposition (Fig. 1). Secondary erosion included areas of the landslide site that had undergone a significant net loss of substrate material caused by active surface erosion following initial landsliding. Primary scars included those areas of the landslide scar that were not bare bedrock and had not undergone active surface erosion. Secondary deposition included those areas where postlandslide erosional materials were being deposited. Primary deposition occurred on areas that received the original landslide debris, but did not receive secondary deposits of erosional material. General site data were also obtained, including slope gradient, aspect, elevation, size, type, and age of landslide.

Results

Inventoried landslides and those sampled were primarily debris avalanches. Surface area (horizontal projection) ranged from 36 to 1287 m^2, elevation from 460 to 1100 m (measured in middle of scar), slope was 40 to 173%, and age from 6 to 28 years. The sampled landslides originated in undisturbed forests, recent harvest units, road cut banks, and road fills (Table 1).

The substrate types were unevenly distributed among landslides and varied in area covered (Table 2). Primary scars covered 64% of the total landslide area, whereas bedrock covered less than 5% of the total landslide area. The sampled landslides in the study area occurred in deep, unconsolidated volcanoclastic soils where bedrock is at least several metres deep and is, therefore, not commonly exposed by landslides.

Areas of primary deposition constituted a relatively small proportion of the total landslide area, because much transported material moved directly into stream channels and was deposited downstream. The area in primary deposits may have been underestimated because of becoming obscured by relatively quick revegetation of thin deposits.

Average vegetation cover for all landslides was 51%, ranging from 7 to 88%. Total vegetation cover and individual species

TABLE 1. Environment, site, and vegetation characteristics of landslide plots in western Oregon

Landslide age (years)	Site type*	Slope (%)	Aspect (°)	Landslide area (m^2)	Elevation (m)	Total vegetation cover (%) (±SD, n = 13–20)
6	RF	74	335	105	850	25.6±20.0
9	RF	80	0	312	550	38.5±21.9
10	FO	100	350	237	790	76.4±24.5
11	FO	173	350	36	760	27.2±32.2
11	FO	70	190	858	790	84.5±16.3
11	CC	70	15	550	730	24.8±31.6
11	RF	52	180	177	1100	35.6±32.5
11	RF	67	335	942	730	47.8±33.3
11	RF	75	165	193	670	9.2±11.0
12	CC	79	10	79	820	38.3±40.2
14	RF	85	150	318	750	82.4±20.2
16	FO	57	100	325	760	66.7±25.8
16	FO	80	235	145	670	57.2±44.6
16	RF	50	170	500	760	65.9±28.1
16	RF	82	10	563	720	77.8±23.2
16	RF	85	130	1115	580	7.1±8.3
17	CC	78	245	512	760	58.2±30.8
17	CC	50	130	236	910	76.9±13.8
17	RC	40	130	452	730	50.0±31.9
18	RC	50	240	373	560	58.0±28.2
19	RF	70	90	1065	490	53.8±31.4
24	CC	80	280	1287	690	11.2±12.8
24	RF	70	20	307	760	86.8±16.6
26	CC	85	105	192	690	69.3±19.6
28	RF	70	110	586	460	42.4±28.9

*RF, road fill; FO, forest; CC, clear-cutting; RC, road cut.

TABLE 2. Average cover for major vegetation types on five landslide substrates

Substrate type	Area in type (%)	Cover (%)				
		Total	Tree	Shrub	Herb	Grass
Bedrock	4.5	19	7	4	8	2
Secondary erosion	11.4	25	8	3	17	2
Primary scar	63.8	51	24	13	22	4
Secondary deposition	6.1	57	28	19	18	2
Primary deposition	14.2	78	45	23	26	4

cover were not significantly (p = 0.05) related to landslide age over the limited span of age available (r^2 = 0.10). Stratification of vegetation cover by substrate type did not improve the relation with landslide age.

Landslide flora included 141 species (some identified only to genus), with 27 species occurring on more than 15% of the plots (Table 3). The vegetation was dominated by *P. menziesii* and *Rubus ursinus* Cham. and Schlecht., which occurred on 58 and 62% of the plots, respectively. *Pseudotsuga menziesii* and other tree species were present as seedlings and saplings, ranging from less than 1 to 10 m tall. The herbs *Anaphalis margaritacea* (L.) B & H, *Trientalis latifolia* Hook., *Hieracium albiflorum* Hook., and *Galium* spp. had a frequency of greater than 40%, but averaged only 1 to 2% cover. The tree species *Tsuga heterophylla*, *Thuja plicata*, *Alnus rubra* Bong., and *Acer macrophyllum* Pursh. had frequencies of 18–27%. *Alnus rubra* averaged 27% cover where present, compared with *P. menziesii*, wich averaged 14% cover.

Certain species were restricted in their distribution among landslides. *Agrostis* spp., annual *Lotus* spp., and two *Festuca* species were found on road-related landslides and on a few landslides within clear-cuttings. These species are often included in seed mixtures that are applied to roadside areas for erosion control.

Pseudotsuga menziesii and *R. ursinus* were present on all landslides except for two very small (237 and 145 m^2) landslides surrounded by old-growth forest. Although the surrounding managed land has been hand planted with *P. menziesii*, only one landslide was planted (see 18-year-old landslide, Table 1). These planted trees were included in the data on vegetation cover.

Vegetation cover varied among substrate types (Table 2). Cover was 19% where bedrock limited rooting medium and progressively increased with more stable soil to 78% on areas of primary deposition. Cover of trees, shrubs, herbs, and grasses (following the classification of Garrison *et al.* 1976) also varied between substrates (Table 3). Trees had their highest average cover on the areas of primary and secondary deposition; trees and herbs had their highest cover on primary scar and bedrock; herbs had their highest cover in erosion areas. Grasses did not have cover greater than 4%, except on some road-related landslides.

Species composition also varied between substrate types (Table 3). Naturally established *P. menziesii* had the highest frequency of the tree species on all substrate types except bedrock. *Alnus rubra* was less frequent than *P. menziesii*, but

TABLE 3. Frequency (F)* and average cover (C)† for major plant species occurring on five landslide substrates in the western Oregon Cascades

Vegetative type and species	Total landslide		Bedrock		Secondary erosion		Primary scar		Secondary deposition		Primary deposition	
	F	C	F	C	F	C	F	C	F	C	F	C
Trees												
Pseudotsuga menziesii	58	14	—	—	33	11	60	14	76	19	76	16
Tsuga heterophylla	27	6	—	—	—	—	25	5	38	4	49	9
Thuja plicata	25	11	—	—	15	5	23	7	45	13	43	23
Alnus rubra	21	27	19	6	19	13	28	31	34	16	22	30
Acer macrophyllum	18	9	—	—	—	—	19	6	17	2	21	28
Shrubs												
Rubus ursinus	62	6	48	1	46	2	59	5	72	7	87	9
Whipplea modesta	28	4	—	—	—	—	26	3	38	6	57	4
Rubus parviflorus	24	4	29	1	19	2	25	4	—	—	30	6
Gaultheria shallon	22	7	—	—	—	—	18	4	34	5	48	12
Acer circinatum	19	11	—	—	—	—	16	11	24	4	40	14
Berberis nervosa	15	1	19	6	—	—	—	—	—	—	34	11
Salix sp.	—	—	—	—	—	—	—	—	28	16	—	—
Ceanothus integerrimus	—	—	—	—	—	—	—	—	21	8	—	—
Ceanothus velutinus	—	—	—	—	—	—	—	—	—	—	18	5
Herbs												
Anaphalis margaritacea	58	2	29	1	46	1	60	2	79	1	57	2
Trientalis latifolia	52	1	—	—	39	1	53	1	72	1	58	1
Hieracium albiflorum	44	1	—	—	37	1	47	1	55	1	43	1
Galium spp.	41	1	29	1	33	1	43	1	38	1	46	2
Epilobium angustifolium and other perennial fireweeds	37	1	—	—	26	1	36	1	34	2	52	1
Epilobium paniculatum and *Epilobium minutum*	34	1	57	1	35	1	36	1	34	1	15	1
Linnaea borealis	28	14	—	—	20	2	25	17	31	2	52	15
Polystichum munitum	27	2	29	1	—	—	28	2	21	1	43	5
Lotus purshiana and *Lotus micranthus*	24	7	19	1	20	7	27	8	28	6	—	—
Petasites frigidus	22	11	—	—	19	5	24	11	28	13	18	13
Viola sempervirens	18	1	—	—	—	—	17	1	41	1	24	1
Equisetum spp.	17	11	—	—	—	—	—	—	34	12	33	14
Vancouveria hexandra	17	2	—	—	—	—	19	2	—	—	19	1
Madia spp.	—	—	33	5	15	1	—	—	—	—	—	—
Mimulus sp.	—	—	29	1	—	—	—	—	—	—	—	—
Anemone deltoidea	—	—	—	—	—	—	—	—	—	—	19	1
Boykinia elata	—	—	—	—	—	—	—	—	—	—	16	2
Grasses												
Agrostis spp.	32	6	29	1	—	—	38	7	28	2	22	11
Festuca arundinacea	17	4	19	1	—	—	17	4	21	7	19	5
Festuca occidentalis	15	3	29	1	15	1	18	3	—	—	—	—
Holcus lanatus	—	—	19	1	—	—	—	—	—	—	—	—
Deschampsia elongata	—	—	19	1	—	—	—	—	—	—	—	—

*Frequency (%) is calculated as the number of plots on which species occurred divided by total number of plots in each category. Only those species exceeding 15% frequency on total landslide or at least one substrate are included; —, frequency less than 15% elsewhere.
†Percentage of average cover is based on all plots on which species occurred.

had a higher cover on areas of secondary erosion and primary deposition and on primary scars. *Tsuga heterophylla* and *Thuja plicata* were more frequent and higher in cover on more stable substrates. *Rubus ursinus* was the most frequent shrub species on all substrates. The annual herbs *Epilobium paniculatum* Nutt. and *Madia* spp. were 1.5 and 2 times more frequent on bedrock than on other substrates, respectively.

Discussion

Vegetation cover of individual landslides presumably increases with time, as illustrated in Fig. 2. The sampling procedure used in this study, however, was to examine landslides ranging up to 30 years old during one time period. The failure to observe a statistically significant increase in vegetation cover over time in this sample is, in part, a result of variation within and among landslide sites. Variation included differences in relative proportion of substrate types among landslides and differences in cover for individual substrate types among slides; this variation resulted from contrasts in aspect, surrounding vegetation, soil types, and other factors.

Determining trends in cover and species composition on landslides and on substrate types is further complicated by the

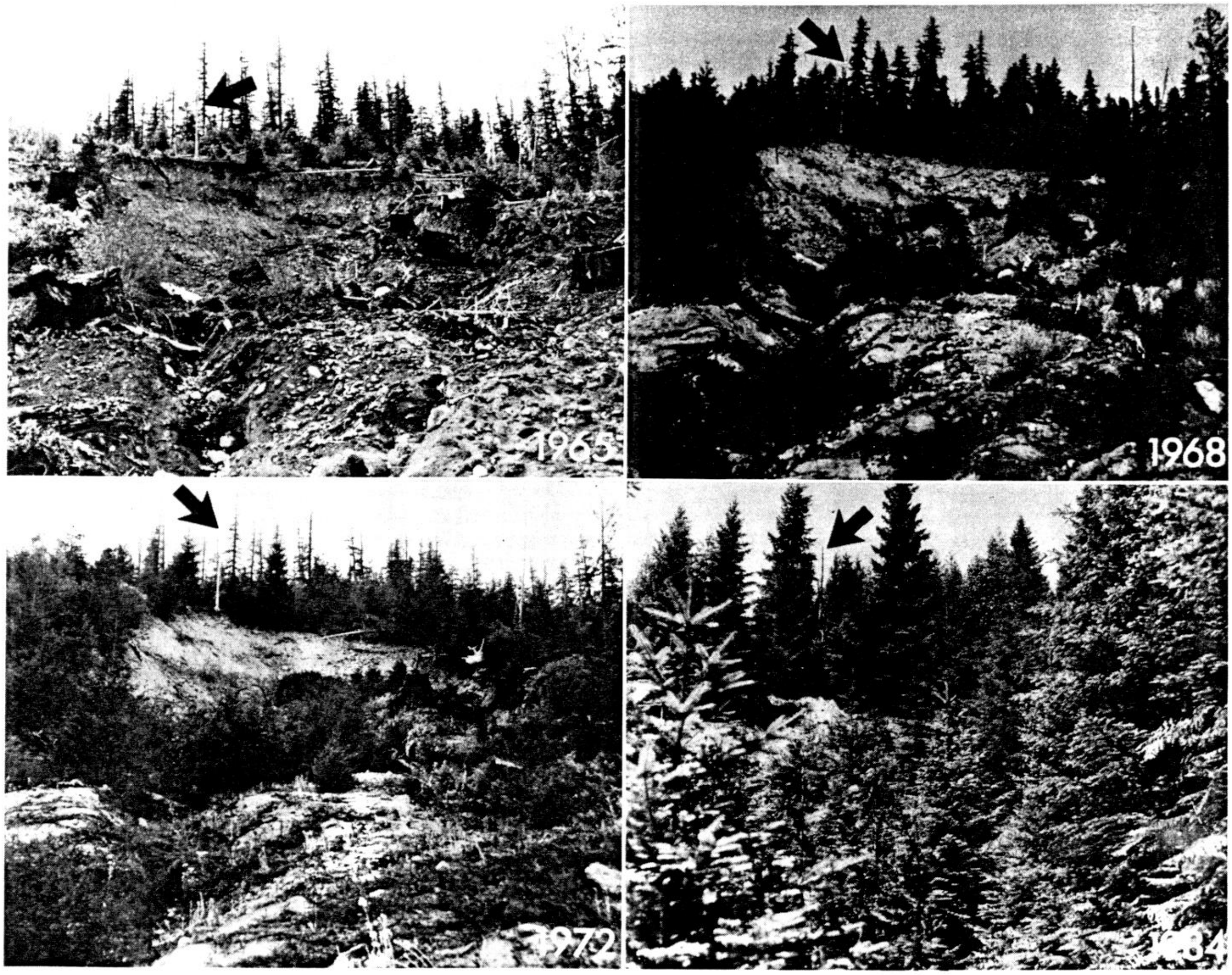

FIG. 2. Chronosequence of landslide revegetation in the western Oregon Cascades. The 1965 photograph was taken the summer after landslide occurrence in December or January. In 1968, *Rubus ursinus* is the major species in the foreground. By 1972, *Pseudotsuga menziesii* is prominent; in 1984, it dominates the foreground. Arrow points to the same tree in each photograph.

small sizes and wide ranges of habitats on individual landslides. Primary scars with their shallow to nonexistent soils and droughty conditions abut areas of primary deposition with their more favorable sites. Water is concentrated at seeps and in gullies, creating a habitat for wet-site species, even within otherwise droughty primary scars and areas of secondary erosion. Consequently, *A. rubra* and *Petasites frigidus* occurred in such areas of this study. The environment of a landslide is influenced not only by its size, shape, setting, and aspect, but also by the composition and stature of adjacent vegetation. The wide range in habitat conditions and shading noted here is also described by Flaccus (1959), Mark *et al.* (1964), and Hupp (1983).

As in our study, Flaccus (1959), Veblen and Ashton (1978), and Bogucki (1976) report patterns of vegetation cover that vary among substrate types. In all three studies, the lowest cover was reported on bedrock or landslide scars and the highest cover was reported on accumulations of material from landslides and secondary erosion. In our study, bedrock and areas of secondary erosion had limited rooting media and unstable substrates, but still maintained some vegetation cover. On the 6- to 28-year-old landslides sampled, total vegetation cover was 19% on bedrock and 25% on areas of secondary erosion. Flaccus (1959) predicted it would take at least 100 years for bedrock areas to revegetate completely.

Landslides remove both above- and below-ground biomass, redistributing it downhill. The removal of all propagules from the primary scar area precludes resprouting of damaged vegetation or germination of seeds stored in soil. Flaccus (1959) suggests that removal of propagules may contribute to the low component of shrub species on landslides. In our study, *Acer circinatum* and *Ceanothus* spp., which sprout or germinate from seeds stored in the soil, had greater frequency on deposition areas than on bedrock, areas of erosion, and primary scars. Removal of vegetation from the primary scar is not always complete, however; small islands of undisturbed or moderately disturbed vegetation may be left in place or transported downslope intact.

The effects of disturbance by landslides may persist because of subsequent erosion processes. We classified 17.5% of the landslide area into secondary erosion and depositional areas. On such areas, overland flow and gully erosion redistribute substrate material and slow revegetation (Flaccus 1959; Bogucki 1976). Landslides are incised into the surrounding soil mass, allowing continuous sloughing of soil, organic matter, and propagules onto the landslide surface (Flaccus 1959; Miles *et al.* 1984).

Stabilization of the landslide area by initially established vegetation may create conditions more suitable for subsequent vegetation development.

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BOGUCKI, D. J. 1976. Debris slides in the Mt. Le Conte area, Great Smoky Mountains National Park, USA. Geogr. Ann. Ser. A, **58**: 179–191.

DYRNESS, C. T. 1967. Mass soil movements in the H. J. Andrews Experimental Forest. U.S. For. Serv. Res. Pap. PNW-42.

FLACCUS, E. 1959. Revegetation of landslides in the White Mountains of New Hampshire. Ecology, **40**: 692–703.

GARRISON, G. A., J. M. SKOVLIN, C. E. POULTON, and A. H. WINARD. 1976. Northwest plant names and symbols for ecosystem inventory and analysis. 4th ed. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PNW-46.

HITCHCOCK, C. L., and A. CRONQUIST. 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle, WA.

HUPP, C. R. 1983. Seedling establishment on a landslide site. Castanea, **48**: 89–98.

KETCHESON, G. L., and H. A. FROEHLICH. 1978. Hydrologic factors and environmental impacts of mass soil movements in Oregon Coast Range. Oreg. State Univ., Water Resour. Res. Inst. (Rep.), WRRI-56.

MARION, D. A. 1981. Landslide occurrence in the Blue River drainage, Oregon. M. S. thesis, Oregon State University, Corvallis, OR.

MARK, A. F., G. A. M. SCOTT, F. R. SANDERSON, and P. W. JAMES. 1964. Forest succession on landslides above Lake Thompson, Fiordland. N.Z. J. Bot. **2**: 60–89.

MEGAHAN, W. F., N. F. DAY, and T. M. BLISS. 1978. Landslide occurrence in the western and central northern Rocky Mountains physiographic province in Idaho. *In* Forest soils and land use. *Edited by* C. T. Youngberg. Proc. North Am. For. Soils Conf., 5th. pp. 116–139.

MILES, D. W. R., F. J. SWANSON, and C. T. YOUNGBERG. 1984. Effects of landslide erosion on subsequent Douglas-fir growth and stocking levels in the western Cascades, Oregon. Soil Sci. Soc. Am. J. **48**: 667–671.

SHIMOKAWA, E. 1984. A natural recovery process of vegetation on landslide scars and landslide periodicity in forested drainage basin. *In* Proceedings: Symposium on Effects of Forest Land Use on Erosion and Slope Stability. *Edited by* C. L. O'Loughlin and A. J. Pearce. Environment and Policy Institute, East–West Center, University of Hawaii, Honolulu, HI. pp. 99–107.

SMITH, R. B., P. R. COMMANDEUR, and M. W. RYAN. 1983. Natural revegetation, soil development and forest growth on the Queen Charlotte Islands: progress report. Can. For. Serv., Fish–For. Interact. Program Work. Pap. 7/83.

SWANSON, F. J., and C. T. DYRNESS. 1975. Impact of clearcutting and road construction on soil erosion by landslides in the Western Cascades Range, Oregon. Geology, **3**: 393–396.

SWANSON, F. J., and M. E. JAMES. 1975. Geology and geomorphology of the H. J. Andrews Experimental Forest, Western Cascades, Oregon, U.S. For. Serv. Res. Pap. PNW-188.

SWANSON, D. N., and F. J. SWANSON. 1976. Timber harvesting mass erosion, and steepland forest geomorphology in the Pacific Northwest. *In* Geomorphology and engineering. *Edited by* D. R. Coates. Dowden, Hutchinson, and Ross, Inc., Stroudsburg, PA. pp. 199–221.

VEBLEN, T. T., and D. H. ASHTON. 1978. Catastrophic influences on vegetation of the Valdivian Andes, Chile. Vegetatio, **36**: 149–167.