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Environment and Forest Regeneration in the Illinois Valley Area of Southwestern Oregon

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Abstract

Multiple regression analyses were used to relate environmental factors to forest regeneration on clearcut and partial cut areas managed by the Bureau of Land Management in the Illinois Valley area southwest of Grants Pass, Oregon. Difficulty of regenerating clearcuttings at elevations between 3,000 and 4,900 feet (914 and 1 494 m) increased with increases in soil coarse fragments, solar radiation, and slash burning. Difficulty of regenerating clearcuttings at elevations between 1,500 and 2,900 feet (457 and 884 m) increased as solar radiation, shrub cover, grass cover, and surface rock plus gravel increased. Difficulty of regenerating partial cuts increased as moisture, slope, soil silt plus clay, and density of canopy increased.

Keywords: Regeneration (natural), regeneration (artificial), environment, southwest Oregon.

Introduction

Southwestern Oregon is a diverse region with many climates, soils, and floras that form complex environments and vary by locality. Forest regeneration is a problem throughout the region, but it also varies by locality. Research personnel with the Pacific Northwest Forest and Range Experiment Station have been relating environment to forest regeneration in southwestern Oregon since 1970 by studying relatively small, reasonably coherent portions of the region (Carkin and Minore 1974; Graham and others 1982; Minore and Carkin 1978; Minore and others 1977, 1982; Stein 1981). The Illinois Valley area located southwest of Grants Pass, Oregon, is one of those portions.

Average annual precipitation ranges from 35 to 90 inches (89 to 229 cm) in the Illinois Valley area (Froelich and others 1982), with only 4 to 9 inches (10 to 23 cm) of this precipitation occurring during the dry season of May through September (McNabb and others 1982). Air temperatures monitored at 35 shaded locations in the Illinois Valley ranged from 17 °F (-8 °C) in January to 104 °F (40 °C) in August 1980. Elevations range from 1,000 to 5,500 feet (304 to 1 676 m). A large flora, complex geology, and diverse topography characterize most of southwest Oregon, but the Illinois Valley area is particularly noteworthy for its endemic plant species and serpentine intrusions. Local vegetation and geology are well described by Atzet (1979).

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We studied the Illinois Valley area to derive functional relationships between selected environmental factors and forest regeneration following timber harvest in clearcut and partial cut areas. These relationships were developed for public land managed by the Bureau of Land Management, U.S. Department of the Interior, but they should apply on land of all ownerships in the study area. Our objective was to compare forested sites in terms of relative difficulty of regeneration.

Methods

Clearcuttings

The 62 clearcut units sampled during 1980 were selected to include as many different combinations of aspect and elevation as possible and to provide a good geographic distribution (fig. 1; table 7, appendix). All were 3 to 9 years old and

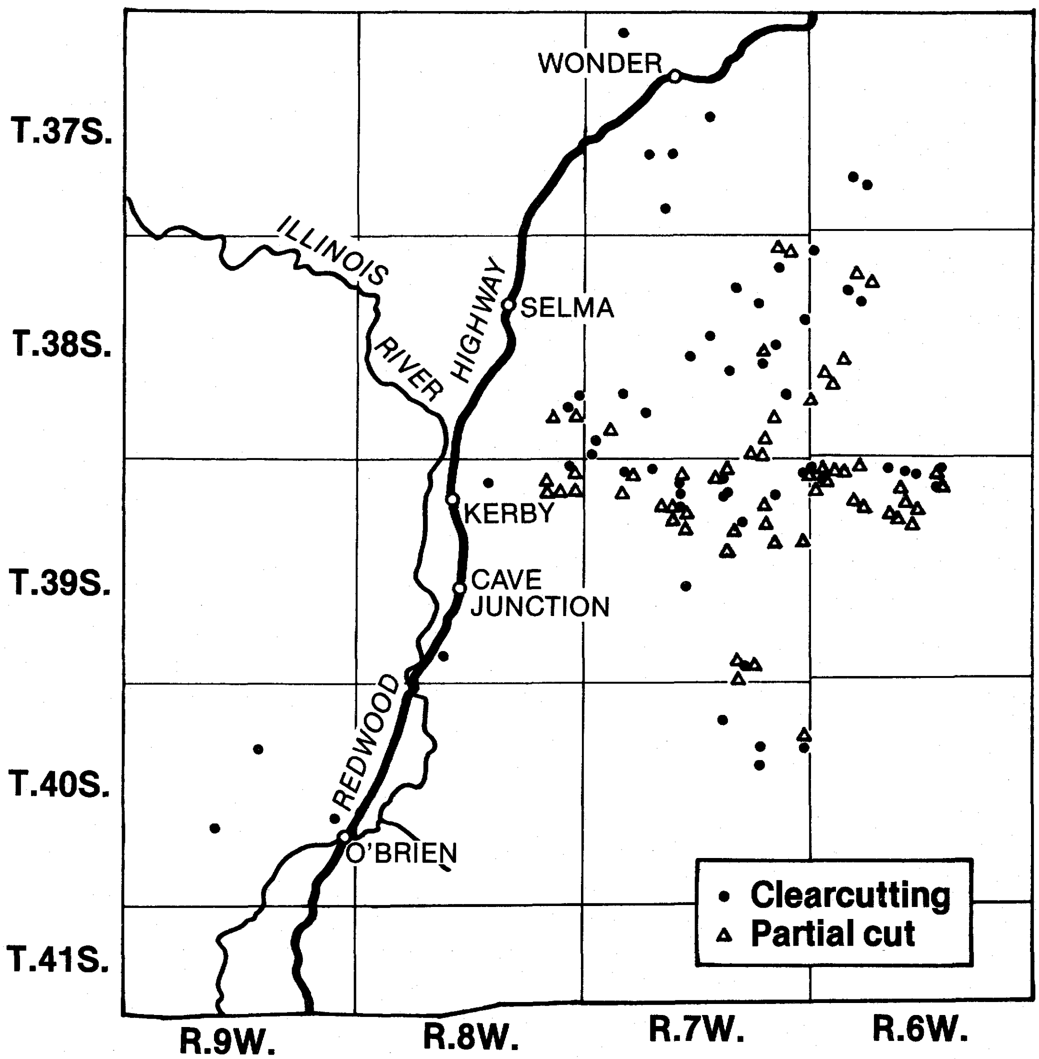

Figure 1.—Study plots in the Illinois Valley area.

had a nearby uncut stand with similar slope, aspect, soil, and elevation to represent preharvest vegetation and environment.[1] A grid of 30 subplots spaced 33 feet (10 m) apart was established on a relatively uniform area in each sample clearcutting.[2] Beginning from a randomly located starting point, we systematically located the equally spaced subplots but did not sample near road fills or edges of adjacent stands. Each subplot consisted of a circle with an area of 1/250 acre (0.0016 ha). Percent slope, degree aspect, number of established postharvest seedlings (by species), and the number of vigorous preharvest seedlings were recorded on each subplot.[3] Subplots supporting one or more established seedlings were considered stocked.[4] Average elevation and the dominant shrub, forb, and grass species were recorded for each clearcut plot. Soil depth was recorded as shallow (less than 20 inches or 50 cm), moderate (20-40 inches or 50-100 cm), or deep (greater than 40 inches or 100 cm).

An uncut stand near each clearcut unit was sampled with 10 subplots spaced 33 feet (10 m) apart. Each subplot consisted of two concentric circles with areas of 1/250 and 1/60 acre (0.0016 and 0.0067 ha). We tallied the number of conifer seedlings less than 4.5 feet (1.4 m) tall, the number of conifer saplings 4 inches (10.2 cm) or less in diameter at breast height, and the percent crown cover of every forb and grass species that occurred on each 1/250-acre (0.0016-ha) circle. Crown cover of every shrub species and understory tree species was recorded for each 1/60-acre (0.0067-ha) circle in the uncut stand. The basal areas of overstory tree species were tallied with a 20-factor prism by diameter class.[5]

Depth of duff, percent cover of surface rock plus gravel on small duff-cleared areas, and percent moss cover were estimated at each of the 10 subplots in the uncut stand. Percent of coarse fragments was estimated in the top 10 inches (25.4 cm) of soil at pits dug on subplots 1, 4, 7, and 10.

Samples of equal volume from a depth of 4 inches (10 cm) in each of the four pits were combined and blended to yield a single soil sample for each plot. All soil samples were air dried immediately and analyzed for cation exchange capacity (ammonium acetate method) and total carbon content (Walkley and Black 1934). Soil texture was determined by using a modified hydrometer technique.

[1]The uncut stands contained differences no greater than 30 percent in slope, 35° in azimuth, and 200 feet in elevation from the clearcut unit.

[2]Uniform was defined as being within a range of 30 percent for slope and 35° for azimuth.

[3]Seedlings of *Pseudotsuga menziesii* and *Abies* sp. were considered established if they had branched before 1980. Establishment of other conifers was determined by size and vigor.

[4]Stocking percentage was calculated for each plot by dividing the number of stocked subplots by 30 and multiplying the result by 100.

[5]Diameter classes were 4-10 inches (10-27 cm), 11-20 inches (28-52 cm), 21-30 inches (53-77 cm), 31-40 inches (78-103 cm) and 41+ inches (104+ cm).

The percent slope, degree aspect, depth of duff, percent moss cover, and percent cover of surface gravel plus rock recorded on the subplots were averaged to obtain values for each clearcut sample plot. We used average slope, average aspect, and the tables of Frank and Lee (1966) to generate a radiation index for each plot. The optimum aspect for regeneration and indexes for slope-adjusted aspect were computed by using the method described by Stage (1976).[6] Slash burning was included in the multiple regression equation by using dummy variables (1 for burned, 0 for unburned).

Plant indicators of relative regeneration success after clearcutting were selected and weighted by using the method described by Minore and Carkin (1978). These indicators were then used to calculate a clearcut regeneration index for each clearcut sample plot. Plant indicators were also used to calculate moisture indexes for the clearcut plots. Data on moisture stress and species present required to select and weight those plant indicators were obtained on 68 additional plots established in relatively undisturbed stands throughout the Illinois Valley area. Each 1/5-acre (0.08-ha) moisture plot contained at least two Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) saplings between 5 and 10 feet (1.5 and 3.1 m) tall. We used a pressure bomb and the technique described by Waring and Cleary (1967) to measure nocturnal plant moisture stress in those saplings during August 1980.

The clearcut plots were stratified by elevation after preliminary examination of the field data: low elevation (1,500 to 2,900 feet or 457 to 884 m) and high elevation (3,000 to 4,900 feet or 914 to 1 494 m). Stepwise multiple regression was then used with each elevation group to correlate environmental variables and indexes to percent stocking and number of seedlings per acre. We excluded variables with coefficients that were not significant ($P < .05$) in these regression analyses. Multiple regression equations with less than seven variables that accounted for the most variation were used as mathematical models for comparing sites in terms of regeneration after clearcutting.

Partial Cuts

We sampled 56 partial cut stands (fig. 1; table 7, appendix) by using the same selection criteria and subplot design used with the clearcuts. Similar measurements were also made of percent slope, degree aspect, depth of duff, percent cover of surface gravel plus rock, soil texture, and regeneration. Plant species present and soil parameters were assumed to be the same after partial cutting as before logging, however, so data on indicator plants and soil were recorded in the sampled partial cuts rather than in adjacent uncut stands. Species present were recorded on subplots 2, 5, 8, 11, 14, 17, 20, 23, 26, and 29. Soil samples and estimates of percent coarse fragments were obtained from pits on subplots 6, 12, 18, and 24.

Density of canopy, basal area of the residual overstory, and basal area of the preharvest stand (stumps plus standing timber) were recorded for each partial cut subplot. Density of canopy was measured in two ways: we dot-counted the

[6] An optimum aspect was empirically determined from our data on regeneration. Indexes for slope-adjusted aspect were then calculated by using sine and cosine of azimuth and percent slope in a multiple regression equation.

reflected image of the canopy with a spherical densiometer and estimated overhead density of canopy by sighting through a 4- by 2.6-inch (10- by 6.5-cm) tube formed by a 10-3/4-oz. (305-g) soup can. The partial cut plots were stratified by timber type: mixed conifer (true fir regeneration absent or subordinate) and true fir (true fir regeneration predominant). All but seven of the plots occurred in the mixed conifer type, however, and only the mixed conifer plots were subjected to the multiple regression analyses used in correlating environment with regeneration.

Results

Clearcuttings

Stocking of postharvest seedlings ranged from 20 percent to 100 percent on the clearcut sample plots. It was similar in the low and high elevation strata, but more seedlings per acre occurred on the high elevation plots, where regeneration tended to be clumpy.

Major competing species on the low elevation clearcuttings were tanoak (*Lithocarpus densiflorus* (H. & A.) Rehd.), canyon live oak (*Quercus chrysolepis* Liebm.), Pacific madrone (*Arbutus menziesii* Pursh), California black oak (*Quercus kelloggii* Newb.), deerbrush ceanothus (*Ceanothus integerrimus* H. & A.), California hazel (*Corylus cornuta* (DC.) Sharp), poison oak (*Rhus diversiloba* T. & G.), hairy honeysuckle (*Lonicera hispidula* (Lind.) Dougl.), creambush rockspirea (*Holodiscus discolor* (Pursh) Maxim.), box blueberry (*Vaccinium ovatum* Pursh), western bracken fern (*Pteridium aquilinum* var. *pubescens* Underw.), modest whipplea (*Whipplea modesta* Torr.), and fescues (*Festuca* spp. L.).[7] Major competitors on the high elevation clearcuttings included golden chinkapin (*Castanopsis chrysophylla* (Dougl.) A.DC.), vine maple (*Acer circinatum* Pursh), Pacific rhododendron (*Rhododendron macrophyllum* G. Don), Sadler oak (*Quercus sadleriana* R. Br.), huckleberry oak (*Quercus vaccinifolia* Kell.), and manzanitas (*Arctostaphylos* spp. Adans.). Most (81 percent) of the clearcuttings dominated by golden chinkapin, California hazel, Pacific madrone, or bracken fern were adequately stocked with postharvest conifer regeneration. Most (73 percent) of the clearcuttings dominated by deerbrush ceanothus were poorly stocked.

Postharvest regeneration at elevations between 3,000 and 4,900 feet (914 and 1 494 m) increased with increases in the indexes for slope-adjusted aspect listed in table 1. Regeneration decreased as radiation indexes increased on clearcuttings at all elevations. Both of these trends were statistically significant ($P < .05$). Regeneration was best on northerly aspects and poorest on southwestern aspects at all elevations. Postharvest regeneration was positively correlated ($r = 0.33$) with moss cover at elevations between 1,500 and 2,900 feet (457 and 884 m) and negatively correlated ($r = -0.42$) with slash burning at elevations between 3,000 and 4,900 feet (915 and 1 494 m). The clearcut regeneration indexes derived from plant indicator species were also significantly correlated with regeneration when appropriate indicator species and values were used for the high and low elevation plots (tables 2 and 3).

[7]Nomenclature is according to Garrison and others (1976).

Table 1—Indexes for slope-adjusted aspect for clearcuttings at elevations between 3,000 and 4,900 feet (914 and 1 494 m)[1/]

Aspect azimuth	Percent slope							
	10	20	30	40	50	60	70	80
Degrees								
10	79	83	87	91	95	99	104	108
20	78	81	84	88	91	94	98	101
30	76	79	80	83	84	86	89	90
40	75	75	75	76	76	77	77	78
50	73	72	70	69	68	66	65	64
60	71	69	65	62	59	56	54	50
70	70	65	61	56	52	47	43	38
80	69	63	57	51	45	39	34	28
90	68	61	54	48	40	34	27	20
100	67	59	53	45	38	30	24	16
110	67	59	52	44	37	29	22	14
120	67	59	52	44	37	29	22	14
130	67	60	53	45	38	30	24	16
140	68	60	54	46	39	32	25	18
150	68	60	54	47	40	33	26	19
160	68	60	54	47	40	33	26	19
170	67	60	53	46	39	32	24	17
180	67	59	52	44	36	29	21	14
190	66	58	49	41	33	24	16	8
200	65	56	47	38	29	19	9	0
210	64	54	44	34	24	14	4	-5
220	64	53	41	30	19	9	-1	-12
230	63	51	39	28	16	4	-5	-17
240	63	50	39	26	14	3	-8	-19
250	63	51	39	27	15	3	-7	-19
260	64	52	40	29	18	7	-3	-14
270	64	54	44	34	24	14	4	-4
280	66	58	49	40	32	24	14	6
290	68	61	54	48	42	35	29	22
300	70	66	61	57	53	48	44	39
310	73	70	68	66	64	62	59	58
320	74	74	74	74	74	74	74	74
330	76	79	80	82	84	86	88	89
340	78	81	84	88	91	94	98	101
350	79	83	87	91	95	99	104	108
360	79	84	88	92	97	101	106	110

1/ Index = 74.89 + 0.60(percent slope)(cos azimuth) + 0.17(percent slope)(sin azimuth) + 0.34(percent slope)(cos 2 azimuth) - 0.09(percent slope)(sin 2 azimuth) - 0.50(percent slope). These indexes reflect the relative difficulty of regenerating clearcuts with respect to their slopes and aspects. High values indicate better regeneration than low values.

Table 2—Indicator species and values used in computing regeneration indexes for clearcuttings at elevations between 3,000 and 4,900 feet (914 and 1 494 m) 1/

Species	Indicator value 2/
Clintonia uniflora (Schult.) Kunth	9
Smilacina racemosa Wats.	9
Lonicera hispidula (Lind.) Dougl.	9
Acer circinatum Pursh	8
Rhododendron macrophyllum G. Don	8
Rubus parviflorus Nutt.	8
Vaccinium membranaceum Dougl. ex. Hook.	8
Lilium spp. L.	8
Pyrola spp. L.	8
Trillium spp. L.	8
Veratrum spp.	8
Vaccinium parvifolium Smith	7
Quercus Kelloggii Newb.	2
Arctostaphylos patula Greene	2
Pteridium aquilinum var. *pubescens* Underw.	2
Quercus vaccinifolia Kell.	1
Polystichum munitum (Kaulf.) Presl.	1
Viola spp. L.	1

1/ A regeneration index for clearcuttings may be obtained by averaging the values of all species present in a given uncut stand.
2/ High values indicate better regeneration than low values.

Table 3—Indicator species and values used in computing regeneration indexes for clearcuttings at elevations between 1,500 and 2,900 feet (457 and 884 m) 1/

Species	Indicator value 2/
Erythronium spp. L.	12
Acer circinatum	11
Melica spp. L.	11
Asarum hartwegi Wats.	11
Campanula scouleri Hook. ex A. DC.	11
Disporum hookeri (Torr.) Nicholson	11
Iris spp. L.	11
Montia spp. L.	11
Viola spp. L.	11
Sanicula spp. L.	3
Smilacina spp. Desf.	1

1/ A regeneration index for clearcuttings may be obtained by averaging the values of all species present in a given uncut stand.
2/ High values indicate better regeneration than low values.

Multiple regression analyses with number of seedlings per acre as the dependent variable accounted for more variation than those with percent stocking as the dependent variable, so we used the number of seedlings per acre as a measure of regeneration success for the clearcut plots. Number of seedlings per acre is expressed as the relative number of seedlings (R#S) in the following equations to emphasize the relative, comparative nature of our results.

At elevations between 3,000 and 4,900 feet (914 and 1 494 m):

$$R\#S = 55.4RI - 7.8CF - 241.1B + 11.6S + 11.4A - 366.3; \quad (1)$$

where:
R#S = relative number of seedlings,
RI = regeneration index (table 2),
CF = percent of soil coarse fragments (top 10 inches or 25.4 cm),
B = slash burning (0 if absent, 1 if present),
S = percent slope,
A = aspect index (table 1);

n = 30,
R^2 = 0.70.

During the winter months, when regeneration indexes are more difficult to obtain, a less precise multiple regression equation may be used:

$$R\#S = 11.2S + 14.6A - 10.0CF - 249.7B - 94.7; \quad (2)$$

n = 30,
R^2 = 0.66.

At elevations between 1,500 and 2,900 feet (457 and 884 m):

$$R\#S = 138.3RI + 178.9C + 0.24E - 9.8(R+G) - 19.6G + 5.2M - 920.2; \quad (3)$$

where:
RI = regeneration index (table 3),
C = percent soil carbon,
E = elevation (in feet),
(R+G) = percent rock plus gravel cover,
G = percent grass cover,
M = percent moss cover;

n = 32,
R^2 = 0.77.

If percent soil carbon cannot be determined in the laboratory:

$$R\#S = 108.2RI - 573.3RAD + 214.3DS - 109.6SS - 6.4SH - 39.6G + 75.3; \quad (4)$$

where:
RAD = Radiation index (table 4),
DS = soil more than 40 inches (102 cm) deep (0 if absent, 1 if present),
SS = soil less than 20 inches (51 cm) deep (0 if absent, 1 if present),
SH = shrub cover (in percent);

n = 32,
R^2 = 0.61.

If both percent soil carbon and regeneration index are difficult or impossible to obtain:

$$R\#S = 805.2RAD + 327.5DS - 249.9SS - 6.4SH - 30.4G + 5.4M + 680.9; \quad (5)$$

n = 32,
R^2 = 0.51.

The regeneration indexes, percent soil carbon, and data on rock plus gravel cover, grass cover, moss cover, and shrub cover used in equations (1) through (5) were all collected in relatively undisturbed stands representative of preharvest conditions. Data on preharvest conditions from undisturbed stands will be essential for valid use of those equations.

The relative, imprecise nature of the results from the equations is illustrated by the observed and predicted values shown in table 11, appendix. Exact numbers of seedlings cannot be calculated in advance, but a comparison of regression results from areas to be harvested should be useful in assessing relative difficulty of regeneration in those areas.

Table 4—Radiation indexes for lat. 42° N.

	Aspect								
Slope	N.	S.	NNE., NNW.	SSE., SSW.	NE., NW.	SE., SW.	ENE., WNW.	ESE., WSW.	E., W.
Percent									
0	0.4704	0.4704	0.4704	0.4704	0.4704	0.4704	0.4704	0.4704	0.4704
10	.4329	.5039	.4359	.5014	.4442	.4942	.4562	.4833	.4700
20	.3930	.5323	.3994	.5278	.4168	.5148	.4416	.4944	.4689
30	.3524	.5553	.3625	.5492	.3898	.5314	.4271	.5032	.4670
40	.3133	.5728	.3270	.5656	.3640	.5441	.4133	.5096	.4644
50	.2786	.5854	.2943	.5773	.3403	.5531	.4005	.5136	.4611
60	.2496	.5935	.2662	.5849	.3191	.5588	.3887	.5156	.4573
70	.2246	.5981	.2424	.5891	.3006	.5617	.3781	.5158	.4530
80	.2030	.5998	.2219	.5906	.2847	.5624	.3685	.5146	.4484
90	.1839	.5993	.2042	.5901	.2710	.5615	.3599	.5124	.4436
100	.1677	.5972	.1887	.5880	.2593	.5593	.3520	.5094	.4388

Source: Frank and Lee (1966).

Partial Cuts

Most (about 90 percent) of the partial cut plots had been cut once in a three-stage shelterwood system, and they probably had not been harvested with the intent of establishing regeneration. All were cut 3 to 21 years before sampling, and all were on sloping terrain. The only regeneration present was of natural origin.

Stocking of postharvest regeneration ranged from 3 to 100 percent in the 49 partial cut stands sampled in the mixed conifer type. It ranged from 17 to 93 percent in the seven stands sampled in the true fir type. Most (72 percent) of the mixed conifer partial cuts with California black oak, canyon live oak, or tanoak as major stand components were poorly stocked with postharvest conifer regeneration. Most (67 percent) of the partial cuts containing California hazel were well stocked, as were half of the stands with prominent Pacific madrone.

Regeneration after partial cutting in the mixed conifer type increased with increasing percent soil carbon and cation exchange capacity. Regeneration decreased with increasing percent silt plus clay. Postharvest regeneration in the true fir type was positively correlated with depth of duff and the amount of moss cover.

Percent stocking was used as the dependent variable in our multiple regression analyses of the mixed conifer partial cuts. It is expressed as percent relative stocking (RS%) in the best regression equation, which accounted for 58 percent of the total variation:

$$RS\% = 11.35507RI - 4.26223MI - 0.38616S - 0.94832(S+C) + 9.99730DS - 0.54080CA + 53.50416; \quad (6)$$

where:
RS% = percent relative stocking,
RI = regeneration index (table 5),
MI = moisture index (table 6),
S = percent slope,
(S+C) = percent soil silt plus clay,
DS = soil more than 40 inches (102+ cm) deep (0 if absent, 1 if present),
CA = percent overhead canopy;

$n = 49$,
$R^2 = 0.58$.

None of the partial cuts included in our analyses had soils less than 20 inches (51 cm) deep, and none were on flat terrain, so equation (6) may not be reliable where very shallow soils occur or where the land is level.

Multiple regression analyses of our limited data on partial cuts in the true fir type were not practical.

Equation (6) does not yield precise results, and it should not be relied upon to provide absolute percentages of partial cut stocking. Its imprecision is illustrated by the observed and predicted values shown in table 12, appendix: predicted values vary from observed values by 12 or less for 51 percent of the plots, but the difference between observed and predicted values exceeds 20 for 18 percent of the sampled partial cuts. Equation (6) does provide estimates that should be useful in comparing areas to be partial cut, however, for the observed and predicted values shown in table 12, appendix, vary similarly when the sample

Table 5—Indicator species and values used in computing regeneration indexes for partial cuts in the mixed conifer type1/

Species	Indicator value 2/
Rubus parviflorus	16
Cornus nuttallii Aud. ex T. & G.	14
Berberis nervosa Pursh	14
Vaccinium parvifolium	14
Pyrola picta Smith	14
Gaultheria shallon Pursh	13
Lonicera ciliosa (Pursh) DC.	13
Pteridium aquilinum var. pubescens	13
Lithocarpus densiflorus	5
Libocedrus decurrens Torr.	5
Quercus chrysolepis	5
Rhus diversiloba T. & G.	5
Ceanothus integerrimus H. & A.	4
Berberis aquifolium Pursh	4

1/ A regeneration index for partial cuts may be obtained by averaging the values of all species present in a given stand.
2/ High values indicate better regeneration than low values.

Table 6—Indicator species and values used in computing moisture indexes1/

Species	Indicator value 2/
Rubus spp. L.	23
Castanopsis chrysophylla (Dougl.) A. DC.	21
Berberis nervosa	21
Pyrola spp.	19
Pinus ponderosa Dougl. ex Loud.	5
Rhus diversiloba	4
Quercus Kelloggii	3
Lonicera hispidula	3

1/ A moisture index may be obtained by averaging the values of all species present in a given stand.
2/ High values indicate more moist conditions than low values.

plots are compared. Plots with high predicted values have high observed values, and plots with low predicted values have low observed values.

Regeneration after clearcutting in the Illinois Valley study area was quite good. Only 25 percent of our sampled clearcut plots were less than 60 percent stocked. Poorly stocked plots occurred with equal frequency at elevations below and above 3,000 feet (914 m), but regeneration problems appeared to differ with elevation. Depth of soil, steepness of slope, and percent cover of surface rock plus gravel were the most important environmental variables correlated with regeneration below 3,000 feet (914 m); slash burning was the most important variable between 3,000 and 4,900 feet (914 and 1 494 m). None of the sampled clearcuttings were above 5,000 feet (1 524 m), where data compiled by Wolfson (n.d.) indicate that clearcutting is impractical.

Most of the low elevation clearcuttings with poor regeneration had shallow soils, steeper than average slopes, more than the average amount of surface rock plus gravel, and higher than average radiation indexes. Slash burning was not correlated with regeneration below 3,000 feet (914 m). Aspect did not seem to be important, but this is uncertain because most of the lower elevation clearcuttings occurred on north and east aspects.

Aspect seemed to be important at high elevations, where 82 percent of the clearcuttings with poor regeneration occurred on southerly aspects. Most of the poorly regenerating high elevation clearcuts had been burned. This correlation of slash burning with poor regeneration does not prove that burning caused poor regeneration at high elevations, however, for regression correlations are not appropriate for determining relationships between cause and effect. Some unmeasured variable associated with both burning and regeneration may have been responsible, or an interacting combination of several factors may have had different effects on the burned and unburned clearcut units.

Dense brush cover was more common on the burned clearcuttings than on unburned clearcuttings, and dominance by *Ceanothus* sp. tended to be associated with slash burning at all elevations. Our data and field observations indicate that deerbrush ceanothus, tanoak, canyon live oak, huckleberry oak, and manzanita adversely affected regeneration on clearcuttings. Those species appeared to be less important than the environmental variables found to be correlated with regeneration, but they should be considered whenever clearcutting is planned.

Natural regeneration was adequate but clumpy in most of the partial cut stands sampled. It was poor on many south and southwest aspects and at elevations below 1,800 feet (549 m) in the mixed conifer type, however, especially where slopes were steep. Partial cut regeneration improved on the south and southwest aspects above 1,800 feet as overstory basal area increased, but only the amount of madrone in that overstory seemed to be positively correlated with better regeneration below 1,800 feet. Advance regeneration was not included in deriving our predictive equations. Therefore, the estimates of relative success of regeneration provided by those equations may be quite conservative on sites where preharvest seedlings and saplings exist.

Site preparation, planting techniques, and condition of the planting stock were important factors influencing the clearcut regeneration measured in this study, but they could not be evaluated in our regression analyses. Consequently, these silvicultural variables constitute unmeasured sources of error in our correlations for clearcuttings. The correlations for partial cuts were less affected by unmeasured variables, for the partial cuts were not planted. We assumed that the effects of environment were not obscured by site preparation or planting treatments and that differences in regeneration related to environmental factors were still evident among the plots sampled.

Our results reflect practices in effect 3 to 21 years before the beginning of this study, and modern regeneration techniques or improved planting stock may result in better regeneration than that indicated by our regression equations. If the new technology is applied on all sites, however, the relative differences among areas should not change with improvements in reforestation. Sites with low regression estimates should still be more difficult to regenerate than those with high regression estimates. The regression equations presented here are not intended to serve as precise, absolute indicators of numbers of future seedlings or percentages of stocking. Their purpose is to indicate where special techniques and additional effort should be considered in planning reforestation procedures.

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Appendix

Table 7—Plot summary, Illinois Valley area, southwest Oregon

(Number of plots)

Plot type	Elevation			Aspect				Slope		Soil depth			Soil coarse fragments		Brush cover			Slash burned	Density of overstory canopy		
	<1,500 ft (457 m)	1,500 3,000 ft (457-914 m)	>3,000 ft (914 m)	N	S	E	W	<40%	40%+	<20 in (51 cm)	20-40 in (51-102 cm)	>40 in (102 cm)	<35%	35%+	Sparse	Moderate	Dense		<35%	35-54%	55%+
Clearcut:																					
3,000 ft-(914-m) elevation and above			30	11	5	8	6	9	21	7	10	13	3	27	12	15	3	17	--	--	--
Below 3,000-ft (914-m) elevation	--	32		15	4	11	2	8	24	4	15	13	14	18	10	17	5	14	--	--	--
Partial cut:																					
Mixed conifer	4	40	5	16	11	12	10	15	34	--	21	28	18	31	30	16	3	--	9	28	12
True fir	--	--	7	--	1	4	2	3	4	1	1	5	--	7	4	3	--	--	2	3	2

Table 8—Pertinent data for clearcuttings at elevations between 3,000 and 4,900 feet (914 and 1 494 m), Illinois Valley Area, southwest Oregon[1/]

Plot number	Location (T.R.S.)	Elevation	Slope	Aspect azimuth	Aspect index	Regeneration index 2/	Slash burned	Soil coarse fragments 2/
		Feet 3/	Percent	Degrees				Percent
19	38-7-1	3,100	48	78	48	5.60	No	50
21	39-6-19	3,200	45	53	50	6.83	No	70
22	38-7-25	3,250	57	347	97	5.60	Yes	85
27	39-7-11	3,650	55	188	30	4.75	No	46
28	39-7-15	3,200	64	107	27	4.00	Yes	45
30	39-7-9	3,000	54	204	20	2.00	Yes	20
32	39-7-9	3,100	37	308	67	5.40	No	65
34	39-7-9	3,100	45	158	43	1.50	Yes	49
36	39-7-3	3,350	30	350	87	7.00	No	55
39	39-7-11	4,100	54	119	33	4.00	No	54
40	39-7-11	4,300	54	105	34	6.60	Yes	60
41	39-7-13	3,350	36	160	50	7.00	No	20
45	39-6-4	3,650	56	215	15	5.00	Yes	38
46	39-6-9	4,000	61	273	18	4.00	Yes	55
47	39-6-6	4,000	35	360	90	7.14	Yes	84
48	39-6-6	3,750	58	93	34	7.75	Yes	38
49	39-6-3	4,800	41	291	48	8.00	Yes	38
50	39-6-3	4,800	46	321	74	8.00	No	44
51	39-6-9	4,750	42	309	65	6.17	Yes	24
52	39-6-9	4,800	27	351	84	8.50	No	40
53	39-6-9	4,200	38	321	74	8.00	No	51
54	39-6-9	4,100	25	303	66	7.83	No	59
55	39-6-8	4,200	45	17	91	8.13	Yes	59
56	39-6-8	4,100	40	131	46	3.80	Yes	75
57	39-6-6	4,600	56	100	34	2.80	Yes	64
58	39-6-6	4,700	38	16	89	6.86	Yes	61
59	39-6-5	4,000	51	305	64	4.50	No	59
60	39-6-6	4,150	35	325	78	5.50	Yes	66
61	39-6-6	4,600	45	116	40	1.33	No	60
62	39-6-6	4,900	55	102	34	3.33	Yes	64

1/ Variables used in the regression equations.
2/ Data from adjacent undisturbed stands representing preharvest conditions.
3/ To obtain elevation in meters, multiply by 0.3048.

Table 9—Pertinent data for clearcuttings at elevations between 1,500 and 2,900 feet (457 and 884 m), Illinois Valley Area, southwest Oregon[1/]

Plot number	Location (T.R.S.)	Elevation	Radiation index	Regeneration index	Shrub cover 2/	Grass cover 2/	Moss cover 2/	Rock plus gravel cover 2/	Soil carbon 2/	Soil depth class 3/
		Feet 4/			- - - - - - - - - - - -	-	-Percent-	- - - - - - - - - - - -		
1	38-7-31	1,500	0.4703	7.14	15	1	26	17	1.06	D
2	39-8-1	1,850	.3491	4.20	8	1	24	51	1.40	S
3	39-7-35	2,650	.2841	6.17	8	5	20	35	1.61	M
4	39-8-1	1,900	.3670	4.20	41	1	12	41	2.22	M
5	39-8-1	2,650	.4678	8.50	2	0	2	31	1.79	D
6	39-8-1	2,750	.5058	5.50	3	2	1	50	1.58	D
7	39-8-1	2,450	.2606	6.71	5	0	4	47	1.82	D
8	39-7-35	2,500	.2491	7.86	2	1	10	49	1.34	M
9	39-7-35	2,900	.2618	6.67	6	4	17	49	1.51	M
10	38-8-25	1,900	.4271	7.25	4	14	3	35	1.20	D
11	38-8-25	1,950	.5138	6.78	8	1	10	40	1.61	M
12	38-6-8	2,400	.2563	7.00	3	1	22	63	1.46	M
13	38-6-8	2,300	.4272	4.83	36	0	1	30	1.62	M
14	39-7-5	2,050	.3503	7.25	68	0	9	60	1.52	D
15	39-7-5	2,450	.5333	6.33	1	0	1	12	1.73	D
16	38-7-35	2,700	.3246	7.83	5	1	24	29	2.07	D
17	38-7-35	2,900	.2821	7.57	2	1	31	67	2 46	M
18	38-7-1	2,800	.2819	5.40	2	1	21	70	3.20	S
20	38-6-19	2,500	.3365	7.75	5	1	15	45	1.37	M
23	38-6-19	2,900	.2706	6.40	7	1	62	73	1.95	M
24	38-7-25	2,800	.3914	5.40	2	1	36	85	2.19	S
25	38-7-25	2,800	.3654	6.00	11	0	52	83	1.34	M
26	28-7-23	2,800	.2667	4.17	1	2	5	50	1.92	S
29	39-7-9	2,800	.5891	1.50	1	1	1	53	1.86	M
31	39-7-9	2,800	.5714	2.50	4	0	1	42	2.54	M
33	38-7-35	2,700	.2389	6.90	3	1	44	21	1.73	D
35	39-7-4	2,550	.2073	5.80	7	0	8	18	1.55	D
37	39-7-3	2,550	.2720	6.14	8	1	24	75	4.86	D
38	39-7-3	2,400	.3162	6.50	12	1	31	52	5.15	D
42	39-7-13	2,600	.5685	7.25	13	0	9	57	2.20	M
43	40-7-12	2,200	.5096	5.40	5	1	13	22	0.58	D
44	40-7-12	2,200	.3573	7.38	14	0	71	39	1.34	M

1/ Variables used in the regression equations.
2/ Data from adjacent undisturbed stands representing preharvest conditions.
3/ D = deep (more than 40 inches or 102 cm); M = moderate (20-40 inches or 51-102 cm); S = shallow (<20 inches or <51 cm).
4/ To obtain elevation in meters, multiply by 0.3048.

Table 10—Pertinent data for partial cuts in the mixed conifer type, Illinois Valley area, southwest Oregon[1/]

Plot number	Location (T.R.S.)	Slope	Regeneration index	Moisture index	Overhead canopy	Soil depth class 2/	Silt plus clay cover
		Percent			Percent		Percent
1	38-7-11	19	6.80	9.33	64	D	20
2	39-8-3	50	8.25	9.50	53	D	23
3	38-8-25	52	7.25	7.67	45	M	35
4	38-6-7	60	10.40	8.89	51	M	17
5	38-7-11	28	8.25	7.29	68	D	17
6	38-7-1	53	12.50	9.00	40	D	20
7	38-6-6	46	17.40	11.00	49	D	24
8	38-6-8	70	13.43	11.75	18	M	17
9	38-7-29	57	7.60	7.14	61	D	30
10	38-7-31	38	8.25	6.00	34	M	25
11	39-7-3	46	21.00	12.10	47	D	5
12	39-7-3	58	17.25	10.75	41	M	21
13	38-7-22	74	13.71	9.89	31	M	16
14	38-7-23	60	3.75	7.00	32	M	34
15	38-7-21	39	9.33	6.88	66	D	27
16	39-7-21	23	7.60	6.88	56	M	19
18	40-7-11	19	14.40	10.89	46	D	28
19	39-8-33	10	11.20	7.00	57	D	6
20	40-7-14	27	12.83	6.33	48	D	32
21	37-7-33	37	8.25	8.20	62	M	31
22	40-8-10	40	7.60	9.00	67	D	9
23	39-7-11	51	21.00	12.00	14	M	8
27	39-7-35	71	12.50	8.57	41	M	21
28	38-7-29	58	15.17	9.50	48	M	16
29	38-7-25	61	12.50	9.89	44	M	26
30	39-7-4	48	14.40	9.40	35	D	16
31	39-7-5	51	13.43	7.14	35	D	29
32	40-7-12	25	17.40	9.38	44	D	25
33	38-7-13	15	8.25	6.00	58	M	26
34	38-7-29	32	7.60	6.17	50	D	29
35	40-8-21	25	7.60	10.60	70	D	23
36	38-7-13	66	11.43	10.29	39	M	41
37	39-6-4	44	17.40	13.75	38	D	20
38	37-7-15	46	8.25	7.67	52	D	12
39	37-6-29	58	17.60	11.75	43	D	8
40	37-7-5	50	8.25	7.14	53	D	13
41	38-7-2	68	17.00	9.86	34	D	16
42	37-7-20	56	12.50	9.13	47	M	16
43	39-8-1	54	7.60	7.67	38	M	30
44	37-6-29	54	10.80	9.50	43	M	21
45	37-7-21	46	3.33	6.75	48	M	11
46	38-7-31	39	10.60	10.00	31	D	37
47	39-7-5	58	14.40	9.25	28	D	35
48	39-7-4	79	12.75	11.00	23	M	10
49	40-7-3	44	8.25	4.80	51	M	23
51	39-6-4	13	21.00	12.20	53	D	17
52	40-8-24	56	7.60	5.00	55	D	23
53	38-7-15	48	14.40	9.50	55	D	35
56	38-8-25	50	7.75	6.40	36	M	32

1/ Variables used in the regression equation.
2/ D = deep (more than 40 inches or 102 cm); M = moderate (20-40 inches or 51-102 cm).

Table 11—Observed and predicted values for the number of postharvest seedlings on clearcut plots, Illinois Valley area, southwest Oregon

Plot number	Elevation	Observed value	Predicted value: Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (5)
	Feet 1/	Number of seedlings per acre 2/					
1	1,500	242	--	--	526	649	643
2	1,850	200	--	--	0	125	198
3	2,650	417	--	--	520	324	357
4	1,900	142	--	--	154	16	156
5	2,650	1,250	--	--	918	925	629
6	2,750	325	--	--	258	491	526
7	2,450	591	--	--	481	833	788
8	2,500	458	--	--	558	725	491
9	2,900	375	--	--	497	449	402
10	1,900	258	--	--	151	250	229
11	1,950	392	--	--	413	416	239
12	2,400	650	--	--	361	624	544
13	2,300	142	--	--	300	116	110
14	2,050	409	--	--	303	433	337
15	2,450	658	--	--	741	658	577
16	2,700	1,250	--	--	1,002	876	814
17	2,900	783	--	--	746	675	578
18	2,800	417	--	--	473	333	274
19	3,100	475	666	649	--	--	--
20	2,500	566	--	--	613	649	28
21	3,200	458	750	683	--	--	--
22	3,250	758	816	874	--	--	--
23	2,900	491	--	--	595	524	724
24	2,800	242	--	--	222	266	267
25	2,800	150	--	--	276	441	598
26	2,800	58	--	--	168	175	176
27	3,650	375	525	500	--	--	--
28	3,200	508	316	317	--	--	--
29	2,800	50	--	--	0	0	175
30	3,000	108	242	399	--	--	--
31	2,800	92	--	--	145	0	200
32	3,100	292	608	633	--	--	--
33	2,700	1,250	--	--	995	833	1,005
34	3,100	125	123	317	--	--	--
35	2,550	317	--	--	637	749	839
36	3,350	1,250	950	974	--	--	--
37	2,550	601	--	--	776	699	837
38	2,400	1,250	--	--	1,107	691	814
39	4,100	475	458	475	--	--	--
40	4,300	200	316	175	--	--	--
41	3,350	1,116	858	849	--	--	--
42	2,600	325	--	--	587	449	188
43	2,200	283	--	--	291	508	606
44	2,200	850	--	--	854	574	688
45	3,650	108	200	133	--	--	--
46	4,000	392	75	21	--	--	--
47	4,000	641	574	533	--	--	--
48	3,750	725	591	433	--	--	--
49	4,800	367	574	449	--	--	--
50	4,800	1,250	1,133	1,091	--	--	--
51	4,750	433	775	841	--	--	--
52	4,800	1,250	1,091	1,074	--	--	--
53	4,200	1,175	991	933	--	--	--
54	4,100	550	650	558	--	--	--
55	4,200	775	950	908	--	--	--
56	4,100	167	12	28	--	--	--
57	4,600	167	92	142	--	--	--
58	4,700	1,250	758	774	--	--	--
59	4,000	641	683	741	--	--	--
60	4,150	150	483	541	--	--	--
61	4,600	317	233	408	--	--	--
62	4,900	192	108	133	--	--	--

1/ To obtain elevation in meters, multiply by 0.3048.
2/ To obtain number of seedlings per hectare, multiply by 2.47105.

Table 12—Observed and predicted values for percent stocking of postharvest seedlings on partial cut plots in the mixed conifer type, Illinois Valley area, southwest Oregon

Plot number	Observed value	Predicted value
	- - - Percent stocking - - -	
1	97	80
2	70	66
3	43	32
4	50	43
5	53	47
6	43	51
7	63	47
8	43	76
9	40	28
10	20	29
11	73	63
12	30	37
13	67	46
14	63	44
15	13	25
16	70	42
18	50	67
19	67	54
20	23	13
21	20	34
22	60	73
23	83	65
27	10	28
28	3	33
29	7	40
30	50	56
31	37	21
32	43	38
33	17	24
34	30	34
35	100	82
36	60	36
37	80	88
38	30	58
39	87	68
40	30	49
41	50	43
42	70	41
43	30	38
44	77	51
45	57	61
46	53	64
47	47	36
48	77	71
49	7	6
51	43	62
52	17	14
53	17	28
56	7	24