Development of Vegetation After Fire, Seeding, and Fertilization on the Entiat Experimental Forest

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INTRODUCTION

FIRE plays an important role in the development, maintenance, and perpetuation of most forested communities of the Pacific Northwest. Ponderosa pine and Douglas-fir forests in north-central Washington are no exception. This region is highly susceptible to fire because of the hot, dry summer climate, steep topography, and explosive flammability of sclerophyllous understory vegetation such as snowbrush ceanothus (*Ceanothus velutinus* Dougl.). Periodicity of fires in the ponderosa pine zone of eastern Washington and Oregon appears to be 18-25 years (Keene, 1940; Daubenmire and Daubenmire, 1968).

After a severe forest wildfire, it is desirable to establish vegetal cover as soon as possible to reduce soil erosion and restore soil-plant nutrient cycles. Both objectives are important for maintaining productivity of forested ecosystems. Restoration of nutrient cycles may be especially important because many nutrient elements once incorporated into biomass and litter materials are converted to oxides upon combustion and scattered as ash. In this form they may be

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susceptible to leaching and erosion loss from the system (Grier, 1972).

Native vegetation of this region is well adapted to regrow after fire. Species such as willow (*Salix* spp.), snowbrush ceanothus, bracken fern (*Pteridium aquilinum* (L.) Kuhn.), birchleaf spiraea (*Spiraea betulifolia* Pall.), and pinegrass (*Calamagrostis rubescens* Buckl.) sprout in profusion after fire. Also germination of snowbrush ceanothus seed is triggered by fire (Gratkowski, 1962).

Despite the apparent ability of native species to revegetate burned areas, the regrowth may be too slow or the density of plants too sparse to provide immediate soil stability and restore nutrient cycles. For this reason, erosion control seeding procedures are implemented immediately after fire. The recommended procedure is to seed 5 to 10 lbs/acre (5.6 to 11.2 kg/ha) of grass and legume seed into the ashes in the late summer or fall after the fire (Friedrich, 1947; Rummell and Holscher, 1955; Lavin and Springfield, 1955).

To date, however, there is little documentation of the regrowth of native species after fire in the ponderosa pine/Douglas-fir zone or success of erosion control seeding and fertilization in the Pacific Northwest.

Our field observations indicate that seeding and fertilization efforts have met with uncertain success in the past. Climate and soil condition are probably the principal reasons for failure of seeding efforts. In eastern Washington, frost heaving in the early spring, rapid soil drying in late spring, and high soil temperatures in mid-summer are important factors that limit success of seeding ventures. Another reason for failures may be a deficiency of nitrogen and sulfur in the soil which we have documented for many soils of this region (Klock, Geist, and Tiedemann, 1971; Tiedemann, 1972). Such deficiencies may be amplified by gaseous losses of nitrogen and sulfur contained in plant litter. DeBell and Ralston (1970) have estimated that 62 percent of the nitrogen in pine litter is released upon ignition.

The lack of information regarding vegetative succession and the variable success of erosion control seeding and fertilization prompted us to initiate a study to:

(1) measure the rate of regrowth of native species and patterns of succession following wildfire.

(2) determine the success of seeding a prescribed erosion control seed mix relative to regrowth of native vegetation.
(3) evaluate the effect of two different sources of nitrogen and one of sulfur on regrowth of native species and growth and development of seeded species.

This paper reports the results of 4 years of study of the natural recovery of vegetation and success of erosion control seeding and fertilization on four watersheds burned by wildfire in 1970.

HISTORY AND PHYSICAL SETTING OF THE STUDY AREA

The site of the study presented in this paper is the Entiat Experimental Forest located northwest of Wenatchee, Washington. As a preface to papers in this symposium by Helvey et al. and Klock and Helvey, a detailed historical and physical description is presented as part of this paper.

The Entiat Experimental Forest was selected in 1957 as representative of much of the forested land east of the Cascade Crest. Three large contiguous watersheds, Fox, Burns, and McCree Creeks, were instrumented by 1959 to measure precipitation and water yield. Water temperature and chemistry measurements were started in 1968 and 1970, respectively. These watersheds were established with the original intent of studying the integrated hydrologic response of forested lands to specific management practices.

The watersheds are tributary to the Entiat River which drains southeast from Glacier Peak into the Columbia River. It is an area of bold and rugged relief with deeply incised streams (Fig. 1). Much of the Entiat River basin was occupied by a valley glacier during the Wisconsin stage of the Pleistocene epoch (Berndt, 1971). The glacier principally occupied elevations below 2,800 feet (850 m). As a result, tributary streams were relatively unaffected and study watersheds are hanging valleys above the main valley floor.

The experimental drainages range in size from 1,168 acres (473 ha) to 1,393 acres (564 ha) and in elevation from 1,800 feet (550 m) to 7,000 feet (2,120 m) above sea level. Mean slope is 50 percent ranging up to 90 percent. Drainage is generally southwest with aspect ranging from southeast to northwest.

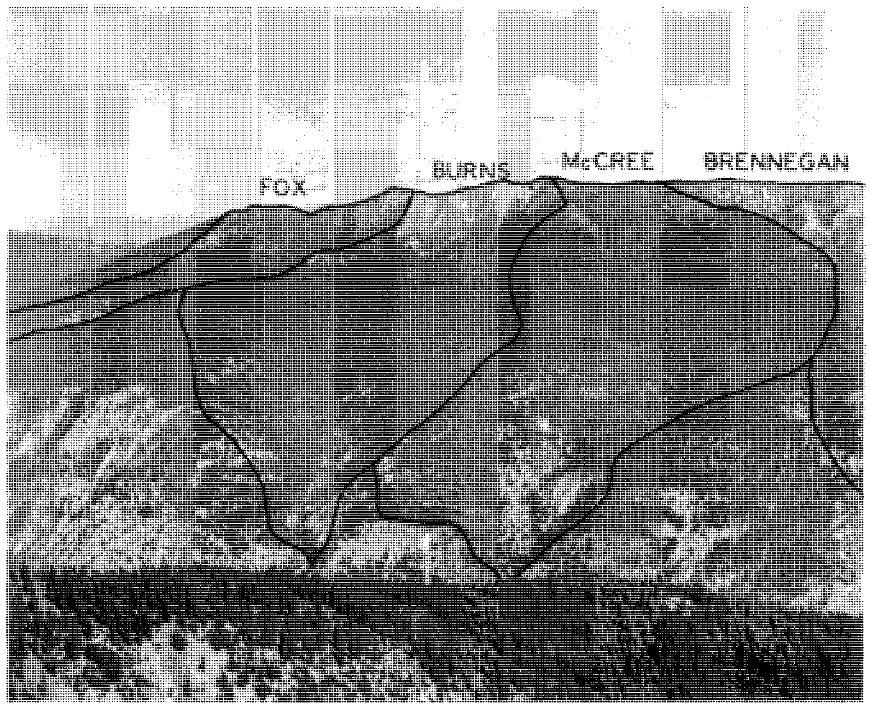

Fig. 1. The Entiat Experimental Forest is an area of bold and rugged relief with deeply incised streams.

Bedrock is principally granodiorite and quartz diorite. Lower sections of each drainage are occupied by fluvoglacial materials resulting from ice marginal deposits during the glacial period. Volcanic ash and pumice, ranging in depth from a few inches to more than 20 feet (6 m), have been deposited as a result of Glacier Peak eruptions since glaciation.

Soils are Entisols of the Choral and Rampart series. Both are well drained and moderately coarse textured.

Climate, as described by Berndt (1971) and Helvey (1972), is typical of east slopes of the Cascade Range. Mean annual temperature at 3,000 feet (920 m) is 44° F (7° C), and average annual precipitation is 22.8 inches (58 cm). Winters are moderately cold and wet, with precipitation occurring mainly as snow from November to May. Summers are hot and dry with only 10 percent of the annual precipitation occurring from June to September.

Pre-fire vegetation of the Entiat Experimental Forest at the lower, more xeric sites of 1,800- to 3,000-foot (550- to 920-m) elevation consisted of an overstory of ponderosa pine (*Pinus ponderosa* Dougl.) with an understory of bitterbrush (*Purshia tridentata* (Pursh) DC.) and serviceberry (*Amelanchier alnifolia* Nutt.) (Tiedemann and Klock 1973). Arrowleaf balsamroot (*Balsamorhiza sagittata* (Pursh) Nutt.), bracken fern, spreading dogbane (*Apocynum androsaemifolium* L.), and bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Sm.) were prominent herbaceous species. Lower elevations are probably representative of the *Pinus ponderosa/Purshia/Agropyron* habitat type described by Daubenmire and Daubenmire (1968).

At intermediate and higher elevations of 3,000 to 5,500 feet (920 to 1,675 m), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) became more prominent, often occurring in almost pure stands on moister sites. Lodgepole pine (*Pinus contorta* Dougl.) normally occurred only in small, dense thickets on these sites. However, a large area on the southwest slope of Fox Creek was an almost pure stand of "doghair" lodgepole pine. Snowbrush ceanothus, willow, and Sitka alder (*Alnus sinuata* (Reg.) Rydb.) were common shrubs at intermediate elevations. Halfshrubs (low shrubs) consisted primarily of Oregon boxwood (*Pachistima myrsinites* (Pursh) Raf.), birchleaf spiraea, prince's pine (*Chimaphila umbellata* (L.) Bart.), and Kinnikinnick (*Arctostaphylos uva-ursi* (L.) Spreng.). Principal herbaceous species were pinegrass, Ross sedge (*Carex rossii* Boott), spiraea, dogbane, and bracken fern. Intermediate elevations are characteristic of the *Pseudotsuga menziesii/Calamagrostis rubescens* habitat type described by Daubenmire and Daubenmire (1968). At elevations over 5,800 feet (1,770 m), whitebark pine (*Pinus albicaulis* Engelm.) was common.

The possibility of achieving original research objectives for these three watersheds was abruptly ended on August 24, 1970, when a dry lightning storm swept north-central Washington, igniting numerous lightning fires. By the end of the first day, the entire Experimental Forest had been severely and uniformly burned. In terms of original objectives, the fire represented a significant loss to the scientific community. However, because of extensive pre-fire data, the fire provided a unique opportunity to assess the effects of severe wildfire on vegetation, soils, water, and climate of forests of the east Cascades. Studies either continued or initiated since the fire include water yield, water temperature, water chemistry, soil moisture, soil surface temperatures, natural recovery of vegetation, effectiveness of erosion control seeding and fertilization, and effects of five methods of post-fire salvage logging on soils and vegetation.

For the purpose of water quality studies, Lake Creek, a watershed adjacent to Fox Creek on the west, is being sampled as an unburned control (Table 1).

To accomplish the objectives of vegetation and salvage logging studies, it was necessary to extend measurements to Brennegan Creek, a watershed immediately to the east of McCree Creek (Table 1).

METHODS

To evaluate natural vegetative regrowth and succession, the Fox Creek watershed of the Entiat Experimental Forest was designated as the control. It remains roadless with no seeding or fertilization. Burns and McCree Creeks, the other two Experimental Forest watersheds, and Brennegan Creek, an adjacent 1,828-acre (740-ha) watershed, were seeded by fixed-wing aircraft with a species mixture normally prescribed for sites similar to watersheds of the Experimental Forest (Perkins, et al. 1971). The seeding mixture resulted in application of 2 lbs/acre (2.2 kg/ha) Latar orchardgrass (*Dactylis glomerata* L.), 1 lb/acre (1.1 kg/ha) durar hard fescue (*Festuca ovina* var. *duriuscula* (L.) Koch), 1 lb/acre Drummond timothy (*Phleum pratense* L.), 1 lb/acre perennial ryegrass (*Lolium perenne* L.). and 1 lb/acre yellow sweetclover (*Melilotus officinalis* (L.) Lam.). Burns Creek was fertilized by helicopter with 249 lbs/acre (280 kg/ha) of ammonium sulfate (equivalent to 51 lbs/acre or 57 kg/ha of elemental nitrogen). McCree Creek received 105 lbs/acre (118 kg/ha) of urea (equivalent to 48 lbs/acre or 54 kg/ha of elemental nitrogen). Brennegan Creek was not fertilized.

Foliar cover of each species was measured on permanent belt

TABLE 1. Treatments applied to watersheds of the Entiat Experimental Forest and two adjacent watersheds since the 1970 wildfire.

Lake Creek	Fox Creek	Burns Creek	McCree Creek	Brennegan Creek
Unburned; control	Burned; no other treatments	Burned; seeded with orchardgrass, timothy, hard fescue, perennial rye, and yellow sweetclover; fertilized with 51 lb/acre (57 kg/ha) of N as ammonium sulfate; logged by tractor over snow and by helicopter	Burned; seeded with orchardgrass, timothy, hard fescue, perennial rye, and yellow sweetclover; fertilized with 48 lb/acre (54 kg/ha of N as urea; logged by tractor over snow and by helicopter	Burned; seeded with orchardgrass, timothy, hard fescue, perennial rye, and yellow sweetclover; not fertilized; logged by high lead, jammer, skyline, helicopter, and tractor

transects established midslope on the south- and west-facing aspects of each watershed. Transect dimensions are 2 feet by 44 feet (0.6 m by 13.3 m). Transects were established systematically from a random start at intervals of 600 feet (197 m) between elevations of 5,600 and 2,400 feet (1,700 and 730 m). Transect orientation conforms to the contour, with steel posts used to mark head and tail stakes. Transects on Fox and Burns Creeks were established immediately following the fire in September 1970. Those on McCree and Brennegan Creeks were established in July and August 1971 at the time the first measurements were taken. Total number of transects is 121.

Vegetal cover was measured as a vertical projection of foliar material onto the ground surface for each species within a 1-ft- (0.3-m-) wide belt along both sides of a tape stretched between the stakes forming the transect. A 1.0-ft^2 (929-cm^2) frame divided into sections of 50-, 25-, 15-, 10-, and 5-percent cover was used to reference cover measurements. Tree seedlings and snowbrush ceanothus seedlings were counted on the transect when cover estimates were made. To account for phenological differences, transects below 3,600 feet (1,100 m) were measured between mid-July and August 10, 1971. Those above this elevation were measured between August 10 and September 1.

RESULTS AND DISCUSSION

By the end of the first growing season after the fire (1971), an average of 8.6 percent of the ground was covered by foliar material of native and seeded species on the four watersheds. The most salient features of the first-year vegetation were the dominance of native species and the rapid development of orchardgrass (Fig. 2). Although most of the native plants sprouted from rhizomes, lignotubers (basal buds of shrubs), bulbs, or other underground organs, native annual plants were abundant on many of the lower elevation transects; and the entire area abounded with snowbrush ceanothus seedlings from seed triggered by fire. Native species retained dominance in vegetative cover during the entire 4 years of study comprising 67 to 78 percent of the total vegetative cover.

During the second year (1972), growth was striking—average

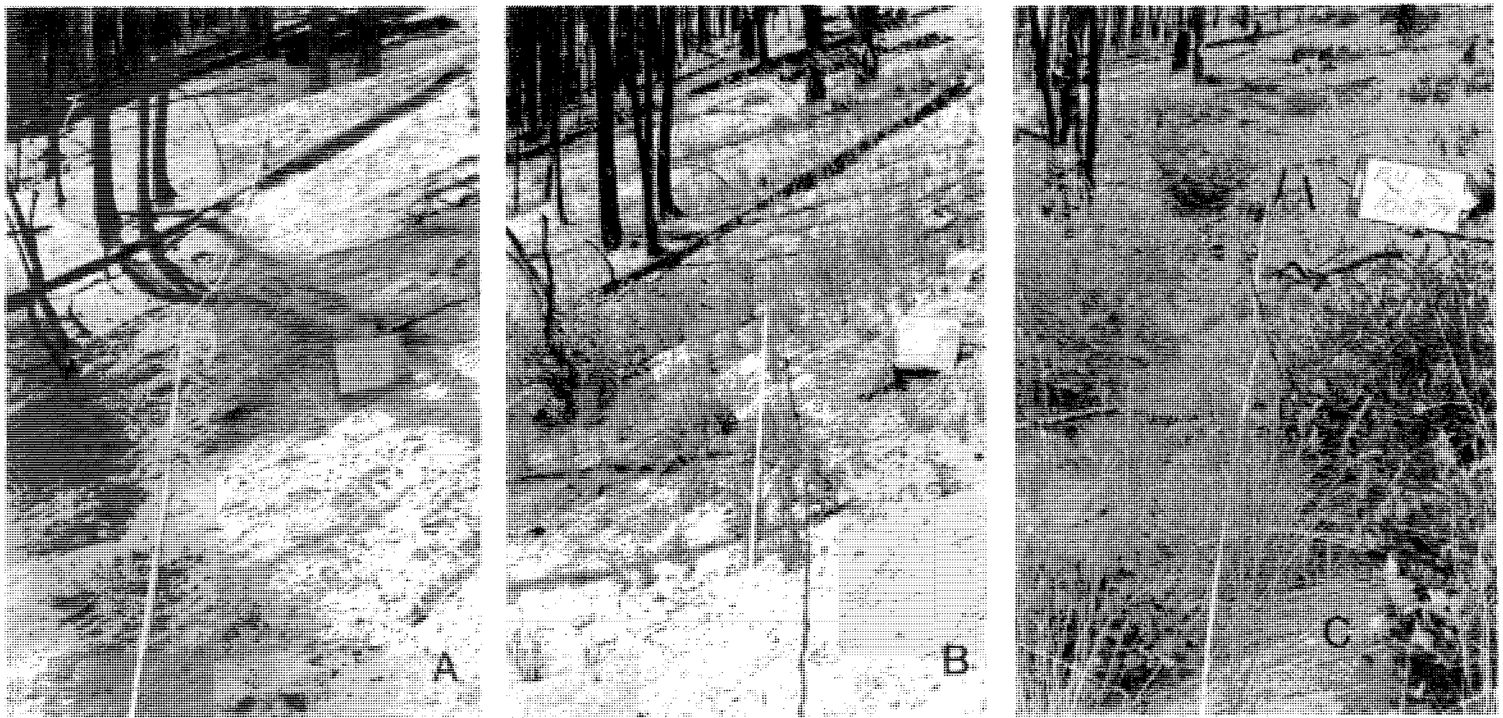

Fig. 2. Development of vegetation on a representative transect on the south aspect of Burns Creek (seeded and fertilized with ammonium sulfate). Grass plants in the foreground of 1971 are orchardgrass. Shrubs became dominant in 1974. *A*, 1970; *B*, 1971; *C*, 1974.

vegetative cover more than doubled to 19.6 percent. Development of vegetation slowed in 1973 with average cover reaching only 22.1 percent. In the 1974 growing season, vegetation growth resumed its earlier rapid development; and average vegetative cover increased to 31.2 percent.

Rapid vegetative development observed during 1971 and 1972 was probably a result of greater than normal winter precipitation during both years. In the winter of 1970-1971, precipitation exceeded 31 inches (79 cm) and in winter 1971-1972, 45 inches (114 cm). Precipitation during the winter of 1972-1973 was only 17 inches (43 cm), resulting in poor vegetation development during the summer of 1973. Precipitation in 1973-1974 was greater than 31 inches (78 cm) and vegetation responded accordingly.

Total vegetative cover the first year was similar among seeded watersheds, ranging from 7.5 percent on McCree Creek to 10.8 percent on Burns Creek. Fox Creek, the control watershed, had the lowest vegetative cover of any watershed—5.6 percent (Fig. 3).

Although average vegetative cover of Fox Creek remained lower than on seeded watersheds during the entire 4 years of study, the maximum difference in cover among watersheds narrowed to 6 percent by 1974.

Despite their more xeric situation, south aspects had slightly higher vegetative cover than west; and it appears that vegetative development is proceeding at a faster rate than on west-facing slopes (Fig. 4). Part of the reason for the difference in average cover (averaged for the four watersheds) by aspect is the extremely low cover on the west aspect of Fox Creek (2.2 percent the first year after fire). Average cover was 9.3 percent for the 4 years of study, compared with 18.8 to 20.2 percent for the other three watersheds (Table 2). Understory vegetation on the west face of Fox Creek was probably sparse before the fire because much of this aspect was occupied by a dense stand of lodgepole pine. Also, bark was burned to the cambium on many stems, indicating that the fire reached extreme temperatures, possibly killing much of the understory vegetation.

Development of vegetation on south aspects was similar among watersheds, despite the variety of treatments imposed. During the

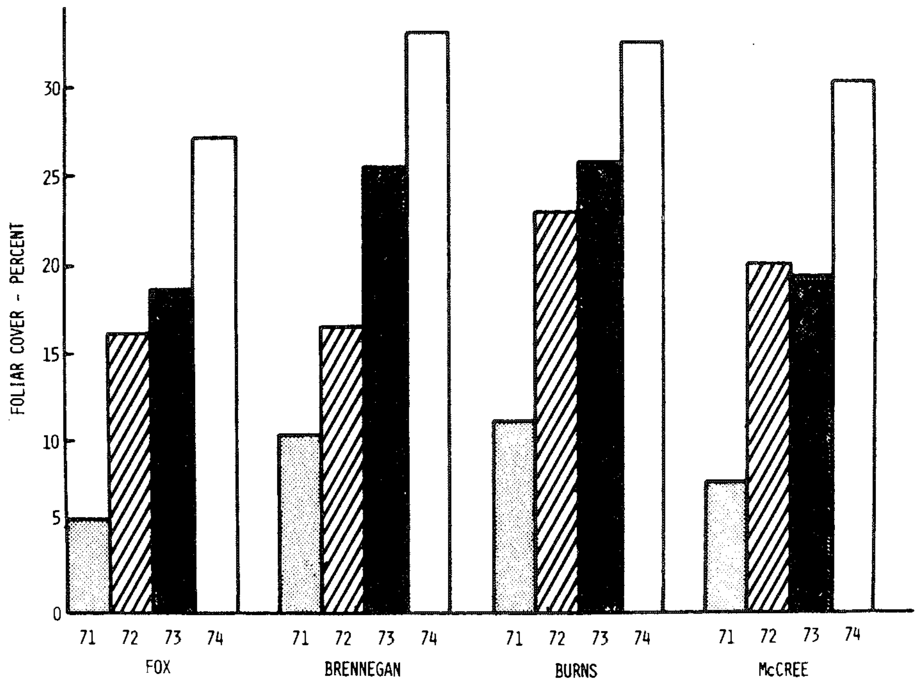

Fig. 3. Development of vegetation cover on study watersheds over a 4-year period.

TABLE 2. Vegetative cover by aspect on each watershed during the 4 years of study.

	Fox		Brennegan		Burns		McCree	
	S	W	S	W	S	W	S	W
	Percent							
1971	8.7	2.2	10.8	9.8	11.6	10.0	8.8	6.3[1/]
1972	26.1	6.2	18.6	14.2	26.9	19.1	18.5	21.5
1973	26.6	10.7	26.4	24.0	28.7	21.8	18.9	19.2
1974	35.9	18.2	37.4	28.6	34.4	30.1	32.3	28.0
Mean	24.3	9.3	23.3	19.1	25.4	20.2	19.6	18.8

[1/]Simple average of values across an individual year does not equal average total cover because of different number of transects on each watershed and aspect.

first year after fire, south aspect cover varied from 8.7 percent on Fox Creek to 11.6 percent on Burns Creek. When the 4 years are averaged, cover was essentially the same on the south aspects of the four watersheds (19.6 to 25.4 percent).

Aspect affinity of certain species is helpful in explaining differences in recovery between aspects. Snowbrush ceanothus is responsible for most of the difference in total cover between aspects. In 1974 average snowbrush ceanothus cover on south aspects was 12.7 percent compared to 6.0 percent on west aspects (Table 3). Although aspect differences were not as striking as for snowbrush ceanothus, bracken fern, Ross sedge, and pinegrass had greater vegetative cover on south aspects than on west.

Species with an affinity for west aspects include Sitka alder, willow, fireweed (*Epilobium angustifolium* L.) and birchleaf spiraea. Both timothy and hard fescue reached their best cover development on the west aspects.

With the exception of pinegrass, our results for vegetation distribution by aspect agree closely with those described by Mueggler (1965). He observed an affinity of alder for north slopes. Snowbrush ceanothus and bracken fern preferred southerly exposures. Distribu-

TABLE 3. Effect of aspect on development of native and seeded species in 1974.

	West	South
	Foliar cover (percent)	
Bracken fern	1.6	3.8
Spreading dogbane	1.6	1.4
Fireweed	1.6	0.7
Hard fescue	1.9	1.0
Orchardgrass	3.4	3.8
Pinegrass	0.3	1.7
Snowbrush ceanothus	6.0	12.7
Ross sedge	0.4	0.9
Birchleaf spiraea	2.2	1.6
Timothy	0.4	0.2
Alder	1.2	(1/)
Willow	2.6	1.1

1/Less than 0.1-percent cover.

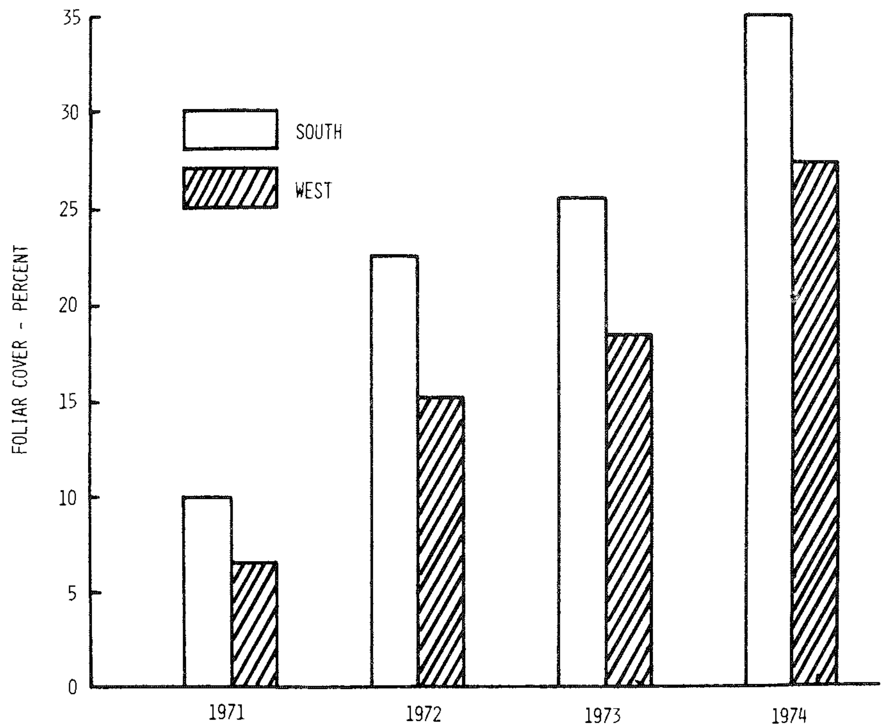

Fig. 4. Effect of aspect on recovery of vegetation after fire, seeding, and fertilization.

tions observed on the Entiat watersheds are similar, with alder showing a preference for the relatively cooler, more mesic west exposure, and snowbrush, and bracken fern, an affinity for the more xeric south slopes. Mueggler detected no aspect preference for pinegrass, but we found it to have an affinity for the southerly exposures.

Vegetation recovery was also closely tied to elevation. Cover was greater at elevations below 3,800 feet (1,150 m) than at higher elevations during all 4 years of study (Fig. 5). Elevation differences in vegetative cover appear to be largely the result of distribution of bracken fern and snowbrush ceanothus. Both had substantially greater cover at elevations below 3,800 feet (1,150 m) than at higher elevations (Table 4). Pinegrass and Ross sedge also reached their

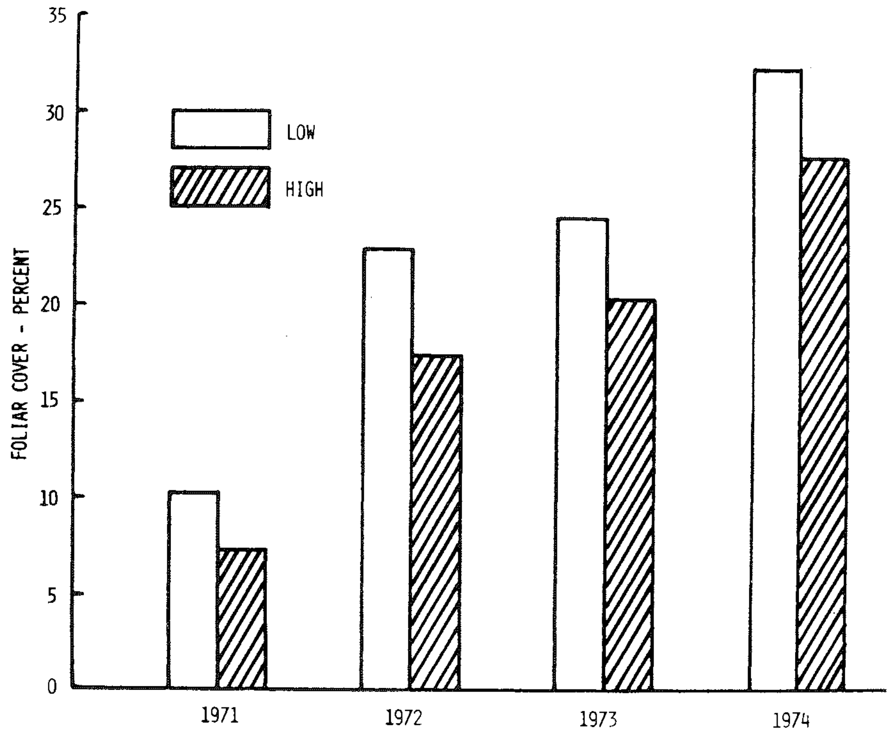

Fig. 5. Development of vegetation at low (730 to 1,150 m) and high (1,150 to 1,700 m) elevations.

best cover development at lower elevations. Birchleaf spiraea and hard fescue cover, in contrast, were greater at elevations above 3,800 feet (1,150 m). Orchardgrass and timothy cover were the same at low and high elevations. A more detailed description of species distribution by elevation and aspect on the four burned watersheds is provided by Tiedemann and Klock (1973).

Vegetative cover provided by each of the three classes of vegetation was similar during the first year, with forbs providing slightly more cover than grasses and grasslike or shrubs (Fig. 6). In 1972 both the grass-grasslike and forb classes provided substantially more cover than the shrub class. Shrub cover became equal to the other

TABLE 4. Elevation affinity of several native and seeded species in 1974.

	Low[1]/	High[2]/
	Foliar cover (percent)	
Bracken fern	6.2	1.0
Spreading dogbane	1.9	1.3
Fireweed	0.4	1.5
Hard fescue	0.9	1.6
Orchardgrass	2.9	3.0
Pinegrass	1.5	0.8
Snowbrush ceanothus	13.4	7.4
Ross sedge	1.1	0.6
Birchleaf spiraea	0.6	2.5
Timothy	0.2	0.3
Alder	0.4	0.7
Willow	2.0	1.7

[1]/730-1,150 m elevation.
[2]/1,150-1,700 m elevation.

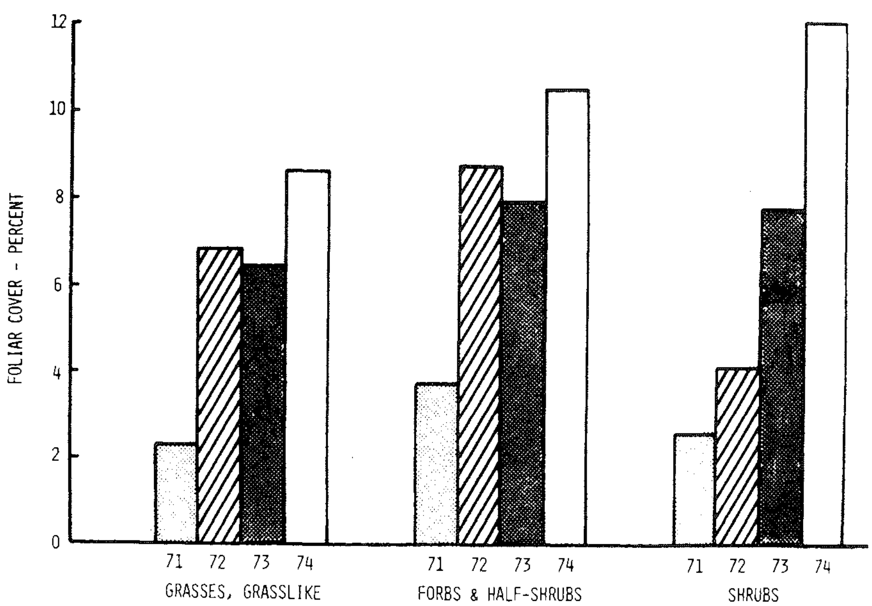

Fig. 6. Average cover of three classes of vegetation during 4 years of study.

two classes of vegetation in 1973, and by 1974 shrubs had developed to the point that they clearly dominated the vegetative cover.

Evaluation of recovery patterns of individual species shows that snowbrush ceanothus and Ross sedge increased in cover during each of the 4 years of study (Table 5). Snowbrush ceanothus cover now occupies nearly 10 percent of the ground surface. Cover values for bracken fern, spreading dogbane, fireweed, and pinegrass have been nearly static since the second year.

Orchardgrass developed rapidly on seeded watersheds, increasing from 1.6-percent vegetative cover the first year to nearly 5 percent in 1972 (Table 6). Orchardgrass cover was static between 1972 and 1974. Hard fescue cover by contrast increased from 0.3 to 2.4 percent between 1971 and 1974. Cover of timothy increased between 1971 and 1972 and then declined. Perennial rye and yellow sweet-clover provided less than 0.1-percent cover in 1971 and 1972 and were not found in the transects in 1973 and 1974.

One indication of the success of seeding was the fact that seeded species comprised one-fourth to one-third of the total cover during the 4 years of study.

However, the relatively low average cover values of seeded species may not be a true indication of the effectiveness of erosion control seeding. Average cover in 1974 was less than 8 percent, but maximum cover of seeded species was 29 percent and cover exceeded 10 percent on more than one-third of the transects. On many sites where cover of native understory species was sparse, seeded species provided most of the foliar cover. Typically, these were sites on

TABLE 5. Recovery of several native species after wildfire. Average cover on four watersheds.

	1971	1972	1973	1974
	Foliar cover (percent)			
Bracken fern	1.6	3.5	2.8	2.7
Snowbrush ceanothus	0.9	3.0	6.0	9.4
Spreading dogbane	0.9	1.4	1.1	1.5
Fireweed	0.2	0.9	0.9	1.1
Pinegrass	0.7	1.2	1.0	1.0
Ross sedge	0.1	0.3	0.5	0.7

TABLE 6. Average foliar cover of seeded species after wildfire on three seeded watersheds.

	1971	1972	1973	1974
		Percent		
Latar orchardgrass	1.6	4.9	4.2	5.0
Durar hard fescue	0.3	1.1	1.6	2.4
Drummond timothy	0.2	0.8	0.4	0.3
Perennial rye	(1/)	(1/)	0	0
Yellow sweetclover	(1/)	(1/)	0	0
Total	2.2	6.7	6.2	7.7
Percent of total cover comprised by seeded species	22	33	26	23

1/Less than 0.1-percent cover.

westerly aspects at elevations above 3,500 feet (1,070 m) occupied prior to fire by moderately dense lodgepole pine or Douglas-fir.

In the field, we noted an apparent inverse relationship between cover of native and seeded species, and plotted cover data from individual transects for seeded species (y) as a function of cover of native species (x). Cover of seeded species tended to decline as cover of native species increased, but a regression analysis yielded and r^2 value of only 0.36.

Development of individual species can be evaluated in terms of their performance described by Hafenrichter et al. (1968). Latar orchardgrass and durar hard fescue performed as described. However, the failure of perennial ryegrass was a surprise because it is described as a rapid-developing, short-lived grass. Drummond timothy is described as a meadow grass that can be used to provide ground cover on burned-over lands. In our study, timothy did not develop as expected. The poor performance of yellow sweetclover was anticipated because it is described as being best adapted to irrigation situations and to soil types other than those encountered on the study area.

Cover values indicate that fertilizer was not effective in stimulating ground cover. However, vigor and height growth of seeded species were substantially greater on fertilized watersheds than on unfertilized Brennegan Creek. Thus, these plants are probably providing better nutrient recapture than unfertilized plants. Crane[2] observed up to a three-fold increase in shoot weight of seeded orchardgrass when fertilized with 200 lbs/acre (224 kg/ha) of N as urea on a burned study site in Brennegan Creek. A commensurate increase in uptake of nutrient ions essential for plant growth would be expected.

Soil binding capacity of the plants is probably improved by fertilization since roots grown under low nitrogen fertility levels tend to be long and sparsely branched and those with high nitrogen levels are short and well branched (Black 1968). Crane showed that root weight was increased by up to two times (significant at $P=0.10$) when fertilized with urea in the Brennegan study site.

Counts of tree and snowbrush ceanothus seedlings have only been summarized for the first year. Tree seedlings (mostly lodgepole pine) were encountered on nearly every transect and averaged 3,160/acre (7,800/ha). Snowbrush ceanothus seedling density was nearly 10 times greater—29,960/acre (74,000/ha).

CONCLUSIONS

Comparison of the total vegetal cover on Fox Creek (control) with that on the seeded watersheds and the fact that seeded grasses comprised 22 to 33 percent of the total cover indicate that seeding is an effective means of supplementing regrowth of native species to provide vegetal cover after wildfire.

Poor performance of perennial rye and yellow sweetclover suggest that these two species can be deleted from the seeding mix for this area under the conditions of this study at a cost saving of more than $0.50/acre ($1.34/ha) without reducing effectiveness of the seeding operation. Studies of the effectiveness of prescribed seeding mixes for other areas of the country would probably result in similar savings.

For decisions on which areas seeding is critical to restore soil

[2]Crane, W. J. B. 1971. Fire-nitrogen fertilizer interaction. Report on file at Forest Hydrology Laboratory, USDA Forest Service, Wenatchee, Wash.

stability and protect water quality, differences in recovery between aspect and elevation appear worthy of emphasis. For the Entiat Experimental Forest, recovery on southerly aspects was similar among watersheds despite the treatment. Recovery of native vegetation was probably sufficient to protect soil and water resources without seeding. On westerly aspects, recovery was slower. Poor vegetative development on the west aspect of Fox Creek (unseeded, unfertilized) was responsible for much of the difference between aspects. Although we cannot be certain that seeding and fertilization of Fox Creek would have improved cover on the west aspect, it is the type of site where seeded species grew most vigorously on the other watershed.

According to Friedrich (1947), a site such as that on the west face of Fox Creek is the type of area best suited for successful seeding. Comparison of the vegetal cover on similar sites in seeded watersheds tends to support this conclusion.

Because of rapid development of native species at elevations below 3,800 feet (1,150 m), it appears that it is more important to seed and fertilize at the higher elevations than at low elevations.

Since vegetation development after fire is closely linked to pre-fire vegetative composition, it appears desirable to develop seeding recommendations based on pre-fire vegetative composition or habitat type rather than elevation or aspect. For example, sites with pre-fire composition of snowbrush ceanothus, bracken fern, and pinegrass should be low in priority for seeding.

Cover values do not give a true indication of fertilizer effectiveness. Vigor and height of seeded species were greater on both fertilized watersheds than on the unfertilized watershed. Greater amounts of organic matter and increased root production by these plants should provide added soil protection and aid in site amelioration. Also, improved growth and increased biomass result in greater uptake and recapture of nutrient elements such as calcium and magnesium.

Two areas of future concern for seeding and fertilizer rehabilitation operations have become apparent in the course of this study.

The first is cost-effectiveness of the operation. Of the $34,800 spent on rehabilitation of Burns and McCree watersheds, $7,180 was for seeding. Some individuals may question if the additional soil binding and nutrient recapture resulting from fertilization justify the expense of $27,600. Although our transect data do not show that fertilizer was beneficial, we believe that it was an effective rehabilitation treatment. The two fertilized watersheds, Burns and McCree, suffered less erosion damage than the other two watersheds during a severe rainstorm in June 1972. Seeded species were particularly effective in stabilizing stream channel areas (Fig. 7). Different logging methods used on the watersheds influenced the amount of erosion, so true benefits gained by fertilization alone cannot be cal-

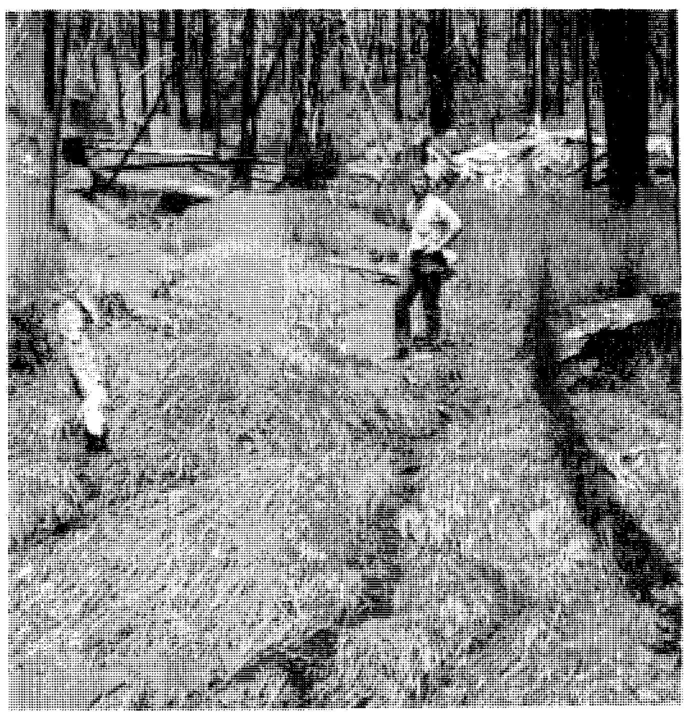

Fig. 7. Dense stand of seeded species was effective in reducing channel scouring resulting from high intensity thunderstorm.

culated.[3] Benefits were undoubtedly very large. It appears, however, that our transect measurements were not sensitive enough to detect the positive effect of fertilization. Additional research and more intense observation on the Entiat watersheds should shed more light on effectiveness of fertilization for soil and nutrient stabilization.

The other concern is the effect of seeding and fertilization on the succession of native vegetation. Orchardgrass, in particular, is a highly competitive plant. It may suppress growth of native forb and halfshrub species resulting in the eventual elimination of some of the native species. Closer examination of successional trends on individual transects may give an indication of the magnitude of this potential problem.

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