Grass-legume mixtures for erosion control along forest roads in westeren Oregon

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ABSTRACT—Attempts were made to identify legume species that would be compatible with grasses in roadside seeding mixtures for use in the mountains of western Oregon. Despite successful germination and early establishment, legumes were unable to compete with grasses and largely disappeared from most roadside stands after 1 year. Grass-legume seed, fertilizer, and straw mulch applied to road backslopes for the most part successfully halted erosion. Rates of erosion from unmulched and bare control plots during the first year after seeding were substantially higher on newly constructed backslopes than on a backslope that was several years old at the time of plot installation. Results indicated that a mulch, as well as seed and fertilizer, should be placed on roadside slopes if soil erosion is to be minimized during the first rainy season following road construction. In addition, infertile subsoils failed to maintain a viable vegetative cover and required refertilization 7 years after plots were initially seeded and fertilized. Bare, unprotected roadside slopes continued to erode at a rather constant rate throughout the course of the study. The loss amounted to about 0.2 inch of soil per year.

CONSTRUCTION of forest access roads often increases soil erosion and stream sedimentation. In steep terrain, road construction may disturb 6 to 8 percent of the area under management, and the bare roadside slopes are especially vulnerable to erosion during the first few months after construction. Fredricksen (*3*), in studying the effects of the construction of 1.65 miles of road in a 250-acre watershed in the Oregon Cascades, reported that stream sediment increased by 250 times during the first rainstorms after construction but dropped almost to preconstruction levels 2 months later.

To minimize soil movement, some sort of cover is needed on roadside slopes as soon after construction as possible. Unfortunately, natural revegetation is extremely slow on these sites because of low soil fertility and unfavorable microclimate conditions.

The Forest Service initiated a roadside grass seeding program in western Oregon and Washington about 18 years ago. Seed mixtures, fertilization treatments, and methods of application are not standardized within the agency; rather, methods vary from forest to forest and even among ranger districts.

Seedings along forest access roads often have been unsatisfactory. In many cases seeded areas were not stabilized at all or erosion was only reduced temporarily. Some of the difficulties encountered include poor germination, rolling of seed to the bottom of cut-and-fill slopes before germination, deterioration of good grass stands after 2 or 3 years, and high winter mortality due to late fall seeding.

Some basic recommendations that have been made to aid seeding success include the following:

1. Seeding should be completed in late summer or early fall, immediately after road construction.

2. Fertilizer applications should be determined by soil sample analyses.

3. Species seeded should be selected to fit the site and to produce fast initial growth for quick stabilization.

4. Inclusion of legumes with grasses for soil stabilization may improve the nitrogen economy of the soil sufficiently to produce a denser, longer lasting stand of vegetation. Preliminary legume trials (*1*) indicated that white Dutch clover, New Zealand white clover, big trefoil, and birdsfoot trefoil were suited to climatic and soil conditions in the mountains of western Oregon.

Despite the seriousness of the problem, there has been little formal research on roadside soil stabilization in the Pacific Northwest. Most information has come from experience and casual observation. This report summarizes results of exploratory field studies I began in 1964. Portions of the information presented here appeared in two progress reports (*1, 2*).

Methods

To assess the effectiveness of grass-legume mixtures in controlling soil erosion, two sets of plots were established on roadside backslopes. The first set was installed in September 1965 on a 5-year-old backslope, which was almost devoid of vegetation and obviously had been eroding. The second set of plots was established in September 1967 on a newly constructed backslope in order that the stabilizing effects of roadside treatments could be followed during the first rainy season after construction.

The experimental design (randomized block) and measurement techniques were the same for both sets of plots. Backslopes at both locations were approximately 1:1 (about 45 degrees), constructed in soils derived from tuffs and breccias. The 1965 plots were located at an elevation of 2,450 feet, the 1967 plots at 3,100 feet. Both sets of plots are located in the Blue River District of the Willamette National Forest.

Five seeding mixtures plus a control were replicated twice at both locations for a total of 12 plots at each site. Plots were 6 feet wide and extended up and down slope for the entire length of the backslope (20 to 25 feet). The five treatments applied were (1) straw mulch and fertilizer, with no seed applied; (2) Blue River District seeding mix, a mixture of four grasses and white Dutch clover; (3) Oregon Highway Department mix, consisting of three grass species plus white Dutch clover; and (4)

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and (5) two experimental mixtures of additional grass and legume species (Table 1). With the exception of the Blue River District mix, all treatments received straw mulch at the rate of 2 tons per acre.

The 1965 plots were installed in late September, the 1967 plots in late August. All treated plots were fertilized with ammonium phosphate at the rate of 400 pounds per acre, both at the time of seeding and the following spring. Control plots, of course, were untreated; and although they were virtually bare at the outset, native vegetation was allowed to invade these plots during the experiment. Figure 1 shows the 1965 plots.

Soil movement on the plots was monitored by periodic measurements of slope elevation. This involved measuring the distance to the soil surface from points on a wire cable stretched between stable, referenced positions at the top and bottom of the slopes. Use of this method minimized disturbance on the measured slope section. Elevations of 45 points (15 at 1-foot intervals along each of 3 transects) were measured in each plot. Change in slope elevation since the last measurement was computed for each point, then averaged among the 45 points to provide a single index of soil loss or gain during the measurement period.

Vegetative cover on each plot also was estimated at frequent intervals. In addition, species composition was noted and recorded.

Vegetative Cover on Plots

Vegetative treatment of roadside slopes must provide fast initial growth and quick cover to minimize soil movement. This is especially true of new slopes where the loose soil is particularly vulnerable to erosion during the first heavy rainstorms.

Figure 1. Roadside seeding plots on a 5-year-old backslope 6 months after seeding.

As shown in figure 2, plant cover on seeded plots during the first winter following seeding ranged from 15 to 45 percent. It is questionable whether such levels of plant cover would, by themselves, effectively curtail erosion. Plant cover during the winter was appreciably greater on the 1965 plots than on the 1967 plots (Figure 2). This was probably due to the elevation difference between the two sites.

On both sets of plots, the Blue River District mixture provided the least plant cover during the first winter after seeding. This apparently was caused by the lack of straw mulch. The mulch applied with the Oregon Highway Department mixture and the two experimental mixtures appeared to reduce downslope seed movement and frost-heaving mortality, thus insuring an even distribution of vegetation.

During the first fall and winter, ryegrasses provided the dominant cover on seeded plots. Annual ryegrass in experimental mixtures 1 and 2 clearly outperformed perennial ryegrass in the Oregon Highway Department and Blue River District mixtures. The annual ryegrass germinated and became established more quickly than did the perennial rye and was about twice as tall by the end of the winter period.

With the exception of the mulch-only and Blue River mixture treatments in the 1965 set of plots, cover on treated plots was satisfactory by the end of the first growing season (Figure 2). Vegetative cover on the 1967 set of plots averaged almost 90 percent — a surprisingly high value. Even the mulch plots established in 1967 averaged over 70 percent cover. Most cover was contributed by ryegrass because ryegrass clippings were used as the straw mulch.

Although legume species were much in evidence during the first spring after seeding, they largely disappeared from most plots by the end of the summer. Virtually the only legumes remaining at the end of the first year were scattered white clover plants near the base of the backslope. The legumes included in these mixtures apparently were unable to compete successfully with the vigorously growing grass. Additional legume species should be tried. Lower rates of nitrogen fertilization might also fa-

Table 1. Grass-legume treatments applied on two sets of plots.

Species	Mulch and Fertilizer		Blue River District Mixture		Oregon Highway Department Mixture		Experimental Mixture No. 1		Experimental Mixture No. 2	
	1965	1967	1965	1967	1965	1967	1965	1967	1965	1967
	lbs per acre									
Colonial bentgrass (*Agrostis tenuis* Sibth.)	0	0	6.25	6.25	0	0	3.0	3.0	3.0	3.0
Creeping red fescue (*Festuca rubra* L.)	0	0	5.00	5.00	18.0	18.0	8.0	8.0	8.0	8.0
Perennial ryegrass (*Lolium perenne* L.)	0	0	3.75	3.75	4.0	4.0	0	0	0	0
Tall fescue [*Festuca arundinacea* (Schreb.) Wimm.]	0	0	8.75	8.75	0	0	20.0	20.0	0	20.0
Chewings fescue (*Festuca rubra* var. *commutata* Gaud.)	0	0	0	0	12.0	12.0	0	0	0	0
Annual ryegrass (*Lolium multiflorum* Lam.)	0	0	0	0	0	0	8.0	8.0	8.0	8.0
Orchardgrass (*Dactylis glomerata* L.)	0	0	0	0	0	0	0	0	20.0	0
White Dutch clover (*Trifolium repens* L.)	0	0	1.25	1.25	6.0	6.0	0	0	0	0
New Zealand white clover (*Trifolium repens* L.)	0	0	0	0	0	0	2.0	2.0	2.0	0
Big trefoil (*Lotus uliginosus* Schkuhr.)	0	0	0	0	0	0	2.0	0	2.0	0
Birdsfoot trefoil (*Lotus corniculatus* L.)	0	0	0	0	0	0	0	2.0	0	0
Red clover (*Trifolium pratense* L.)	0	0	0	0	0	0	0	0	0	3.0
Alsike clover (*Trifolium hybridum* L.)	0	0	0	0	0	0	0	0	0	3.0
'Lana' woollypod vetch (*Vicia dasycarpa* Ten.)	0	0	0	0	0	0	0	0	0	7.0
Total applied	0	0	25.0	25.0	40.0	40.0	43.0	43.0	43.0	52.0
16-20-0 fertilizer	400	400	400	400	400	400	400	400	400	400
Straw mulch	4,000	4,000	0	0	4,000	4,000	4,000	4,000	4,000	4,000

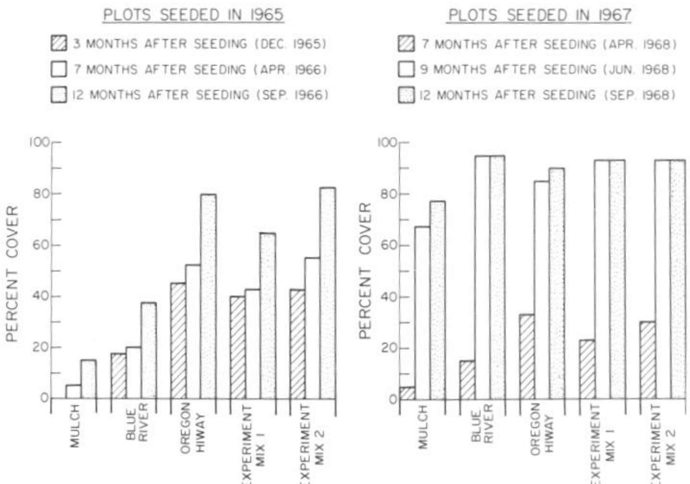

Figure 2. Vegetative cover trends on seeded backslope plots during the first year after treatment.

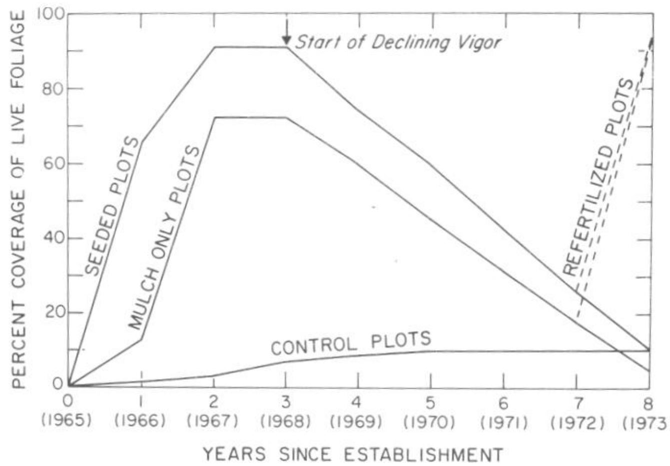

Figure 3. Trends in coverage of live foliage for 8 years after plot establishment. In 1972 one block of plots was refertilized, while the other block remained unfertilized.

vor legume growth by reducing grass vigor.

Fast-spreading, sod-forming grasses dominated the seeded plots by the end of the first year. Bunch-type grasses, such as tall fescue and orchard grass, were present only as scattered individuals. Colonial bentgrass dominated on plots treated with the Blue River District and experimental 1 and 2 mixtures. Creeping red fescue dominated on the Oregon Highway Department plots. End-of-the-year plot descriptions also indicated a good distribution of ryegrass. After the first year, however, ryegrass gradually decreased in importance.

Although plots appeared lush and green for the first 2 years after establishment, the effects of decreasing soil fertility became apparent by the third growing season. The grasses exhibited less vigor and a chlorotic appearance. As a result, live cover on the experimental plots decreased dramatically after the third year following establishment (Figure 3). Plots seeded in 1965 went from an average of 91 percent live cover during the third year to 10 percent live cover 5 years later (8 years after the plots were installed). Despite such depauperate growth, dead grass (thatch) provided sizeable amounts of litter on the plots. Bare soil averaged 10 to 15 percent.

In 1972, treated plots in one block were refertilized with ammonium phosphate at a rate of 400 pounds per acre, while plots in the adjacent block were left unfertilized. Results of this refertilization were astounding

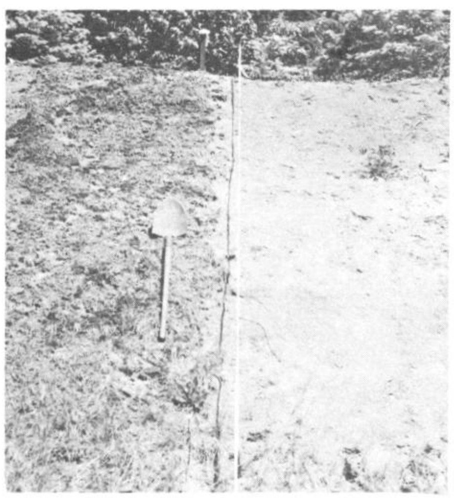

Figure 4. Control and experimental mix 2 plot with no refertilization, 8 years after seeding. Note depauperate grass stand on seeded plot.

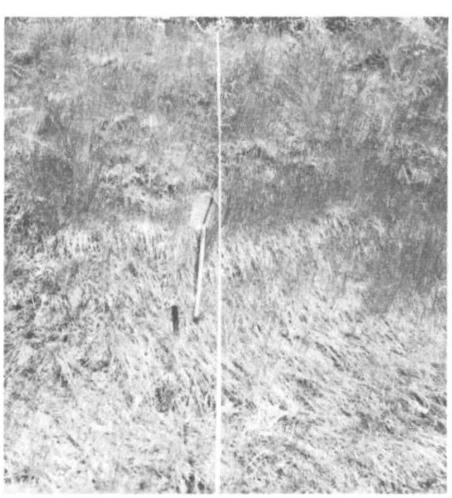

Figure 5. Luxuriant grass on seeded plots 1 year after refertilization. Before refertilization, these plots resembled the seeded plot in figure 4.

(Figures 4 and 5). Within 1 year, foliage on both the seeded and mulch-only plots recovered to an average of 95 percent cover (Figure 3).

Soil Movement on Plots

Slope profile measurements indicated that, as expected, successful grass establishment on road backslopes did indeed curtail soil erosion. Soil stabilization was especially effective on the older backslope plots (Figure 6).

On the basis of 7 years of soil movement data, apparently the only plots to lose appreciable amounts of soil were the unvegetated control plots. These plots lost a cumulative total of 1.44 inches of soil over the 7-year period (Figure 6). This roughly equals a soil loss of 144 tons per acre.

Despite some variation in plant cover characteristics, all five treatments halted soil erosion about equally well. The fact that some plots showed a net gain in slope elevation probably was due to deposition of soil that ravelled down from the top of the backslope onto the measured slope section.

In view of the declining vigor of grass stands on the 1965 plots (Figure 3), it is surprising that measurements after 1969 did not indicate increased rates of soil loss (Figure 6). As previously mentioned, despite extremely depauperate growth, treated plots maintained considerable litter. Bare soil areas were, for the most part, small and discontinuous. The result was localized erosion and deposition, but no detectable net loss of soil from the slope. As the grass stands continue to deteriorate, however, bare soil areas inevitably will grow and coalesce, leading to channelized erosion and soil deposition at the base of the slope.

Measurements of soil movement on plots established on the newly constructed backslope showed these slopes to be somewhat more resistant to stabilization (Figure 7). Although the vegetative treatments certainly reduced soil erosion, long-term trends indicated that even the treated plots apparently lost some soil. Measured losses for treated plots ranged from 0.14 to 0.38 inches of soil for a 5-year period after establishment (Figure 7). Apparently the most ineffective treatment from the standpoint of soil stabilization was the Blue River District mix, the only treatment that did not include a straw mulch. The remaining four treatments (Oregon Highway Department, mulch, and experimental mixes 1 and 2) appeared to be about equally effective in reducing erosion losses. As expected on the newly constructed slopes, the most severe soil losses occurred during the first year after establishment (Figure 7). Even soil losses from the bare control plots decreased substantially after the first year.

First-year soil movement trends for plots on the recently constructed backslope showed the important stabilizing effects of straw mulch (Figure 8). During this period, the plots not protected by a straw mulch (control and Blue River District treatment) lost five to seven times as much soil as the mulched plots. By June, a nearly complete covering of grasses and legumes on all plots, including Blue River District mixture (Figure 2), had substantially reduced soil movement. As a result, the control plots were the only ones to show continued high rates of soil loss during the June through September period (Figure 8).

These results suggest that mulching backslopes may be essential to minimize soil losses during the first few critical months following construction. Especially at higher elevations, the amount of grass-legume growth that occurs during the fall apparently provides insufficient cover to halt erosion. Contrary to appearances, a luxuriant growth of grasses and legumes during the first growing season following fall treatment is not conclusive evidence that soil loss was negligible during the preceding winter months.

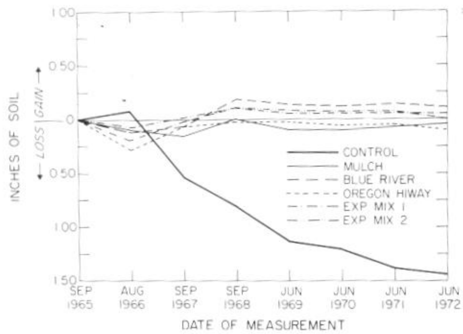

Figure 6. Cumulative soil loss or gain from plots with five vegetative treatments and a bare control on a 5-year-old backslope (1965 plots).

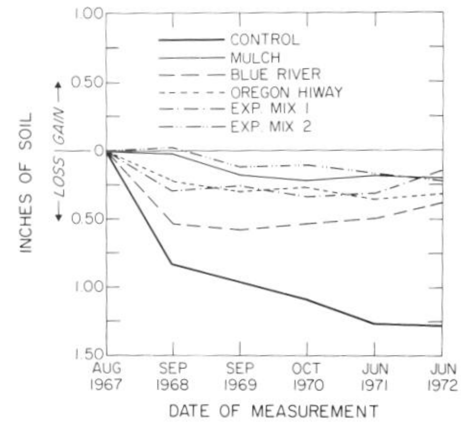

Figure 7. Cumulative soil loss from plots with five vegetative treatments and a bare control on a newly constructed backslope (1967 plots).

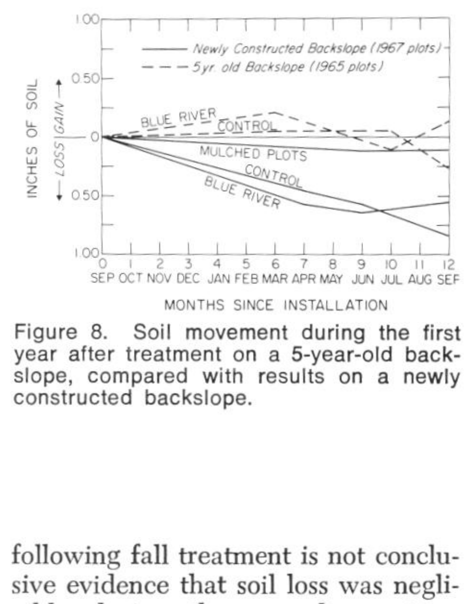

Figure 8. Soil movement during the first year after treatment on a 5-year-old backslope, compared with results on a newly constructed backslope.

Conclusions

Even though the results reported here are based on limited exploratory studies, certain tentative conclusions appear warranted. These conclusions, although preliminary and subject to additional experimental verification, are as follows:

1. The search for vigorous, fast-spreading legume species suitable for use in grass-legume mixtures on subsoils in western Oregon should be expanded. Although our test seedings identified big trefoil and birdsfoot trefoil as promising species, they did not perform well in the roadside plots, probably because of severe grass competition. Better cultural practices may also be needed to improve survival and growth of legumes in grass-legume mixtures. For example, less nitrogen fertilizer should favor legume survival and growth.

2. Soil erosion is substantially higher on newly constructed backslopes than on those that are several years old. Mulch as well as seed and fertilizer should be placed on fresh roadside slopes if erosion is to be minimized during the first rainy season after road construction. In many areas vegetative growth during the fall and early winter is insufficient to curtail erosion. This is especially true at higher elevations, where low temperatures limit rates of grass and legume growth during the fall and early winter.

3. Bare, unprotected roadside slopes erode at a substantial rate over a period of years if vegetative cover is not established. Constantly ravelling soil, coupled with generally low soil fertility, delays vegetative stabilization of slopes — sometimes for many years. In this study bare backslopes eroded at a rate of about 0.2 inch of soil per year.

4. Even a partial cover of grasses and associated litter effectively curtails erosion from backslopes. Although localized erosion may occur in isolated patches of exposed soil, eroded material is deposited above downslope vegetation or litter. This results in little net loss of soil from the slope.

5. A grass mulch plus fertilizer treatment may curtail erosion as effectively as a treatment that also includes seeding with a variety of grasses and legumes. To be effective without seeding, the mulch should be one that already includes abundant seeds, such as ryegrass hay.

6. Roadside seedings may require refertilization every 4 to 7 years. Without refertilization, some stands

may deteriorate to the extent that a new cycle of erosion is initiated. My experience indicated that even stands that had been declining in vigor for 4 years responded quickly and satisfactorily to refertilization.

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