COMPARISON OF SLOPE TREATMENTS FOR REDUCING SURFACE EROSION ON DISTURBED SITES AT REDWOOD NATIONAL PARK

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ABSTRACT

During the winters of 1980, 1981, and 1982, sediment and runoff were collected from adjacent, isolated plots located on disturbed, bare soil areas at four watershed rehabilitation sites in Redwood National Park. The goal was to compare the effectiveness of surface erosion treatments in reducing sediment yield. Plot treatments included straw mulch, grass-legume seed mix, or hydromulch with seed mix. The 1980-81 data show that treated plots yield much less sediment than the unprotected plots (i.e., straw = 95-97% less than unprotected; grass-legume seed mix = 60-88% less than unprotected; and hydromulch with seed mix = 70% less than unprotected). At one site, Maneze Creek in 1981, four plots were bared, rototilled and left untreated to determine the variability between test plots and to define a range for the mean sediment yield. Mean sediment yield from the four plots (within 95% confidence limits) ranged from 4.5 to 8.2 tons/ac with 82 in of rain.

INTRODUCTION

The primary objective of the watershed rehabilitation program at Redwood National Park (RNP) has been to reduce accelerated erosion related to past logging and associated road building in and around the park. Most of the rehabilitation effort is aimed at reducing stream channel erosion and surface erosion on bare hillslopes. During watershed rehabilitation at RNP, logging road and skid trail stream crossings are excavated, oversteepened road fill near streams is pulled back, and road cuts on prairie slopes are recontoured, leaving many acres of bare soil. If stream channels and bare soil areas are left unprotected, erosion of the channels and ground surface may occur.

Surface erosion occurs when raindrop impact detaches soil particles (rainsplash) and overland flow (runoff) entrains the particles and transports them downhill. The sediment may be deposited downhill if the gradient decreases or if the ground surface is more favorable for infiltration (Dunne and Leopold 1978). At rehabilitation sites, sediment derived from surface erosion on recontoured roads is deposited downslope in areas with dense vegetation while that from excavated stream crossings and perched fill above streams enters the stream system. For controlling surface erosion that would lead to the introduction of sediment to stream channels, various treatments are applied to the short slopes flanking a stream channel after the removal of road fill by heavy equipment. Lower application rates of similar treatments are applied to outsloped roads and decompacted road surfaces primarily to aid in revegetation rather than for erosion control. To determine the effectiveness of surface treatments for reducing sediment yield and to define a range of sediment yield values from bare soil areas, a study involving the use of slope treatment plots with troughs to collect sediment and runoff was initiated in 1979.

METHODS

A comparison of three methods for measuring slope erosion performed by California Department of Transportation concluded that the sediment collection trough method was both, ". . . easy to use and provides very accurate results of current erosion rates because it traps the eroded sediment which can then be measured . . ." (Howell and Racin 1978). Therefore, sediment collection troughs with slope

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treatment plots were employed to measure slope erosion. Each test plot was 10 ft wide along contour and 20 ft long down the slope with a peaked apex 25 ft up slope from the base (Fig. 1). The area of a plot was 1/200th ac. This configuration approximates side slope lengths of small excavated stream channel crossings. Each plot was bordered with 1 ft wide strips of sheet metal buried vertically so that 6 in of metal was exposed. The border isolated the plot from external surface runoff and shallow interflow. All runoff and sediment from a plot was collected in a sheet metal trough spanning the down slope edge of the plot (Fig. 1). The trough was equipped with a 5 in wide lip on the upslope side that conducted runoff into the trough while a removable sheet metal roof prevented direct entry of rain. A hose from the trough led down to a tipping bucket assembly where overflow was measured and recorded.

The sites selected for the plots were areas of fairly uniform 40-55% slope which had been worked by heavy equipment. At one site the slope averaged 65%. The plots were located on outboard edges of outsloped roads or large sideslopes of excavated stream crossings which could accommodate side-by-side plots. Plots were installed on fill overlying either quartz-mica schist or greywacke sandstone bedrock. Soil type was disregarded since logging activities and rehabilitation obliterated many of the individual soil properties.

Treatments were applied to the plots before the winter rains. On most plots, the treatments were unaltered for two or more seasons to determine the year-to-year change in sediment yield and runoff. Seeded plots were allowed to germinate and form a sparse cover before sampling started. Initially, samples were collected from 1 to 20 times during the season according to the volume of sediment produced. In 1981 and 1982, 5 to 10 samples were collected from first season plots.

At sample collection time: 1) rainfall at the test plot site was measured from a storage rain gage; 2) runoff water stored in the troughs was measured and then drained; 3) runoff recorded by the tipping bucket counters was noted; and 4) sediment in the troughs was collected. Grab samples of the overflow indicated there was no significant loss of sediment. The sediment collected from each trough was dried in ovens at 110° C and then weighed. Field notes accompanying the samples described any difficulties that may have altered the accuracy of the data. In some cases, runoff was flowing under the lip of a trough. Under this circumstance, the affected data from the sampling period was not used.

Sediment yield values varied considerably due to the quantity, intensity, and timing of the rain that fell during each sampling period. Variation due to the quantity of rainfall was eliminated by the calculation of a sediment yield/precipitation (S/P) ratio having the units of tons of sediment/ac/in of rain. The ratio allowed for comparison of plots at different sites or of a single plot in successive years. Runoff data are incomplete due to tipping bucket malfunctions, and are not presented here.

Analysis of the particle size distribution of sediment deposited in the troughs could not be completed for inclusion here. Comparison of size distribution variation with time, size of storm, quantity of runoff and type of surface treatment will be attempted and presented at a later date.

RESULTS

Following the heavy equipment phase of the work, sediment trough plots were installed in 1979 and 1980 at four watershed rehabilitation sites (Table 1).

Treatments applied to the plots included: 1) straw mulch spread by hand; 2) a grass seed mix and a grass-legume seed mix applied by hand; 3) fertilizer spread by hand on the seeded plots; and 4) hydromulch with a grass-legume-wildflower seed mix applied by a spray technique (Table 2).

By 21 September 1979 all areas worked by heavy equipment at the Bond Creek 79-1 site had been seeded with the grass seed mix at 50 lb/ac and fertilized at 500 lb/ac. In addition, plot #1 received 5000-10,000 lb/ac of straw mulch (3-5 in deep). Plot #3 was treated on 25 October 1979 with an additional 100 lb/ac of the grass seed mix (a total of 150 lb/ac). Sampling was started 25 October 1979. The three plots were sampled during winters of 1980 and 1981 (Table 3).

In the first season, plot #2 (50 lb/ac of grass seed) yielded 1.3 tons/ac of sediment with 61 in of rain or 0.022 tons/ac/in. Plot #1 (straw and grass seed) yielded 90% less sediment than plot #2. Plot #3 (150 lb/ac of seed mix) yielded 75% less sediment than plot #2.

Figure 1

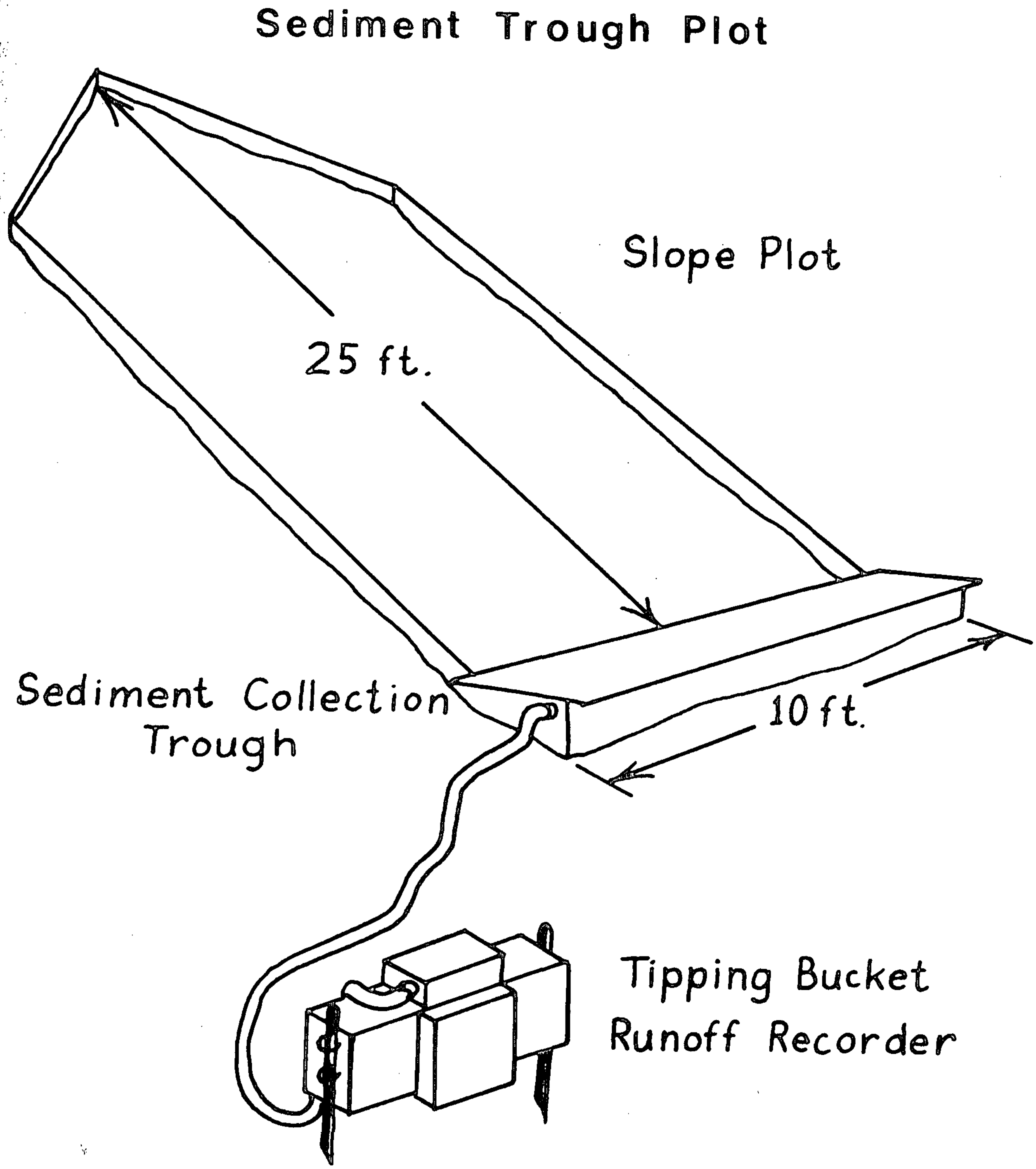

Sediment Trough Plot
Slope Plot
25 ft.
Sediment Collection Trough
10 ft.
Tipping Bucket Runoff Recorder

Table 1

Location of Plots

Site	Number of Plots	Bedrock Type	Installation Date
Bond Creek 79-1	3	schist	Fall 1979
Bridge Creek 79-2	2	schist	Winter 1979-80
Maneze Creek 80-2	4	sandstone	Fall 1980
Bridge Creek 80-3	3	schist	Fall 1980

Table 2

Seed Mix Content

	Species	Percent Mix (weight)
Grass Seed Mix	Linn Perennial Rye	17.0
	Creeping Red Fescue	17.0
	Akaroa Orchard Grass	33.0
	Highland Colonial Bentgrass	33.0
Grass-Legume Seed Mix	Durar Hard Fescue	17.8
	Highland Colonial Bentgrass	0.6
	Blando Brome	28.5
	Mt. Barker Subclover	30.3
	Lana Vetch	22.8
Hydroseed Mix	Wildflower	15.0
	Crimson Clover	53.0
	Grass-legume seed mix	32.0

Table 3

Bond Creek 79-1 Sediment Trough Plot Data

	Plot #1	Plot #2	Plot #3
Slope (%)	45	49	51
Treatment	straw & grass seed	grass seed	grass seed
Application rate (lb/ac)	6,000-10,000/50	50	150
a. 1979-1980			
Number of samples	17*	19	19
Precipitation (in)	60.0	60.0	60.0
Sediment yield (tons/ac)	0.14	1.35	0.33
Sediment yield/precip. (tons/ac/in)	0.002	0.022	0.006
b. 1980-1981			
Number of samples	1	1	1
Precipitation (in)	50.3	50.3	50.3
Sediment yield (tons/ac)	0.016	0.042	0.012
Sediment yield/precip. (tons/ac/in)	0.0003	0.0008	0.0002

*Due to the low yield of sediment, fewer samples were collected during the season.

During the second winter, the sediment yields from all three plots dropped 85-90%. Plot #2 still had the highest sediment yield, but differences between yields were judged insignificant.

At the Bridge Creek 79-2 site, both plots were left untreated and were sampled through the 1979-80 rainy season (Table 4a). For the 1980-81 season, plot #1 was covered with 6,000-10,000 lb/ac of straw, while plot #2 was unaltered (Table 4b).

During the first winter, the two plots responded with comparably high sediment yields. The average S/P ratio for the two Bridge Creek plots was three times greater than the ratio for plot #2 at Bond Creek (50 lb/ac grass seed). During the second winter, S/P from plot #2 (bare soil) was 88% less than that of the prior season, while S/P from plot #1 (straw) was 98% less than that from the first winter, when it was bare. In summer 1980, plots were constructed at Bridge Creek and Maneze Creek watershed rehabilitation sites to compare the effectiveness of straw, applied at 6,000-10,000 lb/ac, with the grass-legume seed mix and fertilizer, applied at 50 lb/ac and 500 lb/ac, respectively. At the Bridge Creek 80-3 site, grass-legume seed mix was applied on 23 September 1980. Monitoring started 25 October 1980. A portion of the outsloped road, upon which the plots were located, began sliding downhill midway through the rainy season. Data were collected until 29 January 1981, when the plots were abandoned (Table 5). The untreated plot produced 2.5 tons/ac of sediment with 27 in of rain or 0.092 tons/ac/in. Plot #2 (grass-legume seed mix) yielded 60% less sediment than the untreated control plot. Plot #3 (straw) yielded 95% less sediment than the control plot.

Table 4

Bridge Creek 79-2 Sediment Trough Data

	Plot #1	Plot #2
Slope (%)	67	67
a. 1979-1980		
Treatment	none	none
Number of samples	20	20
Precipitation (in)	45.5	45.5
Sediment yield (tons/ac)	3.48	3.07
Sediment yield/precip. (tons/ac/in)	0.076	0.067
b. 1980-1981		
Treatment	straw	none**
Application rate (lb/ac)	6,000-10,000	--
Number of samples	3*	7
Precipitation (in)	61.3	61.3
Sediment yield (tons/ac)	0.07	0.45
Sediment yield/precip. (tons/ac/in)	0.001	0.008

*Due to the lower yield of sediment, fewer samples were removed during the season.
**Plot was unaltered.

Table 5

Bridge Creek 80-3 Sediment Plot Data

1980-1981	Plot #1	Plot #2	Plot #3
Slope (%)	40	43	40
Treatment	none	grass-legume seed	straw
Application rate (lb/ac)	--	50	6,000-10,000
Number of samples	6	5*	3*
Precipitation (in)	27.1	27.1	27.1
Sediment yield (tons/ac)	2.49	1.00	0.13
Sediment yield/precip. (tons/ac/in)	0.092	0.037	0.005

*Due to low yield of sediment, fewer samples were removed during the season.

At the Maneze Creek 80-2 site, four plots were installed on an excavated stream crossing side … near a major logging haul road. Easy access to the plots allowed for the testing of a hydromulch …seed treatment commonly used by the California Department of Transportation, in addition to …spread by hand, grass-legume seed mix with fertilizer applied by hand, and bare soil (Table 6a). …were treated by 25 September 1980, and sampling started 5 November 1980. Before the next …season the four plots at Maneze were burned and rototilled to a depth of 8-12 in to approximate …surface conditions of a freshly disturbed rehabilitation site. The plots were left untreated and were …pled through the 1981-82 rainy season (Table 6b).

At the end of the first season, the control plot yielded 4.5 tons/ac of sediment with 41 in of rain …0.112 tons/ac/in. S/P for plot #1 ([st]raw) was 97% less than the untreated plot. Plot #3 (grass-[leg]ume seed) yielded 88% less than the untreated plot, and plot #4 (hydromulch with seed) yielded …% less than the untreated plot.

During the second season, a continuous record of sediment yield and rainfall was collected from 5 …vember 1981 to 4 March 1982. S/P values for plots #3 and #4 were slightly less than for plots #1 [an]d #2 (Table 6b). Although determined to be insignificant, the differences may be attributed to the …dual seed from the previous year, which provided some surface protection.

Table 6

Maneze Creek 80-2 Sedment Trough Plot Data

	Plot #1	Plot #2	Plot #3	Plot #4
Slope (%)	41	42	47	45
a. 1980-1981				
Treatment	straw	none	grass-legume seed	hydromulch with seed
Application rate (lb/ac)	6,000-10,000	--	50	50-100
Number of samples	9	9	9	10
Precipitation (in)	42.4*	40.6*	42.2*	48.1*
Sediment yield (tons/ac)	0.13	4.54	0.60	1.67
Sedment yield/precip. (tons/ac/in)	0.003	0.112	0.014	0.035
b. 1981-1982				
Treatment	none**	none**	none**	none**
Number of samples	7	7	7	7
Precipitation (in)	82.2	82.2	82.2	82.2
Sediment yield (tons/ac)	7.84	6.70	5.51	5.27
Sedment yield precip. (tons/ac/in)	0.095	0.081	0.067	0.064

…mple periods do not coincide, resulting in different precipitation totals.

…s were burned, rototilled and left untreated.

DISCUSSION

The variation of S/P with time at the Maneze Creek plots during 1980-81 is shown in Fig. 2. The soil, hydromulch with seed, and grass-legume seed mix plots show S/P decreasing with time. This ratio follow the decreasing trend in rainfall intensity during the sampling periods. Other influencing ...s include decreasing sediment availability and increasing vegetative growth.

Fig. 3 shows daily rainfall at Maneze Creek for the sampling periods, estimated by correlating ...ic precipitation readings at the Maneze plots with daily precipitation readings at the Prairie Creek Hatchery, 14 mi NW. A general decrease in average daily rainfall occurred toward the end of the ...le season. The bars in the upper graph are rainfall totals for the sample periods which are outlined ... lower graph.

The effectiveness of the treatments at reducing sediment yield is indicated in Fig. 2a by the ...ve positions of the points plotted for each sample period. Plot #1 (straw) has a consistently low ratio. S/P for plot #3 (grass-legume seed) is initially higher than plot #1 but by late January is not ...icantly different from the strawed plot. An increase in the density of ground cover on the seeded from December to February is documented by photographs. Plot #4 (hydromulch with seed) has ...her S/P ratio than the hand-seeded plot. A likely explanation for this is that the lower 2 ft of the ...omulch with seed plot were inadvertently untreated. Plot #2 (bare soil) for all sample periods has ...ghest S/P value.

The variation in S/P values between the four bare soil plots at Maneze Creek in 1981-82 was not ...icant at the 5% level (F-test) compared with the variation in S/P values within a plot. To define a ...e of sediment yield values for bare soil plots during the first rainy season following disturbance, ... confidence limits for mean sediment yield based on the t-distribution were calculated from the ... sediment yields for the four plots. For a season with 82 in. of rain, the mean sediment yield range ... to 8.2 tons/ac, equal to a mean S/P range from 0.055 to 0.100 tons of sediment/ac/in of rain.

CONCLUSIONS

Three conclusions can be drawn from this study:

1) Straw is more effective for surface erosion control than the other tested treatments. In all ...es the sediment yields from strawed plots were less than 10% of the sediment yields from adjacent ...ated plots;

2) All seeded plots were less effective than strawed plots and the effectiveness of the seeded plots ...ed considerably. The variation was attributed to the timing and density of the formation of an ...ive vegetative cover;

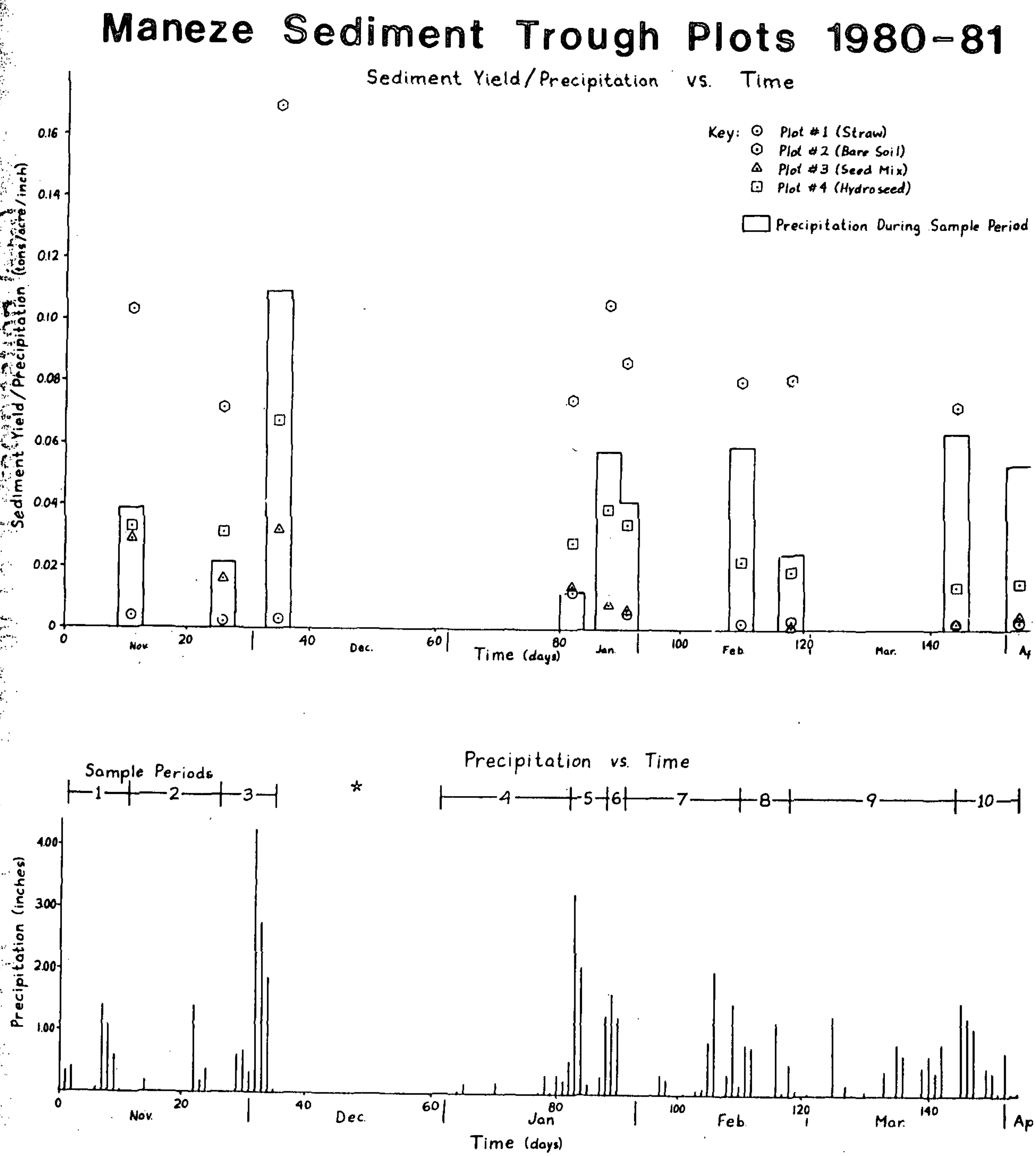
3) Most erosion occurred on disturbed sites during the first rainy season. Of the four plots ...ored for two successive seasons, with no alteration of the treatment, the S/P value for the second ...on was never greater than 15% of the value for the first season.

MANAGEMENT RECOMMENDATIONS

Selection of the erosion control practices used in Redwood National Park was the result of ...sions between rehabilitation project geologists, associated Park scientists in the fields of geology, ...ology, and botany, and personnel from outside agencies. A summary of the advantages, ...antages and recommendations, including costs, of these techniques was presented in a ...randum Report by Weaver and Seltenrich (pers. comm.). The purpose of this study was to ...ine the effectiveness of various surface treatments at controlling surface erosion on short, ...bed, bare soil slopes between 40 and 55%. Recommendations based on the results of this study

1) Straw mulch applied at 6,000-10,000 lb/ac is highly recommended for immediate protection of ...oil areas from surface erosion. Lesser rates appear to be effective at reducing erosion as seen on rehabilitation sites in the park and are scheduled for testing in the 1982-83 season;

Figure 2



*Precipitation for this period is not shown.

Total Sediment Yield ($\frac{tons}{acre}$) Divided by Total Precipitation (inches)

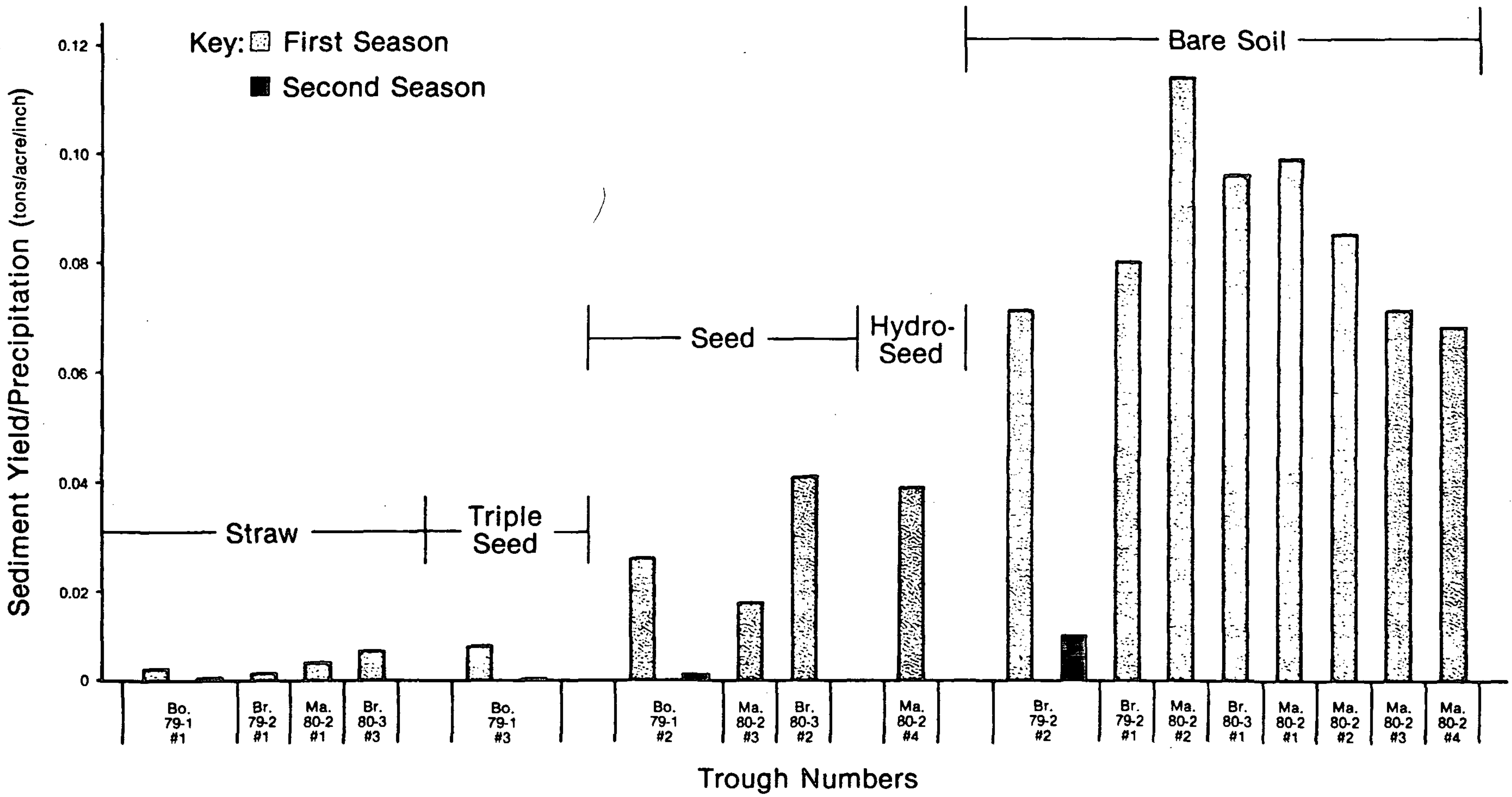


Figure 3

2) Hand application of grass seed and grass-legume seed mix with fertilizer at 50 lb/ac and 500 lb/ac, respectively, is recommended for reducing erosion when a dense cover (90% or more) can be produced. When the timing of the application does not provide a dense cover before erosive rains begin, the effectiveness starts low and increases with growth. The effectiveness of these treatments is low on harsh sites, where adequate growth of vegetation cannot be produced;

3) Hydromulch combines seed, fertilizer, and a wood fiber mulch which is sprayed over the ground surface. Results of the study indicate that hydromulch with seed was not as effective as hand seeding. This discrepancy was probably due to the poor application of hydromulch. A heavy, continuous cover would probably considerably reduce surface erosion because a mulch is provided before the seed germinates and grows. The use of hydromulching is recommended. However, it should be restricted to sites with vehicular access;

4) We recommend that treatments be applied prior to the first erosive rains following disturbance. s/P values for the first rainy season were at least eight times greater than subsequent rainy seasons;

5) An application of grass seed at 150 lb/ac or of straw mulch at 6,000-10,000 lb/ac together with 50 lb/ac of grass seed is effective at reducing erosion. These treatments are not recommended when native vegetation is desired because extremely high ground cover inhibits natural recolonization (Reed and Hektner 1983). However, Reed and Hektner (1983) found that efforts made to re-establish vegetative cover of colonizing species is more successful if the ground surface has been treated with moderate applications of seed, fertilizer and straw mulch.

ACKNOWLEDGEMENTS

The senior author's involvement has been limited to the analysis of data during the last three months and the preparation of this paper. Thanks are extended to Lisa Babcock, Randy Klein, Rick LaHusen, Mary Ann Madej, Ron Sonnevil, and Bill Weaver for their invaluable help in sorting through and discussing the data. Andre Lehre of Humboldt State University deserves special thanks for his aid and encouragement in interpreting and presenting the data, as well as for his critique of the paper. Assistance in statistics was provided by R. Khazanie, William Lennox, and Bob Thomas. Thanks are also extended to the following people for reviewing and commenting on previous drafts of the manuscript: Lisa Babcock, Greg Bundros, Danny Hagans, Randy Klein, Rick LaHusen, Mary Ann Madej and Ken Utley. Sherry Smith merits mention for her perseverance in typing the manuscript. Ray Rice supplied us with our first five sediment collection troughs, and Chuck Culver gave us the design for the tipping bucket runoff recorder. People responsible for initially designing the study were Anne Choquette, Mark Seltenrich, and Bill Weaver. The slope plots, sediment collection troughs and tipping bucket assemblies were installed by Mark Alpert, Lisa Babcock, Anne Choquette, Kathleen Considine, Bob Mallonee, Mark Seltenrich, and Bill Weaver.

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