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SURFACE EROSION CONTROL TECHNIQUES ON NEWLY CONSTRUCTED FOREST ROADS

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Summary:

A newly constructed forest road was treated with three erosion control treatments: wood excelsior erosion mat, native grass species, and exotic grass species. The study evaluates treatment methods on the basis of sediment reduction and runoff volume reduction compared to no treatment. The erosion mat treatment was most effective in mitigating erosion losses with a 98 percent reduction in cutslope sediment production and 88 percent reduction in fillslope sediment production. No significant difference was found between the erosion mat and grass treatments.

Keywords:

Forest roads, Soil Erosion, Conservation Practices, Slopes, Economics

Surface Erosion Control Techniques on Newly Constructed Forest Roads

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INTRODUCTION

Roads have been identified as the major source of soil erosion from forest lands (Patric 1976, Swift 1984b). It is estimated that up to 90 percent of sediment produced from forest lands comes from roads. Sedimentation degrades the quality of forest streams and can be detrimental to wildlife habitat (Elliot et al. 1994). Sediment from roads can clog spawning beds, shorten the life of reservoirs, and degrade drinking water.

Hundreds of kilometers of roads are constructed on forest land each year as a means of accessing tracts for harvesting or other management operations. Sediment is produced from all aspects of the road surface: traveledway, fillslope, cutslope, and ditching. There is potential for significant loss of soil from forest road construction if erosion control techniques are not employed to reduce sediment production. It is important to assess the effects of techniques employed as a means of erosion control. This paper reports findings from the evaluation of erosion control practices on forest road cutslopes and fillslopes.

PREVIOUS RESEARCH

It is recognized that forest lands erode at minimal levels as long as the surface remains undisturbed. Erosion from undisturbed forest land is less than 0.27 tonnes/ha/year which is less than the normal rate of geologic erosion yielding 0.49 to 0.82 tonnes/ha/year (Beasley 1979, Patric 1976, Smith and Stanley 1965, Yoho 1980). Unacceptable levels of soil erosion occurs when the forest cover and forest floor are disturbed by forest operations. Forest road construction has been cited as being the dominant source of erosion in the forest of the eastern United States (Patric 1976). Road construction soil erosion requires special attention because sediment is usually carried directly from road construction sites to streams (Elliot et al. 1994, Reid and Dunne 1984). Sediment from roads causes damage to the environment by clogging spawning beds and shortening the life of reservoirs.

In North Carolina, 5,238 cubic meters of soil loss was measured in four years from 3.7 kilometers of road, and up to 90 percent of sediment following logging operations came from temporary and permanent roads (Hoover 1952). Effective methods to control erosion from forest roads would, therefore, directly influence the quality of water in the forest ecosystem as a result of logging operations.

In a study of three watersheds in Oregon it was noted that the first storm carried a peak sediment concentration of 1,850 mg/l, which was 250 times the expected concentration from an undisturbed watershed. The concentration then decreased to about 9 times the expected concentration in 9 weeks after this initial event (Fredricksen 1965). This study showed that road construction may increase sediment in streams draining watershed areas from 2 to 150 times the amount produced from undisturbed watersheds during the first year.

The establishment of plant and litter cover is the most important deterrent to surface erosion (Berglund 1976). In the mountains of western Oregon, five different seeding mixtures were used on a 5-year-old 1:1 cutslope to assess the effectiveness of grass-legume mixtures in controlling soil erosion (Dyrness 1975). Effective control of erosion depended on fast initial growth and quick cover to minimize soil erosion. The study showed the importance of mulching to minimize soil losses during the first few months following construction. The control treatment and a Blue River mix treatment were absent of mulch and proved to be the least effective in the first year after being implemented.

The effects of surface cover types, their combinations, and the ground coverage on soil loss were studied by Benkobi et al. (1993) using a rotating boom rainfall simulator. They found that a combination of rock cover and vegetation litter may offer effective erosion control. Meyer et al. (1972) found an inverse correlation between rock cover and erosion rate. Coverage of 34 tones/ha of stone showed severe rills, whereas 303 tones/ha of stone was an effective erosion control treatment.

Burroughs and King (1989) identified four specific road components for which control methods could be employed. Sediment production has been studied from all four components of the road prism identified by the researchers: traveledways, fillslopes, cutslopes, and roadside ditching. Based on this research sediment production was partitioned with 60 percent from fillslopes, 25 percent from traveledways, and 15 percent from the cutslope and ditching.

OBJECTIVES

Much research has been done on the production of sediment from traveledways in various geographical areas in the United States. The extent of research on slopes has not been as detailed, especially for the conditions common to the southern United States. The purpose of this study was to give valuable information on sediment production from road sideslopes in the southern United States. The overall objective of this research was to assess the effectiveness of various erosion control treatments on sediment production from two of the most critical road components; cutslopes and fillslopes.

METHODOLOGY

Soil

A field experiment was conducted to assess the effectiveness of surface erosion control techniques in mitigating soil loss from steep road sideslopes. The study site is located in the Shoal Creek Watershed on the Talladega National Forest, near Heflin, Alabama. Soil on the test site is composed of the Tatum series, a fine loamy mixed thermic Typic hapludult belonging to the Ultisol order of soils. The residuum is formed from slate and phyllite. The surface layer is about 13 cm thick over a red clay loam subsoil about 53 cm thick. The underlying material is highly weathered slate. The test soil exhibits a permeability of 1.52 - 5.08 cm/hr and is classified as having a moderate erosion hazard (USDA-SCS 1979). The road was constructed on steep hillslopes ranging from 2 to 65 percent. The test area encompassed 100 m of road which was constructed to access the area for management and harvesting operations.

Plot Design

A randomized block design, chosen to minimize the variation due to plot location along the road, was employed to test the three treatment effects of erosion mat control, native grass control, and exotic grass control.

Treatment	**Description**
Treatment A	Wood Excelsior Erosion Mat
Treatment B	Native Grass
Treatment C	Exotic Grass
Treatment D	Bare (Control)

Two investigations were made relating to erosion control treatments; cutslope and fillslope erosion control. Twelve test plots were established on a 43-45 percent west facing cutslope and another twelve plots were established on a 60-68 percent west facing fillslope. The cutslope and fillslope test areas were located parallel to each other (Figure 1).

Both grass plots were mulched with hay at a rate of 4.48 tonnes/ha. The native grass plots were seeded with a mixture of Big Bluestem, Little Bluestem, and Alamo Switchgrass at a rate of 11.23 kg/ha of each. The exotic grass plots were seeded with a mixture of Fescue(KY31) at 28.07 kg/ha, Pensacola Bahai at 22.45 kg/ha, Annual Lespedeza at 5.61 kg/ha, and White Clover at 11.23 kg/ha. The erosion mat plots consisted of the same seeding mixture as exotic grass plots in combination with a wood excelsior erosion mat.

Plots were designed to insure that rainfall and surface runoff within each plot was discrete. Plots were 1.52 m x 3.05 m in size and located with the longest length along the slope length. A test plot area of 4.65 m^2 was used in calculation of runoff and soil loss from all plots. Each plot was bounded on all sides by wooden boards, 20 cm high, driven into the slope surface with a 10 cm diameter gutter located at the bottom. The gutter was connected to storage containers using 10 cm diameter PVC pipe. Runoff from plots was collected in 130 liter storage containers (Figure 2).

Analysis

The sampling process involved taking two types of runoff samples; suspended and deposited sediment samples. After rainfall events, rainfall amounts and intensity information were recorded from a universal recording rain gauge located on site. The depth of runoff collected in storage containers was measured to determine total plot runoff volume. Suspended sediment grab samples were taken from each storage container top water with 500 ml sampling bottles. Runoff top water was then dipped off without causing deposited sediment to become suspended. The remaining deposited sediment was then rinsed from storage containers into 13 L sampling buckets. Suspended sediment samples and deposited sediment samples were then transported to the lab for analysis.

Suspended sediment samples were run in replicate. Three replicates of 100 ml were filtered through Gelman type A/E filters of known weight and then oven dried at 105°C for at least 24 hour or to constant weight. The difference between oven dried weight and the tare weight of filters was divided by the sample volume to determine suspended sediment concentration.

Deposited sediment was air dried in a greenhouse and weighed. Moisture contents after drying ranged from 0 to 1 percent moisture on a dry basis. Total sediment produced from treatments was determined as the sum of suspended and deposited sediment.

Percent area coverage was used to determine vegetative germination in each of the seeded treatments. Three coverage determinations were made during the study to quantify vegetative establishment. Cover was determined using a quantitative visual assessment modified from agricultural row crop procedures. Points were classified as either covered or bare using a rod with 10 fixed sampling points located at 10 random points in the plot. Percent cover was simply the number of points identified as covered during the assessment periods.

RESULTS AND DISCUSSION

The target vegetative establishment was not achieved on the test plots. A severe hurricane event (Hurricane Opal) hit the research area on October 5, 1995, immediately after seeds had been applied, which caused problems with plant establishment. The event had such a severe rainfall intensity that many of the seeds were washed from the test area. The hurricane had a weighted average intensity of 23.8 mm/hr with one period where the intensity was as high as 39.2 mm/hr. This single storm event accounted for a total of 177 mm of rain on the site in 36 hours.

In addition to the excessive rainfall, the timing of seeding the native grass plots was later than optimal to achieve establishment of a rooting system. The seeds began to germinate but the first frost came earlier than usual for the area. There was some establishment from fescue mulch but many of the seeds had been washed from the site by the hurricane. Due to the poor germination of native grass this treatment was basically a mulch only treatment. All the mitigation of erosion could be attributed to the mulch applied to the treatment and very little from native grass.

Figures 3-6 show sediment production and runoff volume from slopes during the 6 month study period. As reported in the previous literature, sediment production was highest immediately after road construction and began to fall off for the erosion mat treatment and the exotic grass treatment. Sediment production from the native grass treatment and the control followed the same trend as the other plots in the first couple of months after construction. As the road slopes aged the native grass plots and the control behaved differently from the other treatments in that there was increased sediment production during the winter months of the study (Observations #9-13). This could be due to the effect of freezing and thawing action on the soil without grass cover and rooting system. Observation #9 covered a period where the first hard freeze occurred for the area with temperatures around -10°C.

The first three months of the study represents the largest percentage of sediment production in all treatments except the cutslope treatments of native grass and the control. These two treatments show large increases in sediment production for the last three sampling events. The largest percentage of sediment production during the first three months was shown by the erosion mat, representing 88 percent and 98 percent of total sediment loss on cutslopes and fillslopes, respectively. During this establishment period, exotic grass exhibited 61 percent of the treatment total cutslope soil loss and 65 percent of the treatment total fillslope soil loss.

Mitigation

Sediment loss from the control plots(Treatment D) averaged 24.8 kg/plot with an average runoff volume of 998 L per plot on cutslopes (Figure 7). The erosion mat treatment on cutslopes brought about a 98.6 percent reduction in sediment loss with a 17.4 percent reduction in runoff volume as compared to the control. Exotic grass plots followed erosion mats in sediment mitigation with 93.0 percent reduction in soil loss, but with an increase of 3.5 percent in runoff volume. The native grass plots were least effective with a 66.3 percent reduction in sediment production from the cutslope and a 10.4 percent increase in runoff volume.

Fillslope sediment production from control plots(Treatment D) averaged 20.2 kg/plot with an average runoff volume of 1055 L per plot. Fillslope erosion mat plots had a 88.3 percent reduction in sediment production and a 36.6 percent reduction in runoff volume as compared to the control. Native and exotic grass plots represented a 80.9 percent and 86.8 percent reduction in delivered sediment, respectively. Runoff volume was reduced in both native and exotic grass treatments by 25.1 percent and 53.8 percent, respectively. Sediment production from both the native grass treatment and the control were considerably less on the fillslope than on the cutslopes. This trend was the inverse of that exhibited by the erosion mat and exotic grass. This effect is probably due to the differences in surface coverage exhibited by the erosion mat and exotic grass treatments.

Statistical Analysis

Data was analyzed using SAS with a randomized complete block design on both slopes (SAS 1988). Results from Duncan's Multiple Range Test on the means showed no significant difference at the 0.05 incidence level between blocks used in the experimental design. Sediment production from the control on cutslopes had a mean sediment production of 24.769 kg which was significantly different from all other cutslope treatments. Erosion mat, native grass, and exotic grass treatments with means of 0.345, 8.352, and 1.742 kg, respectively, were not significantly different on the cutslope. Runoff volumes from cutslope treatments were not significantly different (seen in Table 1).

Fillslope sediment production followed the same trend as the cutslope with the control at a mean of 20.204 kg being significantly higher than all other fillslope treatments. Erosion mat, native grass, and exotic grass treatments with means of 2.358, 3.866, and 2.669 kg, respectively, were not significantly different. Fillslope runoff volume did show significant differences, however the control was significantly higher than all other treatments with a mean of 1055 L. The erosion mat and native grass treatments were not significantly different from each other, with means of 669 and 791 L, respectively. The erosion mat also showed no significant difference from exotic grass which had a mean production of 487 L.

The differences in behavior of cutslope and fillslope runoff volumes were expected based on the nature of the slope materials. Cutslopes are generally composed of in situ soil. Cutslopes are formed from the operation of scraping away top layers of the soil at an angle. Infiltration through this consolidated soil is usually less than in loose soil which results in the production of more surface runoff. Treatments used on these slopes would have less effect on changing the runoff pattern.

Fillslope runoff volumes were more dependent on the erosion control treatment technique. These slope are composed of loose material scraped away from the cutslopes and road bed. The soil on fillslopes are generally loose and not compacted which is the direct inverse of cutslope soil. Loose soil material that make up the fillslopes allows more infiltration during the establishment period. Erosion control treatments have a greater effect on fillslope surface runoff due to their capability to slow runoff (Table 1).

Costs

The cost associated with the most aggressive treatment utilized in the study (erosion mat) was $10359/ha (Table 2). This cost seems very high when compared to that of the grass treatments ($2470/ha.) and no treatment($0), but other factors must be considered apart from installation costs. The cost associated with sediment production for a given area should be considered. The added cost of the erosion mat may be justified if the road is constructed near sensitive areas that can be damaged by increased pollution such as streams, reservoirs, or recreational areas.

The effect of installation cost can also be balanced by considering the cost associated with maintenance. Road maintenance, depending on severity of damage, can mean higher cost than those incurred during the construction process. The aggressive erosion mat treatment would likely have the least amount of maintenance cost over the life of the road slope. The highest maintenance cost would be associated with a bare slope due to potential erosion damage. Maintenance cost associated with the road would be directly affected by the standard of surface erosion control techniques employed.

CONCLUSION

There was no significant difference in sediment production of the three treatments utilized in this examination. The erosion mat treatment did give a 98.6 percent reduction in sediment production on cutslopes and a 88.3 percent reduction in sediment production on fillslopes when compared to the control of no erosion protection. The exotic grass was the second most effective treatment; it gave a 93.0 percent reduction in sediment production on cutslopes and a 86.8 percent reduction on fillslopes. The native grass treatment was least effective of the treatments in mitigation of sediment production with a 66.3 percent reduction on cutslopes and 80.9 percent reduction on fillslopes.

Results show that the employment of some type of erosion control is necessary to decrease erosion losses. Bare slopes produced more sediment (from 3 to 71 times more) than slopes treated with some type of erosion control. The type of control technique is dependent on the reduction in sediment production required for a particular area.

More research is needed to evaluate the effectiveness of surface erosion control techniques of road slopes. This evaluation was unable to show the effect of different grass species on sediment production due to the problems encountered with poor germination of native grass species. Native grass is thought to be the more effective grass treatment but this could not be determined in this examination. Further research is needed to evaluate the effectiveness of grass treatments.

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Table Means and Significance of Treatments.

Treatment	Sediment Weight Mean(kg)	Std.Dev.(kg)	Range(kg)	Runoff Volume Mean(L)	Std. Dev.(L)	Range(L)
<u>Cutslope</u>						
Erosion Mat	345a	68	277 - 412	825a	75	739 - 880
Native Grass	8352a	1752	6671 - 10167	1115a	95	1011 - 1196
Exotic Grass	1742a	295	1565 - 2082	1035a	68	956 - 1078
Bare (Control)	24769b	14053	11930 - 39782	998a	206	771 - 1173
<u>Fillslope</u>						
Erosion Mat	2358c	2652	487 - 5393	669ab	148	502 - 785
Native Grass	3866c	1065	3018 - 5061	791a	276	481 - 1013
Exotic Grass	2669c	1013	1953 - 3828	487b	52	434 - 538
Bare (Control)	20204d	939	19123 - 20823	1055c	114	926 - 1141

Means with same letter are not significantly different (alpha = .05)

Table 2. Cost of Erosion Control Treatments.

Treatment	Description	Cost/ha
Erosion Mat	Seeding/Mulching(Exotic)	$2,470
	Wood Excelsior Mat	$7,531
	Mat Staples	$358
	Total	$10,359
Native Grass	Seeding/Mulching(Native)	$2,470
Exotic Grass	Seeding/Mulching(Exotic)	$2,470
Bare (Control)	No treatment	**

Figure 1. Field Design showing each treatment in blocks 1, 2, and 3.

CUTSLOPE

A-1 C-1 D-1 B-1 C-2 A-2 B-2 D-2 D-3 B-3 C-3 A-3

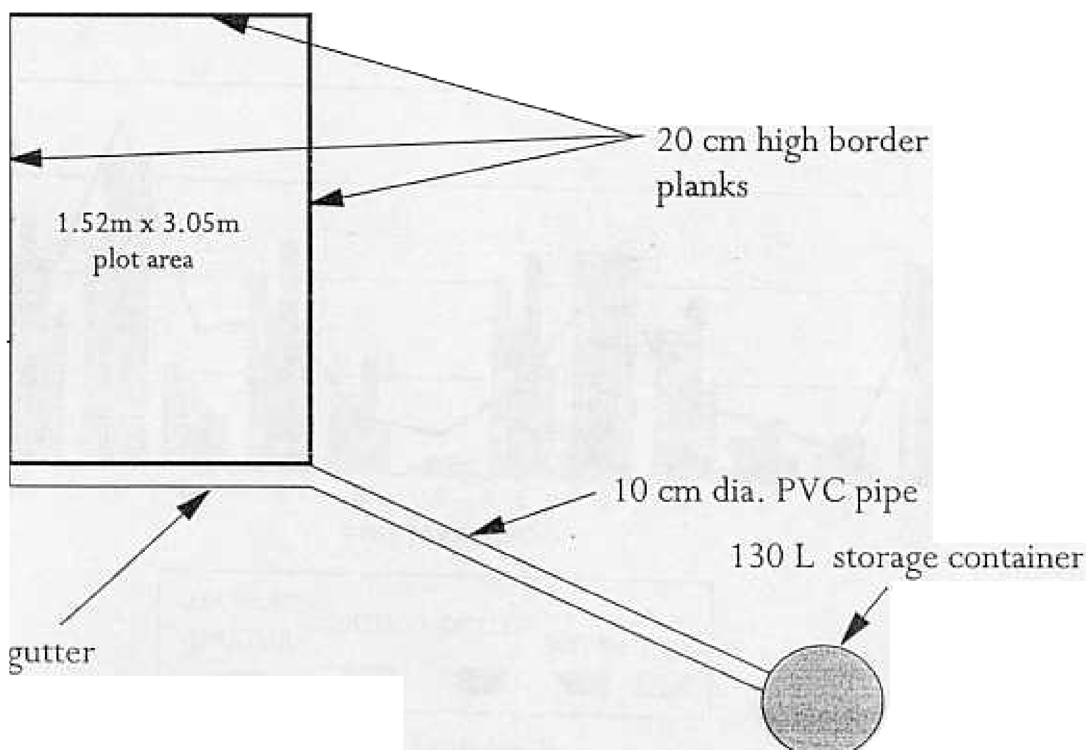
Newly Constructed Forest Road

A-1 C-1 D-1 B-1 C-2 A-2 B-2 D-2 D-3 B-3 C-3 A-3

FILLSLOPE

A - Wood Excelsior Erosion Mat
B - Native Species Grass
C - Exotic Species Grass
D - Control (Bare)

Figure 2. Individual Plot Design



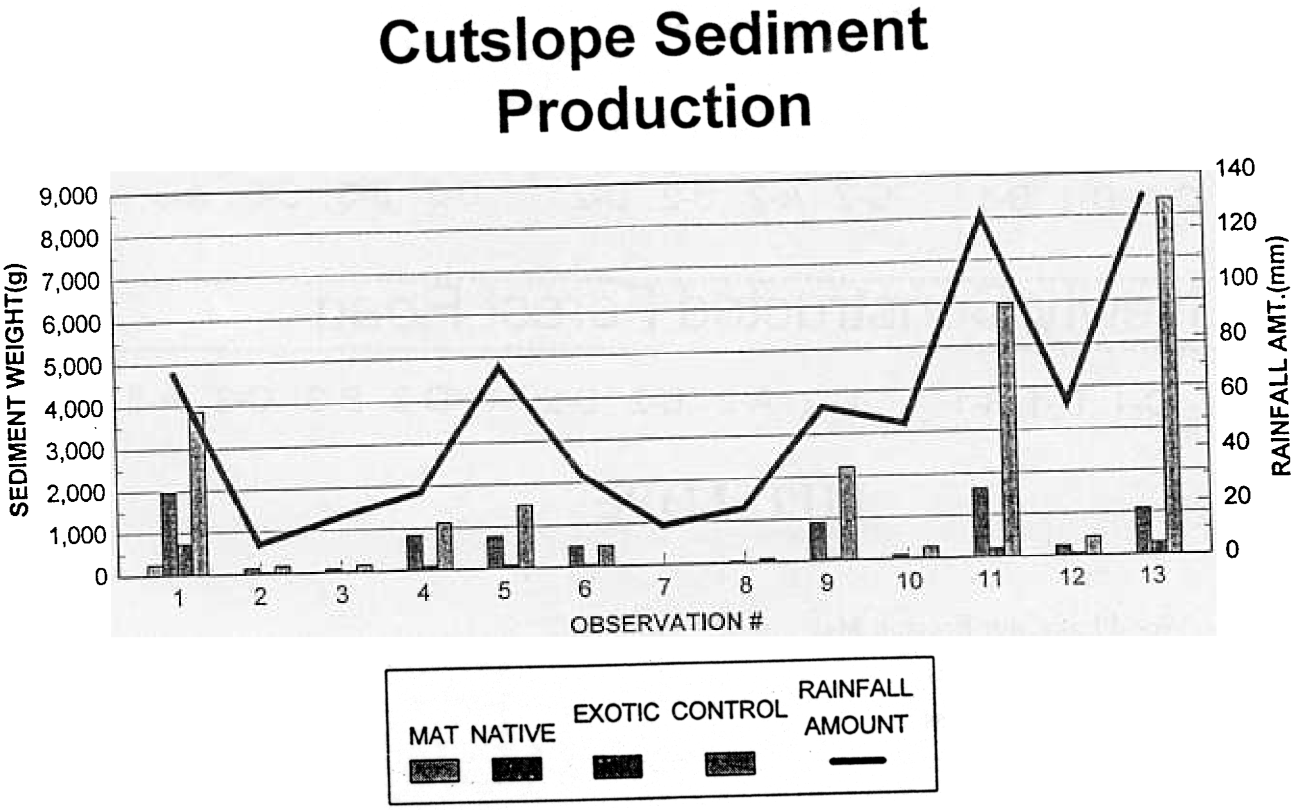


Figure 3. Cutslope sediment production during study period.

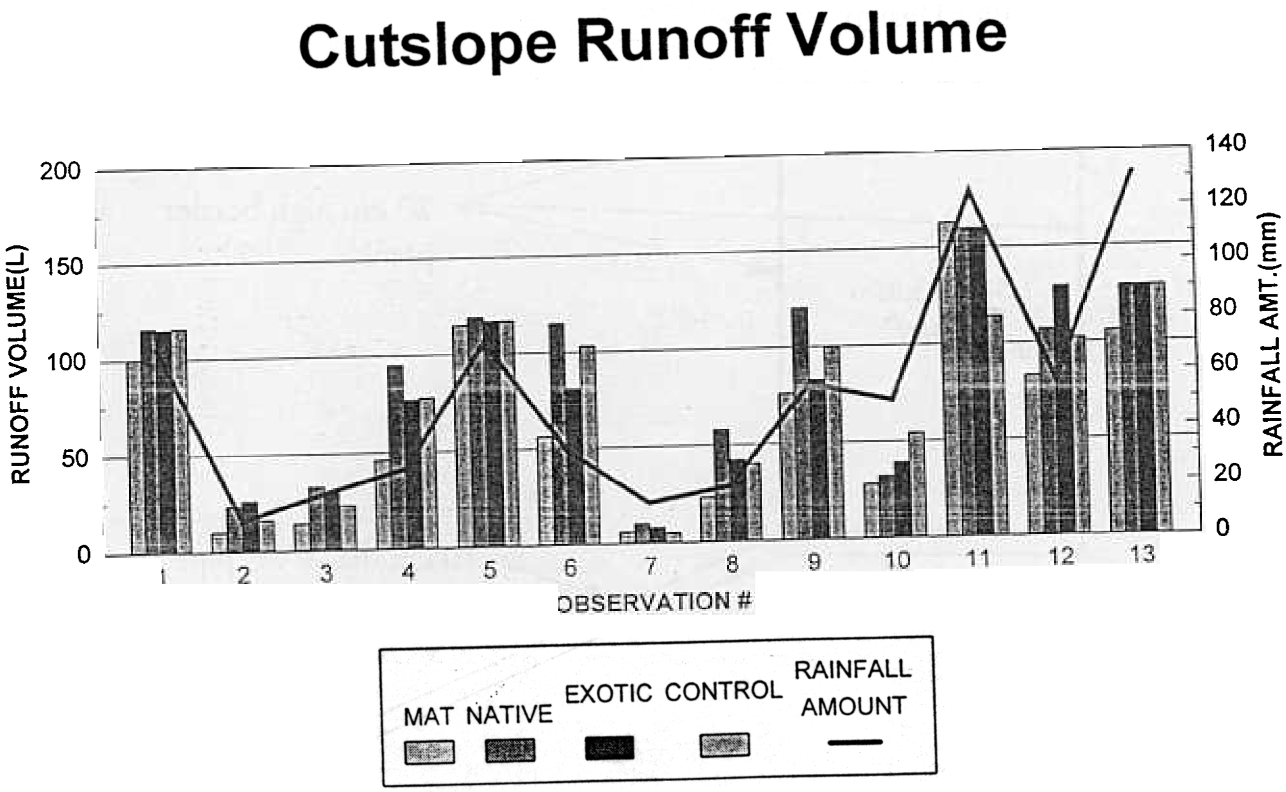


Figure 4. Cutslope runoff volume during study period.

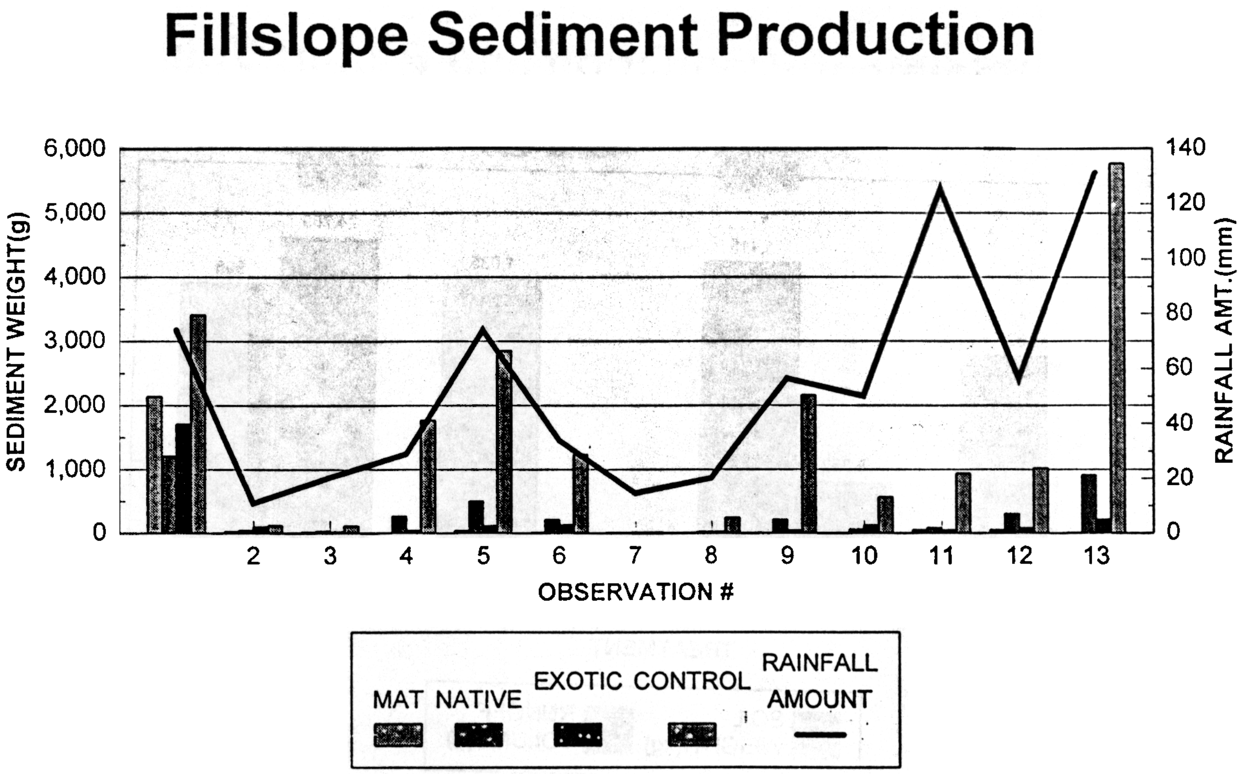


Figure 5. Fillslope sediment production during study period.

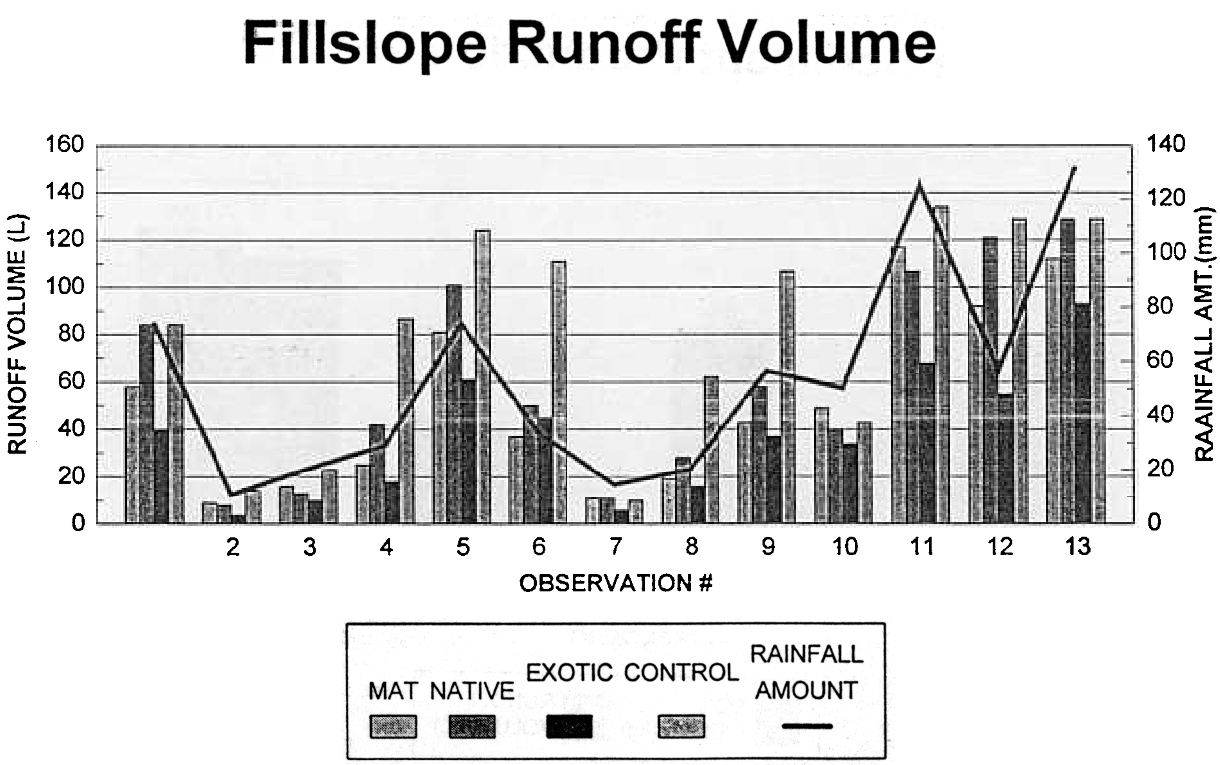


Figure 6. Fillslope runoff volume during study period.

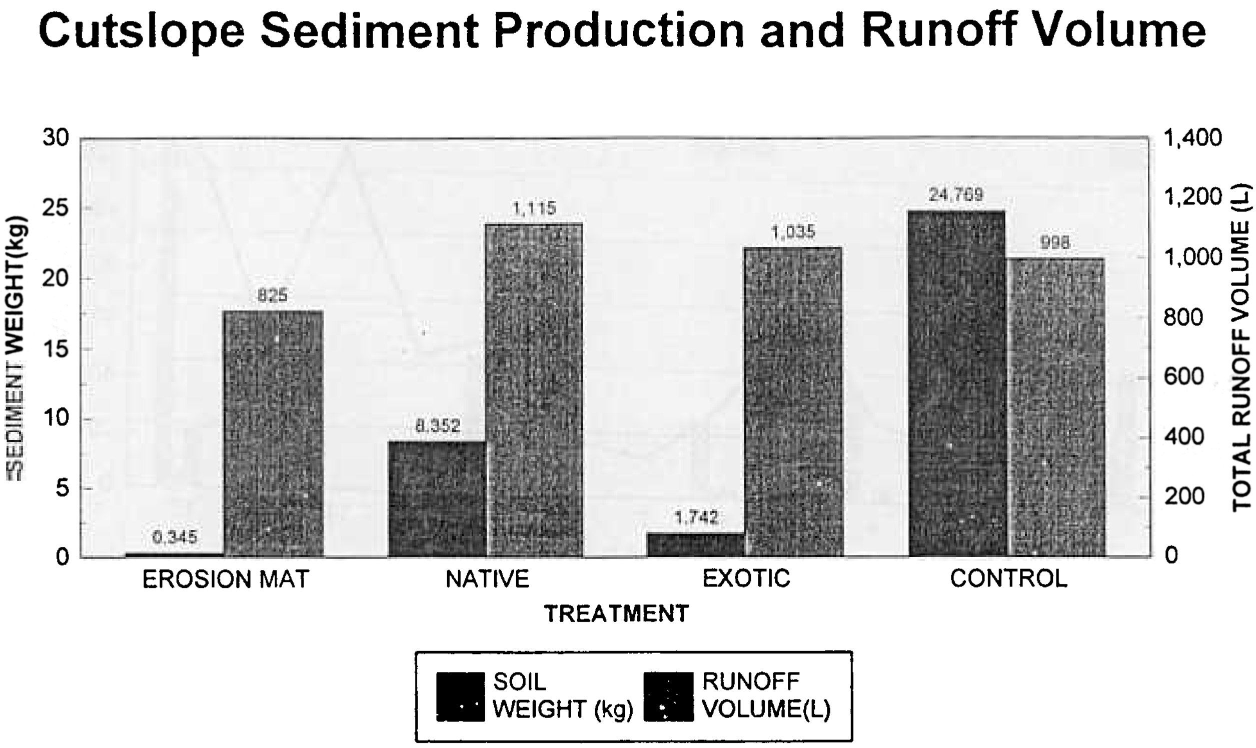


Figure 7. Cutslope mean sediment production and runoff volume.

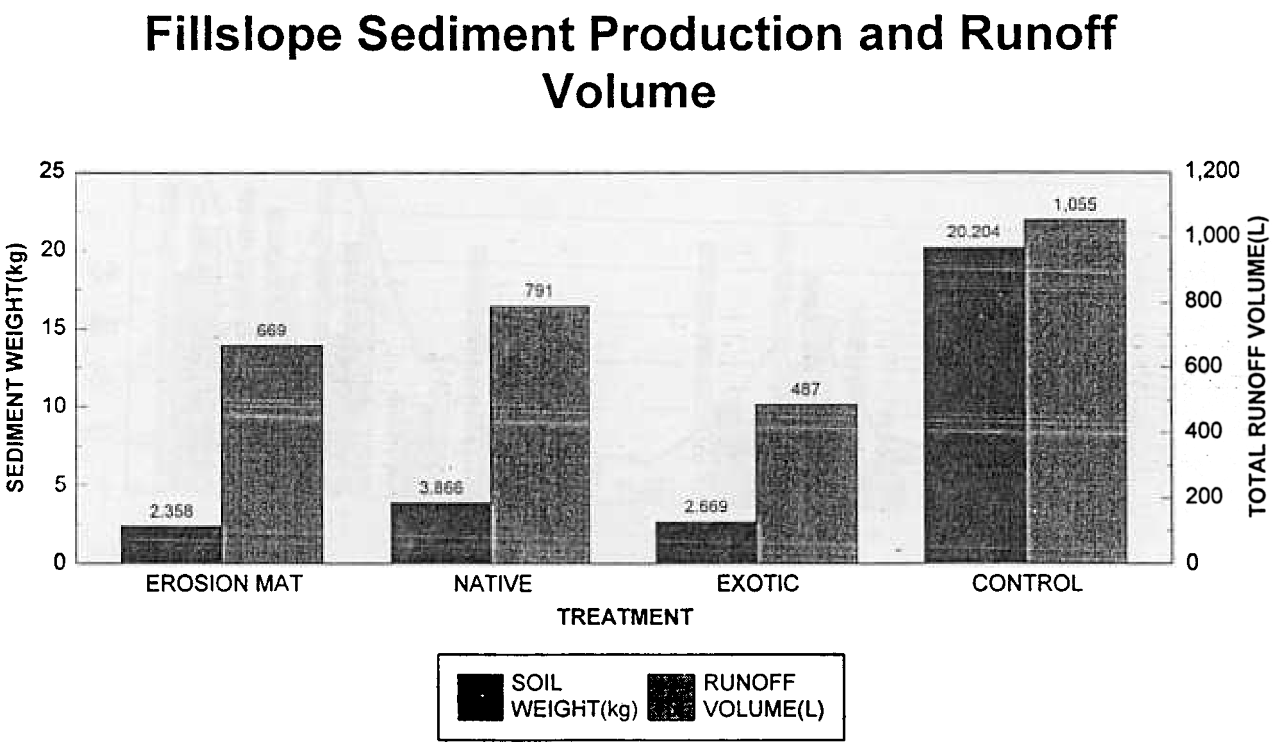


Figure 8. Fillslope mean sediment production and runoff volume.