

Runoff and Erosion Characteristics of a Revegetated Surface Mined Site in Western North Dakota

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A rainfall simulator was used to measure runoff and soil loss from undisturbed, harvested, bare and surface mulched treatments on a revegetated, surface mined site. Measured soil losses were greatest on the bare treatment and least on the undisturbed plots. Application of straw mulch reduced erosion by 66 per cent over the bare condition. As vegetation becomes established on surface mined areas, the erodibility of recently topsoiled sites will be significantly reduced.

INTRODUCTION

The erosion potential existing on bare topsoil areas has been identified by previous research and field experience (2). The possibility for greatest soil loss occurs during the period between topsoil replacement and establishment of a protective vegetative cover. As plant cover progressively develops, sediment yields from reclaimed areas would be expected to correspondingly decrease.

Lusby and Toy (4) reported greater runoff and soil losses from two rehabilitated coal mining areas in Wyoming as compared to nearby undisturbed sites. However, little additional detailed information of this type is presently available. The purpose of this investigation was to determine the runoff and erosion characteristics of a revegetated surface mined site in western North Dakota.

PROCEDURE

The study area was located at North American Coal Corporation's Indian Head Mine near Zap, North Dakota. This area was mined in 1971 and reshaped in 1973. Topsoil taken from a soil classified as a Flaxton fine sandy loam was transported in July 1975 to a study area having a 10.4 per cent slope. The topsoil contained 55 per cent sand, 26 per cent silt and 19 per cent clay. The clay loam spoil material with sodium adsorption ratio of 37 on which the topsoil was placed was disked to a depth of 3 to 4 inches prior to topsoil placement.

Borders for the replicated plots were installed in May 1976. Plots were 13.3 feet across the slope by 72.6 feet long and were separated by a 6.7 foot border area. The site was seeded in May 1976 using a rangeland grass mixture recommended by the North Dakota Public Service Commission.

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Runoff and erosion measurements were collected during August 1977 using a rainfall simulator similar to an apparatus designed and constructed at Colorado State University. This device is described in detail by Holland (3). Figure 1 shows the sprinkler head grid system in operation at the study site.



Figure 1. Sprinkler head system to simulate rainfall on water runoff and soil erosion experiments.

The system delivered rainfall at an intensity of approximately 2.3 inches per hour (iph) and was maintained at an operating pressure of 28 pounds per square inch. A large nearby impoundment served as a water supply.

Sprinklers were located in a staggered grid pattern at 20 foot intervals along the delivery line with a spacing of 17 feet between lines. Rotating sprinkler heads were mounted on 10 foot riser units. Each head assembly was equipped with a flow regulator designed to deliver a discharge of 9 gallons per minute. Water was delivered to the riser units through 3 inch diameter aluminum irrigation pipe.

Simulated rainfall was applied to four surface treatments: a) undisturbed, b) harvested, c) bare and d) mulched. The undisturbed treatment was similar to conditions existing on revegetated areas. The vegetative cover was cut approximately $\frac{3}{4}$ inch above the soil surface and removed for the harvested treatment. Plant residue

was removed and the plots were then rototilled to provide a bare surface condition. The mulched treatment consisted of application of wheat straw at a rate of ½ ton per acre. This application rate produced a cover approximately equal to that occurring on the undisturbed treatment (5).

Data listed for the bare and mulched treatments are averages of two replications. Vegetative cover in the upper portion of one replicated plot was disturbed a few days before testing. Therefore, runoff and erosion data listed for the undisturbed and harvested treatments represent nonreplicated results.

Two simulated rainfall events were applied to each surface treatment. The first application (initial run) was conducted at existing soil water conditions and the second application (wet run) approximately 24 hours later. Artificial rainfall was applied approximately 24 hours prior to the initial run on the undisturbed treatment for a duration of 12 minutes, the time required for initiation of runoff. This was done to assure more uniform soil water conditions for each surface treatment.

Average application rates were determined by collecting rainfall using 1 inch wide channels placed diagonally at four locations across each of the plots. A trough extending across the bottom of each plot gathered runoff, which was measured using an HS flume with stage recorder. Runoff samples were collected in quart jars at 3 minute intervals during the runoff events.

Adjustments for deviations from the design intensity were made to the runoff and soil loss information (6). Runoff data were adjusted by the amount the actual application differed from 2.3 iph. Soil losses were modified by the ratio of $(2.3)^2$ to the square of the actual intensity.

Vegetative cover for each of the surface treatments was determined by the point quadrant method (4). A clear plexiglass sheet with 100 nails arranged on a 1-inch grid and protruding through one side was used to measure surface cover. Eighteen random readings were taken to establish per cent residue cover for each surface treatment.

Soil samples for root weight determinations were collected in 3 inch increments to a depth of 12 inches. Samples from 18 locations were then analyzed to determine root weights at varying depths.

Runoff velocity measurements were obtained by timing downslope water movement with the aid of a few drops of food coloring. Average flow rates were determined between 12.5 and 32.5 feet downslope for each of the study plots.

RESULTS AND DISCUSSION

Surface Cover

Precipitation at the study area between May 1 and August 30, 1976 was measured as only 4.28 inches. Therefore, 1976 did not appear to be a good year for grass establishment. Damage to seedlings from rabbits was also apparent on the recently seeded plots.

Residue cover for surface treatments is presented in Table 1. Even following a year that could be considered poor for grass establishment, vegetation covered nearly half of the soil surface. Plant residue on the bare treatment consisted mainly of small roots which were not removed by raking.

Table 1. Per Cent Surface Cover for Several Surface Treatments.^{a/}

	Surface Treatment			
	Undisturbed	Harvested	Bare	Mulched
Surface Cover, %	48	40	7	55

^{a/} Residue cover was determined by the point-quadrant method (5). Data are averages of 18 replications.

Vegetative Yields

The oven dry weights of grasses and weeds at the study site were 140 and 560 pounds per acre, respectively. Much larger annual dry matter yields were found at other research locations (1). Slender wheatgrass was by far the predominate grass species. Much smaller populations of switchgrass and sideoats grama were also present.

Root Weights

Root weights obtained to a depth of 12 inches are shown in Table 2. Root densities were found to be greatest in the 0-3 inch increments. Only minor variations in root weights appeared in the 3-12 inch soil depth. Below normal precipitation during the period of vegetative establishment would be expected to have significantly reduced the amount of root development.

Table 2. Root Weight Analysis.^{a/}

	Soil Depth (in)			
	0-3	3-6	6-9	9-12
Root Weight (g/100g of soil)	0.41	0.13	0.09	0.06

^{a/} Data are averages of 18 replications.

Flow Velocities

Average flow rates taken 50 minutes into the runs are summarized in Table 3. Runoff velocities appear to be nearly equal on the undisturbed and harvested treatment with slightly larger flow rates observed on the mulched plots. Largest flow velocities appeared on the bare topsoil treatment. Changes in runoff velocity with time for each of the surface treatments are shown in Table 4. The most striking differences occurred on the bare runoff plots with a runoff velocity of over 3 times that of other surface treatments.

Runoff and Erosion

Total runoff for the initial plus wet runs was similar for the harvested, bare and mulched treatments as can be seen from Table 5. Total runoff on the undisturbed site was less than one half the amount measured for each of the other treatments. This reduced runoff rate could be partially attributed to a soil water state somewhat less than field capacity during the initial run.

Table 3. Runoff Velocity for Several Surface Treatments.^{a/}

Surface Treatment	Run	Flow Velocity ft./sec. ^{b/}
Undisturbed	Initial	0.15
	Wet	0.15
Harvested	Initial	0.15
	Wet	0.15
Bare	Initial	c/
	Wet	0.52
Mulched	Initial	0.19
	Wet	0.20

^{a/} Average velocity between 12.5 and 32.5 feet downslope as determined visually by rate of dye advance. Readings were taken 50 minutes into the run.

^{b/} Data are averages of two replications.

^{c/} Data missing.

Erosion appeared somewhat larger on the harvested compared to the undisturbed treatment despite similarities in surface cover. Soil loss to runoff ratios, however, were nearly the same for these two surface conditions. Sediment yields on the bare topsoil plots were over twice as large as on any of the other treatments. Surface mulch proved to be effective in reducing erosion. A soil loss reduction of 66 per cent occurred between the bare and mulched treatments. Meyer (6) found that a mulch rate of ½ ton per acre reduced erosion on a 15 per cent slope to less than one third the amount from an unmulched area during a series of intense simulated rainfall events.

The results obtained from this investigation can at best provide only relative soil loss estimates. The sprinkler head grid system delivers rainfall with an average drop size somewhat smaller than that of natural rainfall at a similar intensity. As a result, the kinetic energy and, therefore, erosion potential of simulated rainfall would be expected to vary from that occurring under natural rainfall conditions.

Table 4. Flow Velocities of Water in Runoff Experiments for Different Surface Conditions in a Revegetated Surface Mined Site.^{a/}

Run ^{b/}	Site ^{c/}	Time min	Undisturbed ft/sec	Harvested ft/sec	Bare ft/sec	Mulched ft/sec
Initial	West	10	--	.11	--	--
		20	.11	.11	--	.15
		30	.15	.15	--	.17
		40	.14	.16	--	.16
		50	.15	.15	--	.18
	East	10	--	.11	--	--
		20	.11	.12	--	.19
		30	.13	.15	--	.20
		40	.15	.14	--	.19
		50	.15	.16	--	.21
Wet	West	10	--	.11	.40	.15
		20	.12	.13	.50	.17
		30	.14	.14	.48	.18
		40	.15	.15	.53	.19
		50	.14	.15	.47	.20
	East	10	--	.12	.47	.17
		20	.13	.15	.57	.17
		30	.16	.14	.63	.19
		40	.16	.16	.57	.20
		50	.17	.15	.57	.20

^{a/} Average velocity between 12.5 and 32.5 feet downslope or determined visually by rate of dye advance.

^{b/} Initial and wet runs lasted 60 minutes; application intensity 2.3 iph.

^{c/} Two sites or replications for each treatment were designated West or East.

Table 5. Erosion, Runoff and Infiltration for Rainfall Simulation Study of a Revegetated Surface Mined Site.^{a/}

Surface Treatment	Run ^{b/}	Soil Loss, tons/acre	Runoff in.	Ratio of Soil Loss to Runoff, % by weight	Infiltration in.	Infiltration Rate, in./hr. ^{c/}
Undisturbed	Init + Wet	1.4	0.8	1.2	3.8	1.6
Harvested	Init + Wet	2.7	1.9	1.3	2.7	1.1
Bare ^{d/}	Init + Wet	6.0	1.7	2.8	2.9	1.5
Mulched ^{d/}	Init + Wet	2.0	2.0	0.8	2.6	1.0
Undisturbed	Initial	0.6	0.4	1.1	1.9	1.6
Harvested	Initial	1.4	1.0	1.3	1.3	1.0
Bare ^{d/}	Initial	3.0	0.7	3.1	1.6	1.2
Mulched ^{d/}	Initial	1.1	0.8	1.0	1.5	1.1
Undisturbed	Wet	0.8	0.4	1.3	1.9	1.5
Harvested	Wet	1.3	0.9	1.2	1.4	1.2
Bare ^{d/}	Wet	3.0	1.0	2.5	1.3	1.7
Mulched ^{d/}	Wet	0.9	1.2	0.5	1.1	0.8

^{a/} Plots were 13.3 by 72.6 ft. on a 10.4 percent slope.

^{b/} Initial and wet runs lasted 60 minutes; application intensity 2.3 iph.

^{c/} Data are averages of two replications.

^{d/} Average rate during the last 3 minutes of the runs.

SUMMARY

Erosion and runoff resulting from simulated rainfall were measured on a revegetated surface mined site with undisturbed, harvested, bare and mulched surface treatments. Sediment production from bare topsoil plots was over 200 per cent larger than the harvested treatment. A ½ ton per acre surface mulch reduced soil losses by 66 per cent over bare conditions. Runoff was smallest on the undisturbed plots, averaging 17 per cent of applied rainfall. Runoff rates from harvested and mulched treatments were similar.

This study demonstrates the need for rapid establishment of protective vegetative cover on topsoiled sites. A surface mulch can serve to effectively control erosion during the critical period of grass establishment. Erodibility of recently topsoiled areas is significantly reduced as vegetation becomes established on surface mined areas.

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