COVER, SLOPE, AND RAIN INTENSITY AFFECT INTERRILL EROSION

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INTRODUCTION

Erosion during rainfall results both from the energy of raindrops striking the soil and from the transport energy of concentrated flow in small channels that develop as the excess rainfall collects and seeks out natural or man-made depressions in the soil surface. The erosion due primarily to raindrop impact has been defined as interrill erosion (erosion between rills) and the erosion due to concentrated flow in small channels has been defined as rill erosion. Meyer et al. (1) proposed that these two processes should be studied separately to clarify the role of each in the total overland erosion process. The causes and sources of soil erosion could then be better identified, thus providing a basis for significant progress in controlling soil erosion and in modeling the erosion process.

This interrill-rill concept of erosion was the basis for research by Lattanzi et al. (2) on interrill erosion. The researchers found that soil cover and slope steepness affected soil lost by runoff and raindrop splash from the study area. The significance of these findings prompted a further study of the interrill erosion process at the USDA Sedimentation Laboratory in Oxford, MS.

Materials and Methods

Equipment and methods used for this study were similar to those used by Lattanzi et al. (2). However, a different soil was used, an extra slope steepness was studied, an additional cover condition was added, and another rainfall intensity was applied. Therefore, the new study provided a broader range of data for evaluating interrill erosion as well as nearly duplicating several of the Purdue tests permitting comparison of the interrill erodibility of two different soils.

The soil used, classified as silt loam (Providence series), was obtained from a research plot at the North Mississippi Experiment Station near Holly Springs, MS. The vegetation and a small amount of soil were scraped from the surface when the soil was at a tillable moisture content. The soil was then disked and sieved through a 12-mm mesh screen.

A pan 122 by 122-cm (48- by 48-in.), shown in Figure 1 with all cover conditions, was positioned 3 m. (10 ft.) beneath a rainfall simulator. The test plot was the central 61 by 61-cm (24 by 24-in.) of the pan and was separated from the border areas by vertical metal strips. The surrounding areas were treated identically to minimize border effects. The pan was filled in increments of about 2 cm (0.8 in.) to a depth of 8 cm (3.2 in.). Each increment was hand compressed except for the top 2 cm layer, which was leveled without compaction. Outlets in the bottom of the pan allowed infiltrated water to drain after passing through cotton fabric, screen wire, and wire mesh in that order. Runoff samples were collected at 5-min intervals through a slot below the lower end of the test plot. Splash was collected in a 2.5 by 60-cm (1 by 23.6-in.) removable slot just beyond the runoff collection slot.

Various combinations of four cover types [0, 2 t/ha (0.9 T/A) wheat straw, 8 t/ha (3.6 T/A) wheat straw, and screen canopy], five slopes (1, 2.5, 6, 10, 20%) and two rainfall rates [5.8 and 11.6 cm/hr (2.3 and 4.6 in/hr)] were studied in randomized block design. A series of simulated rainstorms was applied. The initial run, termed the "dry run", was 60 min. It was followed the next day by two 30-min runs separated by a 15-min interval without rainfall. The first of these was the "wet run", and the second was the "very wet run". Immediately after each very wet run the bare plots were covered with screen canopy or the screen canopy was removed from the canopy plots, and an additional 20-min run was made. Tests at all slopes were replicated for bare soil and tests for all covers were replicated at 6% slope. Other tests were made but not replicated because we did not have enough prepared soil.

The data was analyzed for rates and totals of runoff water, soil erosion by runoff, and soil movement by splash. The size distribution of eroded material was also determined. Samples for size analysis were collected during the initial run after 30 min and after 50 min and during the wet and very wet runs after 20 min. These samples were wet sieved to determine size distribution of sediment larger than 63 m.

RESULTS AND DISCUSSION

Runoff

Table I gives runoff data for the conditions studied. Figure 2 shows the considerable differences in runoff rates caused by changes in cover. On the bare soil and that with 2 t/ha cover, surface seals developed quickly and the runoff increased rapidly, whereas for that with screen canopy and the 8 t/ha cover, surface seals did not develop and runoff did not begin until well into the run. Runoff rates for the 8 t/ha straw cover and screen canopy conditions never reached the runoff rate from bare soil. The maximum rates of runoff occurred during the very wet run. The average maximum rates during the very wet run were 4.35 cm/hr from bare soil, 4.50 cm/hr from that with 2 t/ha straw cover, 3.30 cm/hr from that with 8 t/ha straw cover, and 3.60 cm/hr from that under screen canopy.

Slope did not appreciably affect the runoff when no cover was present. However, all data showed a slight increase in runoff with increasing slope for the 2 t/ha straw mulch and screen canopy cover and a considerable increase for the 8 t/ha straw mulch cover. This was probably related to the time the excess water was detained on the soil surface. The straw acted as a barrier to runoff, but increased slope reduced the barrier effect. Under the screen, the soil surface roughness probably formed small detention pockets to delay the runoff of excess water because the raindrop impact did not break down the aggregates. As in the case of the straw mulch, the increased slope reduced detention time. Thus, for all three cover conditions, increased slope decreased detention time which, in turn, reduced infiltration and resulted in greater runoff.

About 35 min into the dry run, the runoff rate began to increase faster, indicating an internal change in the soil—probably colloidal swelling—which continued until the end of the first 60-min run. Comparison with the final average maximum reached during the wet and very wet runs indicated that the runoff rate reached within 95% of maximum during the dry run on the bare plots and those with 2 t/ha cover, whereas runoff from the plots with screen canopy and 8 t/ha cover reached about 70% of maximum.

Doubling the rainfall intensity on bare soil nearly tripled the total runoff for the first 60-minute run and slightly more than doubled the total runoff during the wet and very wet runs on bare soil. These results indicate that during the first 60-min run, the soil profile absorbed about the same amount of water for the higher-intensity rain as for the lower-intensity rain, so the infiltration was about the same for both intensities. Therefore, nearly all the excess rainfall was added to the original runoff which itself amounted to about half the water applied during the smaller rainfall application and thus almost tripled the original runoff. During the wet and very wet runs, the infiltration rate remained very nearly constant. Because the profile was already wetted, the total runoff was slightly more than double that for the lower intensity application.

Soil Loss in Runoff

Table II shows soil lost in interrill runoff. Figure 3 shows that soil loss increased with increasing slope, even though water loss from bare soil was not significantly affected. This may indicate that as slope increased, gravitational effects increased the downslope component of splash and enhanced the movement of sediment by increasing the downslope component of sediment weight as well as flow velocity.

Figure 4 shows the effect of cover conditions on interrill erosion. The data plotted for the cover conditions at 20% slope were not included in the tables because they were not replicated. These data were consistent, however, with the 6% slope data in showing slope, cover, and erosion relationships. Both the replicated and unreplicated data showed clearly that increased cover decreased the soil loss. This can be attributed to several factors. As cover increased, less bare soil was exposed to rainfall, movement of water and sediment was restricted by the contact cover, surface sealing was prevented allowing lesser amounts of runoff at lower velocities, and cover prevented direct raindrop impact which, in turn, decreased movement by splash. The screen canopy greatly reduced interrill erosion.

Slope had an even greater effect on interrill erosion with cover than without as shown by Figure 4. Although the total sediment loss was reduced by increased cover, comparison between 6% slope and 20% slope showed that the greater the cover, the greater the proportion of sediment for an increase in slope.

Splash

Table III shows splash rate to a given area as measured by the splash slot below the runoff catch slot. The material caught in the slot gave a relative measure of sediment movement through the air by raindrop impact. Splash affects interrill erosion in two ways: (1) it continually moves sediment to and from any given erodible area and thus keeps a continuous supply of loose material available for transport by runoff from the interrill area, and (2) it also moves material directly into the rills. The contribution of the second process to total erosion was not considered in this study, but the importance of the first process to erosion from interrill areas can be ascertained from Figure 4 and Table III. Table III shows that splash was near zero under screen canopy and Figure 4 shows that erosion by runoff was very small under screen canopy.

Figure 5 shows that splash rate increases at a decreasing rate as the slope increases. Table III shows that soil cover reduced splash by a much greater percentage than the percentage by which the exposed soil surface area was reduced. For example, 2 t/ha straw covered 60% of the soil area, yet it reduced splash by 80%.

Canopy Effects

Tables I, II, and III show that canopy over an initially loose, bare soil decreases runoff considerably and greatly reduces both soil loss in runoff and soil moved by splash. Canopy was also used in two ways to determine the effects of raindrop impact. Screen canopy was placed over the soil after the final runs on bare soil and removed after the final runs for screen canopy cover. For the first condition, runoff remained essentially constant while average erosion rate decreased from 2.8 g/min to 0.3 g/min. For the second condition where screen was removed, the runoff and sediment rates increased rapidly toward rates common for the final run on bare soil. This shows that interrill erosion is primarily due to raindrop impact.

Rainfall Intensity Effects

Doubling the rainfall intensity on bare soil approximately tripled runoff for the first hour run and doubled it thereafter. Table II shows that doubling the rainfall intensity approximately quadrupled erosion by runoff, and Table III shows that it approximately doubled splash.

Sediment Size Distribution

The sieve analysis showed that sediment size distribution varied considerably from the primary particle distribution. Up to 40% of the sediment was larger than 63 m, although only 2.5% of the primary (dispersed) soil particles were larger than 63 m. The aggregates caught on the sieves were very stable, even when subjected to mild agitation when wet or dry. Since sediment size is a major factor in sediment transport, the transportability of eroded material depends upon the actual size distribution rather than the dispersed size distribution.

Soil Comparison

A comparison was made of some results from this study with those of Lattanzi, et al. (2), who tested a different soil. Perhaps the different runoff curves shown in Figure 2 are the result of a difference in the wetting characteristics of the two soils tested.

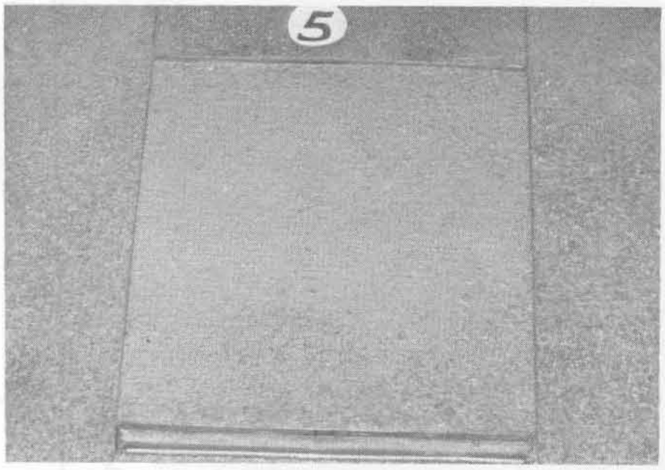
The soil loss in runoff was approximately three times greater for the soil used by Lattanzi et al. (2) than for the soil used in this study while the splash was about the same. As an example, at 6% slope the total soil loss from the Russell soil was 1234 g/m^2 for the first hour while the soil loss from the Providence soil was 412 g/m^2. Notably, however, Lattanzi et al. (2) found that the splash rate was highest for the initial run and decreased for successive runs, but the data in Table III show the reverse was true for this soil.

SUMMARY OF RESULTS

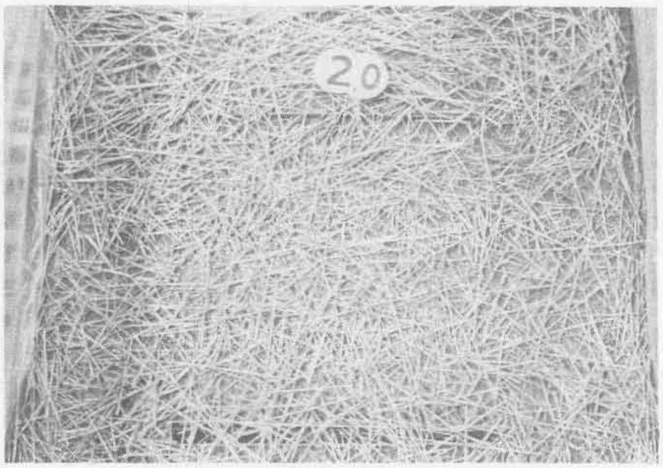
1. Interrill runoff from bare soil remained essentially constant with change in slope.
2. Two metric tons per hectare of wheat straw reduced runoff slightly and 8 metric tons per hectare greatly reduced runoff.
3. Screen canopy greatly reduced runoff.
4. Covering a bare soil with canopy after 2 hours of rainfall had little effect on runoff rate but greatly reduced erosion rate, but removing canopy after 2 hours of rainfall on canopy-covered soil caused a major increase in both runoff and erosion rates.
5. Interrill erosion increased moderately with increasing slope for bare soil.
6. Interrill erosion was considerably reduced by 2 metric tons per hectare of wheat straw and virtually eliminated by 8 metric tons per hectare of straw or screen canopy.
7. Detachment of soil particles by raindrop impact is the major factor in interrill erosion.
8. Soil splash increased slightly with increasing slope.
9. Cover reduced splash by a percentage greater than the percentage of the surface covered.
10. Increased slope increased soil erosion relatively more when the soil was covered than when it was bare.
11. Doubling rainfall intensity on bare soil approximately quadrupled runoff erosion and approximately doubled soil movement by splash.

REFERENCES

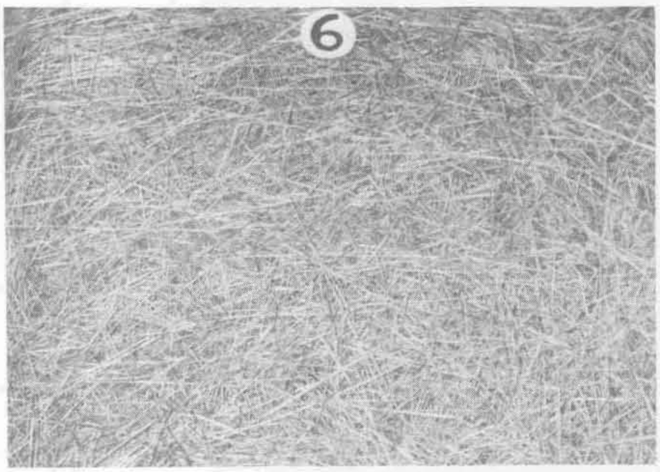
1. Meyer, L. D., G. R. Foster, and M. J. M. Romkens. 1975. Sources of soil eroded by water from upland slopes. 1972 Sediment Yield Workshop Proc., USDA Sedimentation Laboratory, Oxford, MS. ARS-S-40: 177-189.
2. Lattanzi, A. R., L. D. Meyer, and M. F. Baumgardner. 1974. Influences of mulch rate and slope steepness on interrill erosion. Soil Sci. Soc. Am. Proc. 38: 946-950.



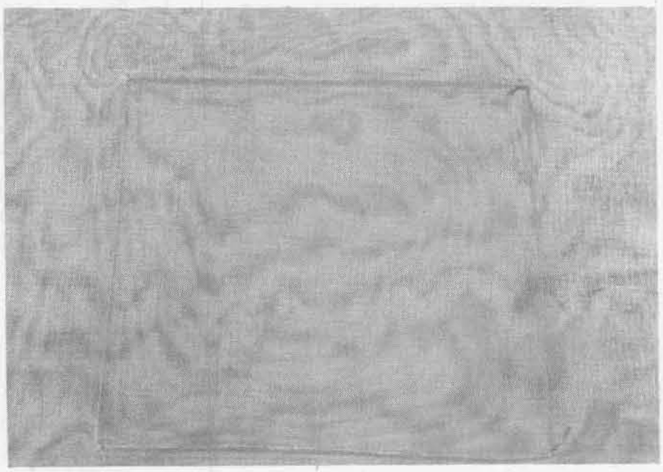
(a) No cover



(b) Cover of 2 t/ha wheat straw



(c) Cover of 8 t/ha wheat straw



(d) Screen canopy: two layers of screen 2.5 cm apart; lower screen is about 2 cm above the soil surface.

Figure 1: The four cover conditions

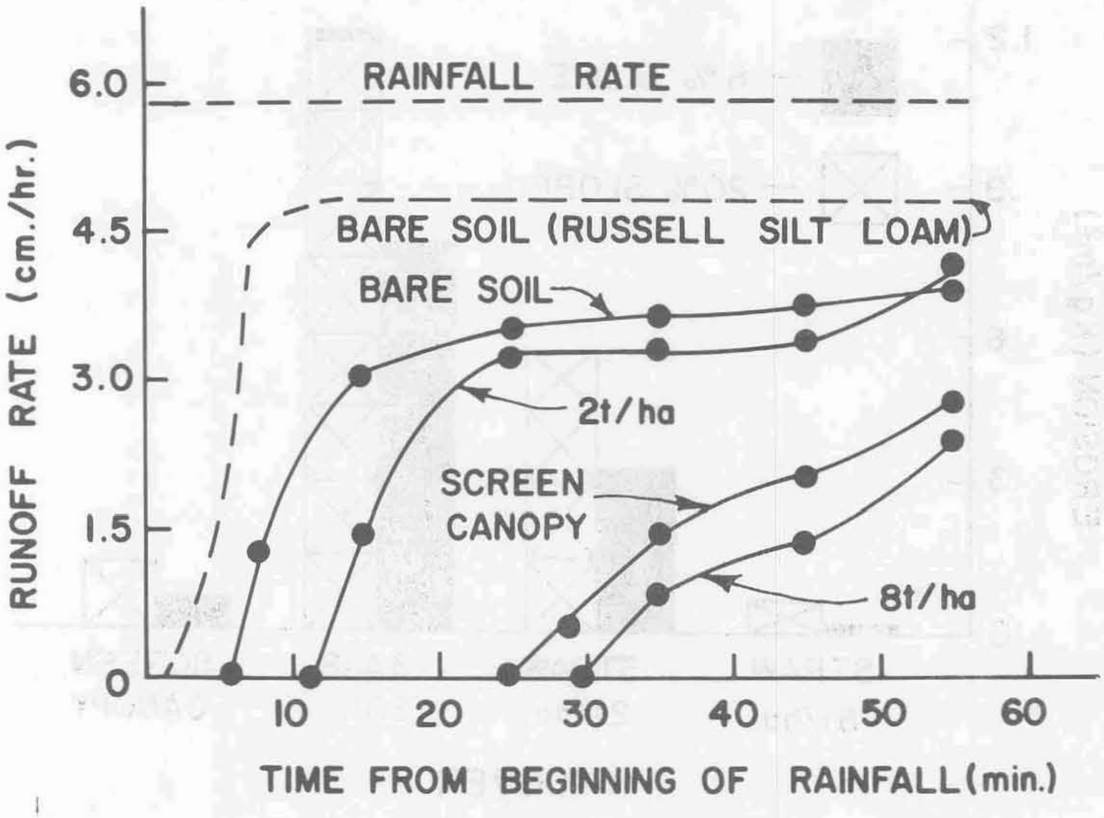


Figure 2: Variation of runoff rate with time. Each curve is the average for all slopes. The curve for Russell silt loam was reported by Lattanzi, et al (2).

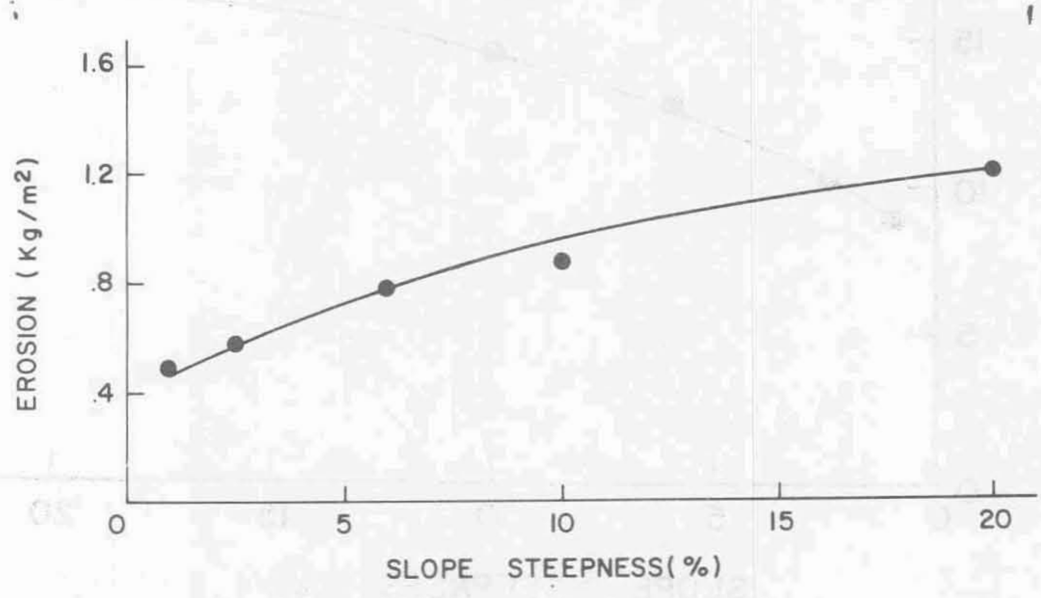


Figure 3: Effect of slope on total erosion during 2 hours of rainfall.

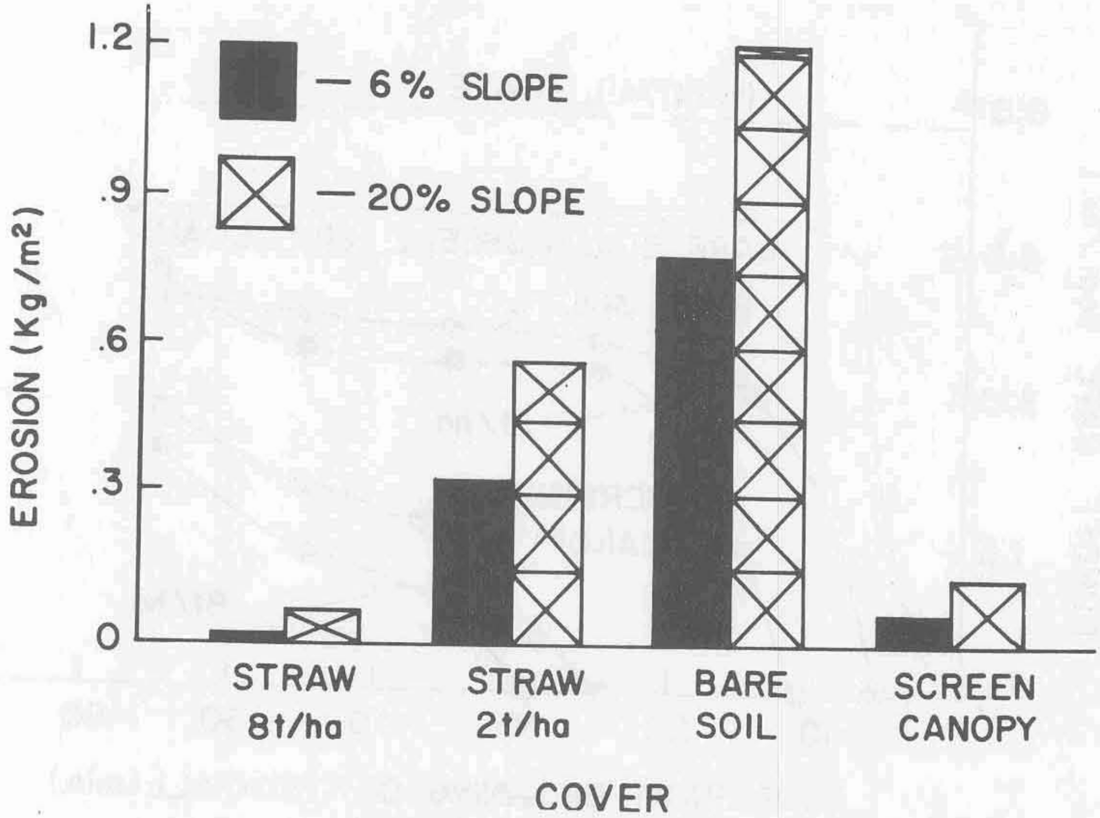


Figure 4: Effect of cover on total erosion for 2 hours rainfall.

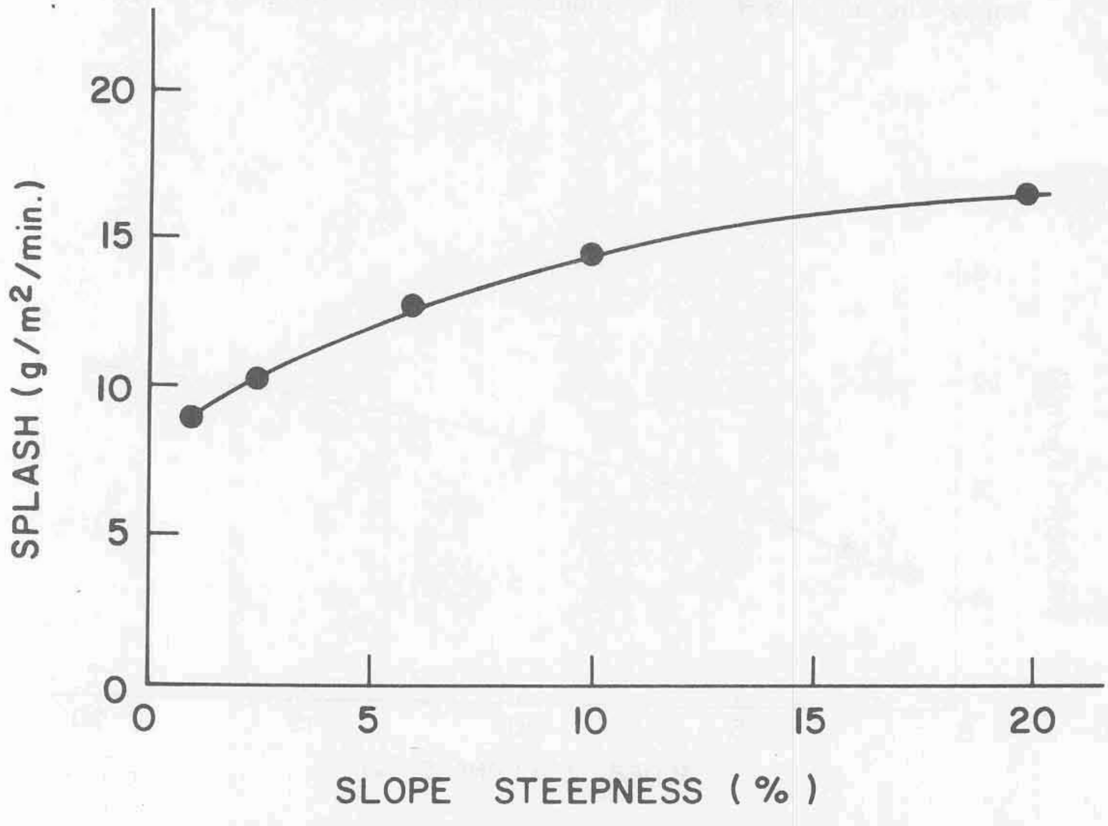


Figure 5: Effect of slope on average splash rate for bare soil.

Table I - Water lost as runoff.

Rainfall Intensity		Cover	Water Loss*+ S=1%	S=2.5%	S=6%	S=10%	S=20%
			---	---	kg/m^2	---	---
5.8 cm/hr.							
Initial Run	(60 min.)	none	34.8	34.4	34.8	35.3	36.3
Wet Run	(30 min.)	none	23.9	22.1	21.8	22.6	21.0
Very Wet Run	(30 min.)	none	24.6	24.4	22.5	22.7	22.9
Initial Run	(60 min.)	2 t/ha straw			27.9		
Wet Run	(30 min.)	2 t/ha straw			20.9		
Very Wet Run	(30 min.)	2 t/ha straw			22.4		
Initial Run	(60 min.)	8 t/ha straw			1.0		
Wet Run	(30 min.)	8 t/ha straw			5.6		
Very Wet Run	(30 min.)	8 t/ha straw			9.8		
Initial Run	(60 min.)	screen canopy			11.2		
Wet Run	(30 min.)	screen canopy			15.5		
Very Wet Run	(30 min.)	screen canopy			18.6		
11.6 cm/hr.							
Initial Run	(60 min.)	none			87.7		
Wet Run	(30 min.)	none			47.7		
Very Wet Run	(30 min.)	none			48.0		

***Values shown are averages of two replications.**
+S = Slope

Table II - Soil lost in runoff.

Rainfall Intensity		Cover	Soil Loss in Runoff*+ S=1%	S=2.5%	S=6%	S=10%	S=20%
			---	---	g/m^2	---	---
5.8 cm/hr.							
Initial Run	(60 min.)	none	222.5	287.5	412.0	537.5	618.2
Wet Run	(30 min.)	none	122.0	119.5	153.0	259.5	245.5
Very Wet Run	(30 min.)	none	141.5	168.0	212.0	285.5	350.5
Initial Run	(60 min.)	2 t/ha straw			141.5		
Wet Run	(30 min.)	2 t/ha straw			77.0		
Very Wet Run	(30 min.)	2 t/ha straw			101.5		
Initial Run	(60 min.)	8 t/ha straw			2.1		
Wet Run	(30 min.)	8 t/ha straw			8.1		
Very Wet Run	(30 min.)	8 t/ha straw			10.6		
Initial Run	(60 min.)	screen canopy			18.2		
Wet Run	(30 min.)	screen canopy			13.4		
Very Wet Run	(30 min.)	screen canopy			12.4		
11.6 cm/hr							
Initial Run	(60 min.)	none			1831.5		
Wet Run	(30 min.)	none			837.0		
Very Wet Run	(30 min.)	none			983.5		

***Values shown are averages of two replications.**
+S = Slope

Table III - Soil splash rate.

Rainfall Intensity		Cover	Soil Splash*+ S=1%	S=2.5%	S=6%	S=10%	S=20%
			-----------g/m^2 of collector slot per min.-----------				
5.8 cm/hr.							
Initial Run	(60 min.)	none	8.9	10.3	12.8	14.6	16.5
Wet Run	(30 min.)	none	6.5	5.4	8.0	10.1	11.1
Very Wet Run	(30 min.)	none	9.7	6.0	8.4	11.4	12.6
Initial Run	(60 min.)	2 t/ha straw			2.3		
Wet Run	(30 min.)	2 t/ha straw			1.8		
Very Wet Run	(30 min.)	2 t/ha straw			1.5		
Initial Run	(60 min.)	8 t/ha straw			.2		
Wet Run	(30 min.)	8 t/ha straw			.3		
Very Wet Run	(30 min.)	8 t/ha straw			.2		
Initial Run	(60 min.)	screen canopy			.1		
Wet Run	(30 min.)	screen canopy			.3		
Very Wet Run	(30 min.)	screen canopy			.1		
11.6 cm/hr.							
Initial Run	(60 min.)	none			21.8		
Wet Run	(30 min.)	none			17.3		
Very Wet Run	(30 min.)	none			18.9		

***Values shown are averages of two replications.**
+S = Slope