AN EVALUATION OF SOIL RIPPING AND SOIL PITTING ON RUNOFF AND EROSION IN THE SEMIARID SOUTHWEST

Wayne C. HICKEY, Jr and E.J. DORTIGNAC (*)

ABSTRACT

This study was begun in 1958 as a cooperative effort of the Bureau of Land Management, U.S. Department of Interior, and the Forest Service, U.S. Department of Agriculture, to evaluate the relative effectiveness and duration of mechanical treatments produced by a soil "ripper" and soil "pitter".

Subsoil ripping was more effective in reducing runoff and erosion from test plots than were artificially built surface depressions or pits. Precipitation, surface runoff, and eroded material were measured for 3 years. A total of 82 runoff plots, each 310 square feet in area, were used. The study area was on the easily eroded shale-derived soils near Cuba, New Mexico, on the Rio Puerco.

For untreated soils, surface runoff was as high as 89 percent of storm rainfall, and erosion as high as 4,000 pounds per acre. Ripping reduced surface runoff 96 percent and erosion 85 percent in the first year after treatment. Three years after treatment, the reductions amounted to 85 percent for runoff and 31 percent for erosion.

Depressions or surface pits caused reductions of only 12 to 24 percent of surface runoff and 16 percent in erosion the first year after treatment. At the end of 3 years, surface runoff was reduced only 10 percent and erosion was about the same from treated and check plots.

It was observed early in the first year of study that some of the untreated (check) plots on the ripped site were failing to yield runoff, and some of the treated plots on the pitted site were improving in their ability to reduce surface runoff. A careful survey of the study areas showed that subterranean channels were being formed and runoff was occurring below the surface of the ground. This phenomenon of cutting underground channels for subsurface flow has been previously reported in Arizona where it was called soil piping.

It is possible that the mechanical treatments used in this study initiated or speeded up soil piping.

RÉSUMÉ

Cette étude a été commencée en 1958 grâce à l'effort coopératif du Bureau National d'Utilisation des Terres (Bureau of Land Management) et du Service National des Forêts (Forest Service) pour évaluer l'efficacité et la durée relative du traitement mécanique de sol produit par des machines à ouvrir le sol, à l'éventrer (soil ripper) et des machines à percer le sol des creux (soil pitter).

L'ouverture, l'éventration du sous-sol a été plus efficace pour réduire l'écoulement superficiel et l'érosion des parcelles d'expérience que n'ont été les dépressions de surface ou les trous artificiellement préparés. Précipitations, écoulement de surface et matériel érodé ont été enregistrés pendant trois ans. On a employé 82 parcelles d'écoulement, chacune mesurant 310 pieds carrés (28.8 m^2). Le terrain d'observation se trouvait dans les sols d'érosion facile d'origine schisteuse près de Cuba (New-Mexico), sur le Rio Puerco.

Pour les sols non traités, l'écoulement de surface s'élevait à 89% des précipitations d'averse et l'érosion atteignait 4.000 livres par acre (4483 kg/ha). L'éventration réduisit l'écoulement de surface de 96% et l'érosion de 85% au cours de la première année de traitement. Trois ans après ce traitement, les réductions s'élevèrent à 85% pour l'écoulement et à 31% pour l'érosion.

Les dépressions ou creux de surface produisirent, la première année après le traitement, des réductions d'écoulement superficiel de 12 à 24% seulement et de 16%

(*) Range Conservationist (Research) and Forester (Research), Forest Service, U.S. Department of Agriculture, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Research reported here was conducted in cooperation with the University of New Mexico at Albuquerque.

d'érosion. A la fin des trois ans, l'écoulement de surface fut réduit de 10% seulement, pendant que l'érosion des parcelles traitées et celle des non traitées demeura à peu près la même.

On remarque très tôt dans la première année d'observations que quelques-unes des parcelles non traitées du côté éventré ne produisaient pas d'écoulement et que quelques-unes des parcelles traitées du côté troué amélioraient leur capacité à réduire l'écoulement superficiel. Une étude attentive du terrain d'observation montra que des conduits souterrains étaient en cours de formation et que l'écoulement avait lieu sous la surface du sol. Le phénomène consistant à couper des conduits souterrains pour l'écoulement en sous-sol a été exposé en Arizona, où on l'a nommé tuyautage du sol.

Il est possible que le traitement mécanique employé dans cette expérience ait initié ou avancé le tuyautage du sol.

Hold precipitation where it falls to increase plant growth and decrease erosion. For the arid Rio Puerco country in New Mexico, this is a reasonable premise for the land manager. The question is, how ? Two types of equipment for mechanical land treatments, designed to answer this question, have been used in treating extensive areas of the Puerco. These are a "soil ripper" (Jayhawk S & S Soil Saver, or Jayhawker Ripper(*) and a "soil pitter" (Calkins Pitter).

This study was begun in 1958 as a cooperative effort of the Bureau of Land Management and the Forest Service to evaluate the relative effectiveness and duration of treatments produced by these types of equipment. A further objective of the study was to determine runoff and erosion rates for two sites in the Rio Puerco drainage.

The soil ripper is a machine normally pulled by a D-8 Caterpillar tractor or equivalent, and consists of two 3-foot chisels or teeth 7 feet apart. Mounted just behind and above the tooth or chisel is a rotating auger (Figure 1). As the machine is pulled through the ground, each tooth cuts a furrow about 4 inches wide and 30 inches deep. About two-thirds of the way down this furrow, a channel about a foot in diameter is created by the action of the rotating auger. These dimensions vary with the soil type and conditions at time of treatment.

The soil pitter basically consists of a square axle with pentagonal "wheels", each of which has five 16-inch teeth mounted 3 feet apart. Extra 600-pound weights may be added to the axle to provide proper penetration in different soil types. This machine may be pulled by a wheeled tractor or in series with heavier equipment. As the machine is pulled along, the teeth are driven into the ground, then pulled out. This action forms a pit about 16 inches deep surrounded by radiating fractures in the soil structure. The diameter of the pits is normally about 8 inches, but depends upon moisture conditions at time of treatment.

1. Study sites

The Rio Puerco watershed comprises over one-fourth of the Upper Rio Grande Basin. It contributed only 5 percent of the water yield, yet it contributes nearly half of the sediment carried into the main channel of the Rio Grande (Dortignac, 1956).

There are 3,900,000 acres within the Rio Puerco drainage. The headwaters lie north of Cuba, New Mexico, at an elevation of 10,600 feet, and the channel runs 125 miles to the south where it empties into the Rio Grande at an elevation of 5,000 feet. The drainage is irregular in outline but is approximately 85 miles in width.

The Rio Puerco is not a perennial stream. Runoff occurs only in the early spring as a result of snowmelt in the headwaters, or during the summer months as a result of high-intensity rainstorms. The mass movement of sediment occurs during the

(*) Use of a trade name in this publication does not constitute endorsement.

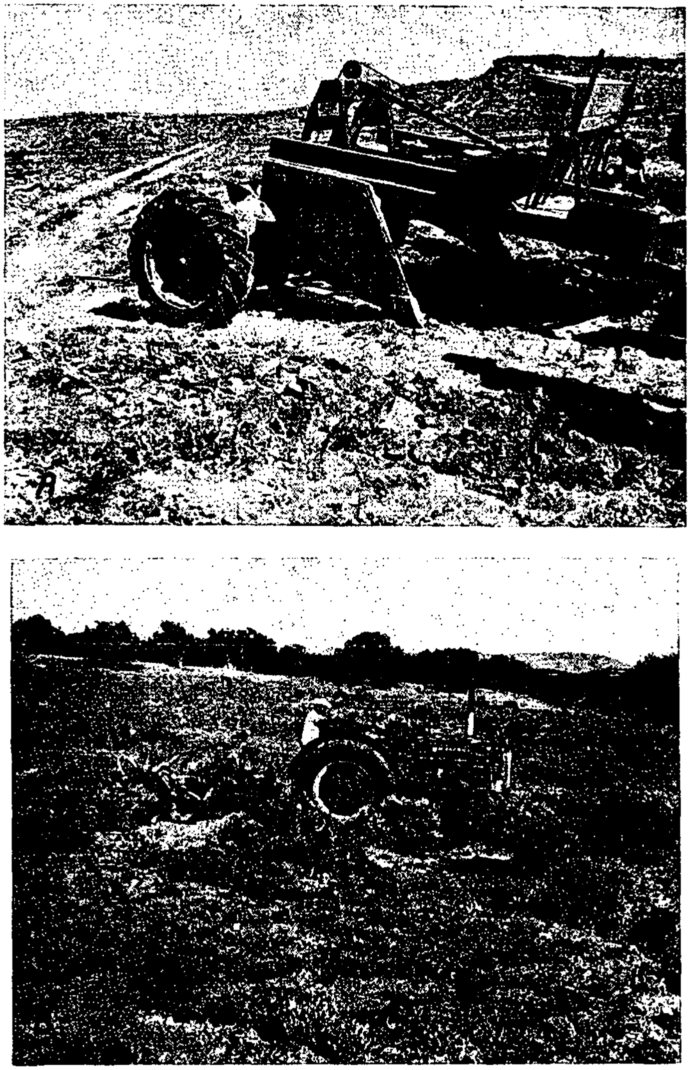

Fig. 1 — *A*. The Jayhawk soil ripper. *B*. The soil pitter.

spring and summer. In the lower elevations, runoff has not been reported between December 1 and May 1. Average annual precipitation varies from more than 18 inches at the headwaters to less than 10 inches at the river's mouth.

Principal forage grasses found in this region are alkali sacaton (*Sporobolus airoides*), galleta (*Hilaria jamesii*), and blue grama (*Bouteloua gracilis*). Chamiza (*Atriplex canescens*), a forage shrub, is also found throughout the region. Since these dominant plants are all nutritious and highly palatable, grazing use has been heavy and constant. The region was stocked in the 1600's and reached peak loads just prior to the Civil War. Stocking was excessive until the end of World War II when the Bureau of Land

Management began to reduce stocking rates and cross fenced the region. Many areas have now reached the point where from 90 to 97 percent of the ground does not have a perennial vegetative cover. This allows excessive runoff from summer convective thunderstorms characteristic of the region.

Alluvial soils predominate, and vary in depth from a few inches to a hundred feet or more. Mancos shale underlies most of the drainage, and may be found as outcroppings or at varying depths beneath the alluvia. Cretaceous sandstone was laid down on the Mancos shale, and is usually found in its pure form as caps on the flat-topped mesas. These two parent materials are continually eroding away and forming new soil. Soils vary from sandy loams to silty clays; composition depends on the proximity of the parent material. An extensive network of vertical walled gullies covers most of the Rio Puerco drainage.

The study sites are about 35 miles south and west of Cuba, New Mexico. Both climate and vegetation at the ripping and pitting sites are representative of the Puerco drainage. Mancos shale as parent material was present at both sites. At the ripping site it occurs as outcroppings in some plots, and lies as deep as 25 feet beneath others. At the pitting site, this material occurs at varying depths from 1 to 35 feet. Soils are deeper on north aspects and shallower on south aspects. Most of the shale outcroppings in this region are found on south aspects.

Both sites were cut by numerous fingering gullies characteristic of the region.

Precipitation for the period of study was as follows:

	1 May to 1 Dec.		1 Dec. to 30 Apr.	
	Ripping	Pitting	Ripping	Pitting
1959	5.04	6.73	3.89	4.93
1960	6.45	6.39	1.87	2.49
1961	*5.74*	*5.38*	*2.20*	*2.44*
Average:	**5.74**	**6.17**	**2.65**	**3.29**

2. Methods of study

Runoff plots 10 feet wide and 31 feet long were used to measure runoff and erosion (Garcia et al., 1962). These were laid out on the contour in groups of 16 on both north and south aspects. Additional groups were installed at the ripping site to determine differences, if any, between upper slopes having an average gradient of 10 percent and lower slopes with a 5-percent gradient.

Mechanical land treatment was conducted so as to provide untreated or check plots randomly distributed throughout each group of 16 plots. Since the pitting operation is not restricted to the contour, treatment was done in an uphill-downhill operation which allowed the untreated portions to be bypassed. Ripping, however, is done on the contour. To protect check plots, large timbers were used to move the equipment over the untreated portions to minimize soil disturbance.

Runoff was measured directly in barrels located in a trench below the runoff plots. Each barrel was agitated and aliquot samples were taken to determine sediment production.

Precipitation was measured by open standard gages for total amount and by recording gages for intensity and duration. Recording rain gages were kept in operation between May 1 and December 1 each year.

3. Results

3.1. *Storm Characteristics*

Because of low intensity early spring and late fall storms, the number of storms per year and the number of storms producing runoff differ.

Rainfall for the period began in early May. Intensities increased during July, August, and September and ended each year with a low intensity rainstorm of 2 to 4 days duration in the latter part of October or early November.

Intensities of individual storms fluctuated greatly. With the exception of storms that produced little total precipitation, there were usually several peaks for each storm. Highest 3-minute intensities varied from 1.4 to 4.5 inches per hour (Table 1). Lower intensity storms produced runoff when they were of sufficient duration to amply wet the soil. Small storms of greater intensity tended to seal the soil surface and thus produced runoff.

TABLE 1

Storm characteristics for the period of study

	Unit of measure	1959		1960		1961	
		Rip	Pit	Rip	Pit	Rip	Pit
Peak 3-minute intensities of storms producing runoff:	In./hr.						
Highest		3.00	2.04	1.35	3.60	4.50	3.30
Lowest		0.18	0.17	1.35	1.05	0.23	0.60
Average		1.13	0.89	1.35	2.48	2.05	1.97
Storms producing runoff	Number	11	9	1	5	8	7
Storms, 1 May-1 Dec.	Number	17	13	20	14	17	13
Date of First Storm		11 May	5 May	6 May	10 June	29 June	29 June
Date of Last storm		2 Nov.	2 Nov.	5 Dec.	5 Dec.	13 Nov.	6 Nov.

3.2. *Runoff*

Runoff from untreated plots was as high as 62 percent of precipitation on the north aspect and 58 percent on the south aspect of the ripping site. At the pitting site, runoff was a maximum of 67 percent of precipitation on the north aspect and 89 percent on the south aspect. The north aspects at both sites are silt loam soils, while those on the south vary from a clay at the ripping site to a silty clay loam at the pitting site. At the pitting site, more runoff occurred from the south aspect than from the north aspect. This would be expected since the south aspect was a finer-textured soil. The reverse of this was found at the ripping site, where runoff was considerably more on the north aspect. An attempt will be made to explain this in the section entitled Observations and Inferences.

Reduction of runoff due to treatment was quite variable. Ripping as a soil treatment was 100 percent effective on both the north and south slopes for the first storm. Overall yearly effectiveness was 96 percent for both the north and south slopes at the end of the first year. Only one storm occurred on the ripped site during the second year of study, a 2.48-inch rain with a peak intensity of 1.4 inches per hour. Runoff was reduced 77 and 61 percent for the north and south slopes. The ripped site entered the third year of measurement with a 79 and 62 percent effectiveness; the third-year averages, however, were 82 and 89 percent for north and south slopes. Over a three-year period of study, the effectiveness of ripping declined approximately 15 percent (Tables 2 and 4).

Pitting was 47 percent effective on the north slope and 16 percent effective on the south slope for the first runoff-producing rain. The first-year average was 24 and 12 percent. Runoff was produced five times on the pitted site during the second year of study. It entered the year with a 55 percent effectiveness for north slope and 31 percent for south slope, which decreased to an overall average of 13 percent for the north slope and 25 percent for the south slope. The pitted site entered the third year of study with a 34 percent effectiveness on the north slope and a -23 percent on the south slope. At the end of the year, these values averaged 13 and 6 percent, respectively (Tables 3 and 5).

3.3. *Erosion*

Reduction in erosion due to ripping was 100 percent on both slopes at the first rain. The yearly average was a 95 percent reduction for the north and a 75 percent reduction for the south slope in 1959. Reductions for the only storm in 1960 were 65 and 64 percent, respectively. The third year of study began with 77 and 78 percent reductions, and ended with 55 and 7 percent reductions for the north and south slopes (Tables 2 and 4).

Pitting as a treatment practice reduced erosion 7 percent on the north and 11 percent on the south slope at the first runoff-producing rain. First year's averages were 16 and 17 percent for the north and south slopes, respectively. Pitting entered the second year of study with a -0.3 percent effectiveness for the north aspect and 35 percent for the south. The yearly averages were 15 and 25 percent for these aspects. At the first rain in the third year of study, pitting was 24 and 5 percent effective on north and south aspects. By the end of the third year, pitting had ceased to be effective in reducing erosion. On the north slopes erosion was reduced by only 4 percent, while on the south slopes, erosion from the treated plots exceeded that on the untreated plots by 4 percent (Tables 3 and 5).

3.4. *Rainfall-Runoff Relations*

The amount of rainfall in excess of 0.25 inch per hour was highly significant as related to surface runoff at both study sites with a 0.91 correlation coefficient at the ripped site and 0.64 at the pitted site. Both were significant at the 1 percent level. The duration or total time in which this excess fell was more closely correlated to surface runoff, and gave a correlation coefficient of 0.82 at the ripped site and 0.85 at the pitted site. These are also significant at the 1 percent level.

TABLE 2

Average surface runoff and erosion on ripped and untreated soil, by storm

Date of storm	Precipitation		Surface runoff				Erosion			
			North		South		North		South	
	North	South	Ripped	Untreated	Ripped	Untreated	Ripped-	Untreated	Ripped	Untreated
	in.	in.	in.	in.	in.	in.	lb/acre	lb/acre	lb/acre	lb/acre
1959										
26 May	0.59	0.26	—	0.248	—	0.150	—	—	—	—
21 June	.27	.30	0.002	.054	0.003	.019	5.6	191.8	43.2	38.3
25 June	.07	.10	—	.002	—	.001	—	7.7	—	.7
3 August	.29	.36	—	.002	—	—	—	5.3	—	—
7 August	.79	.68	.024	.419	.004	.065	9.1	472.2	16.5	30.2
10 August	.39	.39	.014	.112	.003	.018	38.0	122.2	3.9	12.0
14 August	.44	.43	.013	.179	.T	.050	26.7	513.6	—	118.0
26 August	.70	.70	.026	.278	.010	.073	30.2	576.5	10.9	87.5
1 Oct.	.19	.18	—	.001	—	—	—	—	—	—
3 Oct.	.27	.27	—	.002	—	—	—	9.9	—	—
31 Oct.	.94	1.04	T	.467	—	.085	—	319.0	—	13.0
1960										
18 Oct.	2.48	3.21	.051	.218	.152	.386	27.0	76.2	90.3	252.3
1961										
3 July	.48	.45	.003	.014	.005	.013	14.4	62.5	4.9	22.1
2 August	.91	.93	.120	.445	.032	.190	301.8	790.8	93.1	267.3
11 August	.45	.47	T	.019	—	.002	—	52.6	—	16.5
17 August	.67	.58	.091	.412	.017	.159	237.5	877.2	27.6	276.5
3 Sept.	.22	.10	—	.007	—	—	—	13.7	—	—
9 Sept.	.35	.35	.024	.080	T	.014	66.8	183.3	—	200.8
18 Sept.	.46	.45	.070	.261	.007	.065	1078.6	2035.9	1507.9	974.7
30 Oct.	1.11	1.08	.031	.166	T	.032	177.5	135.6	T	5.5

3.5. *Observations*

It became obvious early in the first year of study that certain individual plots at both sites on south aspects were not functioning as expected. For instance, certain untreated (check) plots on the ripped site were failing to yield any runoff. Certain treated plots on the pitted site were improving in their ability to reduce surface runoff.

TABLE 3

Average surface runoff and erosion on pitted and untreated soil, by storm

Date of storm	Precipitation		Surface runoff				Erosion			
			North		South		North		South	
	North	South	Pit-ted	Un-treated	Pit-ted	Un-treated	Pit-ted-	Un-treated	Pit-ted	Un-treated
	in.	in.	in.	in.	in.	in.	lb/acre	lb/acre	lb/acre	lb/acre
1959										
26 May	1.16	0.96	0.413	0.776	0.434	0.515	1382.7	1493.7	1627.4	1831.2
27 July	.16	.21	—	—	.012	.022	—	—	53.8	66.8
28 July	.39	.55	.214	.250	.316	.375	623.6	645.7	1216.1	1251.0
6 August	.33	.26	—	—	.002	.004	—	—	3.2	7.7
7 August	.58	.65	.165	.194	.297	.367	61.1	153.5	200.6	145.8
10 August	.20	.22	—	—	.006	.013	—	—	2.8	11.6
20 August	.18	.20	.022	.039	.051	.067	50.1	117.4	155.6	201.7
26 August	1.19	1.49	.659	.779	1.043	.978	1378.2	1825.7	3125.2	4146.7
5 Oct.	.15	.17	—	—	—	—	—	—	—	—
2 Nov.	1.96	1.26	.583	.665	.872	1.118	248.0	244.9	454.6	625.7
1960										
14 August	.28	.39	.010	.022	.045	.065	37.4	37.3	48.5	74.5
22 August	.20	.15	.022	.032	—	—	64.0	76.6	—	—
10 Oct.	.40	.41	.120	.150	.123	.152	69.6	122.6	131.4	167.2
24 Oct.	3.48	3.32	.911	1.022	.690	.922	217.3	192.2	173.7	236.1
10 Nov.	.25	.19	.047	.053	.009	.020	33.6	45.7	24.6	29.5
1961										
3 July	.51	.54	.040	.061	.112	.091	79.6	104.3	317.6	334.8
10 July	.88	.54	.556	.528	.272	.357	1287.3	1174.3	1062.8	960.5
3 August	.17	.23	—	—	.008	.008	—	—	17.6	16.5
11 August	.52	.41	.041	.071	.078	.090	63.8	47.8	22.5	29.2
21 August	.80	.59	.180	.182	.142	.156	119.8	131.0	115.2	91.7
13 Sept.	.39	.39	.109	.113	.088	.122	168.8	236.1	198.1	174.2
1 Nov.	1.73	1.45	.109	.111	.164	.150	54.8	59.4	19.3	19.7

The two study areas were carefully surveyed. Small (1/4-inch diameter) holes were observed in the untreated plots. Excavation of similar holes in soil adjacent to the study site showed that these openings went down and out in a downhill direction and increased in diameter along the main axis.

TABLE 4

Relative effectiveness of ripping in reducing runoff and erosion, by storm

Date of storm	Precipitation		Rain as runoff (*)		Reduction in surface runoff		Reduction in erosion	
	North in.	South in.	North %	South %	North %	South %	North %	South %
1959								
26 May	0.59	0.26	42.0	57.7	100.0	100.0	—	—
21 June	.27	.30	20.0	6.3	96.3	84.2	97.1	-12.8
25 June	.07	.10	2.9	1.0	100.0	100.0	100.0	100.0
3 Aug.	.29	.36	.7	—	100.0	—	100.0	—
7 Aug.	.79	.68	53.0	9.6	94.3	93.8	98.1	45.4
10 Aug.	.39	.39	28.7	4.6	87.5	83.3	68.9	67.5
14 Aug.	.44	.43	40.7	11.6	92.7	100.0	94.8	100.0
26 Aug.	.70	.70	39.7	10.4	90.6	86.3	94.8	87.5
1 Oct.	.19	.18	.5	—	100.0	—	100.0	—
3 Oct.	.27	.27	.7	—	100.0	—	100.0	—
31 Oct.	.94	1.04	49.7	8.2	100.0	100.0	100.0	100.0
1960								
18 Oct.	2.48	3.21	8.8	12.0	76.6	60.6	64.6	64.2
1961								
3 July	.48	.45	2.9	2.9	78.6	61.5	77.0	77.8
2 Aug.	.91	.93	48.9	20.4	73.0	83.2	61.8	65.2
11 Aug.	.45	.47	4.2	.4	100.0	100.0	100.0	100.0
17 Aug.	.67	.58	61.5	27.4	77.9	89.3	72.9	90.0
3 Sept.	.22	.10	3.2	—	100.0	—	100.0	—
9 Sept.	.35	.35	22.9	4.0	70.0	100.0	63.6	100.0
18 Sept.	.46	.45	56.7	14.4	73.2	89.2	47.0	-54.7
30 Oct.	1.11	1.08	15.0	3.0	81.3	100.0	-30.9	100.0

(*) From untreated plots

It was observed during a storm on the pitted site that certain depressions treated with the soil pitter were draining, and the water in them was swirling as it went down. At the start of the study the average depth of pits had been determined, by use of a soil probe, to be 16 inches. These pits when remeasured, were increasing in both depth and subterranean diameter. Soil probes were constructed of a pointed 3/8-inch steel rod 48 inches long with a 12-inch crossbar on top. Pits near the study plots were probed with this device throughout 1959, and by the early summer of 1960 the 4-foot probe could be inserted quite easily and rotated which indicated that the below-ground diameter was indeed increasing. Adjacent excavations showed that, in these instances,

TABLE 5

Relative effectiveness of pitting in reducing runoff and erosion, by storm

Date of storm	Precipitation		Rain as runoff (*)		Reduction in surface runoff		Reduction in erosion	
	North in.	South in.	North %	South %	North %	South %	North %	South %
1959								
26 May	1.16	0.96	66.9	53.6	46.8	15.7	7.4	11.1
27 July	.16	.21	—	10.5	—	45.5	—	19.5
28 July	.39	.55	64.1	68.2	14.4	15.7	3.4	2.8
6 Aug.	.33	.26	—	1.5	—	50.0	—	58.4
7 Aug.	.58	.65	33.4	56.5	14.9	19.1	60.2	-37.6
10 Aug	.20	.22	—	5.9	—	53.8	—	75.9
20 Aug.	.18	.20	21.7	33.5	43.6	23.9	57.3	22.9
26 Aug.	1.19	1.49	65.5	65.6	15.4	-6.6	24.5	24.6
5 Oct.	.15	.17	—	—	—	—	—	—
2 Nov.	1.96	1.26	33.9	88.7	12.3	22.0	-1.3	27.3
1960								
14 Aug.	.28	.39	7.9	16.7	54.6	30.8	-0.3	34.9
22 Aug.	.20	.15	16.0	—	31.3	—	16.4	—
10 Oct.	.40	.41	37.5	37.1	20.0	19.1	43.2	21.4
24 Oct.	3.48	3.32	29.4	27.8	10.9	25.2	-13.1	26.4
10 Nov.	.25	.19	21.2	10.5	11.3	55.0	26.5	16.6
1961								
3 July	.51	.54	12.0	16.9	34.4	-23.1	23.7	5.1
10 July	.88	.54	60.0	66.1	-5.3	23.8	-9.6	-10.7
3 Aug.	.17	.23	—	3.5	—	—	—	-6.7
11 Aug.	.52	.41	13.7	22.0	42.3	13.3	-33.5	22.9
21 Aug.	.80	.59	22.8	26.4	1.1	9.0	8.5	-25.6
13 Sept.	.39	.39	29.0	31.3	3.5	27.9	28.5	-13.7
1 Nov.	1.73	1.45	6.4	10.3	1.8	-9.3	7.7	2.0

(*) From untreated plots

the soil pitter had penetrated the parent material (Mancos shale). Subterranean channels were being formed, and runoff was occurring below ground. On the basis of these observations, the Bureau of Land Management decided against further treatments of this type on areas where the soil depth was 6 feet or less.

Throughout the study, additional plots improved in their ability to decrease surface runoff. At the ripped site these were first observed on the lower slope, south aspect, then the upper slope, south aspect, and by the end of 1961 on the lower slope, north aspect. Although this phenomenon was first observed on the south aspect of the pitted site, it seemed to become progressively more pronounced on the north aspect.

3.6. *Inferences*

This phenomenon of cutting underground channels for subsurface flow has been previously reported (Fletcher and Carroll, 1948) (Carroll, 1949) in Arizona where it was called soil piping. Prior to this study, however, it was not recognized as a major problem on the Rio Puerco drainage. A general reconnaissance survey of the Puerco drainage indicated that piping was generally taking place over a large portion of the drainage. A few instances were found in which pipes draining into the existing gully system were as much as 10 feet in diameter. A superficial underground reconnaissance of these pipes indicated that they decrease in diameter, but spread similar to a root system. There are indications that these systems are continually dropping to a lower level in a downhill direction. It appears that the main stream channels are not piping to deeper levels only where such action is prevented by a layer of sand.

Pipes seem to occur with greatest regularity in pure deposits of Mancos shale and in alluvial soils where Mancos shale was a predominant parent material. Soils in this region contain a great deal of salts which apparently dissolve readily. Pipes seem to function best after long dry spells. When rains are frequent, the smaller pipes do not flow.

The theory has been advanced that the high concentration of salts in Mancos shale dissolves upon contact with water and the decrease in volume facilitates piping. The shale or shale soils have a high concentration of clays, which are the last to be deposited when flow stops or slows down. These colloids contract as they dry and expand when wet. This could account for the intermittent flow of the smaller pipes. It is possible that anything that increases either the velocity or volume of water in a given confine is detrimental in this region.

It is also possible that overall treatment effects speeded up the piping phenomenon on the study sites more than would normally take place in nature. A trench 8 feet wide, 4 feet deep, and approximately 250 yards long was made to house runoff collection barrels below each group of 16 plots. Although piping appears to be a natural phenomenon throughout the region, this trench could have accelerated the action in the study area. Piping in its most obvious forms first showed up in these trenches, which collected large amounts of runoff from the land surrounding the runoff plots themselves.

3.7. *Discussion*

Although the studies answered many of the questions concerning the treatments applied and their effectiveness on these particular soils in this particular region, a greater number of unanswered questions were brought to light:

1. Variation in runoff and sediment production on mechanically treated plots.

a) What combination of factors causes the extreme storm-to-storm variation in runoff and sediment within a single year?

b) What factor or combination of factors cause a recovery of efficiency from the last storm of 1 year to the first storm of the following year?

2. Soil piping

a) How does it operate?

b) What factors influence it most?

c) What can be done to stop it or at least reduce its destructiveness?

d) Do land treatment measures induce or increase soil piping?

4. Conclusions

1. Soil ripping is highly effective in reducing surface runoff. The study has not progressed to the point where it is possible to predict the annual rate of decline of this effectiveness.

2. Soil ripping is effective in reducing erosion on the silt-loam soils of the north slopes, but at the end of the third year, there was very little reduction on the clay soils of the south slopes.

3. Soil pitting is not so effective in reducing surface runoff and erosion in this region. On these particular soils, pitting has lost its effectiveness at the end of 3 years.

4. Because of the risk of increasing soil piping, ripping is not a suitable land treatment practice on a shale soil that is so shallow that the ripping operation penetrates to the parent material.

BIBLIOGRAPHY

CARROLL, Paul H. (1949). Soil piping in southeastern Arizona. *U.S.D.A., SCS, Regional Bul.* **110**, 21 pp., illus.

DORTIGNAC, E.J. (1956). Watershed resources and problems of the Upper Rio Grande Basin. Rocky Mountain Forest and Range Experiment Station, 107 pp., illus.

FLETCHER, JOEL E. and Paul H. CARROLL. (1948). Some properties of soils associated with piping in southern Arizona. *Soil Science Soc. of Amer. Proc.* (13) pp. 545-547, illus.

GARCIA, George, WAYNE C. HICKEY, Jr., and E.J. DORTIGNAC. (1963). An inexpensive runoff plot. U.S. Forest Serv. res. note RM-12, 8 pp. illus. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colo.