Rainfall Effects on Soil Surface Characteristics Following Range Improvement Treatments[1]

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Highlight

Range improvement treatments—brush clearing, pitting, and seeding to grass—were imposed on twenty-four 6 by 12-foot plots near Tombstone, Arizona. One summer's rainfall of average amount and intensity reduced roughness due to pitting; and such other surface characteristics as erosion pavement and exposed soil approached a state of stability similar to the untreated plots. Surface runoff exhibited little correlation with treatment, but showed a statistically significant negative correlation with crown cover of vegetation.

In the semiarid Southwest, rainfall is too little in amount and uncertain in distribution to maintain vegetation that adequately protects the soil. Rainfall often occurs in severe storms that produce large volumes of surface runoff and cause serious erosion.

Because of the sparsity of vegetation, soil surface conditions become important in the infiltration-runoff balance. The purpose of this study was to determine effects of seasonal rainfall on soil surface characteristics after various treatments used in range reseeding and improvement, and to evaluate possible effects of range conservation practices on water yield.

In a range conservation program, brush control and reseeding of grasses in cleared or depleted areas, together with soil treatments that impede runoff and help establish reseeded grasses, are important measures. Although more or less successful methods of reseeding semidesert rangelands have been worked out, few data are available showing how such induced changes in vegetation affect yields of water and sediment. Also, although benefits from range management have been amply demonstrated, few experimental data are available that show the length of time required for stabilization of the soil surface after pitting, contour furrowing, or brush removal.

Caird and McCorkle (1946), working in grassland areas of Texas, found that contour furrows in rangeland functioned from four to seven years, during which a twofold increase in forage production was noted. On the other hand, Valentine (1947) found that certain structures, such as widely spaced terraces, brush dams, and contour structures, intended to conserve runoff from semidesert rangeland in New Mexico, did not improve vegetation cover.

Many studies draw attention to the importance of vegetation in reducing runoff. Duley and Kelly (1939) reported that vegetational cover and litter have a greater effect on infiltration rates than slope, intensity of rainfall, or soil type. Rauzi (1960) indicated that, regardless of soil type, water-intake rates depend on the type of plant cover, the amount of standing vegetation, and the amount of mulch material on the ground. Beutner and Anderson (1942) found that mulch and grass cover decreased surface runoff as much as 20 to 60%.

The literature indicates that the surface layer of the soil is usually the most important factor in water intake. Alteration of the surface by pitting, contour furrows, etc., to allow longer infiltration opportunity, usually increases water intake for a time; but without adequate vegetation cover, compaction from raindrops causes puddling, lessening infiltration rates and increasing runoff (Stallings, 1952; Ellison, 1945; 1949).

Several investigators have used microrelief meters to measure changes in soil surface characteristics (Kuipers and van Ouwerkeck, 1963; Burwell, 1964; Mesavage and Smith, 1962; Subcommittee, Range Research Methods, 1963). All of these relief meters are based on the same principle. A frame is placed over the area to be measured, and sliding pins are dropped through it to the soil surface. A measurement board behind the tops of these pins allows direct reading of ground elevations, and microrelief may be determined from these readings.

The principal objective of this study was to investigate changes in the soil surface resulting from one summer rainy season following brush removal, pitting, seeding, and combination of these treatments. Subordinate objectives were to investigate:

1. Relations of soil surface characteristics resulting from these treatments to on-site runoff.
2. Influence of treatment on soil movement.
3. Influences of vegetational cover on rainfall-induced changes of the soil surface.
4. Relation of on-site runoff to vegetational cover.

Study Area and Methods

The area selected for the study lies within the Walnut Gulch Experimental Watershed, a 58-square-mile watershed surrounding Tombstone, Arizona, where the Agricultural Research Service of the U. S.-

[1]*Contribution from the Southwest Branch, Soil and Water Conservation Research Division, ARS, U. S. D. A., in cooperation with the Arizona Agricultural Experiment Station.*

D. A. is conducting hydrologic research.

Average annual precipitation is approximately 14 inches, of which about 60% falls during convectional thunderstorms in July, August, and September. With rare exceptions, these are the only storms that produce runoff. The remaining 40% falls as rain or snow resulting from low-intensity, frontal storms, most of which occur during the winter months.

The study site was selected for uniformity of soil, slope, aspect and vegetation. The soil, a gravelly sandy loam, was derived from a calcareous base material. Texture to a depth of 4 inches is approximately 55% gravel, 33% sand, 5% silt, and 7% clay.

Vegetation of the site was comprised mainly of shrubs: whitethorn *(Acacia constricta* var. *vernicosa)*, creosotebush *(Larrea tridentata)*, tarbush *(Flourensia cernua)*, and scattered plants of a few others. Although grass plants were sparse, there was some black grama *(Bouteloua eriopoda)*, bush muhly *(Muhlenbergia porteri)* and fluffgrass *(Tridens pulchellus)*.

Twenty-four 6- by 12-ft plots, established before the summer rainy season of 1963, were left untreated until January 1964. Each plot was bordered by a partially buried, galvanized plate. Runoff from the plot was diverted into two 55-gallon covered containers, and the collected water was measured after each storm. Two plots were equipped with water-level recorders to determine time and rate of runoff. Rainfall was measured with a recording rain gauge near the center of the site. The imposed treatments, replicated three times in a randomized factorial arrangement, comprised seeding to grass, clearing of brush, and soil pitting, alone and in all the possible combinations. As a check, three plots were untreated. Clearing of brush was accomplished by manually uprooting all shrubs with the least possible soil disturbance. Pitting, to simulate that done with an eccentric disk, was done with a shovel. The soil was turned downslope, leaving a pit 6 inches deep and 4 ft long. The pits were about 2 ft apart, arranged across the plot on the contour. For seeding, native hay was spread on the plot and then raked to cover the seed. The hay was left on the plot as a mulch. A fairly good stand of native perennial grasses was established the first year.

Surface characteristics and vegetational cover were measured with the microrelief meter in June and in September 1964, before and after the summer rains. Characteristics recorded were: (1) microtopography, or roughness of the soil surface; (2) erosion pavement (particles 2 mm in diameter or greater); (3) exposed soil (particles less than 2 mm in diameter); (4) litter; (5) crown cover of vegetation.

The relief meter used in this study consists of a plot frame, meter frame, measurement board, and 11 sliding pins (Fig. 1). The plot frame is an angle-iron frame placed around a plot. The plot frame rests on mounts, parallel to the soil surface.

The meter frame is placed across, and perpendicular to, the plot frame. There are 23 positions at 0.5-ft intervals along the plot frame.

The meter frame contains 11 pins spaced at 0.5-ft intervals across the plot. Thus, there is a total of 253 point measurements for each 6- by 12-ft plot.

To determine microtopography, or roughness, elevation of each pin was read from the measuring board when the point of the pin touched the soil surface. From the 253 readings, the "roughness index" was determined. As the plot frame was parallel to the ground surface at the edges of the plots, the datum surface from which point readings were made was essentially parallel to the plot surface. The statistical variance, which depends on the deviations of the points from their mean, is used as the index of roughness. The variance was arrived at by using the formula:

$$s^2 = \frac{\Sigma X_i{}^2 - \dfrac{(\Sigma X_i)^2}{n}}{n-1}$$

where: s^2 = variance

X_i = each relief meter elevation reading

n = number of measurements (253).

From the statistical equation $s^2{}_1/s^2{}_2 = F$, it is possible to determine whether there exists a difference (or if a significant change took place) in the "roughness index" during the summer. In the formula, the numerator is the larger of the two roughness indices determined for each plot.

For determination of the other characteristics, the microrelief meter was used as a point-quadrat frame. When the pins were lowered to the soil surface to make the elevation readings, the object touched by the pin point was recorded and the percentage of the ground occupied by that characteristic was calculated.

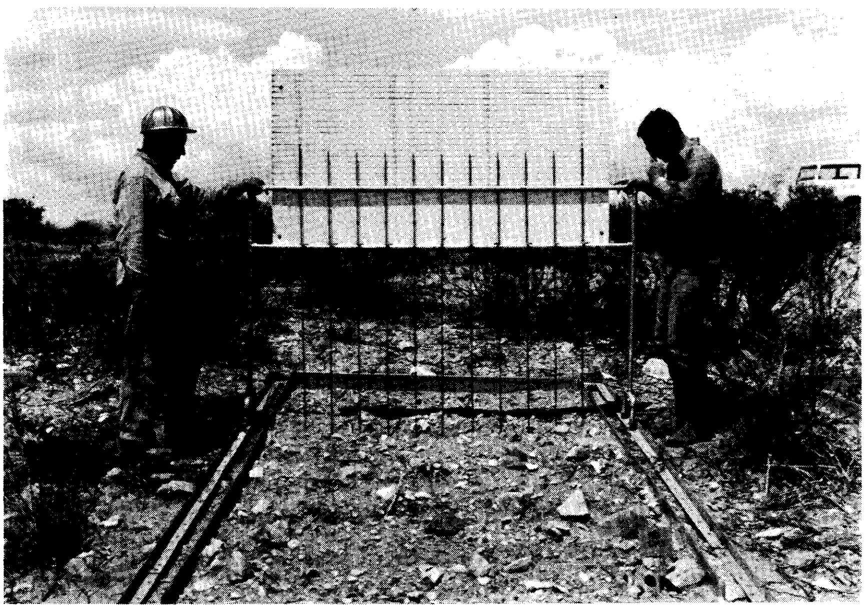

FIG. 1. Reliefmeter in place on a cleared, pitted, and seeded plot. Measurement being made prior to onset of summer rainy season 1964.

Table 1. Runoff (inches) by treatments from convective storms as affected by treatments.[1]

Date (1964)	Rainfall (inches)	Control	Clear	Pit	Clear, Pit	Seed	Clear, Seed	Pit, Seed	Clear Pit, Seed	Mean
July 14	.37	.054	.086	.018	.020	.017	.036	.018	.018	.033
July 23	1.49	.358	.485	.262	.456	.217	.463	.209	.304	.344
August 1	.52	.195	.267	.183	.222	.123	.180	.126	.165	.183
August 9	.62	.109	.168	.085	.166	.043	.104	.060	.079	.102
August 17	.82	.435	.535	.398	.516	.231	.372	.242	.410	.392
September 9	1.00	.384	.540	.430	.561	.137	.296	.213	.299	.358
September 10	1.02	.388	.400	.356	.475	.209	.346	.238	.389	.350
Total	5.84	1.923	2.481	1.732	2.416	.977	1.797	1.106	1.664	1.762

[1] Runoff figures larger than the mean of all plots are underscored.

When a plant was struck by the point, the scientific name was recorded. If in its descent the pin struck the aerial portion of a plant, the height of the pin on the measurement board was recorded along with the species name. An analysis of variance was made on each group of plots containing the same treatment to determine whether a statistically significant change, related to the characteristic studied, had occurred.

Table 2. Changes in roughness index during summer 1964.

Treatment	Pooled s^2 before summer rains	Pooled s^2 after summer rains	Change in s^2	Percentage change in s^2	F[1]
Control	33.98	30.83	− 3.15	9.27	1.10
Clear	41.18	32.65	− 8.53	20.71	1.26**
Pit	92.80	53.92	−38.88	41.90	1.72**
Clear, Pit	117.96	55.42	−62.54	53.02	2.13**
Seed	25.42	28.23	+ 2.81	11.05	1.11
Clear, Seed	11.07	12.01	+ 0.94	8.49	1.08
Pit, Seed	100.14	78.52	−21.62	21.60	1.28**
Clear, Pit, Seed	96.30	55.08	−41.22	42.80	1.75**

** Change significant at the 1 percent level.

[1] F is the ratio $\frac{s^2 \text{ larger}}{s^2 \text{ smaller}}$. With pooled s^2 of three replications, there are 756 degrees of freedom per treatment. For significance at the 1 percent level, F must be 1.22; at the 5 percent level, 1.16.

Results

The study site received 7.65 inches of precipitation between July 10 and September 13, 1964. Of this amount, 5.84 inches fell during seven runoff-producing storms (Table 1). These seven storms yielded almost 2 inches of surface runoff from the untreated plots.

One season's data on surface runoff show little correlation between runoff and treatment (Table 1). Plots that were pitted and/or cleared had generally more surface runoff than plots that were seeded. Reduced runoff seemed to be related to the pitting treatment in the earlier summer storms, but later in the summer pitting was related to increased runoff.

Microrelief

Response of surface roughness (microrelief) to 1964 summer rainfall relative to treatment is presented in Table 2 as roughness indices. Each index is the mean of those from the three replications of the treatment. The response varied from statistically nonsignificant changes in the untreated, the seeded, and the cleared and seeded plots to statistically highly significant changes in the plots of the other treatments.

Control.—The untreated plots showed a slight, nonsignficant decrease in surface roughness.

Cleared. — The cleared plots showed that summer rains caused a significant decrease in roughness.

Pitted.—Roughness of the pitted plots before the rainy season was nearly three times that of the untreated plots. After the rains, it had been reduced by 42%, but it was still much higher than that of the untreated plots.

Cleared and Pitted.—The combination of pitting and brush removal left the plots of this treatment with a higher roughness index than that of any other treatment. In the fall, however, this had been reduced to a value comparable to that of the "pitted only" plots.

Seeded.—The seeded plots increased in roughness, but the increase was not statistically significant.

Cleared and Seeded. — The cleared and seeded plots were initially the smoothest of all treated plots. The summer rains had a slight roughening effect.

Pitted and Seeded.—Initially, pitting and seeding in combination left the plots very rough. Although there was a significant

Table 3. Soil surface materials before and after summer rains (Percent soil cover).

	Erosion Pavement (Rock 2mm or more)			Soil (Less than 2mm)			Vegetation[1] (at ground level)		
Treatment	Before	After	Change	Before	After	Change	Before	After	Change
Control	57	59	+ 2	30	26	− 4	13	15	+ 2
Clear	57	57	no change	39	31	− 8**	4	12	+ 8**
Pit	38	54	+16**	54	34	−20**	8	12	+ 4**
Clear, Pit	54	64	+10**	44	29	−15**	2	7	+ 5
Seed	62	64	+ 2	16	22	+ 6**	22	14	− 8**
Clear, Seed	65	70	+ 5	21	25	+ 4**	14	5	− 9**
Pit, Seed	44	62	+18**	37	28	− 9	19	10	− 9**
Clear, Pit, Seed	43	54	+11**	42	36	− 6	15	10	− 5**

[1] Includes basal cover, prostrate plants and litter.
** Change significant at the 1 percent level of probability.

smoothing of the plots, it was less than other plots included in the pitting treatment.

Cleared, Pitted, and Seeded.— Reduction of roughness in the plots that were cleared of brush, pitted, and seeded was comparable to the plots that were pitted only. They decreased in roughness more than the pitted and seeded plots, but less than the cleared and pitted plots.

Changes in Soil Surface Characteristics

Response of soil-sized particles at the surface and of basal cover of vegetation to the summer rains varied with treatment (Table 3). In the untreated plots, no statistically significant changes in erosion pavement, soil-sized particles or basal area of vegetation were observed. On the plots cleared of brush, there was no change in erosion pavement, but the percentage of soil particles under 2 mm decreased and litter increased by statistically significant amounts. On the pitted plots and those pitted and cleared, erosion pavement increased and percentage of particles less than 2 mm decreased by statistically highly significant amounts.

At the end of the summer rains, seeding alone, and in all combinations of treatments, was accompanied by a statistically significant decrease in litter. This was probably due to the removing of mulch litter through overland runoff.

Table 4. Reduction in soil volume in ft² upper and lower halves of the study plots[1].

Treatment	Upper half	Lower half	Diff.
Control	0.73	1.23	+ .50
Clear	0.52	1.19	+ .67
Pit	1.10	1.45	+ .35
Clear-Pit	1.60	1.53	− .07
Seed	1.14	1.41	+ .27
Clear-Seed	1.25	1.21	− .04
Pit, Seed	1.95	2.04	+ .09
Clear-Pit-Seed	1.02	.67	− .35

[1] Based on elevation change of each half plot.

Effect of Treatments on Soil Movement

Numerous studies have shown a direct relation between degree and length of slope and the force that water can exert on the eroding surface. The longer the slope, the greater is the amount of erosion or soil loss. The study plots were measured to determine the elevational change of the soil surface following summer rains and to compare the amount of erosion on the upper and the lower half of each plot. The results are presented as the mean values of the three replications of each treatment (Table 4). Under four treatments—the control plots, the cleared plots, the pitted plots, and the seeded plots—erosion on the lower half of the plot was considerably greater than that on the upper half. On the plots that were cleared and pitted, cleared and seeded, or pitted and seeded, it was nearly equal on the two halves. In contrast, erosion on the upper half of the cleared, pitted, and seeded plots was considerably greater than that on the lower half.

Crown Cover Effects

Runoff values per storm were compared using an analysis of variance appropriate to factorial experiments. Although the clear and seed treatments appeared to have affected runoff, inter-replication variation was such that significance could not be established.

The nonsignificant effects of treatment, coupled with the tendency for plots where cover was increased (by seeding) to have less runoff, and plots where cover was decreased (by clearing) to have more runoff, indicated that some characteristic of the plot not brought about by treatments might be important. It appeared that crown cover of vegetation could be more closely associated with runoff than could treatment effects.

Relation of Crown Cover and Surface Runoff.— A linear regression analysis was used to compare mean runoff (Table 1) with percent crown cover. The crown cover was taken as the mean of the measurements before and after the summer rainy season (Table 5). Also, an analysis

Table 5. Changes in vegetation crown cover (percent) summer 1964.

Treatment	Before	After	Mean	Incr.
Control	16.7	36.6	26.7	19.9
Clear	0.5	16.8	9.7	16.2
Pit	10.8	27.9	19.5	17.1
Clear-Pit	0.1	14.6	7.4	14.5
Seed	8.8	44.6	26.7	35.8
Clear-Seed	0	30.8	15.9	30.8
Pit-Seed	7.8	38.6	23.2	30.8
Clear-Pit-Seed	0	33.2	16.6	33.2

was made of the relation between runoff from the storm of September 9, 1964, and the percent crown cover, using the measurements near the time of the storm (at the end of the rainy season). Linear regressions for this comparison showed a high negative correlation between crown cover and runoff, indicating that a decrease in rain-site surface runoff was related to increase in crown cover (Fig. 2 and 3).

Relation of Crown Cover and Microrelief Smoothing.—Percent crown cover was compared to the percent of microrelief smoothing, using data from the 12 plots containing a pitting treatment either alone or in combination with other treatments. These plots were chosen because of the larger microrelief index, which would reflect a change due to rains more readily than would plots having a small microrelief index. Some negative correlation exists between these two factors though it was not found to be statistically significant.

Summary and Conclusions

Much evidence is available on benefits of range conservation treatments, but few experimental data are available on adjustments of the soil surface after such treatments. The purpose of this study was to determine effects of rainfall on soil surface characteristics after various treatments used in range improvement.

The study after one season indicates some of the relationships between soil surface characteristics, range improvement treatments, and crown cover of vegetation on the one hand, and runoff generation and soil erosion on the other. The observed runoff and soil erosion resulted from summer rainfall of about average amount and intensity.

Microrelief Changes. — Before any treatment, the soil surface had become relatively stable, and the summer rains had no significant effect on surface roughness. Change in microrelief appeared to vary with the treatment practice or combination of practices. The plots with large roughness indices following treatment showed greater smoothing by the first season's rainfall than plots with small initial roughness indices. This was due, apparently, to their greater potential for smoothing or microrelief change.

Plots with a combination of seeding and any other practice or practices had smaller microrelief changes following the treatment than plots with the same treatment practices without seeding. This may be a result of the prior smoothing effect of the seeding treatment, as well as later protection of the soil surface by grass.

Changes in Soil Surface Characteristics. — The control plots represent approximate equilibrium with the environment. The pitted plots had soil exposed on the surface which was washed away by the summer rains. The mulch-seeded plots showed a decrease in litter, possibly because of the washing away of litter and uncovering of erosion pavement or soil. From the similarity in erosion pavement and exposed soil on all plots, it appears that

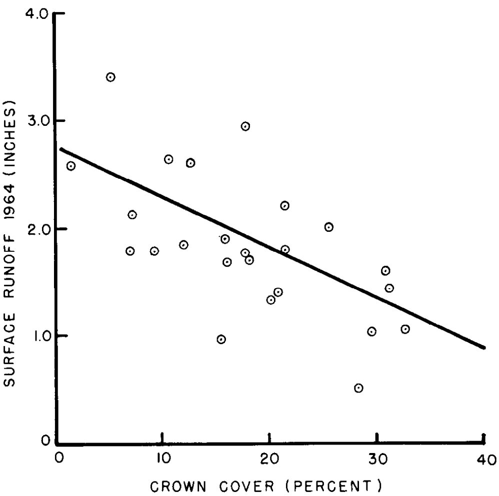

FIG. 2. Relation of crown cover to surface runoff. Total runoff for 8 storms *vs.* crown cover (the mean of measurements made in June and September 1964) (r = −.637**).

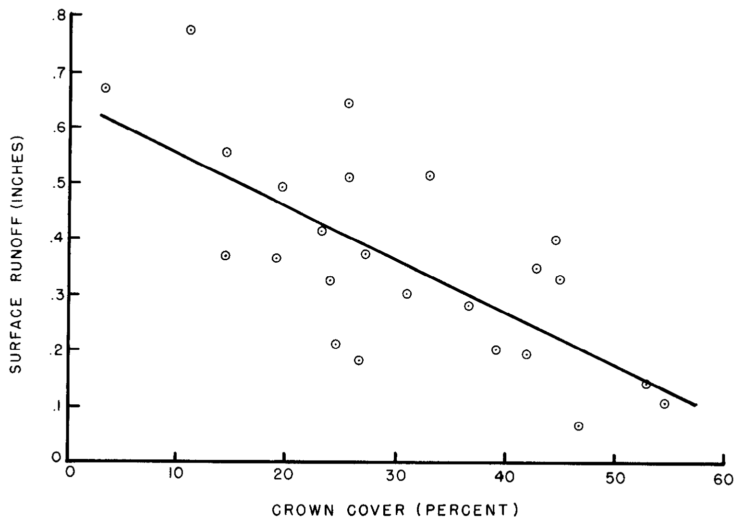

FIG. 3. Relation of crown cover of vegetation to surface runoff. Storm of September 9, 1964 (r = −.717**).

these surface characteristics stabilize after one summer's rainfall.

Soil Movement on the Plots.—Generally, the lower half of the 12-ft-long plots underwent more erosion than the upper half, possibly owing to increased velocity and quantity of surface flow on the lower half. The cleared, pitted, and seeded plots were the only ones showing distinctly greater erosion from the upper half than from the lower half. The cleared and pitted plots, the cleared and seeded plots, and the pitted and seeded plots, showed equal amounts of erosion in the upper and lower halves.

Effects of Treatments on Surface Runoff.—There was little correlation between treatments and surface runoff, although clearing appeared to increase rain-site runoff, and seeding appeared to reduce it.

Effects of Crown Cover.—Crown cover appeared to have a greater effect in reducing rain-site runoff than did soil treatments. As the crown cover increased, the surface runoff decreased significantly. Also, crown cover slightly reduced the microrelief change.

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