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SEASONAL CHANGE IN INFILTRATION AND EROSION FROM USLE PLOTS IN SOUTHEASTERN ARIZONA

J. R. Simanton and K. G. Renard

The authors are Hydrologist and Hydraulic Engineer, respectively, U.S. Department of Agriculture, Agricultural Research Service, Western Region, Southwest Rangeland Watershed Research Center, 442 East Seventh Street, Tucson, Arizona 85705.

ABSTRACT

A rotating boom rainfall simulator was used on 3 x 10.7 m plots to determine Universal Soil Loss Equation (USLE) parameter values. Simulator runs were made in the spring and fall of 1981 on two replications of four treatments on three soil types in southeastern Arizona. The treatments were: natural, vegetation removed, erosion pavement and vegetation removed, and tilled (moldboard plowed and disked). Runoff, infiltration, and soil loss varied significantly between treatments and, most interestingly, between the spring and fall runs. Plot surface characteristics of rock, gravel, soil, litter, and vegetation cover could not explain this seasonal variation in hydrologic response.

INTRODUCTION

Rangeland areas, like many other areas, exhibit extreme variability in the hydrologic processes affecting erosion and sediment yield. As part of a nation-wide effort to improve application utility of the USLE (Wischmeier and Smith 1978) to various regions of the United States, the Southwest Rangeland Watershed Research Center, USDA-Agricultural Research Service, in Tucson, Arizona has been using a rainfall simulator and runoff-erosion plots to determine values for the various USLE factors which might be applicable for rangelands. This work is being conducted on the 150 km^2 Walnut Gulch experimental watershed near Tombstone, in southeastern Arizona (Fig. 1). This watershed is representative of millions of hectares of brush and grass rangeland found throughout the semiarid Southwest. Major vegetation of the watershed includes creosote bush (Larrea divaricata), whitethorn (Acacia constricta), tarbush (Flourensia cernua), black grama (Bouteloua eriopoda), blue grama (Bouteloua gracillas) tobosagrass (Hilaria mutica), and bush muhly (Muhlenbergia Porteri). Soils are generally well drained, calcareous, gravelly loams with large percentages of rock and gravel on the soil surface. Average annual precipitation on the watershed is about 300 mm, and is bimodally distributed, with approximately 70 percent occurring during the summer thunderstorm season of July to mid September.

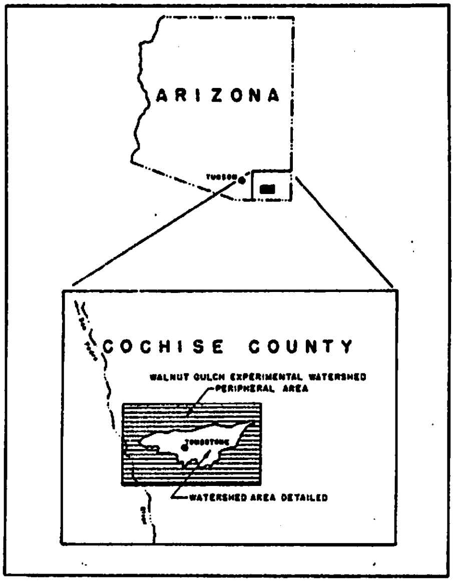

Figure 1. Watershed location map.

Differences between summer and winter precipitation can be tremendous on Walnut Gulch. Summer precipitation is dominated by convective thunderstorms which are limited in areal extent, and characteristically have maximum 5-min rainfall rates greater than 100 mm/hr (Osborn and Simanton 1981). Winter precipitation, though covering larger areas, has maximum 5-min rainfall rates which are usually less than 10 mm/hr (Osborn et al. 1979). This ten-fold difference between summer and winter precipitation rates has a significant effect on runoff and erosion. For example, over 99 percent of the annual Walnut Gulch runoff for the past 25 yr has occurred during the summer thunderstorm season.

Rainfall-runoff studies on Walnut Gulch indicate that variables, such as vegetation and soil moisture, are not as significant as precipitation characteristics when used in rainfall-runoff regression models (Schreiber and Kincaid 1967; Osborn and Lane 1969). However, in other areas where precipitation characteristics are not as dominant, vegetation and soil moisture are important factors (SCS 1972).

Dixon (1975) has suggested that easily measured surface characteristics are indirectly related to infiltration and erosion, and has shown that the two surface parameters (microroughness and macroporosity) that do directly influence infiltration are not easily measured.

The possible effects of soil surface compaction, such as would be expected from cattle grazing, have not been determined for soils on Walnut Gulch. However, studies elsewhere, that have related grazing to increased soil bulk density and decreased infiltration and increased erosion, seem mixed in their conclusions (Gifford and Hawkins 1976).

This paper describes and discusses one year's spring and fall variations in runoff and erosion from USLE study plots, and discusses these findings in relation to plot surface, soil, and vegetative characteristics.

EXPERIMENTAL BACKGROUND

Method

The research plan of this study on application of the USLE to rangelands followed procedures used in rainfall simulation studies to develop values for the USLE soil erodibility factor (Wischmeier and Mannering 1969). This plan includes the use of relatively large plots (3 x 10.7 m long plots are known to show the effects from overland flow erosion), a standard surface treatment (continuous fallow produced by up- and down-slope plowing and disking), standard 9 percent slope, and standard sequences of rainfall inputs. These standard procedures were used so that our results could be compared with results from other USLE research. The study includes seasonal application of simulated rainfall on three treatments and a control that are replicated twice on three soil series, and is expected to continue for at least 3 years.

Soils

The three soil series selected were Bernardino (a thermic Ustollic Haplargid), Cave (thermic, shallow Typic Paleorthid), and Hathaway (thermic Aridic Calciustoll). These are all gravelly loams, and are USDA-Soil Conservation Service bench mark soils for Arizona. They comprise nearly 45 percent of the Walnut Gulch watershed area, and are described in detail by Gelderman (1970).

The Bernardino series is a deep, well-drained, fine-textured soil formed in old calcareous alluvium. This soil can have up to 50 percent, by volume, of gravel and cobbles in the surface 10 cm, and usually less than 35 percent gravel in the remainder of the profile.

The Cave series is a shallow, well-drained, medium textured soil with indurated lime hardpans that have developed at less than 45 cm in old, gravelly and cobbly calcareous alluvium. This soil can have up to 60 percent, by volume, of gravel and cobbles in the surface 10 cm, and usually less than 40 percent gravel in the remainder of the profile.

The Hathaway series is a deep, well-drained, gravelly medium and moderately coarse-textured soil over very gravelly, coarse-textured materials of moderate depths. This soil was formed from gravelly or very gravelly calcareous old alluvium, and can have up to 70 percent, by volume, of gravel and occasional cobbles in the surface 10 cm, and usually less than 50 percent in the remainder of the profile.

Plots

Criteria for plot selection were largely based on requirements set forth during the original development of the USLE, and on constraints of the rainfall simulator. The criteria included: (1) plots had to be in pairs separated by no less than 3 m but no more than 4 m; (2) each pair had to be at least 7 m apart; (3) paired plots had to be parallel; (4) plot slope had to be near 9 percent; (5) plot slope had to be uniform; (6) rills or other obvious drainages must not be present, and (6) plot pairs on each soil series had to be relatively close to one another.

The 24 experimental plots were each 3.1 m x 10.7 m in size, with the long axis parallel to the slope. Each plot was delineated on three sides by 15 cm metal borders that were installed so that 3 cm were inserted into the soil and 12 cm extended above the surface. The downslope end of the plot was delineated by a 20-cm deep metal sheet with a sill plate on one edge. This sheet was inserted into the soil so that the sill plate was flush with the soil surface. The soil-metal interface was sealed with a silicone rubber-paint thinner solution which, upon drying, formed an impervious connecting joint. Runoff from the plots were collected in troughs that divert the water into a runoff-measuring flume equipped with a FW-1 water-level recorder that measures instantaneous discharge. After the plots on each soil series were selected and plot borders installed, plot pairs were randomly assigned their particular treatment.

Treatments

The three treatments imposed included the standard moldboard plowed and disked up and down slope treatment (tilled), a vegetation removed treatment where the vegetation initially was clipped at the ground surface and then controlled with a systemic herbicide (clipped), and a vegetation and erosion pavement (rock and gravel > 2 mm) removed treatment where the vegetation was clipped at the ground surface, as previously detailed, and the erosion pavement was hand picked from the plot to minimize soil surface disturbance (fallow). Two natural cover plots were also selected for each of the soil series. These were used as control plots. The tilled treatment is standard for determining values for the USLE soil erodibility factor (K). The other two treatments and the control were selected to show the effect of both vegetation cover and erosion pavement on soil loss. Prior to treatment, the plots were fenced to exclude cattle grazing.

After treatment, each plot pair was subjected to an initial 60-min rainfall simulation (dry), followed 24 hr later by a 30-min run (wet), which was then followed 30 min later by another 30-min run (very wet). The simulated rainfall rate for each of these runs was about 60 mm/hr. By combining results from the runs, each series of runs provides runoff and erosion data for 30 mm and 60 mm continuous rains, a 90 mm rain with one 24-hr interruption, and a 120-mm rain within approximately a 24-hr period. This simulation sequence was applied to the 24 plots, or 12-plot pairs in the late spring (April-May) and early fall (Oct-Nov) within the same year. The test periods, which are periods of low rainfall probability, were just before and after the summer rainy season (July-Sept).

Rainfall Simulator

The rainfall simulator used was a trailer-mounted rotating-boom simulator capable of applying either 60 or 120 mm/hr rainfall rates (Fig. 2) (Swanson 1965). There are 10 arms radiating from a central stem. The arms support 30 nozzles that are positioned at radii of 1.5, 3.0, 4.6, 6.1, and 7.6 m, with 2, 4, 6, 8, 10 nozzles on each respective radius. The two rainfall intensities (60 mm/hr or 120 mm/hr) are obtained by using either 15 or 30 nozzles. The nozzles spray downward from an average height of 2.4 m, apply about 15 liters/min, and produce drop-size distributions similar to those of natural rainfall (Swanson 1979). Preliminary results of a study of rainfall energies associated with the simulator indicate that the energies are about 80 percent of those of natural rainfall. Because of the simple design and portability of the simulator, many plots can be evaluated in a relatively short time (a complete series of runs can be made on 8 plots in one week).

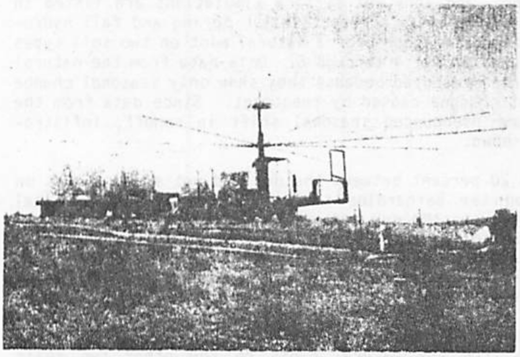

Figure 2. Trailer mounted rotating-boom rainfall simulator.

Field Measurements

Plot surface characteristics and vegetation cover were measured before the initial treatment, and then before the 60-min simulation. Characteristics measured were bare soil (particles < 2 mm in diameter), gravel (particles 2 to 20 mm in diameter), rock (particles > 20 mm in diameter), litter, vegetative basal cover, and vegetative crown cover. A 3.05 m long pin-point meter with holes spaced at 6 cm intervals was used. The meter is placed perpendicular to the plot slope, and rests on the metal plot border at 10 positions along the plot. At each position, 49 pin-point surface and vegetation measurements are made by dropping a pin through each pin hole. Thus, there is a total of 490 point measurements per plot to describe the surface characteristics.

Rainfall amount and application rate were measured with a modified recording raingage that was placed between each plot pair. The raingage was modified to increase its sensitivity to rainfall rate by doubling the rainfall-collecting area and enlarging the recorded time scale. Rainfall distribution over each plot was measured with four small plastic gages that recorded only rainfall amount. One gage was placed near each of the four corners of each plot.

On some early testing of the simulator, three narrow slotted tubes were placed across each plot to check the appliclation amount. This scheme was abandoned when (1) the amounts were found to agree very closely with those obtained from the four small plastic gages, and (2) a small ridge was observed to form on the plot surface beneath each slotted tube because of the interception of the simulated rainfall.

The flumes used to measure runoff have a capacity of about 4 liters/sec, and have sloped floors to minimize sediment deposition. The water-level recorders were sensitized so that small changes in runoff are noticeable on the runoff hydrograph. Figure 3 illustrates a complete plot pair field arrangement.

Sediment samples, manually collected in quart sample bottles, were taken at the flume exit periodically during the runoff period. Sampling intervals were dependent on changes in the runoff rate, with frequent sampling when discharge was changing rapidly. The shortest sampling interval was 1 min, usually during the first 10 min of the runoff, and the longest was no more than 15 min, usually toward the end of the run, when runoff rate was relatively constant. The time when the sample was collected was recorded for later correlation to the runoff hydrograph and calculation of sediment discharge rate and amount.

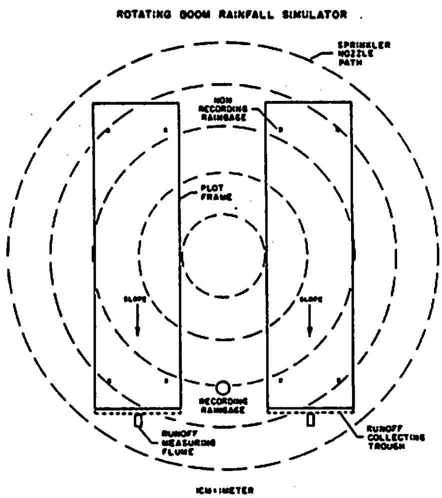

Figure 3. Typical plot layout with schematic of simulator nozzle path.

Data Analysis

Plot vegetative cover and surface characteristics were tabulated and converted to percent cover for subsequent correlation to runoff, erosion, and treatment effect. Rainfall records were digitized and tabulated to give rainfall hyetographs for use in infiltration studies. Analog records from the water-level recorder on each flume were digitized, converted to discharge rates, and tabulated to give a hydrograph and runoff volume.

Sediment samples were analyzed for total concentration and particle-size distribution was determined (Haverland and Cooper 1981). Sediment discharge rates and total soil loss were calculated using sediment concentration values and the runoff hydrograph. Sediment trapped in the flume was measured and distributed in proportion to the flow rate.

RESULTS AND DISCUSSION

Average surface characteristics for the spring and fall rainfall simulations for the different soil-treatment combinations are shown in table 1. Vegetation data for the natural control plots are listed in table 2. Spring and fall runoff and sediment treatment averages for the dry, wet, and very wet surface simulations are listed in tables 3, 4, and 5, respectively. Spring and fall hydrographs and sedigraphs for a natural plot on two soil types are shown in fig. 4 through 6. Only data from the natural plots are presented because they show only seasonal change and not changes caused by treatment. Since data from the plots on the Cave and Hathaway soils exhibited the same pronounced seasonal shift in runoff, infiltration, and soil loss, only the Hathaway plot data are shown.

Final infiltration rates in the spring decreased 20 percent between the dry and wet surface runs on the Hathaway soil, and a decrease of only 8 percent on the Bernardino soil. In the fall, the final infiltration rate decreased approximately 20 percent between the dry and wet surface areas on the Hathaway soil and approximately 15 percent on the Bernardino soil. Seasonal differences in final infiltration rates were measured only during the dry surface simulations. There was about a 60 percent decrease in final infiltration rates from spring to fall on the Hathaway soil, and an approximate increase of 60 percent in the spring to fall simulations on the Bernardino soil (fig. 4 - 6).

Soil loss from the Bernardino natural plots was significantly less in the fall, and there also was a significant decrease in runoff volume. The soil loss from the natural plots on the other two soils increased, though not significantly, even though there was a significant increase in runoff (table 3).

One of the main objectives of this USLE plot study was to identify and quantify those soil surface characteristics that have a significant influence on runoff and erosion from rangelands. To eliminate treatment effects, only natural plots were used in a multiple linear regression analysis of the data collected. In effect, correlation coefficients were determined between plot runoff and soil loss and surface characteristics for the spring, fall, and combined season data.

Spring runoff volume was positively correlated with erosion pavement (combined percentage of rock and gravel) (r = 0.90) and grass crown cover (r = 0.93), but negatively correlated with litter cover (r = -0.93) and shrub crown cover (r = -0.90). The correlation coefficient needs to be greater than 0.87 to be significant at the 5-percent level. Soil loss was positively correlated to erosion pavement (0.94).

Table 1. Plot surface characteristics (%)

	Soil (< 2mm)		Gravel 2mm-2cm		Rock > 2cm		Litter		Rock and Gravel	
Treatment (Avg)	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
-Bernardino Soil-										
Natural	28.06	20.00	37.55	53.00	26.33	21.50	6.32	4.00	63.88	75.00
Tilled	62.45	66.50	21.84	8.70	9.28	20.00	6.43	4.80	31.12	28.50
Clipped	32.65	25.00	28.37	43.00	18.68	23.00	20.30	9.00	43.05	66.00
Fallow	63.78	42.00	15.72	46.50	1.63	4.00	18.88	7.50	17.34	50.50
Hathaway-										
Natural	19.80	24.50	33.06	33.00	15.00	24.00	30.00	16.00	48.06	57.00
Tilled	68.68	68.50	12.34	12.00	12.76	18.00	6.22	1.50	25.10	30.00
Clipped	17.34	37.50	36.22	30.00	13.26	26.00	32.86	6.50	49.49	56.00
Fallow	55.51	57.50	6.74	25.00	4.18	6.50	33.57	11.00	10.92	31.50
-Cave										
Natural	29.18	21.50	21.12	39.50	11.22	17.00	35.30	21.00	32.35	47.00
Tilled	52.34	31.50	10.52	12.50	28.47	50.50	8.68	5.50	38.98	63.00
Clipped	29.28	34.50	24.28	36.50	9.49	14.50	36.94	14.50	33.78	51.00
Fallow	63.78	59.00	7.24	29.50	3.68	6.50	24.90	6.00	10.92	33.50
All Soils										
Natural	25.70	22.00	30.60	41.80	17.50	20.80	23.90	13.70	48.10	59.70
Tilled	61.20	55.50	14.90	11.10	16.80	29.50	7.10	3.90	31.70	40.50
Clipped	26.40	32.30	29.60	36.50	13.80	21.20	30.00	10.00	43.40	57.70
Fallow	61.00	52.80	9.90	33.70	3.20	5.70	25.80	8.2	13.10	38.50

Table 2. Vegetative cover (%) natural plots

	Grass		Forb		Shrub		Total	
Soil	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Bernardino								
Crown	11.2	46.3	0.6	18.9	8.1	3.0	19.9	68.2
Base	1.6	1.0	---	---	0.1	---	1.7	1.0
-Hathaway-								
Crown	7.9	36.6	3.1	10.2	10.0	5.8	21.0	52.6
Base	1.68	2.2	0.2	---	0.3	---	2.1	2.2
-Cave-								
Crown	4.1	14.7	0.5	0.8	19.5	15.9	24.1	31.4
Base	1.7	.8	---	---	1.3	0.1	3.0	.9

Fall runoff volume and soil loss were poorly correlated to plot surface characteristic. The combined season correlation matrix also did not indicate sufficient correlation between runoff or soil loss and plot surface characteristics.

The erratic nature of the sedigraphs (fig. 4-6) for all the spring runs may be the result of an observed buildup and breakdown of debris dams on the plots. Under constant rainfall rates, these dams become more a function of surface characteristics than would be expected with varying rainfall intensities of natural storms. The frequency of these debris dam formation and dissipation, and the magnitude of their effects may be dependent on the plot slope, roughness, and amount of litter.

Table 3. Dry surface runoff and soil loss

Treatment (Avg)	Runoff (mm) Spring	Fall	Runoff coefficient (Q/p)† Spring	Fall	Soil loss (gms) Spring	Fall	Sediment concentration (gms/liter) Spring	Fall	Soil Loss (T/ha) Spring	Fall
-Bernardino Soil-										
Natural	34.1	16.1	0.59	0.28	1483	356	1.4	0.7	0.46	0.11
Tilled	0.2	0.3	0.004	0.005	84	139	6.1	5.5	0.03	0.04
Clipped	27.9	32.1	0.49	0.56	1229	2522	1.4	2.5	0.38	0.78
Fallow*	37.8	34.4	0.67	0.60	6946	8005	5.6	7.1	2.14	2.46
Hathaway-										
Natural	18.0	32.4	0.33	0.56	992	1134	1.7	1.1	0.30	0.35
Tilled	5.5	11.2	0.10	0.20	614	1878	3.4	5.4	0.19	0.58
Clipped	20.4	34.3	0.37	0.60	1310	3524	2.0	2.5	0.40	1.08
Fallow	28.2	39.6	0.52	0.69	6486	13076	7.3	10.1	1.99	4.02
-Cave										
Natural	6.6	19.7	0.12	0.36	462	810	2.6	1.3	0.14	0.25
Tilled	0.8	1.7	0.01	0.03	172	186	3.4	4.8	0.05	0.06
Clipped	11.7	38.0	0.20	0.68	808	3549	1.7	2.8	0.25	1.09
Fallow	17.8	34.0	0.30	0.59	1309	13877	4.8	12.6	0.40	4.27
All Soils										
Natural	19.6	22.7	0.35	0.40	979	767	1.9	1.0	0.30	0.24
Tilled	2.2	4.4	0.04	0.08	290	734	4.3	5.2	0.09	0.23
Clipped	20.0	34.8	0.35	0.61	1116	3198	1.7	2.6	0.34	0.98
Fallow	27.9	36.0	0.50	0.63	4914	11653	5.9	9.9	1.51	3.58

Table 4. Wet surface runoff and soil loss

Treatment (Avg)	Runoff (mm) Spring	Fall	Runoff coefficient (Q/p)† Spring	Fall	Soil loss (gms) Spring	Fall	Sediment concentration (gms/liter) Spring	Fall	Soil loss (T/ha) Spring	Fall
-Bernardino Soil-										
Natural	15.6	12.8	0.54	0.44	650	302	1.3	0.8	0.20	0.09
Tilled	2.2	10.4	0.09	0.36	194	1526	3.2	4.0	0.06	0.47
Clipped	15.8	17.1	0.59	0.58	534	1192	1.1	3.1	0.16	0.37
Fallow*	15.6	17.6	0.56	0.61	2970	5842	5.9	10.1	0.91	1.80
Hathaway-										
Natural	8.2	13.3	0.29	0.46	430	521	1.6	1.2	0.13	0.16
Tilled	12.8	17.9	0.48	0.61	1882	3153	4.8	5.7	0.58	0.97
Clipped	10.1	19.8	0.37	0.67	452	1750	1.4	2.7	0.14	0.54
Fallow	12.4	18.3	0.43	0.62	3323	6678	8.2	11.4	1.02	2.05
-Cave										
Natural	4.8	13.1	0.16	0.45	314	462	2.2	1.1	0.10	0.14
Tilled	3.6	4.4	0.12	0.16	436	383	3.9	2.9	0.13	0.12
Clipped	9.3	18.5	0.30	0.64	530	1220	1.6	2.0	0.16	0.38
Fallow	14.3	18.2	0.46	0.64	2788	5436	5.9	9.2	0.86	1.67
All Soils										
Natural	9.5	13.1	0.33	0.45	465	428	1.7	1.0	0.14	0.13
Tilled	6.2	10.8	0.23	0.38	837	1687	4.0	4.2	0.26	0.52
Clipped	11.7	18.5	0.42	0.63	505	1387	1.4	2.6	0.15	0.43
Fallow	14.1	18.0	0.48	0.62	3027	5985	6.7	10.2	0.93	1.84

*Fallow plots had the vegetation clipped, and the erosion pavement was removed from the plot surface.

†Q is the surface runoff in mm; P is the applied rainfall in mm.

Table 5. Very wet runoff and soil loss

Treatment (Avg)	Runoff (mm) Spring	Runoff (mm) Fall	Runoff coefficient (Q/P)[‡] Spring	Runoff coefficient (Q/P)[‡] Fall	Soil loss (gms) Spring	Soil loss (gms) Fall	Sediment concentration (gms/liter) Spring	Sediment concentration (gms/liter) Fall	Soil loss (T/ha) Spring	Soil loss (T/ha) Fall
-Bernardino Soil-										
Natural	18.4	13.2	0.64	0.46	746	342	1.3	0.8	0.23	0.11
Tilled	5.8	13.4	0.20	0.46	435	1488	2.8	3.2	0.13	0.46
Clipped	17.6	18.9	0.62	0.64	758	1654	1.3	3.3	0.23	0.51
Fallow*	17.6	19.3	0.62	0.67	3871	6328	6.7	10.0	1.19	1.95
Hathaway-										
Natural	10.7	15.8	0.40	0.54	514	507	1.5	1.0	0.16	0.16
Tilled	15.7	18.2	0.57	0.62	2616	3508	5.6	6.0	0.80	1.08
Clipped	15.4	20.0	0.56	0.68	648	1697	1.3	2.7	0.20	0.53
Fallow	15.9	23.9	0.58	0.72	4316	6340	8.2	9.4	1.33	1.95
-Cave										
Natural	7.5	14.3	0.25	0.50	363	442	1.6	1.0	0.11	0.14
Tilled	10.8	9.5	0.36	0.32	952	596	2.5	1.9	0.29	0.18
No veg	13.1	17.3	0.44	0.62	598	1290	1.3	2.2	0.18	0.40
	17.5	19.4	0.58	0.66	3384	6146	5.8	9.7	1.04	1.89
All Soils										
Natural	12.2	14.4	0.43	0.50	541	430	1.5	0.9	0.17	0.13
Tilled	10.8	13.7	0.38	0.47	1334	1864	3.6	3.7	0.41	0.57
Clipped	15.4	18.7	0.54	0.65	668	1547	1.3	2.7	0.21	0.48
Fallow	13.0	20.9	0.59	0.68	3857	6271	6.9	19.7	1.19	1.93

*Fallow plots had the vegetation clipped, and the erosion pavement was removed from the plot surface.
‡Q is the surface runoff in mm; P is the applied rainfall in mm.

Analysis of variance (ANOVA) (Duncan's multiple range) among treatments and seasons showed that runoff volumes of the dry surface runs were significantly less (1 percent level) from the tilled plots than any other treatment in both seasons. Other significant differences in dry surface runoff volumes were: (1) fall natural treatments < fall clipped and fallow, (2) average spring runoff (all treatments) < average fall runoff (all treatments). Soil loss from the dry surface runs were: (1) significantly greater (1 percent level) from the fallow treatment than any other treatment in both the spring and fall, and (2) significantly less (1 percent level) from the spring fallow treatment than from the fall fallow treatment.

Although the statistical difference between the runoff volume for the wet or very wet replications was not significant between treatments within a season or between seasons, the SCS Curve Number concept for estimating runoff did indicate a consistent pattern of increasing curve numbers with increasing antecedent moisture (SCS 1972).

The runoff and soil loss differences measured between the spring and fall simulations on the natural plots could not be statistically attributed to any measured surface or soil parameter. However, these seasonal differences might possibly be explained by changes in soil surface compaction (Schumm and Lusby 1963; Rauzi and Smith 1973). The spring runs were made on a soil surface loosened throughout the fall and winter by the combined effects of diurnal soil temperature fluctuations and the wetting and drying of the upper soil layer. This loose soil surface in the spring affected the Hathaway and Cave sites more because of the lower amounts of erosion pavement. This pavement would act as an insulating cover on the Bernardino soil, tend to moderate soil surface temperatures, and reduce soil water evaporation. In the spring, the soils would tend to have a greater initial infiltration rate than the more compacted and crusted soil surface in the fall produced by the high energy associated with the previous summer's thunderstorm rainfall.

To exemplify this, analysis of the natural plot's runoff hydrographs indicates that the time between start of simulated rainfall and runoff is significantly less in the fall than in the spring for the Hathaway and Cave soils, but is not much different for the Bernardino soil (table 6). The loose soil surface also had a dramatic effect on soil loss. Sediment concentration in the runoff in the spring for the natural plots was twice that in the fall (table 3).

Another possibility for these seasonal runoff and soil loss changes could be associated with a recovery from grazing exclusion. The three soil sites chosen had been grazed until the sites were fenced just prior to plot treatments. The recovery from grazing is a combined effect of changes in soil compaction, vegetation density, and litter accumulation. This response may be an important time-related parameter, especially on plot-size areas.

Table 6. Time to beginning of runoff after start of simulated rainfall (min)

	Natural					
Conditions	Bernardino		Hathaway		Cave	
	Spring	Fall	Spring	Fall	Spring	Fall
Dry	3.50	4.00	5.00	3.75	11.50	4.65
Wet	3.00	2.75	5.25	3.75	5.00	3.00
Very wet	2.25	2.00	2.50	1.90	3.60	2.00

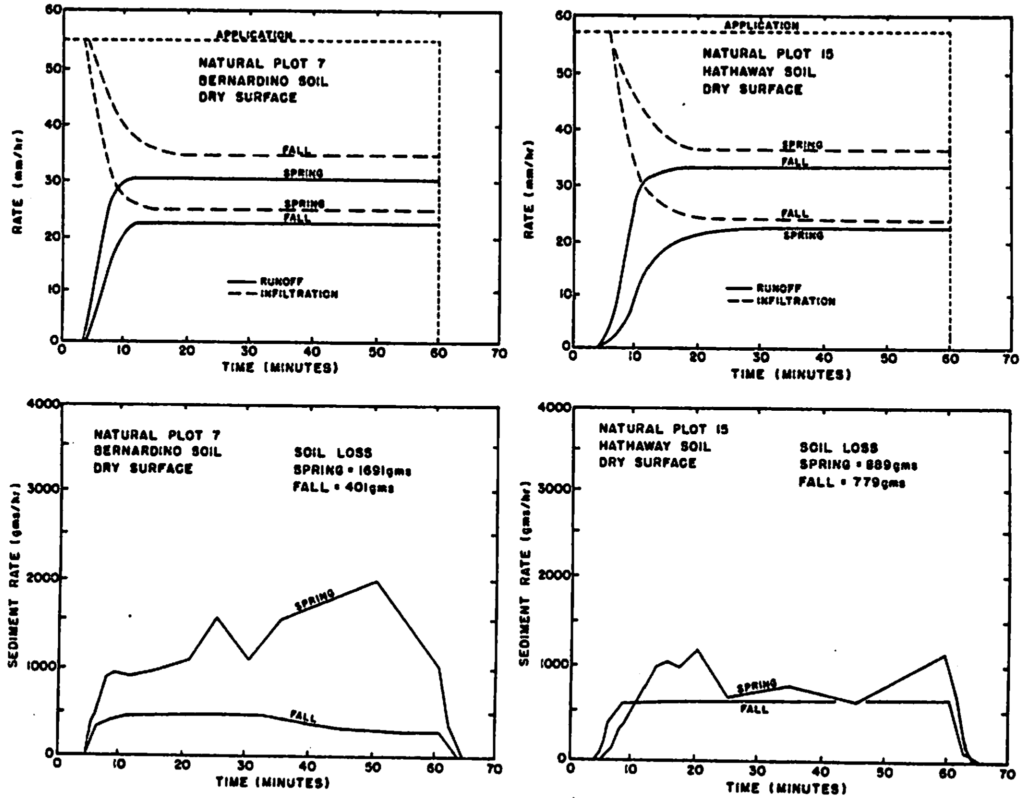

Figure 4. Dry surface infiltration, runoff, and sedigraph.

CONCLUDING COMMENTS

A significant feature of this initial interpretation of the runoff, erosion, and surface characteristics relationships is that one season's or year's data are, even under carefully controlled conditions, very difficult to define in terms of easily measured physical parameters when the data are analyzed using simple ANOVA procedures such as were used here.

At this point in the experimental work, it appears that a great deal of additional work will be needed to understand the cause-effect relationships on these plots. Certainly, the differences in runoff and soil loss between spring and fall for the different soils considered would indicate that either the freeze-thaw mechanism or the exclusion of grazing may be changing the bulk density which, in turn, may markedly change the infiltration and erodibility of these rangeland soils.

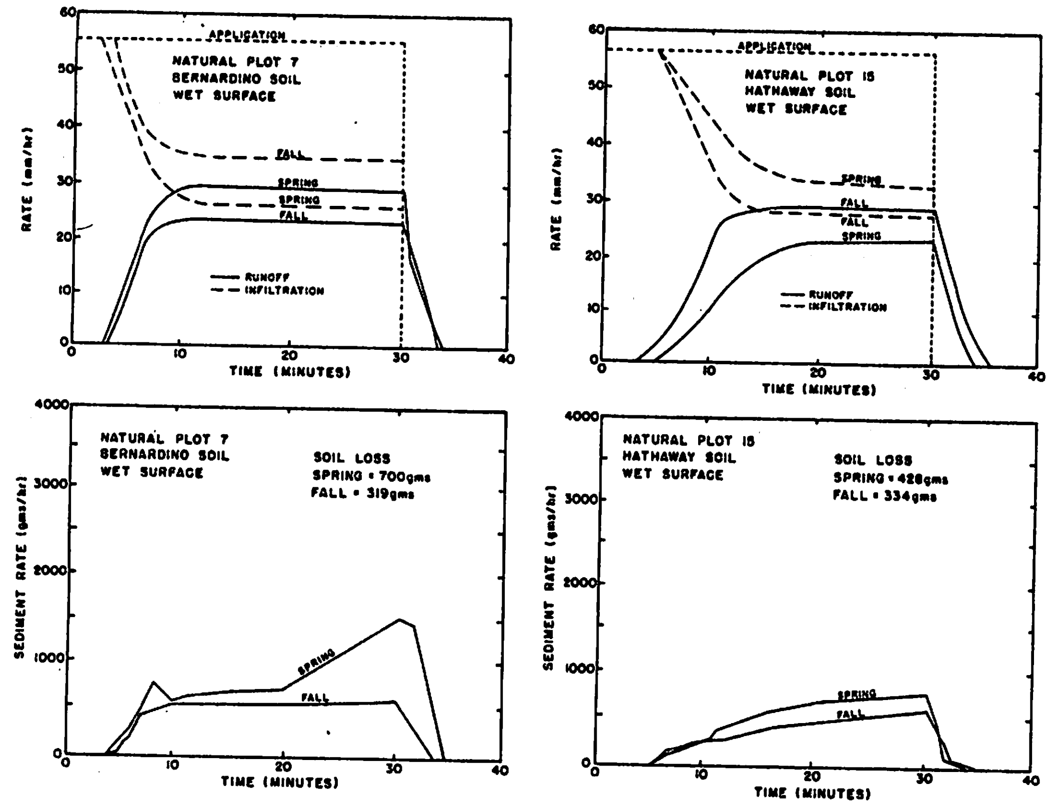

Figure 5. Wet surface infiltration, runoff, and sedigraph.

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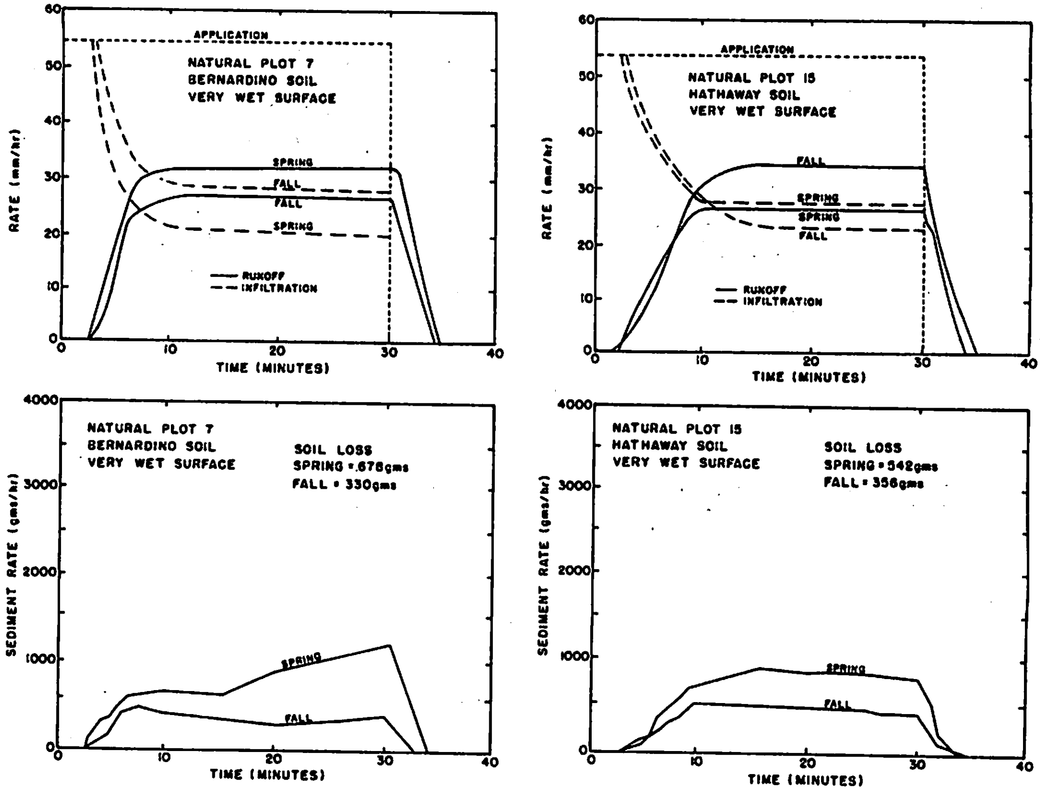

Figure 6. Very wet surface infiltration, runoff, and sedigraph.

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