Rainfall Simulation on Rangeland Erosion Plots

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Key Words: soil loss, rangeland, rainfall simulator, USLE

Abstract

Rainfall simulator studies on erosion plots have been made on rangelands in Arizona, Idaho, New Mexico, and Nevada. An extensive data base has been developed for various ecosystems in these western states. Because the same simulator and similar experimental design were used for all the studies, results can be easily transferred across ecosystems. The experimental design included the use of large plots (10.7 m × 3 m); 60 mm/hr rainfall rate; and natural, bare, clipped, grazed and tilled treatments. Results from these studies have been related to USLE parameters and to effects of various surface and canopy characteristics. The importance of erosion pavement on the erosion process of western arid and semiarid rangelands has been demonstrated, and, in some cases, appears to be more dominant than vegetation canopy.

Introduction

Rainfall simulation is a valuable research tool used in the study of the hydrologic and erosional responses of the natural environment. Pros and cons of rainfall simulation have been well documented (Neff 1979). The major objection to rainfall simulators is that they do not produce natural rainfall energies or variable intensities. However, the major advantage of simulators is that maximum control can be achieved over where, when, and how data are collected and results can be easily compared among ecosystems. Data from rainfall simulation studies can be used by researchers, land managers, and planners to evaluate management or treatment effects on ecosystem response.

The main objective of our rainfall simulation studies was to quantify Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) parameters for rangeland conditions in various western ecosystems. The USLE is used to estimate the long-term average soil loss from agricultural fields. It was not originally intended for western rangelands, but has been adapted as a guide for predicting rangeland erosion.

The equation is:

$A = RKLSCP$

where A = estimated soil loss (t/ha/yr),
R = rainfall erosivity factor (EI units/year)*
K = soil erodibility factor ($t \cdot ha \cdot h/ha \cdot MJ \cdot mm$),
LS = slope-length gradient factor,
C = cover and management factor, and
P = erosion control practice factor.

These factors reflect the major variables which influence erosion by rainfall and resultant overland flow. The equation is primarily based on plot data collected mainly in the eastern United States. Because the equation factor relationships vary in different climatic areas, special considerations are required to extend the USLE to the western United States. The EI for a given storm equals the product of total storm kinetic energy (E) times the maximum 30-min intensity (I_{30}). Our research plan included procedures used in simulator studies conducted to quantify cropland values for the USLE factors. Cropland rainfall simulation erosion research used relatively large plots, a standard surface treatment, 9 percent plot slope and standard sequences of rainfall input (Wischmeier and Mannering 1969). Similar standards were used in our simulator studies so direct comparison could be made to other USLE research.

Method and Materials

Erosion plot studies were conducted using a Swanson rotating boom simulator (Swanson 1965) on 3.05 m × 10.7 m plots in rangelands of Arizona, Idaho, New Mexico, and Nevada. The rotating boom rainfall simulator is trailer mounted and has 10- 7.6 m booms radiating from a central stem. The arms support 30 V-Jet 80100 nozzles positioned at various distances from the stem. The nozzles spray downward from an average height of 2.4 m, apply rainfall intensities of about 60 or 130 mm/hr (depending on nozzle configuration), and produce drop-size distributions similar to natural rainfall. Simulator energies are about 80 percent of those of natural rainfall and the simulator produces intermittent rainfall impulses at the plot surface as the booms pass over the plot. Spatial distribution of rainfall over each plot has a coefficient of variation of less than 10 percent. Changes in rainfall intensities are produced by increasing or decreasing the number of open nozzles; 15 nozzles for 60 mm/hr and 30 nozzles for 130 mm/hr. Because of the simple design and portability of the simulator and because two plots are covered during one run, many plots can be evaluated in a relatively short time. The general procedure included rainfall simulation in the spring and fall on at least two replications of 3 or 4 treatments on more than 1 soil type in each ecosystem studied.

Three rainfall simulation runs were made on each plot pair in the following sequence: dry run - initial 60-min rainfall on dry soil conditions; wet run - 30-min rainfall about 24 hr after the dry run and; very wet run - 30-min rainfall 30-min after the completion of the wet run. Rainfall application rate was measured with a recording raingage and rainfall distribution on each plot was measured with 4 non-recording raingages. Plot runoff was measured volumetrically or by specially designed flumes (4 l/sec maximum capacity) equipped with FW-1 water level recorders that measure instantaneous discharge.

Plot sediment yield was calculated from periodic sediment samples taken throughout the hydrograph. Sampling intervals were dependent on changes in the runoff rate with more frequent sampling when discharge was rapidly changing (Simanton and Renard 1982). During a run, time of runoff initiation, sediment samples, and end of runoff were recorded on field notes for later comparisons to recorder charts. Sediment samples were analyzed for total concentration and particle size distribution and all rainfall, runoff, and sediment data were used in computer programs developed especially for our simulator studies.

Study Sites and Treatments

Rangeland study sites and their major soil, vegetation, and precipitation characteristics are listed and shown in Table 1 and Figure 1.

Arizona Plots:

The Arizona rainfall simulator plots are located on the Walnut

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*EI = Erosivity ($MJ \cdot mm\ ha^{-1} \cdot h^{-1}$): R= summation of EI for individual storms in any year.

Table 1. Descriptions of rainfall simulation-soil loss study sites.

Site designation	Annual precipitation (mm)	Soil description	Predominant vegetation
Arizona Plots, Walnut Gulch:			
Bernardino	300	Thermic, *Ustollic Haplargid*	Blackgrama *(Bouteloua eriopoda),* Sideoats grama *(Bouteloua curtipendula),* Snakeweed *(Gutierrezia Sarothrae).*
Cave	300	Thermic, shallow *Typic Paleorthid*	Creosote bush *(Larrea tridentata),* whitethorn *(Acacia constricta).*
Hathaway	300	Thermic *Aridic Calciustoll*	*False mesquite (Calliandra eriophylla),* creosote bush, snake weed, blue grama *(Bouteloua gracilis),* black grama.
Reynolds Creek:			
Flats	250	Nannyton: Fine, loamy, mixed, mesic typic haplargids	Shadscale *(Atriplex confertifolia),* Cheatgrass *(Bromus tectorum),* Bottlebrush squirreltail *(Sitanion hystrix).*
Nancy	300	Ruclick-Babbington: Fine, montmorillonitic, mesic xerollic duragrid	Big sagebrush *(Artemisia tridentata* subsp. *wyomingensis),* Sandberg bluegrass *(Poa sandbergii),* Cheatgrass, Bottlebrush squirreltail.
Lower Sheep	380	Searla: Fine, montmorillonitic frigid pachic agrixeroll	Low sagebrush *(Artemisia arbuscula),* Sandberg bluegrass, Bottlebrush squirreltail.
New Mexico Plots:			

in the surface 10 cm, and usually less than 40 percent gravel in the remaining profile. Sand, silt, clay, and organic matter in the surface 5 cm are 66, 26, 8, and 1.8 percent, respectively. 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, gravel and occasional cobbles in the surface 10 cm, and usually less than 50 percent in the remainder of the profile. Percent sand, silt, clay, and organic matter in the surface 5 cm are 74, 17, 9, and 1.5 respectively.

Treatments on the Arizona plots were initially imposed in the spring of 1981, and then reapplied, except for the tilled treatment, prior to each season's rainfall simulations. These treatments were: natural cover or no treatment (both grass and shrub), clipped (vegetation clipped at the soil surface and then controlled with a systemic herbicide), bare (vegetation clipped and controlled with systemic herbicide and all surface rock fragments greater than 5 mm removed), and tilled (up and down slope moldboard plowing and disking). The tilled treatment was intended to represent the standard USLE treatment for determination of the soil erodibility factor (K). The clipped treatment was used to determine vegetation effects on erosion and the bare plot was to define the role of rock fragments (erosion pavement) on soil erosion. A pinpoint meter was used to describe plot surface and canopy characteristics before and after initial treatment. The meter is 3.05 m long, with pin holes spaced every 60 mm. The meter was placed perpendicular to the plot slope and rested on the metal plot border at 10 positions evenly spaced along the plot. At each position, 49 pin-point surface and canopy measurements were made by dropping a pin through each pin hole. Characteristics measured were bare soil (particles < 2 mm), gravel (particles 2 to 20 mm), rock (particles>20 mm), litter, vegetative basal cover and crown cover.

Southwest Idaho and North-Central Nevada Plots:

The rainfall simulation plots representative of extensive sagebrush rangelands in the northwest United States were located at 3 sites on the Reynolds Creek Experimental Watershed in southwest Idaho, and at 1 site on the Saval Ranch in north-central Nevada. Season precipitation distributions in the area show a winter maximum and summer minimum, and increases with increasing elevation. Most erosion is associated with snowmelt or rain-on-snow runoff. Detailed soil texture, organic matter, structure, permeability, and erodibility data from plot samples and nearby pits were reported by Johnson et al. (1984).

Treatments on the simulation plots were: (1) tilled - vegetation and coarse roots were removed before rototilling to about 15 cm depth, an approximation of the USLE fallow condition, (2) clipped - all vegetation was cut at the ground surface and removed without serious disturbance of roots and cryptogams, (3) partial clipping -only herbaceous plants were clipped and removed from 2 plots on the Saval Ranch to simulate vegetation removal by cattle grazing, (4) grazed - plots were grazed naturally by cattle a month or two before simulation runs, and (5) ungrazed - cattle were excluded from grazing for about 10 years before simulation runs.

Canopy and ground cover, including vegetation, litter, and rock, were measured by use of a vertical point frame. A total of 160 points were recorded on tilled plots and 520 points on other plots. Partly decomposed plant material and rock/gravel greater than about 2 mm diameter were included as ground cover.

New Mexico Plots:

The rainfall simulator plots in northern New Mexico were established in June, 1982, and are located at the Los Alamos National Laboratory Engineered Test Facility in Los Alamos, New Mexico. This area is typic Pinyon-Juniper ecosystem, and has interspatial grassy areas. Average annual precipitation is about 470 mm, with about 60 percent occurring during the summer months of June through September. Thunderstorms dominate the summer rainy period, and rain and snow occur during the winter months. Two natural cover plots were installed on the Hackroy soil series, which consists of very shallow to shallow, well-drained soils that formed in material weathered from tuff on mesa tops. The soil is commonly observed as the Hackroy sandy loam (Nyhan et al. 1978) and classified as a *Lithic Aridic Haplustal* (clayey, mixed, mesic family). The surface layer of the Hackroy soils is brown sandy loam or loam, about 10 cm thick. The subsoil is a reddish brown clay, gravelly clay or clay loam about 20 cm thick. The depth to tuff bedrock and the effective rooting depth are 20 to 50 cm. The soils exhibit low permeability, low available water capacities, medium runoff and moderate water erosion hazard. Additional study area description from a companion study investigating the hydrology and erosion of shallow land burial trench caps can be found in Nyhan et al. (1984).

Nevada Test Site Plots:

The Nevada Test Site (NTS) plots were established in April of 1983 at Area 11 (plots 1–6), which is located in the transition zone between the Great Basin and Mojave Desert, and near Mercury, Nevada (plots 7–12), in the northern Mojave Desert. Annual precipitation generally varies from 125 to 175 mm of which about 75% occurs between mid-September and late-March and the remaining comes during the summer season as scattered thunderstorms. The two study sites are about 35 air-km apart on soils that have not been given official series names. Both soils are *Typic Durothid* (shallow, mixed thermic). The primary differences between the two soils are in textural class and in parent material. Area 11 soil is coarse-loamy, and formed in material weathered from tuff, basalt, and limestone. Mercury soil is loamy, with randomly dispersed clay pockets, and formed in material weathered from limestone, quartz, and tuff. Both study sites are underlain by silica-lime hardpan; the soils are well drained with medium to rapid runoff, and both have moderate permeability. The Mercury soil has higher water holding capacity primarily as the result of higher clay content and less coarse sand through the profile. Percent coarse sand, fine sand, silt and clay in the surface 5-cm are 15.2, 69.6, 14.5, and 0.7, respectively for the Area 11 soil, and 20.4, 58.8, 14.8 and 6.0, respectively, for the Mercury soil. Plot treatments were the same as the Arizona plots, except that the tilled treatment was not made. Also, the NTS plots had soil moisture measurements made using psychrometric transducers and resistance cells. Other than these two differences, all aspects of the study were identical to the Arizona erosion plot study.

Results and Discussion

Arizona Plots:

Four years, or 8 seasonal rainfall simulations, have been made on the 24 Arizona erosion plots at Walnut Gulch. Data from these simulations and plot surface and vegetation characteristics are given in Appendix A. Summaries of runoff and erosion rates are given in Tables 2 and 3. Light wind and filter plugging problems caused deviations from the planned 60 mm application rate. Runoff and subsequent erosion from the tilled plots were practically nonexistent except for the very wet runs. Because of the unexpected response from the tilled plots, only one replication on each soil was retilled after the first year of runs. This deviation from the original plan was designed so that the recovery rate and response of the tilled plot could be determined. The tilled plot data have not been summarized because of complications involved with sequences of retreatment and invasion of vegetation.

Seasonal Differences: Seasonal (spring–fall) runoff and erosion rate (per EI unit) differences were found throughout the 4-year study period. The magnitude of these differences appears to be treatment and soil variable, but the trend was toward more runoff and consequent erosion from the fall simulations, except for the

Table 2. Average spring (Sp) and fall (Fa) runoff rate (mm/EI)[1] Arizona plots.

Soil	Surface	Natural Sp	Natural Fa	Clipped Sp	Clipped Fa	Bare Sp	Bare Fa
Bernardino	dry	0.017	0.012	0.021	0.038	0.052	0.066
	wet	0.016	0.018	0.029	0.052	0.055	0.060
	very wet	0.025	0.026	0.040	0.057	0.060	0.068
Cave	dry	0.022	0.043	0.028	0.062	0.053	0.069
	wet	0.025	0.044	0.044	0.062	0.055	0.068
	very wet	0.033	0.049	0.052	0.070	0.059	0.076
Hathaway	dry	0.020	0.046	0.028	0.060	0.042	0.064
	wet	0.018	0.035	0.032	0.056	0.039	0.059
	very wet	0.024	0.042	0.040	0.066	0.056	0.069

[1] EI = erosivity (MJ • mm ha^{-1} • h^{-1})

Table 3. Average spring (Sp) and fall (Fa) erosion rates (kg/ha/EI)[1], Arizona plots.

Soil	Surface	Natural Sp	Natural Fa	Clipped Sp	Clipped Fa	Bare Sp	Bare Fa
Bernardino	dry	0.248	0.067	0.379	0.592	9.717	8.468
	wet	0.194	0.102	0.433	0.741	10.489	8.986
	very wet	0.266	0.125	0.669	0.830	10.061	8.612
Cave	dry	0.367	0.486	1.013	1.737	9.547	11.074
	wet	0.414	0.436	1.253	1.543	8.099	9.316
	very wet	0.449	0.437	1.637	1.684	7.371	8.985
Hathaway	dry	0.347	0.389	0.743	1.273	9.882	10.948
	wet	0.244	0.299	0.685	1.260	8.387	9.147
	very wet	0.331	0.360	0.884	1.464	9.705	10.112

[1] EI = erosivity (MJ • mm ha^{-1} • h^{-1})

Table 4. Average runoff and soil loss by treatments, Reynolds Creek and Saval Ranch plots.

Treatment	Runoff (mm) Dry run	Runoff (mm) Wet run	Runoff (mm) Very wet run	Soil loss (gm) Dry run	Soil loss (gm) Wet run	Soil loss (gm) Very wet run
Tilled	37.5	24.1	23.5	22225	15580	13194
Clipped	10.2	9.4	13.3	1309	1133	1406
Part. Clipped	5.4	7.4	11.2	495	488	685
Grazed	6.1	6.5	9.8	681	492	613
Ungrazed	0.3	0.6	2.8	45	41	75

Table 5. Data for rainfall simulator on natural cover plots at Los Alamos, New Mexico (June, 1982).

Plot No.	Treatment	Precipitation (mm)	Erosion Index[1] (MJ • mm • ha^{-1} • ha^{-1})	Runoff (mm)	Sediment (gm)
Dry Surface					
1	NAT	56.06	663	17.97	1866
2	NAT	54.96	638	11.02	1088
Wet Surface					
1	NAT	20.90	184	7.19	626
2	NAT	22.43	212	4.81	310
Very Wet Surface					
1	NAT	28.30	338	20.92	2860
2	NAT	29.16	359	16.47	1637

[1] EI corrected for rainfall simulator and natural rainfall energy differences.

natural plots. The natural cover plots had less erosion in the fall, probably because of the increased vegetative cover produced during the summer growing season. Also, the clipped and bare plots would still be influenced by the soil surface compacting effects produced by the summer thunderstorm rainfall, an effect dissipated by the winter freeze-thaw process that tends to loosen the soil surface before the spring simulator runs.

Soil Differences: Runoff rates among the three soils did not vary as greatly as the erosion rates. The Bernardino soil had lower erosion rates than either the Cave or Hathaway, regardless of the plot treatment. Erosion rate differences between the Cave and Hathaway soils were very small, except for the clipped treatment under which the Cave soil had higher erosion rates (possibly showing a higher soil erodibility and/or more exposed surface soil.

Antecedent Moisture Effects: Runoff rates increased as soil moisture increased (dry surface to wet to very wet) on all soils, treatments and both seasons. Generally, erosion rates were lowest from the wet surface condition.

Treatments: Runoff rates varied between treatments and were affected by both soil and season. The bare plot always had the greatest runoff and erosion rates, regardless of the soil or season, but the magnitude of these rates was greatest in the fall. The natural cover plot had the lowest runoff rate, and again, the fall rates showed the larger treatment differences. Treatment effects on erosion rates were very obvious, with the bare treatment on the Bernardino soil having an erosion rate nearly 90 times greater than the natural cover treatment. The bare treatment erosion rate of the other two soils was nearly 30 times greater than the natural cover treatment. The clipped treatment erosion rate on the Bernardino soil was nearly 8 times greater than that of natural cover treatment. The erosion rate of the clipped treatment on the other two soils was about 4 times greater than the natural cover treatment erosion rate.

Surface and Vegetative Characteristics Effects: Results from the treatment comparisons of erosion rates indicated the effects of various surface and canopy characteristics. Vegetative canopy does affect erosion rates of rangeland soils but not as dominantly as does rock and gravel cover (erosion pavement). Analysis of the erosion pavement effect (rock and gravel particles > 5 mm) on erosion rates indicates that the relationship was exponential and, based on data from the three soils for all runs over the four year period, had an exponent of –0.044 (Fig. 2). These results are very similar to those reported by Simanton et al. (1984), who used only one year of simulator data to develop the erosion pavement-erosion rate relationship. Vegetative canopy, during the first two seasons' runs, did not seem to affect erosion rates. However, as vegetative cover became more dominant on the ungrazed, natural cover plots, the erosion rate difference between the vegetated and clipped plots began to increase until there was an almost tenfold difference in erosion rates between the two conditions. Vegetation type differences did not significantly affect erosion rates; similar rates were found for both grass, grass/shrub, and shrub-dominated canopies.

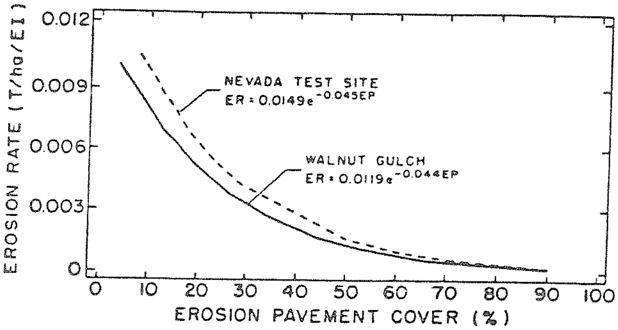

Figure 2. *Relation between erosion rate (ER) and erosion pavement (EP) for the Arizona and Nevada Test Site rainfall simulator erosion plots.*

USLE Parameter Values — K-Factor, C-Factor: Assuming the bare plot represented the USLE "unit plot" (corrected for LS) condition as the most erodible condition possible (C=1), the K factor (t • ha • ha/ha • MJ • mm) value from the simulator results were 0.009, 0.011, and 0.011 for the Bernardino, Cave, and Hathaway soils, respectively. These measured K values are 44, 33, and 43 percent of the K values derived from the soil erodibility nomograph developed by Wischmeier et al. (1971). Measured K values, as reflected in the erosion rate from the bare plots, did not vary between spring and fall simulations but did change over the 4-year study period (see Simanton and Renard in these proceedings). If the measured K values from the bare plot are used to calculate C in the USLE, C factor evaluation can be made from measured erosion and related to surface and vegetation characteristics of the erosion plots. Additional data are being collected to develop rangeland C value tables for different combinations of vegetation and surface conditions.

Southwest Idaho and North-Central Nevada Plots:

Data from rainfall simulation and surface and canopy characteristics of 38 plots from the summer of 1982 are listed in Appendix B. Light wind and slight simulator filter plugging caused some variation in applied rainfall. Runoff from the plots ranged from 0 on a few ungrazed plots to over 90 percent of applied rainfall on some tilled plots. Soil losses also ranged widely, with greatest losses from tilled plots on 9-percent slopes.

Data summaries by treatment show minimal values of runoff and erosion from ungrazed plots, consistently high values on tilled plots, and intermediate values on clipped and grazed plots (Table 4).

USLE soil erodibility factor (K) values, determined from rainfall simulation on tilled plots and by the soil erodibility nomograph (Wischmeier and Smith 1978) using plot soil samples, were compared, and the nomograph K values were slightly higher than measured K values on most of the plots (Johnson et al. 1984). Much of this difference is probably caused by the lack of a true fallow soil surface. Soil erodibility values by rainfall simulation varied widely between dry, wet, and very wet runs, and among sites; however, for practical application, nomograph erodibility values caused only a slight over-prediction of soil loss.

Cover-management factor values for ungrazed plots with rainfall simulation were consistently less than estimated by the subfactor method (Dissmeyer and Foster 1981), probably because higher infiltration capacity was not accounted for as a subfactor. Additional detailed analysis has been made by Johnson et al. (1984).

Soil loss predictions, based on USLE cover factors for rangelands, do not fully account for the complexity of surface roughness, root and cryptogam effects, and diversity of plant cover, both in time and space. However, average cover-management factor values, for grazed plots by the subfactor procedure, were in reasonable agreement with rainfall simulation results.

New Mexico Plots:

Data summaries from 1 season rainfall simulations at the Los Alamos National Laboratories (LANL) natural erosion plots are given in Table 5, and plot surface and vegetation characteristics are presented in Table 6. Both runoff and erosion rates increased with increasing soil moisture as represented by the wet and very wet runs. Though there was a relatively small increase in rates between the dry and wet runs, the very wet run had nearly a threefold increase in erosion rate associated with nearly a twofold increase in runoff rate. Vegetation canopy appears to reduce both runoff and erosion, but the data are limited, and analysis is difficult.

Nevada Plots:

Two years, or 4 seasonal, rainfall simulations have been made on the NTS erosion plots. Data from these simulations and plot surface and vegetation characteristics are given in Appendix C. Data summaries of the runoff and erosion rates are given in Tables 7 and 8.

Seasonal Differences: As with the Arizona plots, seasonal (spring-fall runoff and erosion rate (per EI unit) differences were found throughout the 2 year study period. Fall runoff rates were higher than the spring regardless of the soil. However, on the Mercury soil, the season of higher runoff rates (fall) was not the season of higher erosion rates (spring), indicating that some factor, other than runoff, was controlling erosion.

Soil Differences: The Mercury soil had higher runoff and erosion rates than the Area-11 soil, regardless of the plot treatment.

Antecedent Moisture Effects: Runoff rates increased as soil moisture increased (dry surface to wet to very wet) on both soils under all treatments. Erosion rates were more variable, and decreased on the wet surface runs under the natural treatment. These runoff and erosion responses were very similar to those from the Arizona plots.

Treatments: Runoff rates varied among treatments, and were affected by both soil and season. The bare plot always had the greatest runoff rate, regardless of the soil or season, but the runoff rate was greater in the fall. The natural cover plot had the lowest runoff rate, and again, the fall rates showed the larger treatment differences. Bare treatment erosion rates on the Mercury soil were about 20 times greater than the rates from the natural treatment and 10 times greater than the clipped treatment. The Area 11 bare treatment erosion rates were about 45 times greater than the natural treatment, and about 25 times greater than the clipped treatment. These erosion rate differences between treatments are not as great as found on the Arizona plots, but the general trend of treatment effect is the same, again indicating the importance of erosion pavement on the erosion process.

Surface and Vegetative Characteristics Effects: Erosion pavement appears to be an important factor in the erosion process, but not as dominant as was found on the Arizona plots. Vegetation was more effective in reducing erosion rates on the NTS than on the Arizona plots. Analysis of the effect of erosion pavement (rock and gravel particles $>$ 5 mm) on erosion rates indicated that the relationship was exponential, similar to the Arizona relationship, and based on data from the two soils for all runs over the two year period, had an exponent of -0.045 (Fig. 2).

USLE Parameter Values - K-Factor, C-Factor: Assuming the bare plot represented the USLE "unit plot" (corrected for LS) condition as the most erodible condition possible (C=1) (t • ha • ha/ha • MJ • mm), the K factor value from the simulator results were 0.016, and 0.010 for the Mercury and Area 11 soils, respectively. These measured K values are 38 and 16 percent of the K values derived from the soil erodibility nomograph developed by Wischmeier et al. (1971). The measured K values from the bare plot

Table 6. Plot characteristic data for rainfall simulator on natural cover plots at Los Alamos, New Mexico (June, 1982).

Plot No	Treatment	Slope (%)	Biomass (gm m^{-2})			Leaf area index (x100)			Canopy cover (%)
			Cactus	Grass	Shrub	Cactus	Grass	Shrub	
1	NAT	5.2	63.2	1.0	7.0	2.4	1.1	1.6	63
2	NAT	5.2	25.0	5.0	31.0	1.3	1.7	18.1	78

NOTE: Biomass calculations based on oven dry-weight basis.

Table 7. Average spring (Sp) and fall (Fa) runoff rate (mm/EI)[1], Nevada Test Site.

Soil	Surface	Natural		Clipped		Bare	
		Sp	Fa	Sp	Fa	Sp	Fa
Mercury	dry	0.027	0.048	0.048	0.065	0.062	0.078
	wet	0.037	0.049	0.059	0.075	0.068	0.076
	very wet	0.045	0.060	0.066	0.088	0.077	0.094
Area 11	dry	0.003	0.018	0.001	0.026	0.021	0.057
	wet	0.011	0.016	0.011	0.026	0.043	0.053
	very wet	0.022	0.033	0.026	0.038	0.054	0.062

[1] EI = erosivity (MJ • mm ha^{-1} • h^{-1})

Table 8. Average spring (Sp) and fall (Fa) erosion rate (kg/ha/EI)[1], Nevada Test Site.

Soil	Surface	Natural		Clipped		Bare	
		Sp	Fa	Sp	Fa	Sp	Fa
Mercury	dry	0.514	0.518	1.003	0.871	11.943	9.642
	wet	0.471	0.445	1.069	0.984	14.125	9.708
	very wet	0.581	0.575	1.218	1.341	12.197	11.180
Area 11	dry	0.050	0.167	0.038	0.678	3.531	10.031
	wet	0.189	0.125	0.249	0.302	8.060	10.017
	very wet	0.400	0.211	0.484	0.420	10.682	11.336

[1] EI = erosivity (MJ • mm ha^{-1} • h^{-1})

were used with the measured soil loss from the natural and clipped plots to estimate C values for rangeland conditions at the NTS. Time related changes in the C factor were found, and, when more data become available (the simulator studies are continuing at the NTS), results will be more definitive.

Conclusions

Rainfall simulator studies on erosion plots have been made on rangelands in Arizona, Idaho, New Mexico, and Nevada. An extensive data base has been developed for various ecosystems in these western states, and because the same simulator and similar experimental design were used for all the studies, results can be easily transferred across ecosystems. Results from these studies have been related to USLE parameters and to effects of various surface and canopy characteristics. The importance of erosion pavement on the erosion process of western rangelands has been demonstrated, and appears to be more dominant than vegetation canopy.

Rangeland rainfall simulation erosion studies are a relatively new research area, and the results from our studies have only begun to answer some of the basic questions regarding erosion estimating techniques on rangelands. Additional studies, research approaches, and analyses are still needed to fully understand the rangeland upland erosion processes.

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