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APPLICATION OF THE USLE TO SOUTHWESTERN RANGELANDS

by

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INTRODUCTION

The Universal Soil Loss Equation (USLE), developed by Wischmeier and Smith (1978), is intended to estimate the long-time average soil loss from agricultural fields. The equation is:

A = RKLSCP

where: A = estimated soil loss (tons/acre/year);
R = rainfall erosivity factor (EI units/year);
K = soil erodibility factor (tons/acre/EI unit);
L = slope length factor;
S = slope 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 based on plot data collected mainly in the eastern half of the United States. Because equation factor relationships vary in different climatic areas, special considerations are required to extend the USLE to the Western United States (Brooks, 1976; McCool et al., 1976; Osborn et al., 1977). We have applied the USLE to four small semiarid rangeland watersheds within the Walnut Gulch experimental watershed in southeastern Arizona (Fig. 1) and compared predicted and measured soil loss.

APPLICATION TO RANGELAND WATERSHEDS

The small watersheds used range in size from 3.2 to 11.2 acres. Three are dominated by a brush vegetative cover and the fourth dominated by a grass cover. Slopes of the watersheds range from 1 up to 10%, and the soils are a gravelly loam with an erosion pavement. Average annual rainfall of about 13 inches is measured with 24-hour recording raingages. Runoff, measured with H-flumes, v-notch weirs, and critical-depth flumes, averages about 10% of the annual rainfall on such small watersheds, and occurs almost exclusively during the summer thunderstorm season of July through September. Sediment concentration measurements from these small watersheds consist of time-related samples taken throughout the runoff hydrograph.

Several assumptions were made when we applied the USLE to the soil loss data obtained from these watersheds. We assumed that the soil loss from these small watersheds was equal to the sediment yield, or the sediment delivery ratio was unity; that the P, or erosion control practice factor, was 1 for ungrazed rangelands; that the C, or cover factor, included erosion pavement as part of the ground cover, and that the soil erodibility nomograph (Wischmeier et al., 1971) was giving us representative values for K.

Values for each of the equation's factors were estimated using standard handbook procedures. The R factor for each watershed was determined using recording raingage records and calculated using the procedure outlined by Wischmeier and Smith (1958). This procedure considers rainfall intensity, the energy associated with this intensity, and the maximum 30-min intensity. The units of R are expressed as hundreds of foot-tons per acre x inch per hour. Annual R averaged about 60 units/year for 11 years of data on these watersheds. However, the average annual R for the study period was 73 units for the brushland watersheds and 53 units for the grassland watershed. K factor values were determined using the soil nomograph procedures of Wischmeier et al. (1971). In this procedure, the soil properties of sand, silt, structure, organic matter content, and permeability are considered. Once a value for each of these properties was found, the nomograph was used to arrive at a K factor value of around 0.10 tons/acre/EI. Values of the topographic factors, LS, were determined from handbook tables which present soil loss ratios for various combinations of slope length and slope gradient. The LS values ranged from 0.8 to 2.8 for the four small watersheds. The C values were obtained from the tables in Agriculture Handbook No. 537 (Wischmeier and Smith, 1978),which relate soil loss ratios to field measurements of vegetative cover and ground cover. In our use of these tables, we considered erosion pavement as part of the ground cover. Values for C ranged from 0.012 to 0.038 for the cover conditions on the watersheds studied. Table 1 lists factor values for the four watersheds studied.

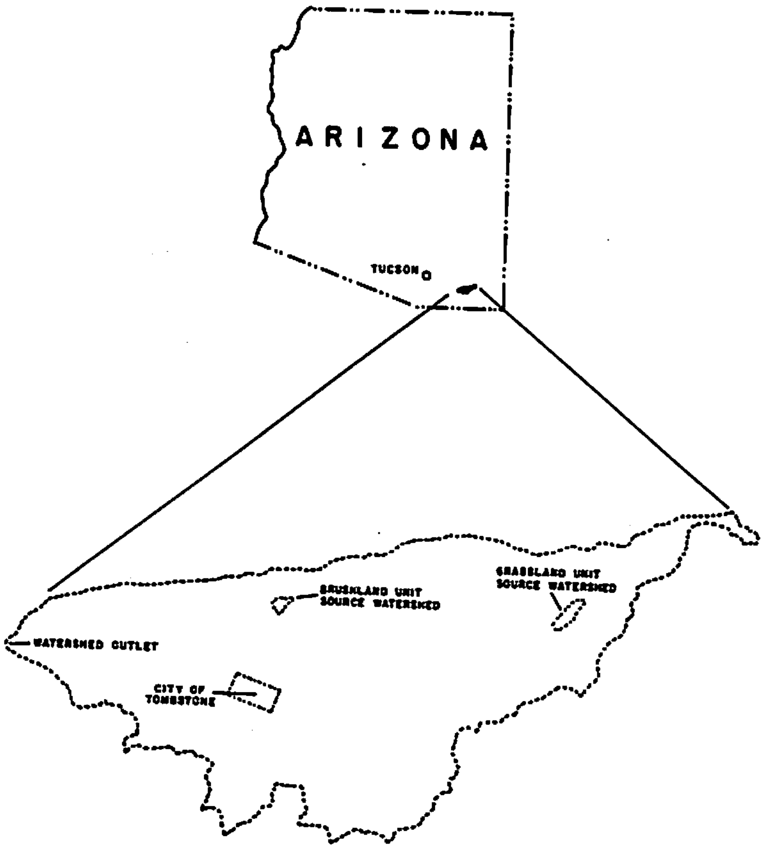

Figure 1. Location map of the Walnut Gulch Experimental Watershed.

Table 1. USLE factor values for four small semiarid rangeland watersheds in southeastern Arizona.

Watershed	Area (acres)	Vegetative Cover	K	LS	C	P
63.101	3.2	Brush	0.09	0.8	.038	1
63.103	9.1	Brush	0.10	1.2	.038	1
63.104	11.2	Brush	0.085	1.2	.038	1
63.112	4.6	Grass	0.085	2.8	.012	1

Table 2. Annual soil losses(tons/acre) from four small Walnut Gulch subwatersheds.

		Brushland							Grassland	
		101 (3.2 acres)		103 (9.1 acres)		104 (11.2 acres)			112 (4.6 acres)	
Year	R	Pred.	Act.	Pred.	Act.	Pred.	Act.	R	Pred.	Act.
1973	64	0.18	0.08	0.29	1.24	0.25	0.35	22	0.06	0
1974	79	.22	.32	.36	2.17	.30	.75	77	.22	.01
1975	185	.51	.94	.85	3.83	.72	1.42	53	.15	.05
1976	30	Watershed		.14	1.08	.12	.31	114	.33	.37
1977	82	treated;		.37	3.04	.32	1.33	54	.15	.05
1978	45	no data.		.21	.89	.17	.08	25	.07	0
1979	25			.11	.21	.10	0	26	.07	0
Avg.	73	.30	.44	.33	1.78	.28	.61	53	.15	.07

We compared 7 years of actual sediment yield data to USLE predicted values of gross erosion for the four small watersheds (Table 2). Average annual soil loss from a 3.2-acre, brush-covered, ungrazed watershed was 0.44 ton/acre. Predicted annual loss was 0.30 ton/acre, or about a 1.5:1 ratio of actual to predicted. An 11.2-acre watershed next to the 3.2-acre watershed differed only in its size, number of channels, and LS factor. However, the actual to predicted annual soil loss ratio was about 2:1, or 0.61 ton/acre actual vs. 0.28 ton/acre predicted. The ratio of actual to predicted annual soil loss from a 9.1-acre watershed adjacent to the 11.2-acre watershed was about 5:1, or 1.78 ton/acre actual vs. 0.33 ton/acre predicted. The 9.1-acre watershed differs from the others in that it has an incised channel drainage network. The actual to predicted annual soil loss ratio was 0.50:1 or 0.07 ton/acre actual vs. 0.15 ton/acre predicted from a 4.6-acre, grass-covered, grazed watershed located approximately 7 miles from the brush-covered watersheds. In general, the USLE seemed to overpredict soil loss from brush-covered watersheds for years with only small runoff events, and seemed to underpredict soil loss for years with large runoff events. On the grass-covered watershed, soil loss was overpredicted, but both the number and magnitude of runoff events were less than those on the brush-covered watersheds.

DISCUSSION

After comparing the actual to predicted soil loss from these small rangeland watersheds, we looked at each equation factor and how semiarid environmental or watershed characteristics affected them.

Rainfall Erosivity Factors.

The R, or rainfall erosivity factor, is the driving force of erosion and soil loss, and without this input, water erosion would not occur. Several investigators have attempted to define R for the western United States (Ateshian, 1974; Wischmeier and Smith, 1978; Renard and Simanton, 1975). In the particular climatic regime of southeastern Arizona, air-mass thunderstorms dominate the rainfall/runoff relationships from rangelands. Thunderstorm rainfall is highly variable and intense, is limited in areal extent, produces nearly all rangeland runoff, and occurs primarily during the summer thunderstorm season of July through September. The R factor includes not only rainfall amount, but also rainfall intensity, which is more variable than rainfall amount. Because of rainfall variability, point estimates of R should be used only in the immediate area (within 0.3 mi) surrounding that point for estimating seasonal erosion (Osborn et al., 1979). In the analysis of the spatial variability of R associated with thunderstorm precipitation, Renard and Simanton (1975) found that for individual storms, R can decrease from 100 units near the storm center to about 30 units in a distance of 2 miles (Fig. 2).

Extreme variability was also found in annual R values (Fig. 3). The variability of annual R is more dramatic when compared to the variability of annual precipitation, and is shown graphically when both summer precipitation and R for the same period are plotted on a probability scale (Fig. 4). The steeper slope of the R plot indicates the greater variability. Also, the largest storm of the year usually dominates the total annual R. In a 16-year period on Walnut Gulch, the greatest storm contributed, on the average, 32% of the annual R with a maximum contribution of 55% (Renard et al., 1974).

Soil Erodibility Factor.

The K, or soil erodibility factor, was determined from the nomograph procedure (Wischmeier et al., 1971). However, the nomograph has not been validated for our rangeland soils. Because of this, we have no verification as to the nomograph's accuracy in determining the erodibility of rangeland soils. Many southwestern rangeland soils are poorly developed and may have erodibility characteristics different from cultivated soils for which the nomograph was developed. Some rangeland soils contain large amounts of carbonates which may provide additional soil particle cohesion. Also, coarse material such as gravel often dominates, with some soil profiles being 70% gravel by volume. In many areas, erosion pavement forms on the soil surface and acts very much like a gravel mulch. This erosion pavement is not considered part of the present soil but, rather, a residual protective cover left when the fine particles are eroded and transported downslope. The role of erosion pavement in erosion and its relation to the USLE are discussed in more detail in the section on the C or cover and management factor.

Slope Length and Gradient Factor.

The LS, or slope length and gradient factor, is simple to determine from a table presented in Agricultural Handbook 537. This table requires only slope length and slope gradient to arrive at an LS factor. However, for rangeland conditions, the slope length may be the most subjective factor of the USLE. Slope length, as defined, is: "...the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or runoff water enters a well-defined channel that may be part of a drainage network..." (Wischmeier and Smith, 1978). This definition requires a judgment as to what a well-defined channel represents. On a typical topographic map from the U.S. Geological Survey, the channel appears to be one size, and on a more detailed aerial photo map it can appear to be another size. Or, if two people actually go to the site and look at the watershed and its drainage network, a well-defined channel will depend upon the scale-terms each of the observers is using in his judgment. These site observations will give a more realistic slope length than is obtained from maps alone. However, if maps must be used, there are a number of methods available to determine both slope length and gradient (Williams and Berndt, 1977).

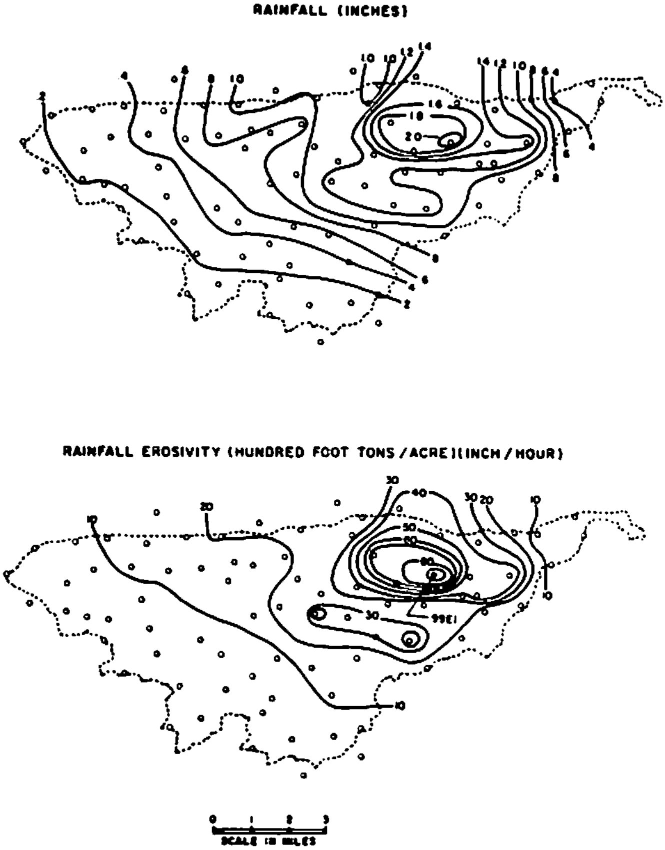

Figure 2. Isohyetal and isoerodent maps for July 22, 1964 storm on Walnut Gulch. (Each small circle represents a recording raingage.)

Cover-Management Factor.

The C factor includes both the vegetative cover and the management scheme used to adjust the seasonal or annual vegetative cover. Because of the complex interactions between cover and management schemes, the C factor is, perhaps, the most difficult to interpret for rangeland conditions. Vegetative cover on southwestern rangelands is, generally, less than 10% basal area with approximately a 30% crown cover. These low cover percentages produce a high C value. Management on these rangelands is usually nothing more than control of grazing rotations and intensities.

Erosion pavements dominate many rangeland watersheds, and they can significantly affect soil losses. These pavements protect the soil from direct raindrop impact and the erosive force of flowing water, causing a significant reduction in erosion. The role of erosion pavement in soil loss was shown in a simulated rainfall study conducted on one of the small brush-covered watersheds on Walnut Gulch (Martinez, 1979). This study showed that, for similar soil and vegetative cover but differing rainfall intensities, the amount of soil splashed by raindrop impact was three times greater from a soil where erosion pavement had been removed than from an erosion pavement covered soil (Fig. 5). Also, erosion pavement reduced the influence of rainfall intensity on amount of soil splashed.

Rock or erosion pavement on the surface acts like a mulch, producing an effect which is included in the C factor. Erosion pavement on these watersheds provided about 60% ground cover which, from published tables in SCS Technical Release 51 (SCS, 1972) and Agriculture Handbook No. 537, give a C estimate of 0.038. The sensitivity of the erosion pavement impact on erosion is shown by the example that, if the estimated pavement cover is only 40%, the estimated soil loss more than doubles.

The influences of the different management schemes, mainly grazing, can only be inferred, because no data have been directly related to the USLE. As the USLE becomes more widely used, the impact of different grazing rotations and intensities can be related to a USLE factor.

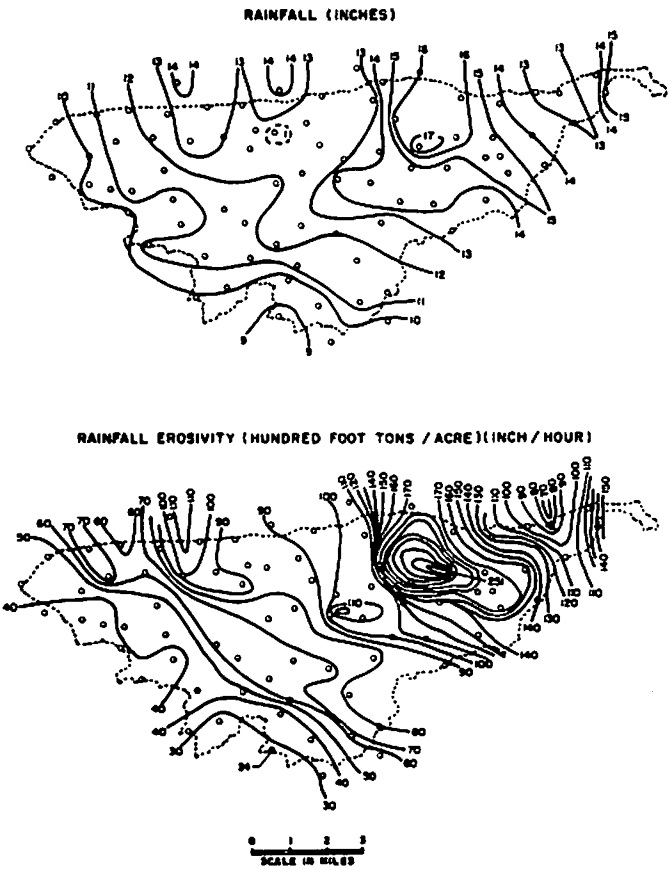

Figure 3. Isohyetal and isoerodent maps for 1964 annual totals on Walnut Gulch. (Each small circle represents a recording raingage.)

Erosion Control Practice Factor.

The influences of conservation measures on erosion and the USLE appear in the P factor. This factor represents the soil-loss ratio of the conservation practice to up- and down-hill culture, and the ratio should be less than one if the erosion-control practice is effective. There are usually no erosion-control practices involved on rangelands, so the P ratio should be 1.0. However, rangeland renovation is beginning to increase, and P values are needed to reflect the erosion changes associated with renovation practices such as pitting, subsoiling, imprinting, and root plowing. In the one application of the change in P associated with rangeland treatment, we found no guidelines or handbook values of P for a root plowing, seeding practice that was used to convert a brush-covered watershed to a grass-covered watershed. The P value was estimated for this practice by solving the USLE using measured sediment yield and the other USLE factor values for the before- and after-treatment periods on a 109-acre watershed. Unfortunately, the watershed is so large that the USLE must be used with a delivery ratio to correlate to the measured sediment yield at the watershed outlet. By considering the pre- and post-treatment conditions, the delivery ratio would remain constant, so we felt more confident with this approach. Solving for P, we obtained a value of 0.13 for the root plowing, seeding practice. Though less than the recommended 0.50 for a contouring practice which looked most like the root plowing, the value was close to the 0.15 recommended for a contour listing. This type of analysis for assessing P value change associated with erosion control practices is limited, because the effects of the practice are dynamic, the practice is not related to the up- and down-hill culture, and watershed hydrologic variability is tremendous. For example, the difference in before and after sediment yields may be a result of the root plowing or the grass establishment, a combination of the two, or a change in rainfall patterns. To be identifiable to a particular erosion control practice, P values need to be assessed on a small scale such as the unit plot from which the USLE was derived.

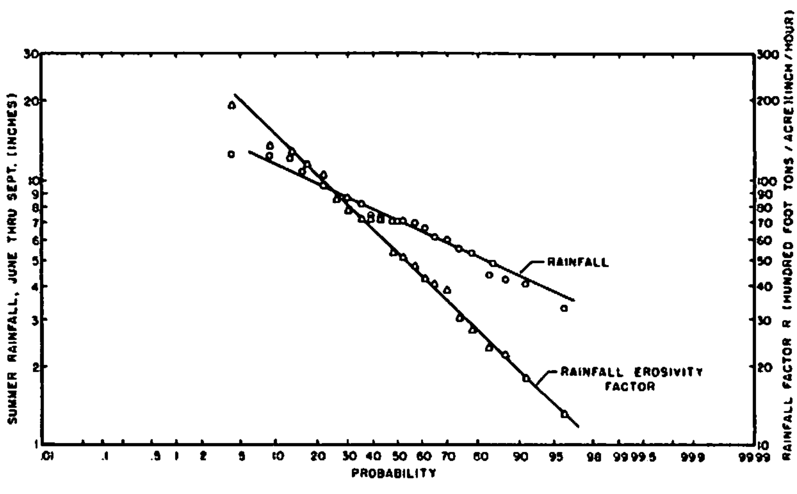

Figure 4. Comparison of rainfall and rainfall erosivity probabilities for a raingage on Walnut Gulch.

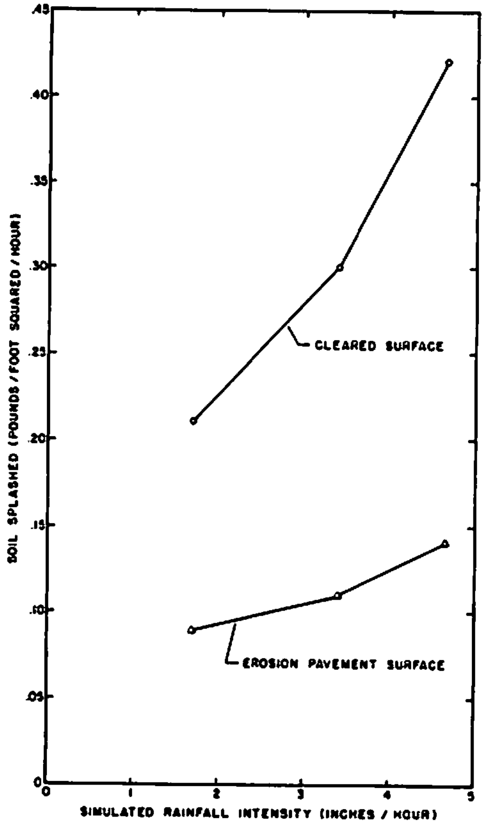

Figure 5. Effect of erosion pavement and rainfall intensity on soil splashed from rainfall simulator plots. (Martinez, 1979.)

<u>Channel Influence.</u>

Channel erosion may be a major sediment source in many rangeland watersheds. An additional term, E_c, may be needed in the USLE to reflect channel erosion contribution to watershed sediment yield (Renard et al., 1974). The USLE was developed from unit plot data for ungullied fields or watersheds. Because of this, it has no factor or relationship accounting for erosion that takes place from the sides or bottoms of these gullies. Gullies or channels may be a major contributor to the sediment yield from even the smallest rangeland watershed. This is evident in the comparison of the two larger adjacent watersheds discussed earlier. The larger watershed, which is 11.2 acres and has a drainage network of meandering channels with gently sloping relatively stabilized banks, had an actual to predicted soil-loss ratio of about 2:1. The other watershed, which is 9.1 acres and has a drainage network of straight, incised channels with banks that were eroding visibly, had an actual to predicted soil-loss ratio of about 5:1. Other factors being equal, the only discernible difference between the two watersheds was the channel type. However, the soil-loss differences between the two watersheds may possibly be due, at least in part, to the efficiency of the channels in moving the eroded material rather than direct contribution of soil from the channel banks. We are currently making precise measurements of the incised channel before and after the runoff season to determine the channel's contribution to sediment yield.

SUMMARY

The USLE includes the major contributing factors involved in soil erosion. However, the relationships among these factors may be different for various climatic regimes. If the USLE is to be applied to rangeland conditions of the semiarid southwest, considerable research is needed into the hydrology-erosion-biotic relationship of this climatic regime. Some factors needing study are: (1) what is the influence of the variability in R on soil loss distributions within a watershed; (2) what soil properties dominate the soil erodibility of rangeland soils; (3) how can interrill flow be distinguished from rill flow on a watershed scale; (4) how much of an influence does the erosion pavement have on soil loss, and does this influence vary with slope length and gradient; (5) what combinations of grazing rotations and intensities affect soil loss the most; (6) how do different rangeland renovation treatments affect soil loss, and (7) how do differing drainage networks affect sediment yield from rangeland watersheds? The USLE can be used to estimate erosion and, in some cases, sediment yield from rangeland watersheds, although the accuracy of such estimates varies. The parameters needed to evaluate each equation factor are easily determined from handbooks and a minimum amount of field work. We have found that by using judgment, factor values can be adjusted for local conditions to improve erosion estimates.

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