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CONTENTS

SEDIMENT YIELD FROM SMALL SEMIARID RANGELAND WATERSHEDS

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INTRODUCTION

Sediment yield, the quantity of sediment moving past a cross-section of a channel in a specified time interval, is sometimes mistakenly assumed to be synonomous with erosion. Material removed from a slope as rill and interrill erosion may be deposited at the toe of a slope, on a flood plain, or at other points within the watershed where the sediment load exceeds the transport capacity of the runoff. Within a channel, material eroded not only from the landslope, but also from the channel bed and banks and from gullies and headcuts, can be a significant part of the sediment transported past a point on the stream. The path that a soil particle takes in moving to a point of lower potential energy is complicated, and the process is often stepwise in time.

Assuming that governing equations for such movements are known, these complexities make physically based equations describing the movement of sediment difficult to use. Thus, more simplified empirical equations are often used. Recent developments in watershed modeling, however, include erosion/sediment transport routines with detailed hydrologic models. These new modeling techniques promise to reflect the effects of different land use and the effects of the variations from year to year resulting from climatic differences. They do, of course, require much more computer time, have different data requirements, and are more expensive to use than the simple empirical models.

Methods for estimating erosion and sediment yield from rangelands are based primarily upon the principles developed in parts of the United States where cultivated agricultural activities are prevalent. Techniques incorporating disturbance of the soil by tillage are not generally applicable to rangelands, so the erosion-estimating techniques must be adjusted to reflect these land use differences for rangelands. Typical problems unique to rangelands are those associated with the different soils (the genesis of western range soils are different from those in humid areas); the existence of erosion pavements (which provide protection from raindrop impact and decrease the shear of water moving over the land); grazing and trampling by animals; and with channel erosion processes which are very important on rangelands.

Renard (1980) detailed seven different methods for estimating sediment yield. Each has different data requirements, vary in complexity, and produce different results. The choice of method depends upon the objective of the investigation. In this further investigation, some sediment yield formulae are

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tested with sediment yield data from nine small watersheds in the Walnut Gulch Experimental Watershed near Tombstone, Arizona.

METHODS TESTED

Pacific Southwest Interagency Committee Method (PSIAC)

The method developed by the Water Management Committee of the PSIAC (1968) was intended for broad planning rather than for specific project formulation where more intensive investigations are required. Although this method was intended for use in areas larger than 10 mi^2, we tested it here on small watersheds to demonstrate a method that might be readily used to estimate sediment yield within a land resource area (Austin, 1965). Testing the method improves the confidence of the user in selecting parameter values that reproduce observed data.

The method requires using nine factors to determine the sediment yield classification for a watershed. The factors are (A) geology, (B) soils, (C) climate, (D) runoff, (E) topography, (F) ground cover, (G) land use, (H) upland erosion, and (I) channel erosion/sediment transport. Each factor is assigned a numerical value from a rating chart (PSIAC, 1968) which is too long to reproduce here. Descriptive terms for three sediment yield levels (high, moderate, low) for each factor are used to select the numerical value. Summing the rating chart values for the nine factors defines a sediment yield rating classification, which in turn can be converted to the average annual sediment yield using Table 1.

TABLE 1.--Sediment yield classification

Rating	Classification	Annual sediment yield ac-ft/mi^2
> 100	1	> 3.0
75 to 100	2	1.0 to 3.0
50 to 75	3	0.5 to 1.0
25 to 50	4	0.2 to 0.5
0 to 25	5	< 0.2

Numerical values for each of the nine factors range from 25 to minus 10. Although only three levels are suggested for general use in the rating chart, a footnote states that, if experience so dictates, interpolation between the three sediment yield levels may be made. Such interpolation was used in this study.

To assist in interpolation between the classifications of Table 1, The data in Table 1 were converted to equation form. Although such precision was not intended for the original method, we felt that such a scheme could provide additional insight into the ability of the technique to reflect differences in the observed data. The equation is:

$$Y = 0.0816e^{0.0353X} \quad (1)$$

where Y = annual sediment yield (ac-ft/mi^2)
e = natural logarithm
X = PSIAC rating factor

Dendy/Bolton Method

Dendy and Bolton (1976) derived sediment yield equations having widespread applicability because they used data from over 800 reservoirs throughout the United States to obtain measured sediment yield values. They segregated the data into areas where runoff was either less than or greater than 2 in/yr.

In areas where runoff is less than 2 in, they derived the equation:

$$S = 1280\ Q^{0.46}(1.43 - 0.26 \log A) \quad (2)$$

where S = sediment yield (t/mi^2/yr)
Q = annual runoff (in)
A = watershed area (mi^2).

Because of widely varying local factors, the authors may not have intended for this equation to be used for a specific location. However, the equation does express a rational relationship for sediment yield that seems realistic for conditions encountered in the Southwest.

To estimate the average annual runoff for a watershed, the relationship developed by Renard (1977) for the Walnut Gulch Experimental Watershed was used:

$$Q = 0.4501\ A^{-0.1449} \quad (3)$$

where the terms are as defined above. Substituting Eq. 3 into Eq. 2 gives

$$S = 887\ A^{-.0667}\ (1.43 - 0.26 \log A) \quad (4)$$

To convert the annual sediment yield to ac-ft/mi^2/yr, the sediment deposited was assumed to weighed 80 lbs/ft^3.

Flaxman Method

Flaxman (1972) developed a regression equation for reservoir design on rangeland watersheds in the western United States relating sediment yield to four parameters. His expression is

$$\log (Y + 100) = 6.21301 - 2.19113 \log (X_1 + 100) + 0.06034 \log (X_2 + 100) - 0.01644 \log (X_3 + 100) + 0.04250 \log (X_4 + 100) \quad (5)$$

where Y = antilog of [log (Y + 100)] - 100
Y = average annual sediment yield (ac-ft/mi^2/yr)

X_1 = ratio of average annual precipitation (in) to average annual temperature

X_2 = average watershed slope (%)

X_3 = soil particles greater than 1.0 mm (%)

X_4 = soil aggregation index

The parameters express climate and vegetative growth (X_1), topography (X_2) and soil properties (X_3 and X_4). The equation explained about 91% of the variance in average annual sediment yield from 27 watersheds ranging in size from 12 to 54 mi^2 in 10 western states.

Flaxman (1974) modified his original sediment yield prediction equation by adding an additional term to reflect the 50 percent chance peak discharge in csm (cubic ft/sec/mi^2). The revised equation included converting the dependent variable sediment yield from acre-ft in the original equation to ton/mi^2. The equation is thus given as

$$\log (Y + 100) = 524.37321 - 270.65625 \log (X_1 + 100) + 6.41730 \log (X_2 + 100) - 1.70177 \log (X_3 + 100) + 4.03317 \log (X_4 + 100) + 0.99248 \log (X_5 + 100) \quad (6)$$

where Y = sediment yield in ton/mi^2 yr,

X_5 = the 50 percent chance peak discharge, csm and

X, X_2, X_3, and X_4 are the same as defined in eq (5).

Renard Method

A method for estimating sediment yield was developed by Renard (1972) and Renard and Laursen (1975). This method uses (a) a stochastic runoff model (Diskin and Lane, 1972) which generates hydrographs for semiarid watersheds in the southwestern United States, and (b) a deterministic sediment tansport relationship (Laursen, 1958). Sediment yield is then computed by simulating individual hydrographs and computing the sediment transport for the simulated hydraulic conditions. Annual runoff and sediment yield is the sum of the yield of individual runoff events. Thus, sediment yield is a function of runoff volume, hydrograph peak, Manning's roughness, slope, hydraulic radius, and the size distribution of the sediment in the streambed. The method was applied and calibrated with sample data for several of the larger watersheds on Walnut Gulch in southeastern Arizona. With the model, a simplified relationship was developed which relates the annual sediment yield to watershed drainage area in the form

$$Y = 0.001846 \, A_a^{-.1187} \quad (7)$$

where Y = average annual sediment yield in ac-ft/ac/yr

A_a = drainage area in acres.

Thus, because of transmission losses (abstractions from runoff by the alluvial channels) in the watershed, water yield decreases with increasing drainage area (drainage density), and this same trend is reflected in the sediment yield relationship. Conversions are required to produce the units comparable to the other methods.

Additional improvements might be made with the method if, rather than using the general relationship shown in eq. (7), actual annual runoff volume were used as input to the stochastic simulation routine along with actual bed material size distributions in the channels of the watersheds used for the testing.

MODIFIED UNIVERSAL SOIL LOSS EQUATION (MUSLE)

Williams and Berndt (1977a) have recognized that the erosion estimates of the USLE can be modified to reflect the transport of sediment in runoff and thereby, extend the use of this technique to larger areas. The Modified Universal Soil Loss Equation is given as

$$Y = 11.8\ (Vq_p)^{0.56}(K)(C)(P)(LS) \qquad (8)$$

where Y = sediment yield from the basin in Mg
V = the surface runoff volume for the basin in m^3
q_p = the peak flow rate for the basin in m^3/s
K = soil erodibility factor
C = cover and management factor
P = the erosion control practice factor
LS = slope length and steepness factor

Values of K, C, P, and LS may be input for each subbasin if the area is large enough to require spatial variability quantification.

To provide the peak flow and runoff volume estimates required by MUSLE, a hydrologic model was used called SWRRB (Williams and Nicks, 1980). The acronym stands for a "Simulator for Water Resources in Rural Basins."

The major processes included in the model are surface runoff, percolation, return flow, reservoir storage, and sedimentation. Surface runoff is computed in the model from daily rainfall values using the SCS (1972) curve number technique. Basically, SWRRB uses the CREAMS (Knisel, 1980) daily rainfall hydrology option modified for application to large, complex rural basins. The major changes involved are (a) adding a return flow component, (b) expanding the model to allow simultaneous computations on several subbasins, (c) adding a reservoir storage component to assist in evaluating the effects of farm ponds on water yield, (d) adding a weather generating model to provide for longer term simulations, and (e) using a better method to predict peak runoff rate. Although computations for predicting water and sediment yields proceed simultaneously, the hydrologic model provides the necessary inputs for MUSLE to compute sediment yield on a daily basis. Details of the model structure and method of computation are not included here because of space limitations.

WATERSHEDS CONSIDERED

The Walnut Gulch Experimental Watershed is a 58 mi^2 (150 km^2) drainage in southeastern Arizona operated by the Science and Education Administration of USDA to evaluate the effect of land use and conservation practices on water and sediment yield of arid and semiarid rangelands. The watershed, in the Southeastern Arizona Basin and Range Land Resource Area (Austin, 1965), is typical of the intermountain alluvial areas of the Southwest. Elevations range from 4200 to 6000 ft above mean sea level. Cover is a mixture of brush and grasses with vegetation basal areas less than 10%. Soils are typically calcareous with large amounts of gravel and cobbles. A gravel pavement can develop as the land surface erodes, and in some areas it represents nearly a 100% cover.

Precipitation in the area, which averages about 14 in/yr, is dominated by summer rainfall (about two-thirds of the annual) consisting of high-intensity, short-duration thunderstorms of limited areal extent. Winter storms are generally of greater areal extent and of low intensity, so that runoff is uncommon. The summer air-mass thunderstorms result in high peak flows that generally carry high sediment loads.

Within the watershed, a number of small earthen dams (stock ponds) provide water for the grazing animals. Topographic surveys of the pond storage area have been made, periodically, to determine sediment accumulations. The nine ponds for which such information was available are shown in Table 2 along with data on the characteristics of the watershed area. The ponds generally have enough storage space so that discharge through the emergency spillway is infrequent. Pond 223 spilled more often than the others.

TABLE 2.--Characteristics of stock tanks at Walnut Gulch and of the contributing watersheds

Tank number	Drainage area mi^2	Record length	Soil association[1/]	Vegetation	Measured annual sediment accumulation $ac\text{-}ft/mi^2$
201[2/]	0.170	1960-70 1971-79	Rillito-Karro	Brush Grass	0.49 0.13
207	0.428	1962-77	Rillito-Cave-Tortugas	Brush	0.11
208	0.356	1973-77	Hathaway-Bernardino	Grass	0.13
212	1.316	1964-77	Cave-Rillito-Laveen, and Tortugas	Brush	0.11
213	0.616	1962-79	Graham-House Mountain	Brush/Grass	0.09
214	0.581	1957-77	Hathaway-Bernardino	Grass	0.37
215	0.136	1966-77	Hathaway-Nickel	Brush	0.70
216	0.325	1962-77	Hathaway-Bernardino	Grass	0.51
223	0.169	1962-77	Rillito-Laveen	Brush	0.30

[1/] From Gelderman (1970).
[2/] The tank drainage was root plowed and reseeded in 1971.

RESULTS AND DISCUSSION

Tables 3, 4, and 5 summarize the parameter values used in the PSIAC, Flaxman, and SWRRB/MUSLE methods, respectively. The Dendy/Bolton and Renard methods (Table 6) are simple one-parameter equations and, as such, are by far the easiest to use.

Table 3.--Summary of the factor values used to estimate sediment yield with the Pacific Southwest Interagency Committee method (Renard, 1980)

Tank number	Factor values[1/]										Computed annual sediment yield ac-ft/mi^2
	A	B	C	D	E	F	G	H	I	Total	
201 B	5[2/]	5	8	2	1	-5	0	10	10	36	0.29
201 G	5	5	8	1	1	0	-10	5	10	25	0.19
207	2	2	8	2	8	-8	-5	10	5	24	0.18
208	5	3	8	2	1	-5	2	5	0	21	0.16
212	3	5	8	1	1	0	0	10	10	38	0.30
213	2	2	8	2	5	-5	0	5	5	24	0.18
214	5	5	8	2	2	0	2	5	15	44	0.38
215	5	3	8	2	1	-2	0	15	15	47	0.42
216	5	5	8	1	2	0	0	10	5	36	0.28
223	5	2	8	2	0	-5	-5	10	20	37	0.29

[1/] The factors are defined on p. 2 of the text.

[2/] Some interpolation between the three yield levels defined in the manual was used.

Table 4.--Prediction of sediment yield from watersheds at Walnut Gulch using Flaxman methods (eq. 5 and 6)

Tank number	Factor values[1/]					Annual sediment yield ac-ft/mi^2	
	X_1[2/]	X_2	X_3	X_4	X_5	Y (eq. 5)	Y (eq. 6)
201	0.192	5.3	72	0	226	-0.180	0.16
207	0.206	6.9	55	0	117	0.049	0.12
208	0.179	8.6	47	0	115	0.313	0.17
212	0.206	5.8	41	0	94	0.142	0.12
213	0.206	11.0	46	0	77	0.375	0.15
214	0.216	8.6	52	0	188	0.154	0.21
215	0.216	8.7	44	0	274	0.249	0.32
216	0.216	12.0	52	0	152	0.341	0.23
223	0.206	9.4	65	0	289	0.085	0.28

[1/] Factor values are defined on p. 5 for use in Eq. 5 and 6.

[2/] Average temperature at Tombstone is 63.1°F. Some adjustment was made based on elevation differences between the Tombstone weather station and the pond (3° F increase per 1000 ft elevation decrease).

Table 5.--Summary of the parameter values used in SWRRB/MUSLE for the Walnut Gulch watersheds

Tank number	T.C.[1/]	Root zone depth	CN_I[2/]	K[3/]	LS[4/]	C[5/]
	(hr)	(in)				
201	.350	15.98	88.13	0.2	0.90	.08/.015
207	.421	15.98	87.19	0.1	0.98	.026
208	.407	20.08	87.45	0.234	0.99	.033
212	.528	15.98	83.97	0.399	0.74	.026
213	.454	20.94	86.51	0.455	2.89	.026
214	.449	20.08	86.63	0.1	1.63	.040
215	.335	20.08	88.25	0.234	1.33	.027
216	.339	20.08	87.57	0.234	1.94	.030
223	.350	15.98	88.13	0.1	1.83	.040

1/ T.C. = time of concentration. T.C. = $.5A^{.2}$ where A = area in mi^2.
2/ CN_I = from regression. CN_I = 88.75 - .00568A where A = area in acres.
3/ K = soil erodibility factors from the USLE nomograph (Wischmeier and Smith, 1978).
4/ LS = measured from topographic maps using Williams and Berndt (1977b) method.
5/ C = USLE cover/management factor from field measurements; erosion pavement was included in this factor.

In developing the estimates of sediment yield with the Flaxman (1974) method given in eq. (6), the 50 percent chance peak flow was determined by taking the maximum annual runoff volume recorded for each stock pond for which data were available. The 50 percent chance volume was read from the annual flood series using a log-normal probability distribution. The value was then converted to CSM using the volume/peak flow equation given in the SCS NEH-4 (1972) as follows:

$$X_5 = q_p \frac{640}{A_a} = \frac{484\ AQ}{D/2 + 0.6\ T_c} \left(\frac{640}{A_a}\right) \qquad (9)$$

where: q_p = peak discharge,
A = drainage area (mi^2),
A_a = drainage area (acres),
Q = two year frequency runoff volume (in),
D = storm duration (assumed = 1 hr), and
T_c = time of concentration (hr).

Although the data are not shown, an independent method was also used to estimate parameter X_5 using NOAA Atlas II estimates of the 2-yr frequency 1-hr precipitation depth with an estimate of the watershed curve number and the widely used curve number equation of SCS:

$$Q = \frac{(P-0.2S)^2}{P + 0.8S} \quad (10)$$

where: P = 2-yr frequency 1-hr duration precipitation (in),
S = potential maximum watershed retention (in),
$S = \frac{1000}{CN} - 10$

Estimates of curve numbers (CN's) for the watersheds involved were the same values used in the SWRRB/MUSLE method. The correlation between observed and predicted, using NOAA Atlas II precipitation estimates, was ($r^2 = 0.077$) poorer than that obtained with the log-normal frequency distribution for observed data. It is, however, the method recommended by Flaxman (1974) when data for a specific watershed are not available. The improvement of the estimated sediment yield is dramatic with the addition of the additional parameter. Estimated sediment yield in the absence of observed runoff data tended to overpredict at low sediment yields and underpredict at higher yields, as was observed for all methods.

As can be seen from the summary, Table 6, the PSIAC method generally agreed most closely with the measured data. The PSIAC and MUSLE methods enabled prediction of the change in sediment yield with changes in cover after the treatment of tank 201 in 1970-71. Several individual watershed estimates agree quite well with the observed data.

Table 6.--Measured and predicted annual sediment yield (ac-ft/mi^2) for select semiarid rangeland watersheds (modified from Renard, 1980)

Tank number	Measured yield	Predicted yield					
		PSIAC	Dendy/Bolton	Flaxman[1] (Eq. 5)	Flaxman[1] (Eq. 6)	Renard	SWRRB/MUSLE
201 B[2]	0.49	0.29	0.83	-0.180	0.16	0.68	0.25
201 G	0.13	0.19					0.05
207	0.11	0.18	0.73	0.049	0.12	0.61	0.05
208	0.13	0.16	0.75	0.313	0.17	0.62	0.08
212	0.11	0.30	0.62	0.142	0.12	0.53	0.08
213	0.09	0.18	0.69	0.375	0.15	0.58	0.80
214	0.37	0.38	0.70	0.154	0.21	0.59	0.11
215	0.70	0.42	0.85	0.249	0.32	0.69	0.21
216	0.51	0.28	0.76	0.341	0.23	0.63	0.43
223	0.30	0.29	0.83	0.085	0.28	0.68	0.15

[1] Flaxman method includes both eq. 5 and 6 estimates.
[2] The B and G refer to brush and grass cover associated with the 1971 treatment of the watershed.

The values assigned to the nine PSIAC factors were made using some interpolation between the three yield levels defined in the manual. We felt that such interpolation was warranted by our detailed knowledge of the watershed and familiarity with the method (the senior author was a member of the committee which developed the method).

The Flaxman (1972) method, surprisingly, was no better than those of the other methods, even though the Flaxman method was developed specifically for conditions in the western United States. Like the PSIAC method, it has no direct term reflecting watershed area. When the additional parameter is used to reflect the 2-yr frequency annual peak discharge, the results improve. The results of the prediction also improved dramatically when the actual flood series was used to estimate the parameter rather than using the simple estimate of precipitation and converting that value to a peak flow.

The Dendy/Bolton method overestimated sediment yield in all cases. The predictions might have improved slightly if actual runoff data had been used to replace the relationship of eq. 3. Thus, an improvement like that obtained with the Flaxman (1974) method might be expected.

The Renard method also overestimated the sediment yield in all but one case. Predictions might improve if the technique were used to simulate the sediment yield using channel characteristics and observed runoff for each individual watershed, rather than the average conditions with which the model was calibrated, and then simplified to the form shown in eq. 7. For example, some of the ponds had grass swales; in other locations, the channels are more rectangular and contain large amounts of sand which more nearly duplicate the conditions of the large watersheds. Thus, sediment accumulation in tanks with sand channels (208, 214, 216, and 223) would be expected to be closer to the predicted, as observed on all but tank 208. If such a scheme were used, it would be somewhat analogous in detail to the SWRRB/MUSLE technique.

The SWRRB/MUSLE method is considerably more complex and, thus, requires more input data than the other methods. However, its results were not significantly closer to the measured values than those of the other methods. Intuitively, we think the problem is not with the MUSLE part of the scheme but, rather, is associated with the inadequacy of the SCS curve number hydrology option used to produce runoff peaks and volumes commensurate with the observed values. Previous work by Simanton et al. (1973), Hawkins (1978a and 1978b), and others, has illustrated problems with using the CN precipitation/runoff relationship.

SENSITIVITY OF PREDICTED SEDIMENT YIELD TO CURVE NUMBER IN SWRRB/MUSLE

Since most summer runoff events in the Basin and Range Province occur under antecedent moisture condition (AMC) I, SWRRB was modified for the purpose of this paper to accept CN I directly as input instead of requiring calculations from CN II as the program was originally written. Input values for CN I were calculated from the SCS curve number equation using observed rainfall-runoff data for Walnut Gulch and solving for the optimum CN. To test the sensitivity of predicted sediment yield to curve number, the calculated CN values were varied $\pm$ 2 and + 10. The results are similar for each of the tanks studied.

As shown in Fig. 1, predicted sediment yield (with the exception of CN + 10) changes very little, with variations within the range of values of curve number typical for Walnut Gulch.

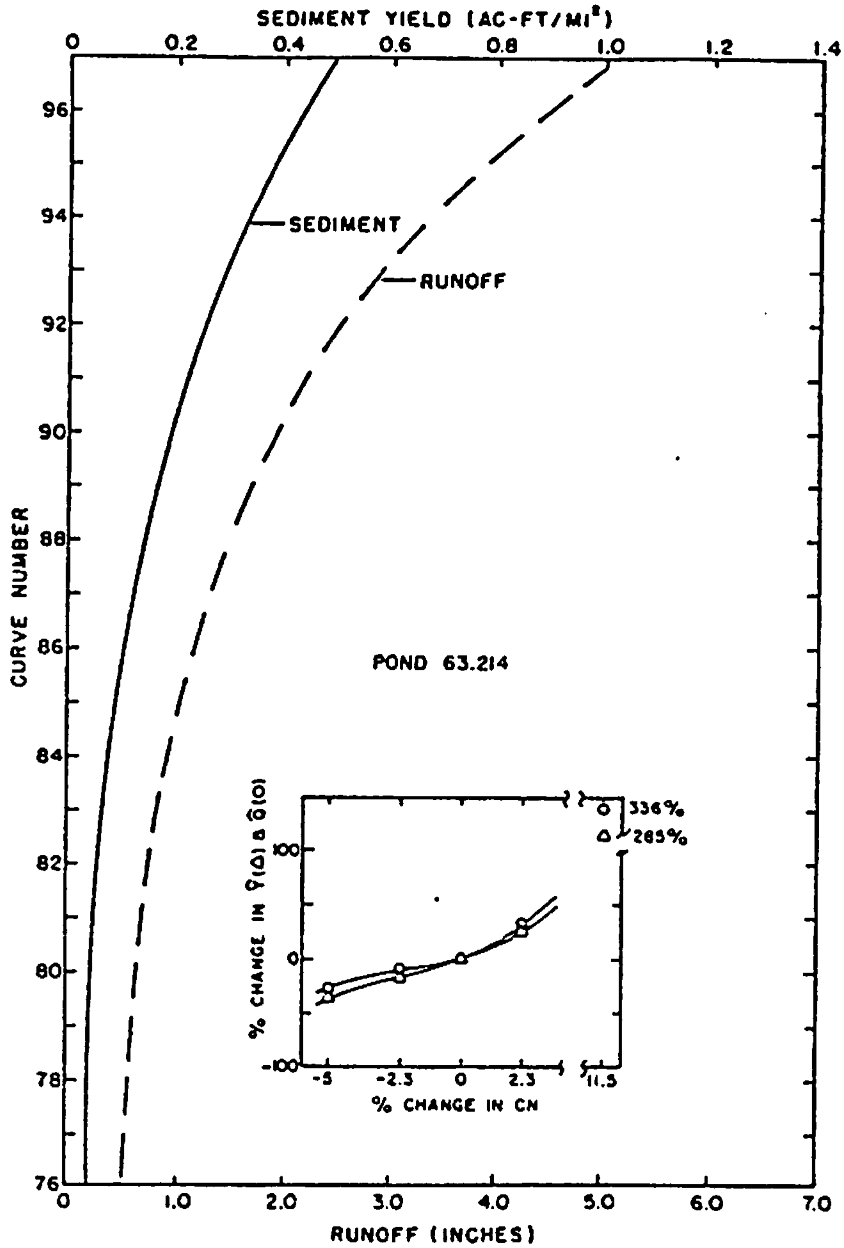

Figure 1.--Sensitivity of runoff and sediment yield to varying curve number.

No sensitivity analysis of sediment yield to the USLE factors (KLSCP) in MUSLE was done since these factors are linearly related to sediment yield and, unlike the runoff factor, remain constant for the period of simulation. However, there is a high potential for error inherent in MUSLE due to the difficulty of evaluating factors like "C" and "K" for a semiarid rangeland environment.

The simulated versus observed sediment yield data for the nine small watersheds on Walnut Gulch are summarized in Fig. 2. Also shown are regression lines and coefficients of determination, r^2, for each method. The results are discouraging. They illustrate that considerable improvement is needed in the technology of estimating sediment yield. The low r^2 values, in most instances, result from one data point. For example, the r^2 for the MUSLE prediction improves to 0.55 by eliminating the prediction on pond 213. From a statistical viewpoint, the PSIAC method is the best of the six methods.

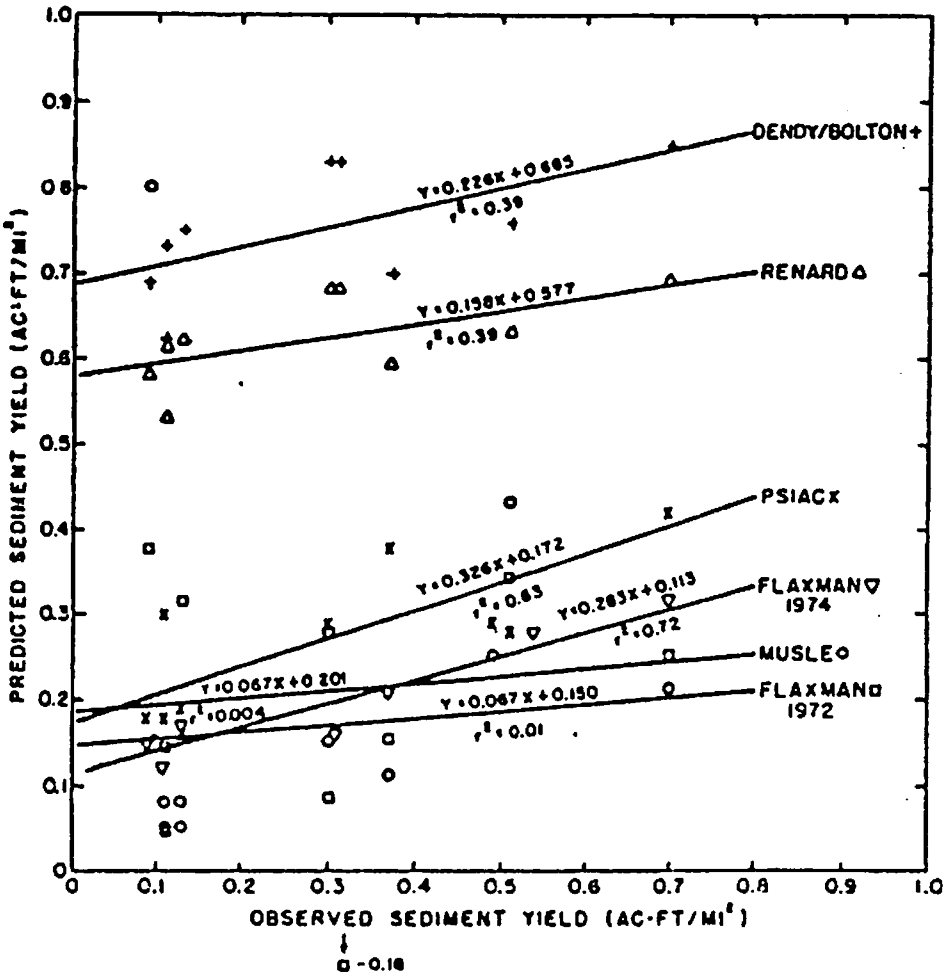

Figure 2.--Correlations of observed and predicted sediment yield for the six prediction relationships tested.

REPRESENTATIVENESS OF SHORT RECORDS

When relatively short records are used in developing and testing prediction schemes, such as the sediment yield methods tested herein, one immediately wonders whether the sample includes all extremes of the climate and if the short-term mean value and standard deviation are the same as that for a long-term record. In the southwestern United States, the coefficient of variation of annual precipitation is maximum for any of the locations considered by Hershfield (1962). Knisel et al. (1979) investigated methods to evaluate the length of record necessary for water resource data collection. One of the methods investigated involved a cumulative surplus/deficit analysis of the annual precipitation. The surplus/deficit analysis depicts trends that may otherwise be obscure and is obtained by cumulating departures from a long-term mean.

Figure 3 illustrates the long-term annual rainfall amounts and cumulative surplus/deficit from the 13.66-in mean for the raingage at Tombstone, within the Walnut Gulch Experimental Watershed. In only 1 yr was rainfall above the long-term mean for the period used in the sediment yield evaluation. The negative slope to the surplus/deficit graph for the period since 1957 illustrates the general dry trend during the study period. Since 1957, rainfall has been about 8% below normal. Thus, the vegetation cover would be expected to be poorer than that for a wetter period, and runoff which transports the eroded material might be less than the long-term mean.

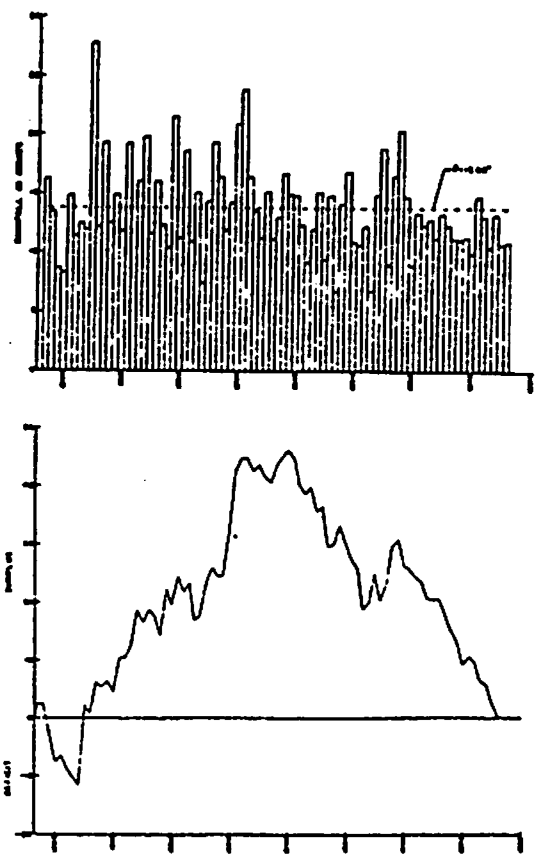

Figure 3.--Annual precipitation and cumulative surplus/deficit for Tombstone, Arizona (Knisel et al., 11).

The importance of an unusual storm in affecting long-term sediment yield trends has been well documented. Thus, it is entirely possible that some of the observed yields are low because of low precipitation/runoff or even the absence of more infrequent events. Stock tanks 214, 215, and 216, on the other hand, have had some large storms during their short records (Osborn and Renard, 1969), which may partly explain why the observed yields for these ponds are larger and somewhat closer for the predicted values.

CONCLUSIONS

1. Predicting sediment yield in the western United States, despite recent developments in water resource models, is difficult and often subjective. The wide variations in watershed characteristics over short distances add to the problem.

2. Of the methods investigated, the PSIAC method appears to give the best results for the amount of work required to make the estimate. The SWRRB/MUSLE method also gave good results (except for pond 213), but the amount of work required for the hydrologic portion of the model is considerable. Certainly, it is potentially a powerful tool for evaluating management practices.

3. Only the PSIAC and the SWRRB/MUSLE methods allow the use of factors (parameters) that reflect management practices. The Renard method also could be used to reflect management practices if the stochastic runoff model and the sediment transport relationship were used directly rather than as simplified with eq. 7.

4. The Flaxman method, as modified in 1974, illustrates some of the improvement which can be obtained by inclusion of an additional term to reflect the 2-yr frequency peak flow. Estimating the peak flow with actual records also improved the correlation between observed and predicted sediment yields over converting the 2-yr precipitation frequency estimate using a rainfall-runoff relationship.

5. The methods tested generally underpredicted sediment yield. The underprediction may, in part, be associated with the questionable representativeness of the climatic sample for the period of observation. Records at all but three of the watersheds were known to be lower than normal in precipitation/runoff, and thus, those results are undoubtedly below what might bé considered the mean annual sediment yield.

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