USE OF THE UNIVERSAL SOIL LOSS EQUATION IN THE TROPICS

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Introduction

Sediment production from the land surface is a normal erosion process. The production of sediment in tropical environments, however, results in more severe consequences than in more temperate climates. This is due to the fact that most nutrients in tropical soils are nearer the surface than in comparable temperate soils and because rainfall intensities are greater resulting in higher, overall runoff and sediment transport rates (Lal, 1977). Agricultural production suffers as a result of decreased soil fertility, roads are damaged due to the exposure of unvegetated slopes and reservoirs rapidly fill with sediments.

The Universal Soil Loss Equation (USLE) has been developed to quantify the sediment production phenomenon on agricultural lands. The equation utilizes factors which, when multiplied together, provide an estimate of the expected soil loss from a parcel of land. The equation is;

$$A = R * K * LS * C * P \qquad (1)$$

where;

- A is the estimated soil loss per unit area
- R is a rainfall factor which accounts for the kinetic energy of a storm
- K is a soil erodibility factor which accounts for edaphic variablility
- LS is a combination of length and slope factors which accounts for topographic influences on erosion rates
- C is a cropping and management factor which accounts for differences in vegetative cover and density
- P is a support practice factor which accounts for such erosion control practices as terracing, contouring, etc.

In this paper we shall present erosion plot data which has been collected in two Central American countries; Honduras and El Salvador. A brief analysis of the factors shall be made and some tentative conclusions will be presented.

Erosion investigations in El Salvador

Sediment yield and runoff data for El Salvador were collected on runoff plots established jointly by the Food and Agriculture Organization (FAO) of the United Nations Development Programme (UNDP) and the Salvadorean Directorate General for Renewable Natural Resources. The plots were established in 1974 on the government forest district outside of Metapan in northwestern Santa Ana Department. The elevation of the area is about 835 metres above sea level and yearly rainfall averaged 1625 mm over the five year study period (Table 1). Average monthly rainfall distribution is shown in Figure 1.

TABLE 1

1975	1976	1977	1978	1979	MEAN
1895	1397	1192	1929	1716	1626

ANNUAL RAINFALL (mm)
Ingenio San Jose, El Salvador

Figure 1

MEAN MONTHLY RAINFALL (mm)
Ingenio San Jose, El Salvador
1975-1979

Soils in the area are red latisols typical of the northern zone of the country. Textures are loams to clay loams on slopes that vary between 24 and 35 percent.

Twelve plots were established with dimensions of 5 by 20 metres (Figure 2). The plots were equipped with runoff-sediment tanks (Michaelson and Sanchez, 1974); rainfall was recorded on a SIAP tipping bucket rain guage and collected in 2 standard guages. In 1975 the plots were divided into three replicates of four treatments; fallow, traditional cropping pattern, strip cropping and bench terraces (Figure 3).

Fallow plots were tilled by hand and raked up and down slope periodically throughout the rainy season. Traditional agriculture plots duplicate the no-tillage, hand-planted, basic grains system indigenous to the mountainous northern zone. Strip cropped plots incorporate two double strips of lemon grass (Cimliopogon citratus) dividing the plots into three equal slopes. Bench terrace plots are divided into five terraces with the backslopes planted to jaraqua grass (Hipparrhenia rifa) and include a brick-lined drainage channel (Michaelson and Heymans, 1975).

Five years of continuous rainfall data was analyzed and actual rainfall energy factors (R) were calculated for 20, 25, and 30 minute intensity intervals using standard USDA methodology (Wischmeier and Smith, 1978; Foster, et al, 1981). The R factor value used in our analysis was for the 30 minute intesity interval. The values are (in units of megajoule millimetre/hectare hour year);

R(20) = 12,694

R(25) = 11,420

R(30) = 10,227

Four years of sediment-runoff data were analyzed, again using the USDA methodology cited above, to obtain annual sediment production values (A) for each treatment. The A factor values are (in units of metric tons/hectare);

TABLE 2

	FALLOW	TRADITIONAL	STRIP CROP	TERRACES
RUNOFF (mm)	252 (σ=52.6)	126 (σ=40.4)	72 (σ=12.9)	199 (σ=32.9)
SEDIMENT (T/ha)	356.4 (σ=82.4)	55.5 (σ= 6.8)	34.9 (σ= 5.5)	13.7 (σ= 3.3)

MEAN ANNUAL RUNOFF AND EROSION

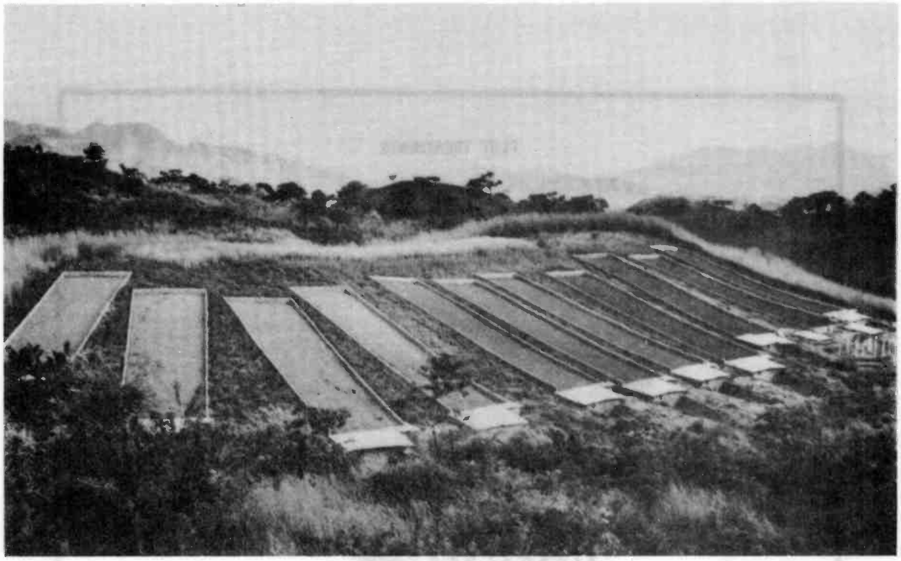

Figure 2

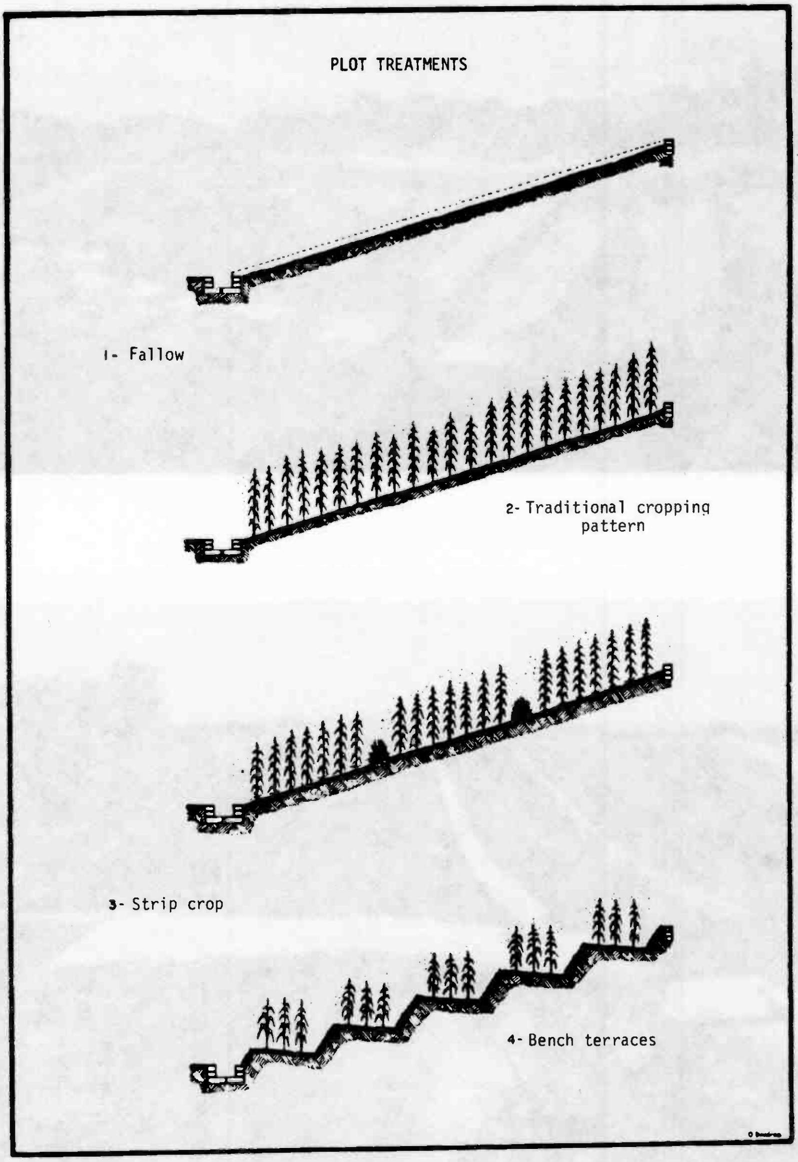
PLOT TREATMENTS
1- Fallow
2- Traditional cropping pattern
3- Strip crop
4- Bench terraces

Figure 3

The length-slope factor (LS) was calculated using the formula presented in Wischmeier and Smith (1978). The factor value for the bench terrace plots is determined over the downslope length of each individual terrace, rather than for the overall plot length. The values, calculated for each plot and averaged by treatment, are (unitless);

Fallow plots: 6.13

Traditional cropping: 7.16

Strip cropped: 6.37

Bench terrace: 3.31

The soil erodibility factor (K) values were determined by two methodologies. Using the nomograph presented by Foster, et al (1981) produced a value of 0.032 (metric ton hectare hour/hectare megajoule millimetre). The second method involved solving the USLE for the K factor using the A value from the fallow plots and setting the cropping factor (C) and the support practice factor (P) values at 1.0. The result was a substantially lower K factor value of 0.0057.

$$K = A / (R * LS) \qquad (2)$$

$$\text{for} \quad C = P = 1.0$$

Cropping factor (C) values were then calculated using the USLE for each treatment using both estimates of the K values for the site. The cropping system used on all three cultivated treatments was the indigenous system of the northern mountain zone. This consists of inter-cropped corn (Zea mays) and beans (Phaseolus spp.). The corn was planted in early May and the beans in early August. The average annual C values are (unitless);

C (K obtained from nomograph): .025

C (K calculated): .14

Supporting practice factor (P) values were then estimated for the remaining treatments (after Arnoldus, 1977). The resulting P values are (unitless);

Traditional cropping: .95

Strip cropped: .67

Bench terraces: .51

Erosion investigations in Honduras

Sediment production in Honduras was monitored starting in May, 1977. The area investigated lies approximately 200 km due east of the sites in El Salvador and 20 km to the west of the capital of Honduras, Tegucigalpa. The elevation of the area is between 1100 m and 1800 m with an average annual precipitation of approximately 850 mm. Three sites were instrumented with Coshocton samplers installed below 3.5 foot H-type flumes. The sites ranged in size from 7 to 22 ha. in extent and were located on brush, forested and traditional agricultural (corn and bean) watersheds. Starting in May, 1978, thirty 1.5 by 6 metre standard USDA runoff plots were installed on different land use classes on three separate soil types and two slope classes with two repetitions. The land use classes were virgin forest, brushlands (regeneration of abandoned agricultural lands), traditional agricultural (corn and bean) lands, grazed lands and burned forest lands. The three soils were; a shallow, sandy loam soils originating from weathered ignimbrites, a deep, well-weathered basalt soil, and a deep, sandy-loam soil. In addition, individual storm runoff volumes and representative sediment loads were obtained along sections of roads using 1.5 foot H-type flumes. (Kramer and Arcoleo, 1980)

A suction filtration technique was used to determine the concentration of sediment in the aliquots obtained from the Coshocton wheel, the runoff plots and from the roadside flumes. Total suspended solids (TSS) were recorded for each stormflow event and summed over the year to provide an estimate of the soil loss for each land use-soil type combination. The data for the 1978 water year (May 1, 1978 thru April 30, 1979) is presented for 28 of the 30 runoff plots in Table 3.

Using the USLE, an estimate of the Cropping factor (C) can be made for each of the land use classes. The estimates are presented in Table 4 along with corresponding estimates using sediment data collected from the flumes. The values for the first three land use classes are substantially lower for the flumes than for the runoff plots. One possible reason is that the areas of the plots are much smaller than the areas measured by the flumes (9 square metres vs. 200,000 square metres).

Table 3
Soil Loss from Runoff Plots in 1978

Plot	Rainfall (mm/yr)	Runoff (mm/yr)	Runoff/Rainfall (%)	pair avg	Soil Loss (kg/ha)	pair avg
AgY	603.5	52.73	8.7		601.2	
AgY	603.5	66.86	11.1	9.9	2141.9	1371.6
AsY	647.7	43.64	6.7		6431.9	
AsY	647.7	67.73	10.5	8.6	4443.3	5437.6
BgY	569.5	67.16	11.8		136.4	
BgY	569.5	66.70	11.7	11.8	218.0	177.2
BsY	647.7	49.93	7.7		21.7	
BsY	647.7	50.75	7.8	7.8	71.0	46.4
FgY	578.6	27.22	4.7		48.7	
FgY	578.6	15.45	2.7	3.7	24.9	36.8
FsY	578.6	31.87	5.5		54.2	
FsY	578.6	10.81	1.9	3.7	27.5	40.9
AgM	687.1	183.47	26.7		4787.8	
AgM	687.1	202.63	32.8	29.8	7358.0	6072.9
BgM	618.7	47.99	7.2		52.7	
BgM	618.7	71.19	10.4	8.8	190.6	121.6
GgM	666.0	178.77	26.0		2393.0	
GgM	666.0	191.2	27.8	26.9	1882.8	2137.5
AgO	563.6	46.19	7.8		534.3	
AgO	563.6	26.26	4.7	6.3	216.7	375.5
BgO	563.6	25.42	4.5		41.5	
BgO	563.6	20.97	3.7	4.1	20.8	31.2
BsO	563.6	14.70	2.6		73.2	
BsO	563.6	22.46	4.0	3.3	96.4	84.8
FgO	563.6	24.82	4.4		23.9	
FgO	563.6	17.70	3.1	3.8	16.2	20.0
FsO	563.6	15.14	2.7		73.4	
FsO	563.6	15.78	2.8	2.8	33.9	53.6

Code:
A - Traditional agricultural plots
B - Brush plots
F - Forested plots
G - Grazed plots

g - Gentle slopes < 10%
s - Steep slopes > 20%

Y - Yauyupe soils
M - Milile soils
O - Ojojona soils

Table 4
Cropping Factors in Honduras

Land use type	Plots	Flumes	SDR
Undisturbed forest and brushlands	.0002	.00002	.613
Grazed lands	.0096	.0004	.507
Agricultural lands	.0226	.0013	.560
Roads and trails	-	1.71	-

The use of a Sediment Delivery Ratio (SDR) as described by Wischmeier and Smith (1978), is also presented in Table 4, and is not sufficient in itself to explain the difference. The difference may be the result of disturbances due to installation of the plots. The analysis of subsequent years of data will be required to determine the source of the inconsistency. Consistent with the methodology used in the study conducted in El Salvador, the K factor was selected using the nomograph designed for that purpose.

Conclusions

The storm intensities typical to tropical regions (Lal, 1977) produce R values higher than those published anywhere within the United States. The use of these R values, in combination with high LS values characteristic of the steep, mountainous zones of Central America produce USLE annual sediment loss values well above those observed on the experimental plots.

The C value for traditional agriculture in Honduras is reasonably close to that obtained in El Salvador (0.023 vs 0.025) when the nomograph technique is used. In both Honduras and El Salvador, the C values estimated are an order of magnitude less than those values which are obtained from the literature (Arnoldus, 1977; Wischmeier and Smith, 1978).

Recommendations

Additional information is needed on the physical soil characteristics of the plots to allow a precise mechanical analysis for K determination by the nomograph method. Crop stages should be examined to explain differences in sediment production as a function of plant development. The effects of various inter-cropping systems also need to be quantified. In light of the limited data base, an event-based analysis may yield more significant values than an annual approach.

Bibliography

Arnoldus, H.M.S., 1977; "Predicting soil losses due to sheet and rill erosion", in Guidelines for Watershed Management, edited by S. Kunkle and J. Thames, FAO Conservation Guide, Vol. 4, Rome, Italy, pp. 99-124.

Foster, G.R., D.K. McCool, K.G. Renard and W.C. Moldenhauer, 1981; Conversion of the Universal Soil Loss Equation (USLE) to SI Metric Units, USDA-SEA, AR, Southwest Rangeland and Watershed Research Center, No. 361, Tucson, Arizona, 15 pgs.

Kramer, J.M. and J. Arcoleo, 1980; Management of the Choluteca River Watershed, US-AID, Supplement 1 to the Natural Resources Management Project Paper, Tegucigalpa, Honduras, 157 pgs.

Lal, R., 1977; "Analysis of factors affecting rainfall erosivity and soil erodibility", in Soil Conservation and Management in the Humid Tropics, edited by D. Greenland and R. Lal, John Wiley & Sons, New York, pp. 49-55.

Michaelson, T. and L.E. Heymans, 1975; Informe Anual de las Parcelas para la Investigacion del Control de la Erosion y Escorrentia Superficial en el Districto Forestal de Metapan, Ministeria de Agricultura y Ganaderia, DGRNR-PNUD/FAO, El Salvador, ELS/73/004 Documento de Trabajo, No. 3, 13 pgs.

Michaelson, T. and J.R. Sanchez, 1974; Establecimiento y Calibracion de 12 Parcelas Elementales para la Investigacion del Control de Erosion y Escorrentia Superficial en el Districto Forestal de Metapan, Ministeria de Agricultura y Ganaderia, DGRNR-PNUD/FAO, El Salvador, ELS/73/004 Documento de Trabajo, 25 pgs.

Wischmeier, W.H. and D.D. Smith, 1978; Predicting Rainfall Erosion Losses - A Guide to Conservation Planning, Agricultural Handbook, No. 537, USDA, Washington, D.C., 58 pgs.