

# A Process-Based Soil Erosion Model for USDA-Water Erosion Prediction Project Technology

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## ABSTRACT

A model was developed for estimating soil erosion by water on hillslopes for use in new USDA erosion prediction technology. Detachment, transport, and deposition processes were represented. The model uses a steady-state sediment continuity equation for predicting rill and interrill processes. Net detachment in rills is considered to occur when the hydraulic shear stress of flow exceeds the critical shear stress of the soil and when sediment load in a rill is less than the sediment transport capacity. Net deposition is calculated when the sediment load is greater than the transport capacity. Rill detachment rate is dependent upon the ratio of sediment load to transport capacity, rill erodibility, hydraulic shear stress, surface cover, below ground residue, and consolidation. Rill hydraulics are used to calculate shear stresses and a simplified transport equation, calibrated with the Yalin transport equation, is used to compute transport capacity in rills. Interrill erosion is represented as a function of rainfall intensity, residue cover, canopy cover, and interrill soil erodibility. The model has capabilities for estimating spatial distributions of net soil loss and is designed to accommodate spatial variability in topography, surface roughness, soil properties, hydrology, and land use conditions on hillslopes.

## INTRODUCTION

The USDA - Water Erosion Prediction Project (WEPP) was initiated in 1985 "to develop new generation water erosion prediction technology for use...in soil and water conservation and environmental planning and assessment" (Foster and Lane, 1987). The computer model for WEPP is based on fundamentals of infiltration, surface runoff, plant growth, residue

decomposition, hydraulics, tillage, management, soil consolidation, and erosion mechanics. Process-based erosion models provide several major advantages over empirically based erosion prediction technology, including most notably; 1) capabilities for estimating spatial and temporal distributions of net soil loss; net soil loss (or gain, in the case of deposition) for an entire hillslope or for each point on the hillslope can be estimated on a daily, monthly, or average annual basis, and 2) since the model is process-based, it can be extrapolated to a broad range of conditions which may not be practical or economical to field test. A process-based erosion model used with a process-based hydrology model, a daily water balance model, a plant growth and residue decomposition model, a climate generator, and a soil consolidation model constitutes a very powerful tool for estimating soil loss and selecting agricultural management practices for soil conservation. This paper will be restricted to the portion of the prediction model that represents erosion mechanics.

The concepts used in process-based erosion models have developed gradually since Meyer and Wischmeier (1969) presented mathematical descriptions of detachment and transport by rainfall and of detachment and transport by runoff as these processes were conceptualized by Ellison (1944). Foster and Meyer (1972) described a relationship for detachment by runoff in which the rate of detachment is a function of the ratio of carried sediment to the transport capacity of the flow. The concept of rill vs. interrill sources of sediment was introduced by Meyer et al. (1975b).

Separating the concepts of empirically-based models from the process-based models has also been gradual because of the lack of a data base suitable for developing relationships for parameter estimation. The recent process-based erosion model (Foster et al., 1981) used in CREAMS (USDA, 1980) uses USLE relationships for determining soil erodibility parameters and makes use of USLE crop-storage-soil-loss ratios (Foster et al., 1980).

The purpose of this article is to present the erosion model used in the WEPP technology. The governing equations for sediment continuity, detachment, deposition, shear stress in rills, and transport capacity are presented. Relationships describing temporal modifications to baseline erodibility parameters (i.e., those measured for a standard condition) as a function of above and below ground residue, plant canopy, and soil consolidation are also presented. The normalized forms of the equations and parameters, the means for characterizing downslope variability, and solution methods are discussed. Measured vs. predicted values of sediment load are plotted and also discussed for several data sets.

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Article was submitted for publication in March 1989; reviewed and approved for publication by the Soil and Water Div. of ASAE in June 1989.

Contribution from the USDA-Agricultural Research Service, National Soil Erosion Research Laboratory in cooperation with the Purdue Agric. Exp. Stn. Journal No. 11877, and the University of Minnesota Agric. Exp. Stn. Journal No. 16936.

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**Acknowledgment:** The authors would like to thank Dr. W. J. Elliot and Dr. J. M. Laffen for providing the data for comparing measured vs. predicted sediment loads.

## GOVERNING EQUATIONS

### Sediment Continuity Equation

The WEPP erosion model computes estimates of net detachment and deposition using a steady state sediment continuity equation, which is

$$dG/dx = D_f + D_i \dots\dots\dots [1]$$

where

- $x(m)$  = distance downslope,
- $G(kg\ s^{-1}m^{-1})$  = sediment load,
- $D_i(kg\ s^{-1}m^{-2})$  = interrill erosion rate,
- $D_f(kg\ s^{-1}m^{-2})$  = rill erosion rate.

Interrill erosion,  $D_i$ , is considered to be independent of  $x$ . Rill erosion,  $D_f$ , is positive for detachment and negative for deposition. For purposes of calculation, both  $D_f$  and  $D_i$  are computed on a per rill area basis, thus  $G$  is solved on a per unit rill width basis. After computations are complete, soil loss is expressed in terms of loss per unit area of the hillslope.

Interrill erosion in the model is conceptualized as a process of sediment delivery to concentrated flow channels, or rills, whereby the interrill sediment is then either carried off the hillslope by the flow in the rill or deposited in the rill. Sediment delivery from the interrill areas is considered to be proportional to the square of rainfall intensity, with the constant of proportionality being the interrill erodibility parameter. The function for interrill sediment delivery also includes terms to account for ground and canopy cover effects. The interrill functions are discussed in detail below.

Net soil detachment in rills is calculated for the case when hydraulic shear stress exceeds the critical shear stress of the soil and when sediment load is less than sediment transport capacity. For the case of rill detachment

$$D_f = D_c [1 - G/T_c] \dots\dots\dots [2]$$

where  $D_c(kg\ s^{-1}m^{-2})$  is the detachment capacity by flow, and  $T_c(kg\ s^{-1}m^{-1})$  is the sediment transport capacity in the rill.

When hydraulic shear stress exceeds critical shear stress for the soil, detachment capacity,  $D_c$ , is expressed as

$$D_c = K_r(\tau_f - \tau_c) \dots\dots\dots [3]$$

where

- $K_r(s/m)$  = a rill soil erodibility parameter,
- $\tau_f(Pa)$  = flow shear stress acting on the soil,
- $\tau_c(Pa)$  = the rill detachment threshold parameter, or critical shear stress, of the soil.

Rill detachment is considered to be zero when shear is less than critical shear of the soil.

Net deposition is computed when sediment load,  $G$ , is greater than sediment transport capacity,  $T_c$ . For the case of deposition

$$D_f = [V_f/q] [T_c - G] \dots\dots\dots [4]$$

where  $V_f(m/s)$  is the effective fall velocity for the

sediment, and  $q(m^2/s)$  is the flow discharge per unit width.

### Hydrologic Inputs

The three hydrologic variables required to drive the erosion model are peak runoff rate,  $P_r(m/s)$ , effective runoff duration,  $t_r$  (s), and effective rainfall intensity,  $I_e$  (m/s). These variables are calculated by the hydrology component of the WEPP model which generates breakpoint precipitation information and runoff hydrographs. To transpose the dynamic hydrologic information into steady state terms for the erosion equations, the value of steady-state runoff,  $P_r$ , was assigned the value equal to that of the peak runoff on the hydrograph. The effective duration of runoff,  $t_r$ , was then calculated to be the time required to produce a total runoff volume equal to that given by the hydrograph with a constant runoff rate of  $P_r$ . Thus,  $t_r$  was calculated as

$$t_r = V_t / P_r \dots\dots\dots [5]$$

where  $V_t$  (m) is the total runoff volume for the rainfall event.

Effective rainfall intensity,  $I_e$ , which is used to estimate interrill soil loss, was calculated from the equation

$$I_e = [( \int I^2 dt ) / t_e]^{1/2} \dots\dots\dots [6]$$

where

- $I$  = rainfall intensity,
- $t$  = time,
- $t_e$  = total time during which the rainfall rate exceeds infiltration rate.

### Flow Shear Stress

Shear stress of rill flow is computed at the end of an average uniform profile length by assuming a rectangular rill geometry. The uniform profile is defined as a profile of constant or uniform gradient,  $\bar{S}$ , that passes through the endpoints of the profile. The shear stress from the uniform profile is used as the normalization term for hydraulic shear along the profile as discussed below. Width,  $w(m)$ , of the rill is calculated using the relationship

$$w = c Q_e^d \dots\dots\dots [7]$$

where  $Q_e$  ( $m^3/s$ ) is the flow discharge at the end of the slope, and  $c$  and  $D$  are the coefficients derived from data from the study of Laflen et al., 1987.

Discharge rate is given by

$$Q_e = P_r L R_s \dots\dots\dots [8]$$

where

- $P_r$  (m/s) = peak runoff rate,
- $L$  (m) = slope length,
- $R_s$  (m) = the distance between flow channels.

The sensitivity of the model to rill spacing,  $R_s$ , and channel width,  $w$ , was investigated by Page (1988). Predicted sediment load was sensitive to rill spacing when an increase in flow shear from increased rill spacing (hence discharge) caused flow shear to exceed

the threshold of critical shear of the soil and initiate rilling. The effect of rill spacing on average sediment loss per unit area was minimal for the condition when shear was always greater than critical. Increased rill spacing causes a greater flow in the rill, a higher shear stress acting on the soil, and greater sediment load. However, this loss of soil must then be averaged over the larger contributing area to the rill, resulting in the relative insensitivity of average soil loss per unit area to rill spacings (Page, 1988).

A similar effect was observed for rill width. Decreased rill width causes increased flow depth and shear. However, the area of scour in the rill is less and hence average soil loss is not greatly affected. A large effect was seen only when increasing flow shear crossed the threshold of critical shear of the soil. Since most sediment is lost for large runoff events where critical shear of the soil was greatly exceeded, the effect of rill spacing and width on predicted soil loss was not found to be great in terms of overall model sensitivity (Page, 1988).

Depth of flow is computed with an iterative technique using the Darcy-Weisbach friction factor of the rill, the channel width, and the average slope gradient. Hydraulic radius,  $R$  (m), is then computed from the flow width and depth of the rectangular channel. Shear stress acting on the soil at the end of the uniform slope,  $\tau_{fe}$  (Pa), is calculated using the equation

$$\tau_{fe} = \gamma \bar{S} R (f_s/f_t) \dots \dots \dots [9]$$

where

- $\gamma$  = the specific weight of water ( $\text{kg m}^{-2} \text{s}^{-2}$ ),
- $\bar{S}$  = average slope gradient,
- $f_s$  = friction factor for the soil,
- $f_t$  = total rill friction factor.

The ratio of  $f_s/f_t$  represents the partitioning of the shear stress between that acting on the soil and the total hydraulic shear stress, which includes the shear stress acting on surface cover (Foster, 1982).

**Sediment Transport Capacity**

Sediment transport capacity, as well as sediment load, is calculated on a unit channel width basis within the erosion component. Sediment load is converted to a unit field width basis when the calculations are completed. The transport capacity,  $T_c$ , as a function of  $x$  is calculated using a simplified transport equation of the form

$$T_c = k_t \tau_f^{3/2} \dots \dots \dots [10]$$

where  $\tau_f$  is the hydraulic shear acting on the soil, and  $k_t$  is a transport coefficient.

Transport capacity at the end of the slope is computed using the Yalin equation. The coefficient,  $k_t$ , is calibrated from the transport capacity at the end of the slope,  $T_{ce}$ , using the method outlined by Finkner et al. (1989). A representative shear stress is determined as the average of the shear stress at the end of the representative uniform average slope profile and the shear stress is used to compute  $T_{ce}$  using the Yalin equation and  $k_t$  is then determined from the relationship

given in equation [10]. Differences between the simplified equation and the Yalin equation, using the calibration technique, are minimal (Finkner et al., 1989).

**NORMALIZATIONS**

**Normalized Parameters**

The erosion computations are made by solving non-dimensional equations and then redimensionalizing the final solution. By nondimensionalizing, shear and transport capacity can be written as polynomials of  $x$ . Thus, the solutions to the detachment and deposition equations are more readily obtained and require less computational time. Conditions at the end of a uniform slope through the endpoints of the given profile are used to normalize the erosion equations. Distance downslope is normalized to the slope length, i.e.,  $x^* = x/L$ . The slope at a point is normalized to the average uniform slope gradient and is expressed as

$$s^* = a x^* + b \dots \dots \dots [11]$$

where  $a$  and  $b$  are calculated from slope input data describing the hillslope.

Note that  $a$  and  $b$  need not be, and usually won't be, constant over an entire slope length. Equation [11] for a given set of  $a$ ,  $b$  values describes a simple slope shape, either convex, concave, or uniform, depending on whether the value of "a" is positive, negative, or zero, respectively. The profile input to the model is processed in such a way as to describe the hillslope in sections of simple slope shapes, and to calculate  $a$ ,  $b$  values for each section.

Shear stress as a function of downslope distance is normalized to shear stress at the end of the uniform slope,  $\tau_{fe}$ . The function for shear stress vs. downslope distance is derived using the Darcy-Weisbach uniform flow equation and the assumption that discharge varies linearly with  $x$ , hence,

$$\tau_f = \gamma ((P_r/C) x s)^{2/3} \dots \dots \dots [12]$$

where  $C$  is the Chezy discharge coefficient ( $C = (8g/f_t)^{1/2}$ ).

Thus the normalized shear stress acting on the soil,  $\tau^*$  (where  $\tau^* = \tau_f/\tau_{fe}$ ), using equations [11] and [12] and assuming that  $\gamma$ ,  $P_r$ , and  $C$  are constant on the hillslope, is

$$\tau^* = (a x^{*2} + b x^*)^{2/3} \dots \dots \dots [13]$$

Sediment load normalized to transport capacity at the end of the uniform slope is

$$G^* = G / T_{ce} \dots \dots \dots [14]$$

Transport capacity normalized to transport capacity at the end of the uniform slope is

$$T_c^* = T_c / T_{ce} \dots \dots \dots [15]$$

Since  $T_{ce}$  is equal to  $k_{t1} \tau_{fe}^{3/2}$ , using equations [10] and [13]

$$T_c^* = k_{tr} \tau^{*3/2} = k_{tr} (a x^{*2} + b x^*) \dots \dots \dots [16]$$

where  $k_{tr}$  is the ratio of  $k_t$  (from equation [10]), as calibrated by Finkner et al. (1989), and  $k_{t1}$  is the value of the transport coefficient for the uniform representative profile.

The model has four erosion parameters, all nondimensional; one for interrill erosion, two for rill erosion, and one for deposition.

#### Rill Detachment Parameters

The parameters for rill erosion are  $\eta$  and  $\tau_{cn}$  given by

$$\eta = L K_r K_{rc} K_{rbr} \tau_{fe} / T_{ce} \dots \dots \dots [17]$$

and

$$\tau_{cn} = \tau_c \tau_{cc} / \tau_{fe} \dots \dots \dots [18]$$

In these equations  $K_r$  and  $\tau_c$  are the baseline rill erodibility and critical hydraulic shear of the soil as determined under standard conditions as defined by Laflen et al. (1987). Standard conditions for cropland are for unconsolidated bare soil immediately after tillage. Some relationships for  $K_r$  and  $\tau_c$  as a function of soil properties were given by Elliot et al. (1988). The parameters  $K_{rc}$  and  $\tau_{cc}$  (non-dimensional) are adjustments to erodibility and critical shear to account for soil consolidation with time after tillage, and also for freeze-thaw effects if present. Methods for calculating the consolidation parameters,  $K_{rc}$  and  $\tau_{cc}$ , were developed and presented by Nearing et al. (1988). The parameter  $K_{rbr}$  (non-dimensional) represents the effect of below ground residue on sediment generation. Relationships for calculating  $K_{rbr}$  were presented by Brown et al. (1989).

#### Interrill Detachment Parameter

The interrill parameter,  $\theta$ , is given by

$$\theta = L D_i / T_{ce} \dots \dots \dots [19]$$

where

$$D_i = K_i I_e^2 C_e G_e (R_s/w) \dots \dots \dots [20]$$

where

- $K_i$  = baseline interrill erodibility,
- $I_e$  = effective rainfall intensity,
- $C_e$  = the effect of canopy on interrill erosion,
- $G_e$  = the effect of ground cover on interrill erosion,
- $R_s$  = the spacing of rills,
- $w$  = the computed rill width (equation [7]).

Relationships between baseline interrill erodibility parameters and soil properties were presented by Elliott et al. (1988). The canopy effect is estimated by

$$C_e = 1 - F_c e^{-0.34H_c} \dots \dots \dots [21]$$

where  $F_c$  is the fraction of the soil protected by canopy cover, and  $H_c$  equals (m) is effective canopy height (Laflen et al., 1985).

The equation for the ground cover effect on interrill sediment delivery is

$$G_e = e^{-2.5 g_i} \dots \dots \dots [22]$$

where  $g_i$  is the fraction of interrill surface covered by residue.

#### Deposition Parameter

The nondimensional deposition parameter,  $\phi$ , is given by

$$\phi = V_f/P_r \dots \dots \dots [23]$$

Fall velocity is computed from an effective diameter and specific gravity of the sediment at the point of detachment using standard drag relationships. The equations derived by Foster et al. (1985) are used to compute the diameter, specific gravity, and fractions of the particle classes primary clay, silt and sand, and large and small aggregates as a function of primary sand, silt, and clay fractions and organic matter content of the surface soil horizon. The effective diameter is computed from the smallest three size classes

$$d_e = \exp\left[\sum_{i=1}^3 \log(d_i)/3\right] \dots \dots \dots [24]$$

where  $d_e$  is the effective particle diameter and  $d_i$  is the diameter of the particle class.

Effective specific gravity is calculated similarly. Fall velocity is computed for a particle class having the effective diameter and effective specific gravity assuming spherical particles and standard drag relationships.

#### Normalized Erosion Equations

The model solves the normalized sediment continuity equations. For the case of detachment the normalized equation is

$$dG^*/dx^* = \eta (\tau^* - \tau_{cn}^*)(1 - (G^*/T_c^*)) + \theta \dots \dots \dots [25]$$

where  $\eta$ ,  $\tau_{cn}$ , and  $\theta$  are the normalized detachment parameters given by equations [17], [18], and [19], and  $G^*$ ,  $T_c^*$ , and  $\tau^*$  are the normalized functions of  $x^*$  given by equations [13], [14], and [16].

Equation [25] is solved using a Runge-Kutta numerical method. The normalized deposition equation is

$$dG^*/dx^* = (\phi/x^*)(T_c^* - G^*) + \theta \dots \dots \dots [26]$$

where  $\phi$  and  $\theta$  are the normalized erosion parameters, and  $G^*$  and  $T_c^*$  are functions of  $x^*$  presented in the above section. Equation [26], with substitutions for the normalized terms, has a closed-form solution.

#### Sediment Yield

The solution of the normalized equations gives  $G^*$  as a function of  $x^*$  for each of 100 increments down the hillslope profile.  $G^*$  is converted to actual load on a per

unit width basis by the formula

$$G = G^* T_{ce} (w/R_s) \dots\dots\dots [27]$$

where G is in terms of kg/s/unit width.

Total load for the entire storm event is obtained by multiplying the load per unit time by the effective storm runoff duration,  $t_r$ . Detachment in each segment is computed from the difference in load in the segment to that in the previous segment. Average soil loss for the profile (kg/m<sup>2</sup>) is obtained from the total load per unit width for the entire storm divided by the slope length.

### DOWNSLOPE VARIABILITY

The WEPP erosion model calculates soil loss for cases involving downslope variability such as surface roughness, cover and canopy differences, soil type, and surface runoff rates. The model does this by dividing the hillslope into homogeneous strips and treating each strip as an independent hillslope with added inflow of water and sediment equal to that coming from the upslope strip. The strips may have complex topography, but within each strip all other properties are considered homogenous.

Finkner et al. (1989) presented the method for calculating non-dimensional shear stress and transport capacity for the case of added inflow of water onto a strip. Non-dimensional shear stress becomes

$$\tau^* = (A x^{*2} + B x^* + C)^{2/3} \dots\dots\dots [28]$$

where

$$A = a / (q_o^* + 1) \dots\dots\dots [29]$$

$$B = (a q_o^* + b) / (q_o^* + 1) \dots\dots\dots [30]$$

and

$$C = b q_o^* / (q_o^* + 1) \dots\dots\dots [31]$$

In the above equations,  $q_o^*$  is non-dimensional influx of water onto the strip given by

$$q_o^* = q_o / P_r L \dots\dots\dots [32]$$

where  $q_o$  is the inflow of water at the top of the strip. Non-dimensional transport capacity for the case of added inflow of water becomes

$$T_c^* = k_{tr} (A x^{*2} + B x^* + C) \dots\dots\dots [33]$$

Solutions of the detachment and deposition equations for the case of strips remain similar to those for the case of no inflow except that the boundary conditions for inflow of sediment change to account for sediment influx at the top of the strip. The form of the deposition equation and its analytic solution also changes slightly. The demoninator of the first term on the right side of equation [26] becomes  $x^* + q_o^*$ . Calculations of water and sediment from the strip act as boundary conditions for the next strip downslope.

### RESULTS

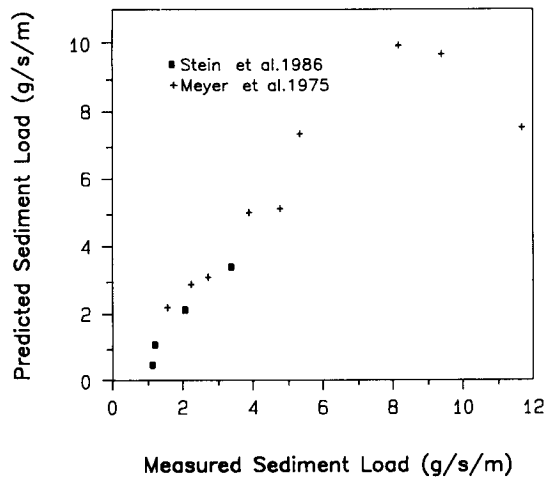
The model was tested on eight sets of rainfall simulation data; four from Laflen et al. (1987), one from Meyer et al. (1975a), one from Stein et al. (1986), one from Meyer and Harmon (1985), and one from Dedecek (1984). All of these data sets included added inflow onto the upper end of the plots so that a range of hydraulic shear stresses were applied to the soil. The purpose of comparing data to model predictions was to test how well the model could compute variations in sediment load due to variations in discharge, slope gradient, and residue given reasonable parameter values for soil erodibility.

The data sets from Laflen et al. (1987), Meyer et al. (1975a), and Stein et al. (1986) were for bare soil conditions in preformed furrows at essentially constant slope gradient. Inflow was added incrementally to the upper end of each furrow so that the furrows were subjected to a range of discharge levels. Rill erodibility parameters were obtained using the optimization technique described by Nearing et al. (1989). For the data set of Laflen et al. (1987), interrill erodibility values were also estimated from the optimization procedure. These results (Fig. 1) indicate how well the model estimates soil loss from furrows as a function of flow discharge for several data sets. The units in these figures are in terms of mass per unit time per unit width of plot, i.e., they are in terms of sediment load on a unit hillslope width basis.

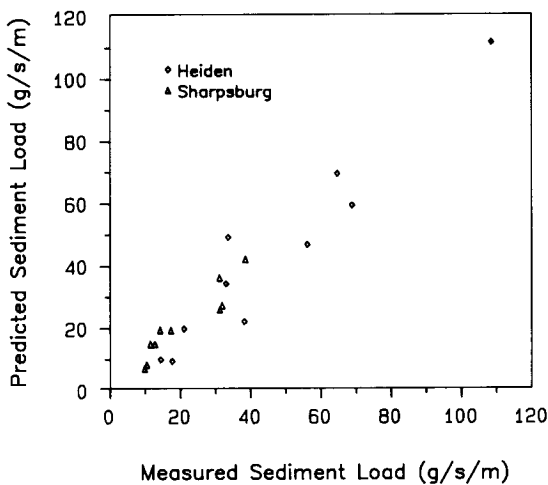
Meyer and Harmon (1985) studied the effects of slope gradient, discharge, and rainfall intensity on soil loss from furrows under bare soil conditions. Slope gradient ranged from 0.5% to 6.5%, rainfall intensities were 26 mm/h, 70 mm/h, and 108 mm/h, and three levels of added inflow to the upper end of the furrows were used. Interrill erodibility was estimated from the reported sideslope sediment delivery data, and rill erodibility was estimated using the optimization technique on the rills with 5.0% and 6.5% slopes. Figure 2 shows measured vs. predicted sediment loads for the very wet run data with all slopes, inflows, and intensities represented.

Meyer and Harmon (1985) interpreted their data for soil loss vs. slope gradient in terms of erosion processes. They found that soil loss increased substantially when slope increased from 0.5% to 2%, but leveled off between 2% and 5%, and increased again at 6.5% slope. The soil loss at 2%, 3.5%, and 5% was essentially equal to that expected from interrill sideslope erosion as estimated from the interrill data. Thus they concluded that at 2%, 3.5%, and 5% slope (for their conditions) transport capacity in the rills was sufficient to carry all interrill sediment out of the furrow, but shear stress was not great enough to appreciably scour the furrow channel. At 0.5% slope, the transport capacity of the rill was not great enough to carry all the interrill sediment so that some of the sediment was deposited in the rills. At 6.5% slope, the shear stress in the rills was great enough to cause scour, or rill detachment, in the furrow.

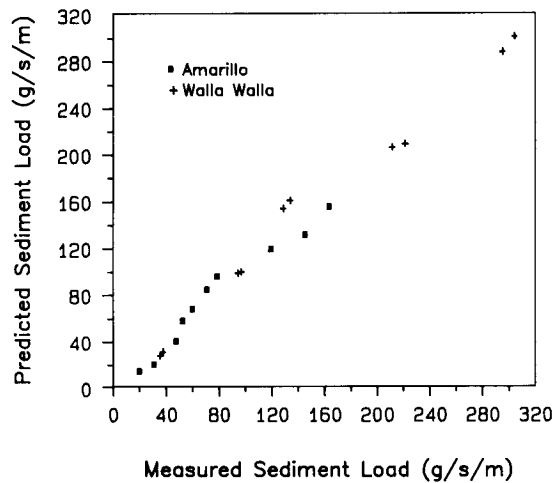
Figure 3 shows the measured and predicted values of sediment load vs. slope gradient for the 70 mm/h and 108 mm/h rainfall intensity data. The values of load at 0.5% slope reflect deposition of interrill sediment in the rills, the values of load at 2%, 3.5%, and 5% slope reflect sideslope soil loss with negligible rill detachment, and the values of load at 6.5% slope reflect both rill and



(a)



(b)



(c)

Fig. 1—Measured vs. predicted sediment loads for the (a) Stein et al. (1986) and Meyer et al. (1975) data, (b) Laflen et al. (1987) data for Heiden and Sharpsburg soils, and (c) Laflen et al. (1987) data for Amarillo and Walla Walla soils.

interrill erosion. These results indicate that the erosion model can effectively represent major erosion and sedimentation mechanisms in rill and interrill areas as represented by the data set of Meyer and Harmon (1985).

Dedecek (1984) studied the effect of surface and buried residue on soil loss from 10.7 m by 3.0 m plots. Rainfall intensity was 60 mm/h and four levels of extra inflow of clear water were added incrementally to the

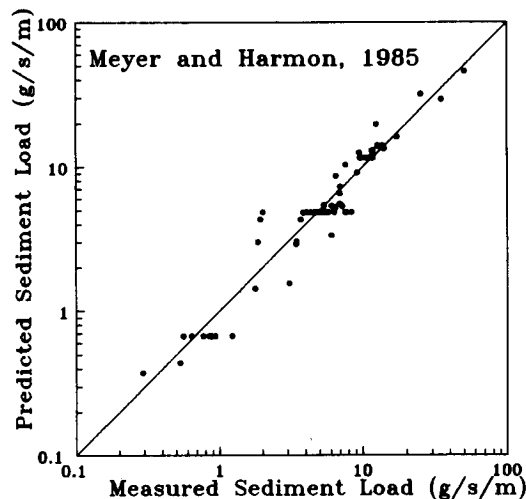
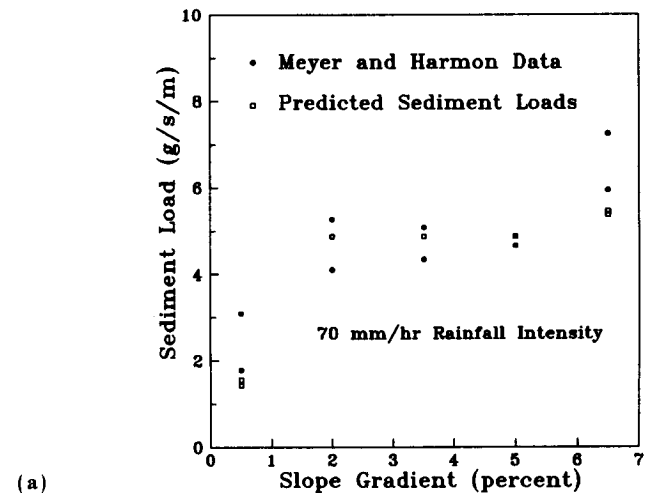
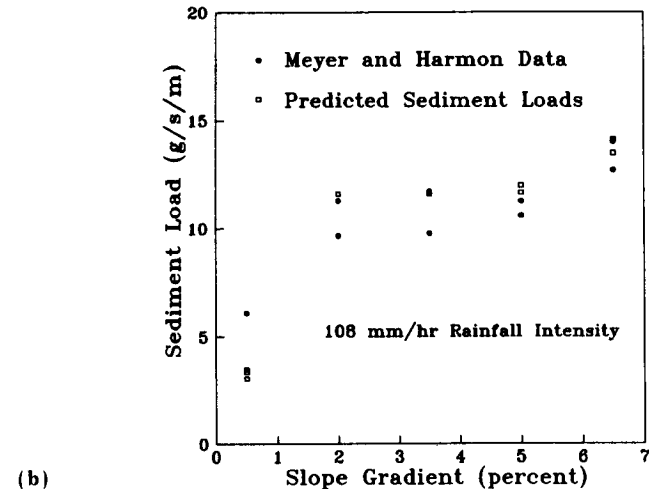


Fig. 2—Measured vs. predicted sediment loads for the Meyer and Harmon (1985) data.

upper ends of the plots. Wheat residue was used, with surface residue ranging from 0% to 48% cover and buried residue ranging from 0 t/ha to 4 t/ha. Erodibility parameters were estimated using the optimization procedure of Nearing et al. (1989) on the plots with no



(a)



(b)

Fig. 3—Measured and predicted sediment load vs. slope gradient for the Meyer and Harmon (1975) data for the cases of no added inflow and rainfall intensities of (a) 70 mm/h and (b) 108 mm/h.

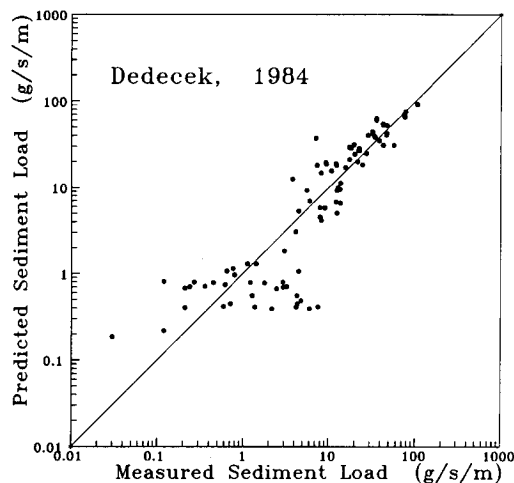


Fig. 4—Measured vs. predicted sediment loads for the Dedecek (1984) data for varying combinations of surface residue and buried residue amounts.

residue. Figure 4 shows the results of measured vs. predicted sediment loads. Results for high discharges, which represent by an order of magnitude the greatest amount of soil loss, indicate that the model satisfactorily represents the effects of surface and buried residue on soil loss.

### SUMMARY

The WEPP erosion model uses a steady state sediment continuity equation as the basis for computing net erosion detachment and deposition. Like other recent erosion models, such as the one used in CREAMS (Foster et al., 1981), the WEPP erosion model calculates erosion from rill and interrill areas and uses the concept that detachment and deposition rates in rills are a function of the portion of the transport capacity which is filled by sediment. Unlike other recent models, the WEPP erosion model partitions runoff between rill and interrill areas and calculates shear stresses based on rill flow and rill hydraulics rather than sheetflow (Page, 1988).

The model presented here does not rely upon USLE relationships for parameter estimation. Erodibility parameters can be based on the extensive field studies of Laflen et al. (1987) and Simanton et al. (1987) which were specifically designed and interpreted for the erosion model. Temporal variations of erodibility are based on the consolidation model of Nearing et al. (1988). Adjustments due to cropping management effects are directly represented in the model in terms of plant canopy, surface cover, and buried residue effects on soil detachment and transport. These adjustments are made possible with the plant growth and residue decomposition routines in the WEPP model. Finally, because the WEPP erosion routines make use of daily water balance and infiltration routines which are spatially varied, the model can calculate erosion for th case of non-uniform hydrology on hillslopes.

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