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The Water Erosion Prediction Project: Model Overview

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A new generation of water erosion prediction technology is being developed by the USDA Water Erosion Prediction Project (WEPP). The WEPP models are a new erosion prediction technology based on fundamentals of stochastic weather generation, infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics. The hillslope or representative profile version of the model discussed herein provides major advantages over existing erosion prediction technology including capabilities for estimating spatial and temporal distributions of soil loss. The new technology is expected to replace the Universal Soil Loss Equation as the primary erosion prediction tool used by action agencies. The model user requirements, model structure, and experimental program for WEPP are summarized.

Introduction

Erosion equations currently used to estimate or predict soil erosion by water have been of significant benefit in developing and evaluating soil conservation systems for the last several decades (i.e. see Wischmeier & Smith 1978 and Foster et al. 1981). As useful as the current technology is, it does have its

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limitations due to the lack of process-based equations and validation data (i.e. see ASCE 1982 and SRM 1984).

Recently, there have been increased efforts to develop more fundamentally-based or process-based erosion prediction technology. Concurrent technological advances in hydrology, soil science, erosion mechanics, and microcomputers have provided the necessary basis for development of process-based erosion prediction models.

In 1985 the U. S. Department of Agriculture (USDA) initiated a national project called the USDA Water Erosion Prediction Project (WEPP) to develop a new generation water erosion prediction technology. To establish essential communication and cooperation among the scientists and user agency representatives in WEPP, a set of User Requirements (Foster 1987) were published. These User Requirements describe in detail the product of the Project and how it is to function. They also provide a guide or blueprint for model development and provide the responsible officials with a means of judging performance of the final product--a suite of computer programs to predict soil erosion by water. Lane et al. (1988b) describe the background and scope of the Project and outline specific equations and model formulations used in WEPP.

Scope and Applications

Expected users of the new technology include current users of the Universal Soil Loss Equation (USLE), and anticipated uses include conservation planning, project planning, resource inventory and assessment, and specialized erosion prediction and modeling.

The WEPP water erosion prediction technology is to apply to field-sized areas with the representative profile version restricted to hillslopes and fields without channels (the watershed and grid versions described in the User Requirements will deal with erosion on watershed scales). The length of the representative profile or hillslope where WEPP can be appropriately applied depends upon the topography and land use controlling stream channel density as well as upon the required accuracy of the erosion predictions.

The WEPP hillslope procedures compute sheet and rill erosion associated with overland flow and sprinkler irrigation but do not consider classical gully erosion. The technology is applicable on croplands, rangelands, and disturbed forest areas. The procedures are limited to areas where the hydrology is dominated by overland flow and surface runoff and should not be applied where partial area response hydrology and subsurface flow dominate.

The new erosion prediction technology is being developed for use by action agencies responsible for erosion prediction and control. Therefore, the technology is applicable to a broad range of conditions, is designed to be easy to use and explain, and is being validated for the intended applications. The WEPP technology is designed to be operational on personal computers and operate quickly so that several management/land use alternatives can be evaluated in a rather short period of time.

Basic Concepts

The basic concepts guiding the development of the WEPP hillslope model are that soil loss or sediment yield at the bottom of a slope is determined by processes of rainfall and runoff erosivity, and by sediment detachment, transport, and deposition in overland flow. Overland flow processes are conceptualized as a mixture of broad sheet flow (interrill flow) and concentrated flow (rill flow). Runoff routing down the hillslope is represented by the kinematic wave equations for broad sheet flow to determine the peak flow rate. Discharge at the peak flow rate is then partitioned into interrill flow and rill flow dependent upon the mean number of rills per unit area. The interrill and rill flows are then used to calculate sediment detachment, transport, and deposition, and thus sediment yield, at all points along the hillslope.

Model Structure

The WEPP model is designed on the basis of fundamental processes to describe erosion in overland flow. The model includes components for climate, snow accumulation and melt, infiltration, runoff, water balance, plant growth, tillage and residue decomposition, soil disturbance and consolidation, overland flow hydraulics, and erosion. These components have been developed and assembled in the hillslope model and are currently being validated and documented in the Model Documentation (Lane & Nearing 1989) and elsewhere.

The climate component is a weather generation program and a storm disaggregation procedure. The weather generator provides daily precipitation, maximum and minimum temperature, solar radiation, wind run, and relative humidity. The rainfall events are described by a storm depth, a storm duration less than 24 h, a relative time during the storm to peak rainfall intensity, and peak rainfall intensity. A double exponential function uses these storm data to disaggregate the storm rainfall into time-rainfall intensity data as required for the infiltration component. The snow/frost model routines accumulate and melt the pack to provide input to the infiltration component.

The infiltration component uses the Green-Ampt infiltration equation and its solution for unsteady rainfall (Chu 1978) to partition the rainfall into that entering the soil profile and that available for runoff. Infiltration parameters are obtained from soil properties (Rawls & Brakensiek 1983) and modified for land use and management by the soils component of the model. Runoff routing in overland flow is based on the kinematic wave equations and their analytic solution (Lane et al. 1988a) using hydraulic resistance coefficients reflecting surface conditions and management practices (Engman 1986; Gilley et al. 1987).

The water balance component is based on that developed by Williams et al. (1985) and provides estimates of soil moisture in the profile for the infiltration, plant growth, and residue decomposition calculations. The plant growth component computes above ground biomass for water balance calculations and to provide canopy and ground cover estimates for the erosion component and below-ground biomass for the root distribution and soil erodibility calculations.

The erosion component represents interrill sediment detachment and transport and rill detachment, transport, and deposition. Calculations are by five or more sediment size fractions similar to the CREAMS model (Knisel 1980) and use a modification of the Yalin equation (Foster 1982) to compute sediment transport capacity. Overland flow is partitioned into interrill flow and rill flow using the number of rills per unit area using a procedure similar to the one developed by Page (1988).

Field Experiments

A comprehensive field experimental program has been conducted to develop an initial data base on about 70 major soils in the United States. A major component of the experimental program was rainfall simulator studies on erosion plots with the Swanson rotating-boom rainfall simulator (Swanson 1965) using experimental procedures for croplands (Laflen et al. 1987) and rangelands (Simanton et al. 1986). Details on experimental site selection are given by Alberts et al. (1987) and on soil measurements and characterizations by West et al. (1987).

Briefly, the major purposes of the cropland experiments were to characterize soil properties at the experimental sites, determine soil erodibility parameters for the model, and to relate soil erodibility parameters to soil properties. The relationships between soil properties and soil erodibility could then be used in the future to extend model application beyond the initial soils data base. The rangeland experiments had the same objectives and the objective of including land use and cover-management factors in the initial data base.

Additional Information

Further information on WEPP is available from L. J. Lane, USDA-ARS, 2000 E. Allen Rd., Tucson, AZ 85719. Copies of the WEPP User Requirements and the Model Documentation are available from J. M. Laflen, USDA-ARS, National Soil Erosion Research Laboratory, Purdue University, West Lafayette, IN 47907.

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