Enhanced WEPP Model Applicability for Improved Erosion Prediction

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Abstract: Application and implementation of soil erosion prediction models is very challenging due to a variety of factors. New physical process-based models require large numbers of input parameters related to climate, soil, topography and management, so obtaining and organizing the appropriate inputs can be difficult and time-consuming. Model users are commonly expected to define "representative" hillslopes, meant to represent the topography and soil for a field or field region. However, this procedure is not always clear and different people often create different "representative" hillslope profiles, and consequently, simulate different rates of soil erosion. The Water Erosion Prediction Project (WEPP) model was developed by the United States Department of Agriculture from 1985-1995, and can be used to simulate erosion, deposition and sediment delivery from small watersheds (1 to 500 ha) and hillslope profiles in those watersheds. WEPP is a process-based model intended to ultimately replace soil loss predictions based upon the Universal Soil Loss Equation (USLE). One reason for the relatively slow rate of adoption of WEPP by some action agencies within the United States has been because of difficulties associated with ease of use and model input creation. Since about 1997, major efforts in WEPP have focused on creation of user-friendly interfaces as well as procedures for automatically generating topographic inputs from digital elevation data, which might be obtained from a variety of sources. New software includes a stand-alone Windows program and an Internet Web-Browser interface. Automated techniques involve use of Geographic Information Systems and Digital Elevation Models, and can rapidly create an objective set of topographic inputs for the model, as well as organize extremely complex watershed model applications, which a user can then review and modify as appropriate. This presentation will describe the WEPP software and procedures as tools for conducting erosion model simulations on hillslope profiles and small watersheds.

Keywords: Soil erosion: Erosion prediction; Process-based model; User interfaces

1. INTRODUCTION

Soil erosion and sediment loss are becoming increasingly greater concerns in the world, due to on-site impacts in reducing soil productivity and off-site impacts of impaired water quality (Figure 1). New legislation and policies, for example related to Total Maximum Daily Load (TMDL) of pollutants in water, will likely become reliant upon computer simulation models to assess the current status of a watershed and evaluate the effects of implementation of a variety of alternative management strategies.

Generally accepted procedures for estimating soil loss on a particular field or small watershed with existing technologies can be time-consuming, expensive, and prone to user error. For example, the most widely used method to estimate sheet and rill erosion on a piece of land is through application of the Universal Soil Loss Equation (USLE) [Wischmeier and Smith, 1978] or its revision, the Revised Universal Soil Loss Equation (RUSLE) [Renard et al., 1997]. USLE technology is applied to one or more "representative" hillslope profiles that a user can estimate from field measurements or derive from topographic maps. These profiles must closely represent slope steepness and length, which are critical variables for any erosion estimation model. Also, any important differences in soil properties and management practices need to be located on the profiles.

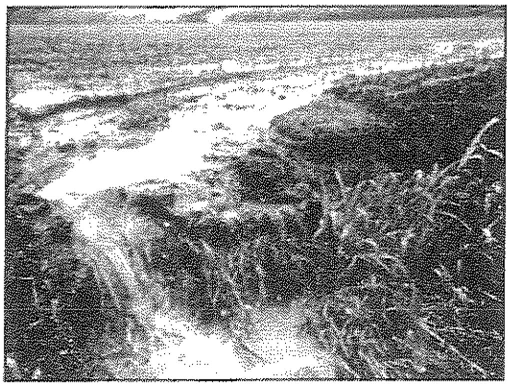

Figure 1. Soil erosion by water can have serious on-site and off-site impacts.

Unfortunately there can be a multitude of slope profiles in any given field, and determining appropriate ones to best represent soil erosion by water can be a highly subjective task with large variability in "representative" profiles derived by different observers. This can lead to substantial uncertainty in erosion modeling results and estimates of sediment delivery from fields and small watersheds.

Empirical erosion prediction technologies such as USLE and RUSLE are also limited in their usefulness for certain types of assessments. Generally, these technologies should only be applied to portions of fields undergoing net detachment, since the experimental database used to develop USLE was only on sloping field plots with no deposition. USLE and RUSLE are lumped models that predict long-term average annual soil loss at a location. They were not designed to predict sediment deposition, runoff, event soil loss, or watershed sediment yield.

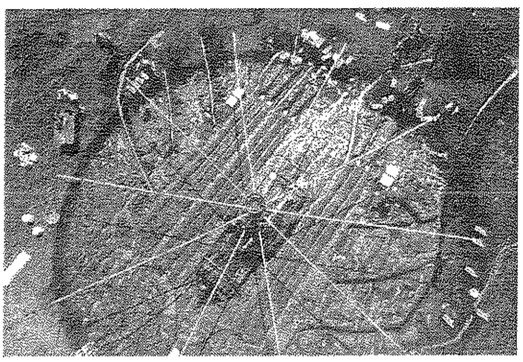

Figure 2. Field rainfall simulator experiments were used to obtain baseline erodibility parameters for WEPP [Laflen et al., 1991].

New process-based erosion prediction technologies have been developed by the USDA-Agricultural Research Service over the past 15 years. The Water Erosion Prediction Project (WEPP) model is a continuous simulation, distributed parameter, erosion model for application to hillslope profiles and small watersheds [Flanagan and Nearing, 1995]. A large series of field experiments with simulated rainfall were conducted in 1987-89 to obtain model parameters for infiltration and erodibility on cropland and rangeland (Figure 2).

WEPP operates on a daily time step and simulates processes important to erosion by water, including infiltration, runoff, detachment by raindrops and flowing water, sediment transport and sediment deposition. Runoff, erosion, and sediment yield are estimated for every precipitation event that may occur. The model was designed for application to small catchments (<500 ha) in which the dominant erosion processes are sheet, rill, and small channel detachment and deposition as a result of overland flow (from rainfall, snowmelt, or irrigation).

Defining the area of application for WEPP model inputs, however, can be more difficult than that for the USLE or RUSLE. In the most basic types of applications, "representative" slope profiles are also required to approximate the topography, soils, and management. Without digital elevation data, the user must create all of the model topographic inputs using field measurement of one or more slope profiles and/or using elevation contour maps.

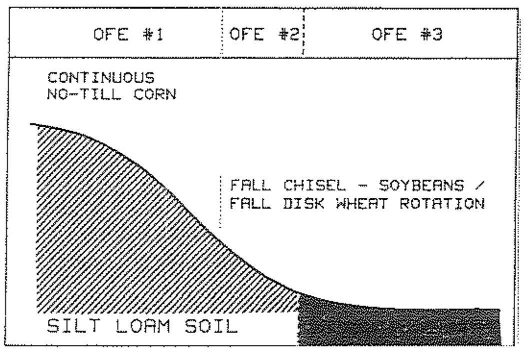

Figure 3. A WEPP profile with non-uniform slope shape, soil, and management. OFE breaks (top) indicate how model inputs must be structured.

Figure 3 shows a typical hillslope that might be simulated by WEPP. Here, an S-shaped profile shape has a flat section at the top of the hill that increases to a steep section in the center, then decreases to a low slope steepness at the bottom. WEPP treats regions of unique soils and management as individual Overland Flow Elements (OFE), on which separate water balance, plant growth, tillage, and residue levels are tracked. In the figure, three OFEs are present, the first with corn on a silt loam soil, the second with soybeans/wheat on a silt loam soil, and a third with soybeans/wheat on a clay soil. It is quite likely that sediment deposition would be predicted somewhere on OFE 3 in this example.

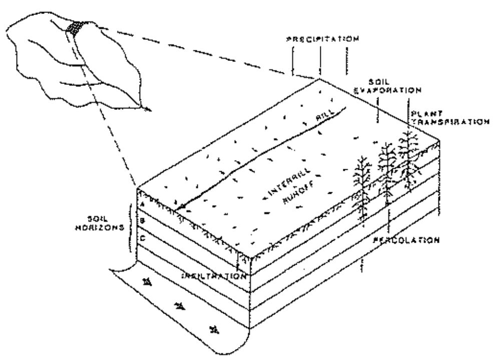

Figure 4. A hillslope showing some simulated model processes, and how a profile is located in a small watershed [Flanagan and Nearing, 1995].

Setting up WEPP model simulations of hillslope profiles is thus very similar to USLE/RUSLE applications. Watershed simulations, however, with WEPP or any other similar model can be much more difficult to adequately construct and parameterize. In addition to describing the soil, topography, and cropping/management on every hillslope (Figure 4), this same information must be provided for each channel segment, additional parameters are needed for channels and impoundments, and the entire watershed must be properly structured for correct runoff and sediment routing [Flanagan and Livingston, 1995].

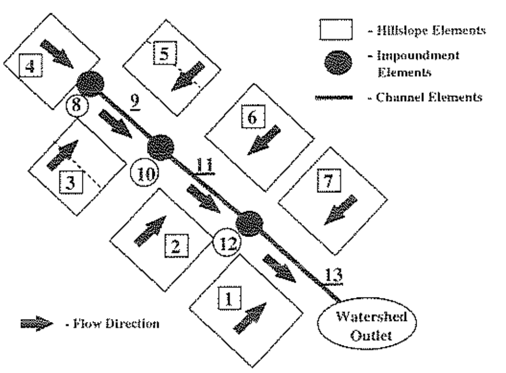

Figure 5. An example WEPP watershed that represents a small field [Flanagan et al., 2001].

For example, for a relatively small watershed, Figure 5 shows the structure required for a model simulation with seven hillslopes, three impoundments, and three channel segments. This might be used to represent a field of a few to tens of hectares, and would take considerable time for an expert WEPP model user to set up, structure properly, and parameterize. As one moves from small field areas up to larger fields and catchments, the increasing number of channels, hillslopes, and potential impoundments can make setting up a model simulation by hand extremely challenging.

2. APPLICATION OF WEPP WITH NO DIGITAL ELEVATION DATA

2. 1 Stand-alone Windows Interface

During the development of the WEPP model by ARS and other scientists, a DOS-based interface was developed in the early 1990s to allow model testing and validation [Flanagan et al., 1994]. While satisfactory for its intended purpose, this interface was text-based and not sufficiently easy-to-use for target WEPP model users (field conservation planners). Also, changes in operating systems on personal computers (PCs) conflicted with proper function of the DOS program, so alternative software to allow easier application of WEPP on modern PC platforms (Windows 95, 98, NT, etc.) was greatly needed.

An initial prototype of a WEPP Windows interface for hillslope profile simulations was developed and released in April 1998 for testing and evaluation. While all functionality was not present, the initial version did allow graphical depiction and selection of hillslope profile inputs, development of new climate, soil, slope inputs, and management inputs, and graphical depictions of soil loss and other outputs.

The interface was substantially revised, and full functionality added to it to allow WEPP model simulations of small watersheds in addition to hillslope profiles. A version was publicly released in April 2001, and is available from the National Soil Erosion Research Laboratory (NSERL) Internet site (http://topsoil.nserl.purdue.edu) or on CD-ROM.

In WEPP hillslope applications using the Windows interface, a default project is automatically loaded that contains pointers to the four basic inputs (climate, soil, slope, management) needed to run a model simulation (Figure 6). The project description is then used to depict the profile graphically, along with any breaks for different management or soils. The profile graphic contains three layers: management on top, slope in the middle, and soil on the bottom. A user may click on a region to select it, or can double click on it to edit the model input parameter values.

Hovering over sections of the graphic and using a right mouse click allows one to view/edit the parameters, copy, cut, delete, or paste region information, change the length of a region, or insert a new break point. Break points can be moved by selecting them and holding down the left mouse button. For those preferring to select and edit input parameters from picklists, that option is available on the left and bottom regions of the screen.

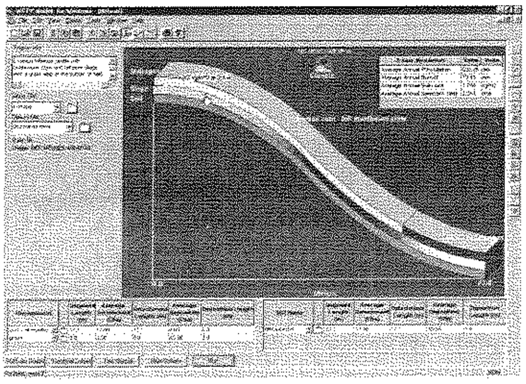

Figure 6. Screen of WEPP Windows interface showing both graphical hillslope profile depiction with multiple OFEs and picklists for selection of slope, climate, management, and soil inputs.

In Figure 6, a slope profile is shown that contains row-crop corn management under conventional fall-plow tillage on the upper portion of the profile, and a grass strip on the lower part of the profile. The WEPP model simulation is run by clicking on the "Run" button at the bottom of the screen. The interface translates the view into WEPP inputs, executes the model and interprets WEPP output files. The simulation results are displayed in text fields (top right, bottom left and right) and graphically (in the center profile layer in shades of red for soil detachment rates and shades of green for deposition rates). In the example shown, high detachment occurs on the steep portion of the slope that is tilled, while substantial deposition is predicted at the end of the slope in the grass strip. Also, the mouse cursor will display the point values for predicted soil detachment or deposition rates when it is hovered over the slope layer.

Additional detailed spatial and temporal output graphics are available, as well as a table view to allow set-up of a large number of runs at a single time and on a single screen.

Watersheds can also be simulated using the Windows interface. Background images, for example scanned from an aerial photograph or soil survey, can be imported into the interface screen view. The user can use known distances in the image to properly scale the watershed project. A watershed can be most easily built by locating the terminal channel point at the outlet, then inserting (with a right mouse click) channel, hillslope or impoundment elements in the catchments. Elements previously parameterized can be selected out of the databases and modified as necessary.

In Figure 7, an example watershed is shown, with six hillslope regions and three channel segments. A model simulation was run, and WEPP predicted the soil loss, deposition, and sediment delivery from each hillslope and channel. The interface graphically depicts the relative soil loss rates on the differently managed hillslope regions in shades of red (detachment) and green (deposition). Extensive text outputs are also available.

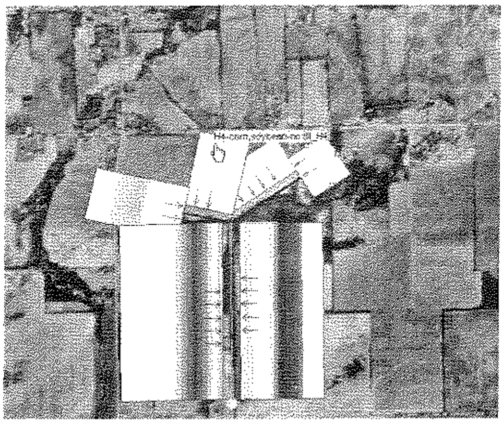

Figure 7. View from WEPP watershed simulation showing multiple hillslopes and channels, with an aerial photograph image as a background. Relative soil detachment and deposition rates are displayed.

2.2 Web-Browser Interfaces

Many users interested in soil erosion and sedimentation problems may not know the exact type of model that may best meet their specific needs and type of application. Before installing a large modeling package and delving into detailed technical and user documentation, they might want to quickly try out a simple version of the technology to see if it even has application to their problem. Also, they may not yet have the target operating platform needed for the complete model.

In these situations, Web-Browser interfaces can be very useful. As long as a user has a computer connected to the Internet, with Browser software (Internet Explorer, Netscape, etc.), they can access and run a model simulation on a server machine.

A prototype WEPP Web-Browser interface has been available for about a year and is accessible from the NSERL site for evaluation (http://octagon.nserl.purdue.edu). A user must first select their state of interest, which then loads the appropriate climate and soil databases into the picklists. Slope characteristics must be entered, and land management must be selected from a picklist as well. Summary runoff, soil loss, and sediment yield results are presented, as well as a graphical depiction of the soil loss rates on the profile (Figure 8). In the future, a larger database of typical managements by state needs to be developed and incorporated into this interface.

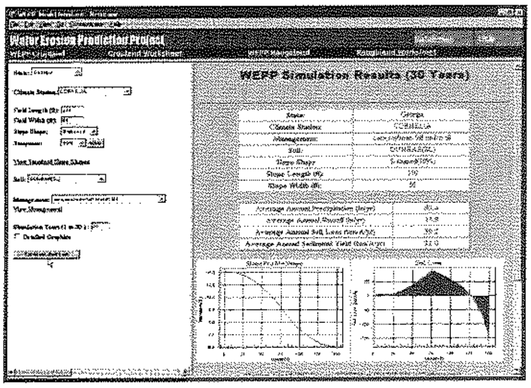

Figure 8. Screen of WEPP Web-Browser interface with input fields and picklists on left and text and graphical output on right.

Web-Browser interfaces targeted toward specific applications of the WEPP model are also planned for the future, for example, to simulate erosion at various locations under a center-pivot sprinkler irrigation system. The U.S. Forest Service has developed Web interfaces for WEPP applications on forested lands and forest road cuts (http://forest.moscowfsl.wsu.edu/fswepp).

3. APPLICATION OF WEPP WITH DIGITAL ELEVATION MODELS

Application of WEPP or other natural resource models can become increasingly complex and difficult as the size of the area to be modeled increases. The only practical way in most situations to conduct erosion and sediment yield assessments is to utilize digital terrain information, and tools that can rapidly delineate and structure model simulation runs.

At the NSERL, a geo-spatial interface for WEPP (GeoWEPP) has been developed to allow relatively easy model applications using commonly available digital elevation data or more detailed information, if available. GeoWEPP is an extension to the desktop Geographical Information System (GIS) ArcView 3.0 (developed by Environmental Systems Research Institute) that uses Digital Elevation Models (DEMs) and Digital Raster Graphs (DRGs) to derive and prepare valid WEPP model inputs to conduct hillslope and watershed soil erosion and sediment yield analyses.

GeoWEPP utilizes procedures described by Cochrane and Flanagan [1999] and Renschler et al. [2001a]. The approach is based on analyzing a DEM using the TOPAZ (TOpographic PArameteriZation) tool, developed by the USDA-Agricultural Research Service [Garbrecht and Martz, 1997]. TOPAZ delineates watershed boundaries, locates channels, delineates hillslope subcatchments, and provides information on flow paths within the hillslope regions (Figure 9). Custom software was written to develop slope input files for WEPP from the TOPAZ flow path data. The GIS is mainly used to reproject the input data from different sources and display the erosion model inputs and outputs.

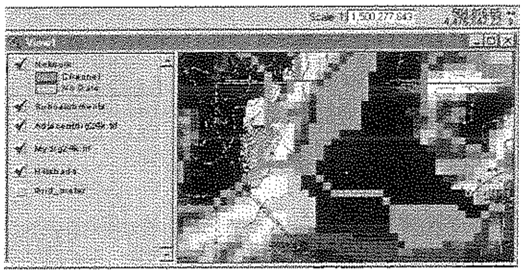

Figure 9. Screen of GeoWEPP in which a watershed and hillslopes have been automatically delineated by TOPAZ using DEM data.

Flow paths can be used as individual hillslope profiles for simulation with WEPP. Optionally, the topographic information from all profiles in hillslope subcatchments can be used to determine "representative" profiles, that are then used in a watershed simulation with WEPP (Figure 10).

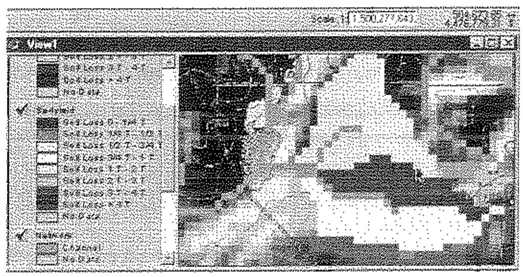

Figure 10. Screen of GeoWEPP in which WEPP simulation has been run using "representative" hillslope profiles and relative sediment yield rates from each area are depicted.

In contrast to the off-site assessment of sediment yields from representative hillslopes into the channels and to the watershed outlet, the flow path method merges the soil loss results of all possible flow paths into a channel by weighting each flow path according to its length and contributing area. The resulting GIS map shows a spatial on-site assessment of the detachment and deposition rates within the watershed (Figure 11). "Hot spots" of high erosion or deposition are then easy to identify, and targeted soil and water conservation practices (reduced tillage, buffer strips, etc.) can be evaluated and potentially recommended for use.

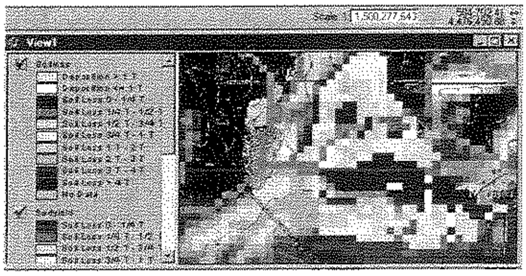

Figure 11. Screen of GeoWEPP in which WEPP model simulation has been run using all flow paths, and resulting spatial soil erosion rates displayed.

4. CONCLUSIONS

WEPP model technology developed over the past few years is providing users of erosion prediction technology with better and easier ways to estimate soil loss on profiles and small watersheds. Standard Windows, GIS, and Web-Browser programming techniques make the interfaces familiar to new users in many ways, which then makes learning simpler and training easier.

While the stand-alone Windows interface is a useful tool for applying WEPP technology, it still requires substantial user inputs and control. Techniques such as the GeoWEPP approach are what will be needed in the future, as more and better digital geospatial information becomes available at the field level. Precision farmers using Global Positioning Systems (GPS) [Renschler et al, 2001b] and construction site managers already have terrain data available that has the potential to be used for soil erosion model inputs. The vast amount of available environmental data on climate, terrain, soils and land cover/use offers great potential to quickly gather inputs for a new site of interest and simulate scenarios to assess on-site and off-site impacts of land use changes.

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