WEPP: Science, Basics, Definitions

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“The NSERL – to provide the knowledge and technology needed by land users to conserve soil and water for future generations.”
Presentation Outline

- WEPP development / background
- Science in the model
- Basics on WEPP simulations and application
- Definitions of the WEPP world
Rainfall / Runoff / Erosion Event
Sheet and Rill Detachment
Why Predict Soil Erosion?

- **Conservation Planning** – evaluate land management alternatives to reduce soil erosion to acceptable levels.
- **Resource Inventories** – estimate current and projected erosion levels and their impact on natural resource base.
- **Sediment Delivery Prediction** - Estimate sediment generation and delivery off-site, and evaluate management strategies to minimize sediment losses and impacts. (Use in other models for this as well.)
WEPP – Process-Based Technology for Runoff, Soil Erosion and Sediment Loss Assessment
WEPP Objective

The objective of the Water Erosion Prediction Project is to provide new generation erosion prediction technology for use by Action Agencies, and others involved in conservation planning and environmental assessment.
The WEPP Model

- Physical process-based
- Distributed parameter
- Continuous simulation (as well as single storm simulations)
- Implemented on personal computers
- User-friendly interfaces, and nationwide databases
WEPP Model Background

- WEPP modeling effort initiated in 1985.
- Core Team of ARS, SCS, FS, BLM scientists
- Field experiments for model parameterization in 1987-88 on cropland and rangeland soils
- FORTRAN model code mainly developed from 1985-1995
- Validated WEPP hillslope and watershed model released in 1995, with full documentation and a DOS interface
- Updated model releases every 1-2 yrs since
WEPP Field Experiments in 1987-88

33 Cropland Soils
24 Rangeland Soils
WEPP predicts soil loss and sediment delivery from hillslope profiles.
WEPP predicts erosion and sediment delivery from fields and small watersheds
WEPP Advantages

- Models the important physical processes governing erosion (climate, infiltration, runoff, ET, detachment by raindrops, detachment by flowing water, deposition, etc.).
- Simulation of nonuniform slope, soils, cropping/management.
- Large U.S. databases for climate, soils, and crops.
WEPP Advantages

- Temporal and spatial estimates of soil erosion.
- Estimates of sediment deposition and delivery from hillslope profiles.
- Estimates of detachment and deposition of sediment in ephemeral gullies and other small channels.
- Prediction of sediment deposition in impoundments.
WEPP Disadvantages

- Use currently limited to hillslope profiles and small watersheds
  - Limited to rainfall/snowmelt/irrigation water inputs that result in overland flow runoff
  - No perennial stream processes
  - No classical gully processes
- Large number of model inputs are required due to the many model components. Databases must be populated if WEPP is to be easily used by field level conservationists.
WEPP can be used to -

- Predict sheet & rill erosion, sediment deposition, and sediment delivery from hillslopes.

- Estimate erosion & deposition in channels such as ephemeral gullies and grass waterways.
WEPP can be used to -

- Determine impacts of impoundments
- Predict runoff & sediment delivery from small watersheds
Major Model Components

- Climate Simulation
- Surface & Subsurface Hydrology
- Water Balance & Percolation
- Soil Component (Tillage impacts)
- Plant Growth & Residue Decomposition
- Overland Flow Hydraulics
- Hillslope Erosion Component
- Channel Hydrology & Hydraulics
- Channel Erosion
- Surface Impoundment Element
WEPP science

- Stochastic weather generator (CLIGEN)
- Daily updating of soil, plant, residue params.
- Infiltration predicted using a Green-Ampt equation modified for unsteady rainfall.
- Runoff volume is predicted from rainfall excess adjusted for depressional storage.
- Peak runoff rates using kinematic wave eqn.
- Steady-state sediment continuity equation.
- Detachment function of rain intensity, excess flow shear stress, adj. erodibilities, crit shr.
- Modified Yalin equation for sed. trans. cap.
How WEPP simulation works:

- Every day – compute status of the soil, live biomass, and dead residue cover.
- If there is rainfall, snowmelt, or irrigation, determine if runoff occurs.
- If runoff predicted to occur, determine amount and rates, determine soil detachment, sediment transport, and any sediment deposition.
Cropland Applications

- Determine erosion and sediment yield rates based upon current land management
- Evaluate various management strategies, including various
  - Crop rotations
  - Tillage alternatives
  - Strip cropping
  - Buffers
  - Waterways
  - etc.
Rangeland Applications

- Determine impacts of present range management
- Predict effects of changing management –
  - Grazing level
  - Burning
  - Herbicides
Forest Applications

- Forest Planning
- Impacts of:
  - Timber harvesting
  - Road construction
  - Road maintenance
  - Road traffic
  - Controlled burning
  - Wildfire
- Off-site impacts
  - Stream water quality
  - Fish spawning areas
Other Model Applications

- Construction sites
- Highways (embankments, channels)
- Mines
- Landfills
- Military training areas
- Any hillslope or small watershed in which soil erosion by water is the concern, and the scale is small enough that the driving forces are raindrop impact and/or excess flow shear stress detachment by overland flow (runoff from excess rainfall, snowmelt or irrigation).
Example – WEPP Grass Buffer simulation

Cropped area in Yellow.

Detachment in RED

Grass buffer in dark Green

Deposition in light GREEN
Example – WEPP small watershed simulation
Soil detachment or deposition depicted graphically on sub-basins within a small watershed.

GeoWEPP – Geo-spatial Interface for WEPP implemented as an extension in ArcView/ArcGIS.
WEPP Web Browser Interfaces

WEPP Model Interface - Netscape

Water Erosion Prediction Project

WEPP Simulation Results (30 Years)

State: Georgia
Climate Station: CORNELIA
Field Length (ft): 150
Field Width (ft): 60
Slope Shape: S-shaped
Steepness: 10%

View Standard Slope Shapes

Soil: DUNBAR(SL)
Management: corn, soybean - fall mulch till

View Management

Simulation Years (1 to 30): 30
Detailed Graphics

Calculate Soil Loss

Average Annual Precipitation (in/yr): 61.4
Average Annual Runoff (in/yr): 13.8
Average Annual Soil Loss (ton/A/yr): 39.2
Average Annual Sediment Yield (ton/A/yr): 22.0

Slope Profile Shape

http://milford.nserl.purdue.edu
WEPP geospatial Web Watershed Results

5. WEPP Simulation Results: The WEPP simulation results are displayed as soil loss maps. The flowpath results show soil loss from all flowpath runs by cell. The hillslope results show the average soil loss of each subcatchment from a WEPP watershed simulation. (NY_templateEtopa24.html)

Layers
- DRG Images (TerraServer)
- Landuse (USGS NLCD 1992)
- Orthophotos (TerraServer)
- Roads
- Rivers
- Soils (STATSGO)
- Channel Network
- Subcatchments
- Boundary
- Soil Loss - Flowpaths
- Soil Loss - Hillslopes

Redraw Map
Full Extent

To change the landuse click on the Rerun WEPP Model to do another simulation on the same watershed.

Rerun WEPP Model

Reclassify Output Maps
Save Watershed Setup
New Watershed - Same General Area
New Watershed - Different Area

Text Summary of Simulation Results:
- Soil Deposition > 2 t/ha/year
- Soil Deposition 0 - 1 t/ha/year
- Soil Loss 10 - 1.25 t/ha/year
- Soil Loss 2.5 - 3.75 t/ha/year
- Soil Loss 1.25 - 2.5 t/ha/year
- Soil Loss 0.75 - 1 t/ha/year
- Soil Loss 0.25 - 0.75 t/ha/year
- Soil Loss 0 - 0.25 t/ha/year

http://milford.nserl.purdue.edu
Current Model Development

Testing/enhancement of WEPP science model

- Enhanced channel hydrology to allow application to larger watersheds. Cooperators at WSU and Univ. of Idaho have incorporated new channel flow routines, and a simple baseflow component.

- Utilizing results from other NSERL research into ephemeral gully formation and detachment, to improve these predictions in the model.

- Model testing using predicted changes in climate over the next century.

- Adding code to allow simulation of chemical transport (nutrients and pesticides) for water quality assessments.

- Adding code to simulate effects of changing atmospheric CO$_2$ concentrations on plant growth, to improve model’s ability to assess impacts of future climate change.
Model Development (cont.)

Enhancement/expansion of WEPP interfaces & databases

- Development of new default cropping/management inputs
  - Linkage to NRCS LMOD database
  - All crops and tillage operations in LMOD are used, and parameter values for WEPP simulations added.
  - Existing RUSLE2 in LMOD has over 26,000 rotations.
  - New WEPP sets are compared to similar RUSLE2 ones, and modified for conformity

- Development of internet-based GIS interfaces
  - Web-based hillslope and watershed interfaces
  - Web-based GIS watershed interfaces
    - Prototype on NSERL website, being tailored for NRCS use.
    - Targeted grant projects for Great Lakes Forested watersheds and for the Lake Tahoe Basin.
    - Cooperation with SWAT model developers to allow WEPP and SWAT simulations at any location in world using global geospatial climate and soils databases.
WEPP watershed online GIS interfaces

Great Lakes WEPP Watershed
Online GIS Interface

September 2011

Mapping
Projects
Help

Double-click to zoom in, and drag to pan. Hold down the shift key and drag to zoom to a particular region.

Zoom to Zip Code or City, State:

Go

Example: Pullman, WA

Start Over with New Area | Undo All Changes
Upload a DEM

- Show Legend
- Units
  - SI
  - English

Minimum Source Channel Length (m):
Critical Source Area (ha):

Build Channel Network

Statements and Disclaimers | Privacy Policy | Contact Information
Definitions of the WEPP world

- Hillslope profile
- Overland Flow Element (OFE)
- Peak runoff rate
- Effective rainfall intensity
- Interrill erodibility, rill erodibility, critical hydraulic shear stress
- Effective hydraulic conductivity
Hillslope Profiles and Overland Flow Elements (OFEs)
INPUT RAINFALL VARIABLES

- Total precipitation - rain or snow \((p)\)
- Duration of precipitation \((d)\)
  - One storm a day
- Time to peak intensity \((T_p)\)
  - Fraction of duration where peak precipitation intensity occurs
- Ratio peak intensity to average intensity \((I_p)\)
Ip = Peak intensity/avg intensity

Time to peak intensity - Tp

Time varying intensity - exponentially increases from time zero to peak, and decreases from peak to end of duration

Average rainfall intensity = Total precipitation/duration

Duration
Infiltration rate

Average rainfall intensity

Instantaneous rainfall intensity

Time varying infiltration: Green-Ampt, based on capillary potential, soil moisture deficit, and effective hydraulic conductivity.
Runoff rate = difference between rainfall intensity and infiltration rate.
Erosion and sediment transport at this peak runoff rate and over this time.
RILL & INTRERRILL EROSION
Rill Detachment = $[K_r (\tau - \tau_c)][1 - G/T_c]$

\[ \tau = \text{Hydraulic Shear} = \gamma R S \quad R = A/WP = \sim D \]

$K_r$ - Rill erodibility, $\tau_c$ - Critical hydraulic shear, $G$ - Sediment load, $T_C$ - Sediment transport capacity, $D$
RILL DETACHMENT

Hydraulic Shear

Tc

Rill Detachment

Freshly tilled

Consolidated

No Till

Kr
\[ D_i = K_i \cdot I \cdot q \cdot S_f \cdot \text{ADJ} \]

- \( D_i \) - Interrill detachment
- \( K_i \) - Interrill erodibility
- \( I \) - rainfall intensity
- \( q \) - runoff rate
- \( S_f \) - slope factor
- \( \text{ADJ} \) - adjustment factors
DEPOSITION

When sediment load \((G) > \text{transport capacity} \ (T_C)\), deposition occurs. Based on size distribution and fall velocity of sediment being transported.
Rill width - Can be set to constant (Furrow irrigation?)
Generally computed based on flow rate at lower end of OFE.

Channel width - computed based on flow rate, when depth=last tillage depth, widens till hydraulic shear=critical hydraulic shear

Last tillage depth

.
Hillslope Model Inputs

- Climate input file (daily precipitation info, temperatures, radiation, wind)
- Slope input file (slope profile description – length, width, gradients)
- Soil input file (infiltration and erodibility parameters; soil texture, O.M., etc. by layer)
- Cropping/management input file (plant, residue, tillage parameters and dates)
Watershed Model Inputs

- All hillslope model inputs for all hillslopes in the watershed
- Channel input files (channel description, geometry, roughness, etc.)
- Impoundment input files (impoundment description, parameters)
- Watershed structure file (describes all of the linkages for all channels, hillslopes, and impoundments)
WEPP Model Outputs

- **Main output** – runoff, erosion, sediment yield summaries by storm, month, year, or average annual.
- **Plot output** – plotting soil loss with distance down profile.
- **Graphics output** – large file containing 92+ daily outputs
- **Specialized text outputs** – storm output, OFE output, water, soil, crop, yield.
- **Return period summaries**
Any Questions?
For further information:

NSERL Web Site
http://topsoil.nserl.purdue.edu

And check for WEPP under the “Software” link.