WEPP Model Background, Status, and Current Projects

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"The NSERL – to provide the knowledge and technology needed by land users to conserve soil for future generations."

Presentation Outline

- **Erosion Prediction History**
- **WEPP Model Background**
- **Model Status – 2015**
- **Current Projects**
- **Summary**

Scales of interest

0.01 to 1 ha – Hillslope scale

Hillslope profiles in agricultural fields, forested areas, rangeland parcels, landfills, mines, highways, construction sites, etc.

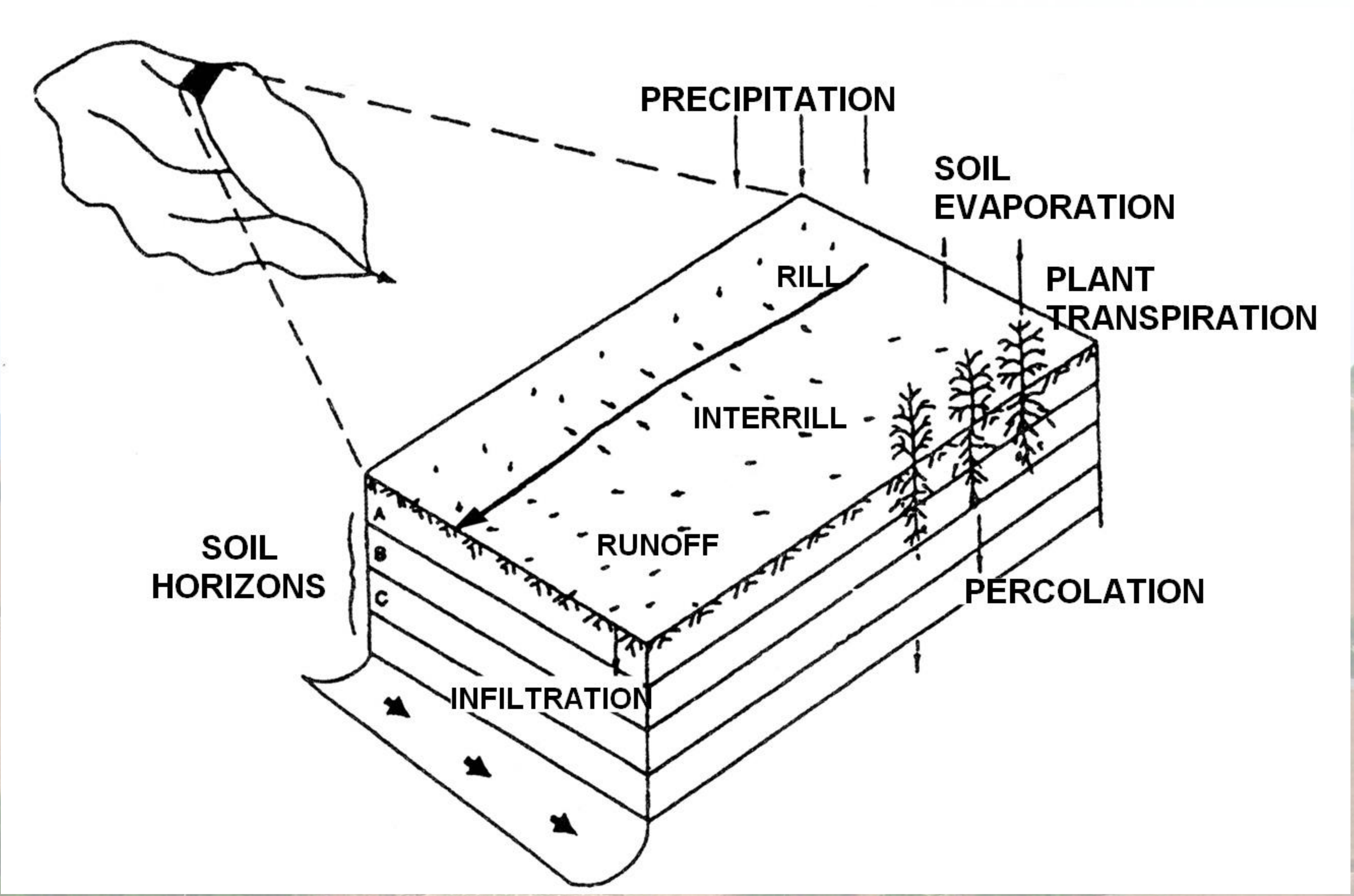
1 to 1000 ha – Field, farm scale

Small watersheds in agricultural fields, on farms, in forested catchments, construction sites, etc.

Important Processes at these Scales

- Precipitation (and weather in general) – rainfall occurrence, volume, storm duration, intensity
- Surface hydrology – infiltration, pondage, ET, runoff
- Subsurface hydrology – percolation, seepage, lateral flow
- Hillslope erosion processes – detachment by rainfall, shallow flow transport, rill detachment by flow shear stress, sediment transport, sediment deposition.
- Channel erosion processes – detachment by flow shear stress, sediment transport, downcutting to a nonerodible layer, sediment deposition.

Hillslope region from a small watershed



Erosion Prediction History

- Early tools developed in the 1940’s-1970’s were all empirically-based.
- Universal Soil Loss Equation (USLE) and revisions
- Beginning in late 1970’s, efforts began to focus on process-based modeling.
- ANSWERS and CREAMS models were first distributed parameter hillslope/watershed models with some physical processes represented. They still used USLE for sediment generation.
- In 1985, the Water Erosion Prediction Project (WEPP) was initiated by USDA, at a meeting in Lafayette, Indiana. The goal of this project was to develop next generation erosion prediction technologies, including a physical process-based soil erosion model, to ultimately replace the existing empirically-based USLE and derivatives.

The WEPP Model

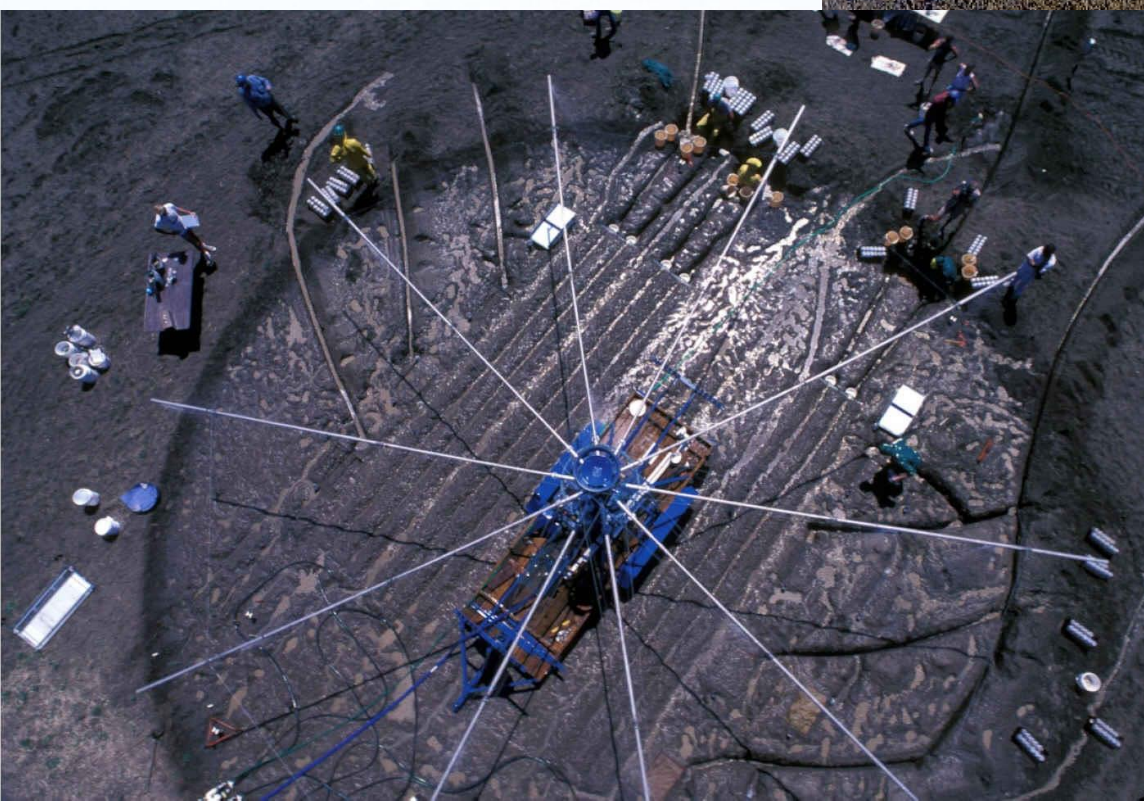
- Physical process based
- Distributed parameter
- Continuous simulation (as well as single storm simulations)
- Implemented on personal computers
- User-friendly interfaces, and nationwide databases

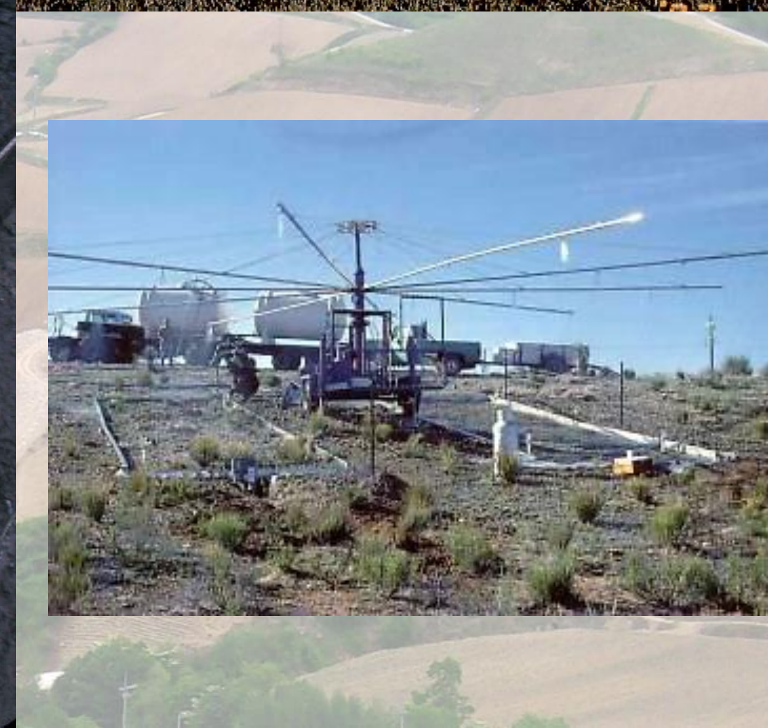
WEPP Model Background

- WEPP modeling effort initiated in 1985.
- Core Team of ARS, SCS, FS, BLM scientists formed
- 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.

WEPP Field Experiments in 1987-88

24 Rangeland Soils





WEPP Model Background (cont.)

- After FS and NRCS evaluation of WEPP and DOS-based interface, development of a Windows-based model interface begun in 1996.
- Windows interface for hillslope profiles and small watersheds released in 1999.
- Web-based interfaces developed by both the USDA-Forest Service RMRS and by ARS at the NSERL from 1999 – present.
- Geospatial interfaces to WEPP developed by ARS and SUNY-Buffalo from 1998-present.

WEPP Model Background (cont.)

- **Continual development work on WEPP model since 1995, particularly with Washington State University, Forest Service, and University of Idaho**
  - Improved representation of forested regions
  - Improved subsurface lateral flow, restrictive layers
  - Improved winter hydrology, frost/thaw, snow melt
  - Improved channel hydrology representation
- **Latest developments are geospatial, web-based watershed interfaces and applications.**

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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

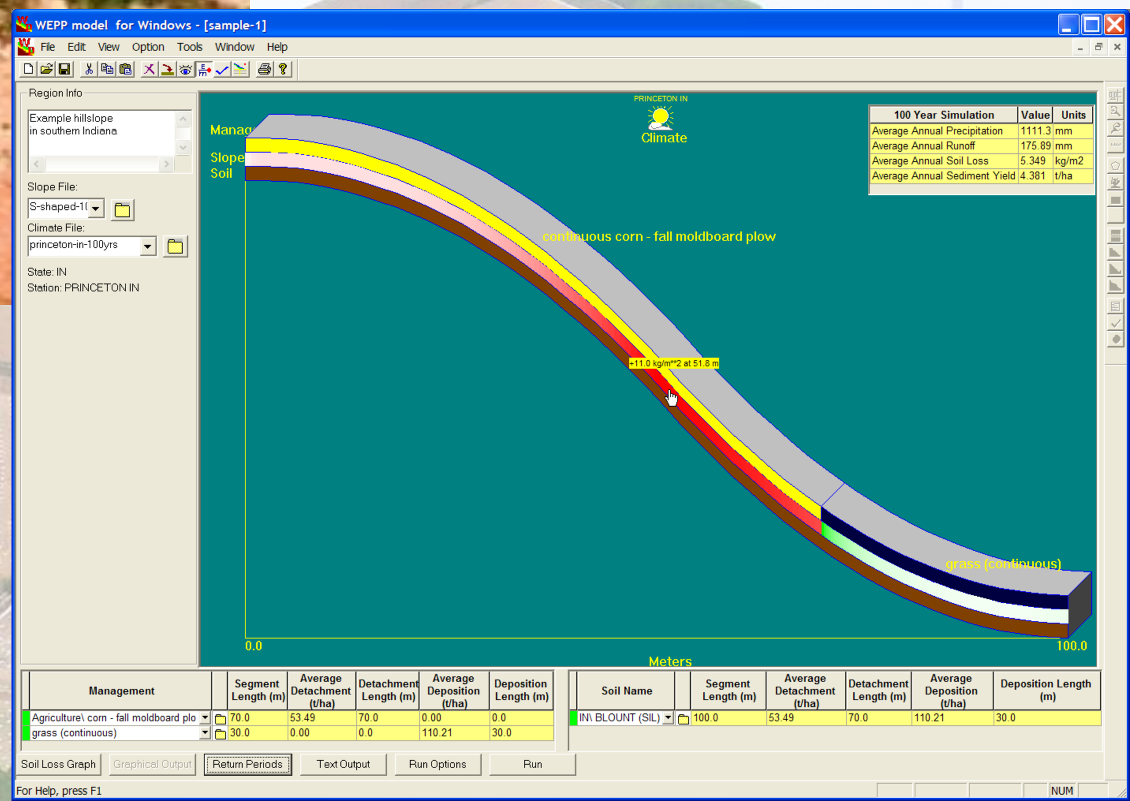
WEPP science

- Stochastic weather generator (CLIGEN)
- Daily updating of soil, plant, residue parameters
- Infiltration predicted using a Green-Ampt Mein-Larsen equation modified for unsteady rainfall.
- Runoff volume is predicted from rainfall excess adjusted for surface depressional storage.

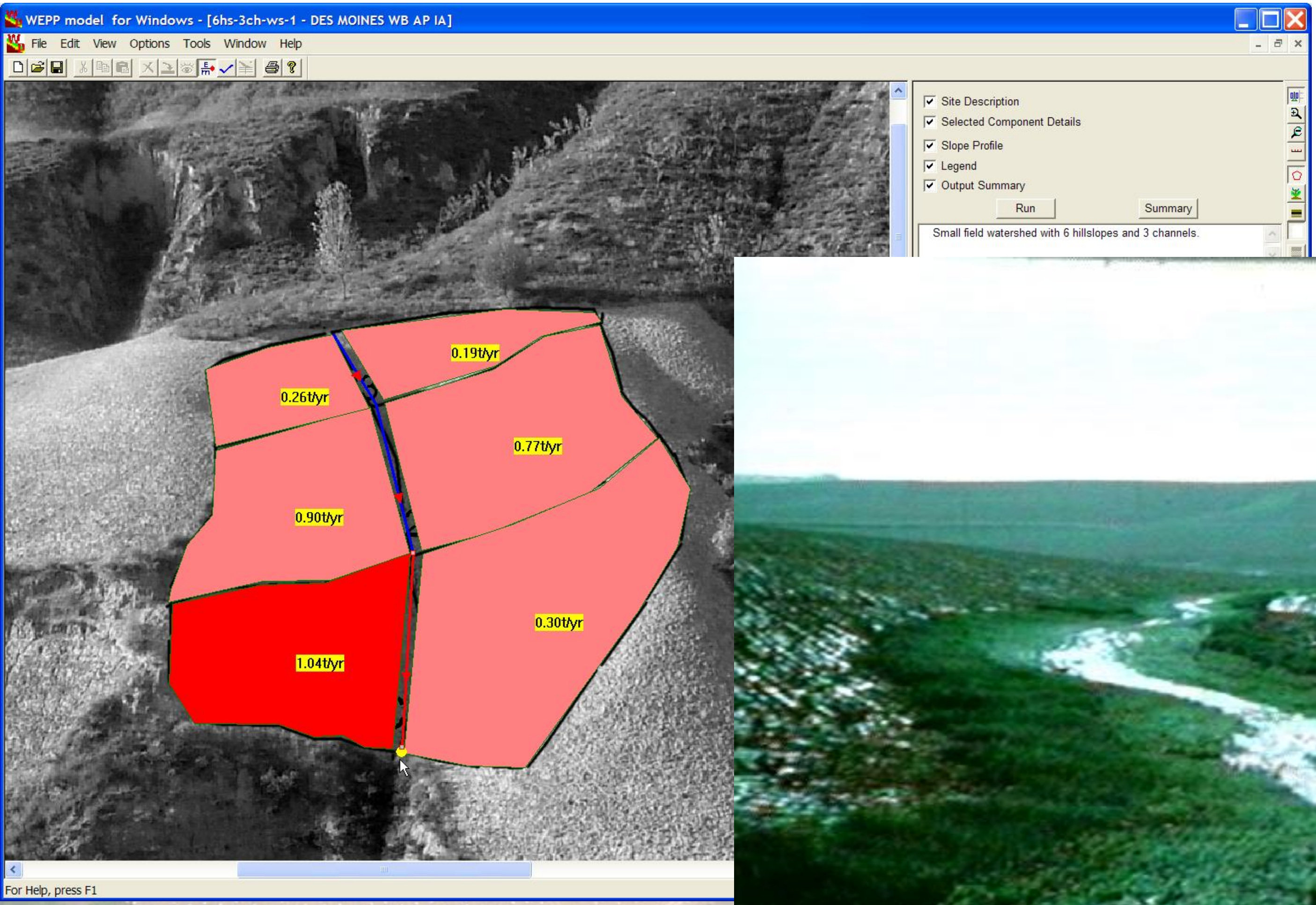
WEPP science (cont.)

- Peak runoff rates predicted using kinematic wave equation solution
- Steady-state sediment continuity equation
- Detachment function of rain intensity, excess flow shear stress, adjusted erodibilities, critical shear
- Modified Yalin equation for sediment transport capacity

WEPP predicts soil loss and sediment delivery from hillslope profiles.



WEPP predicts erosion and sediment delivery from fields and small watersheds



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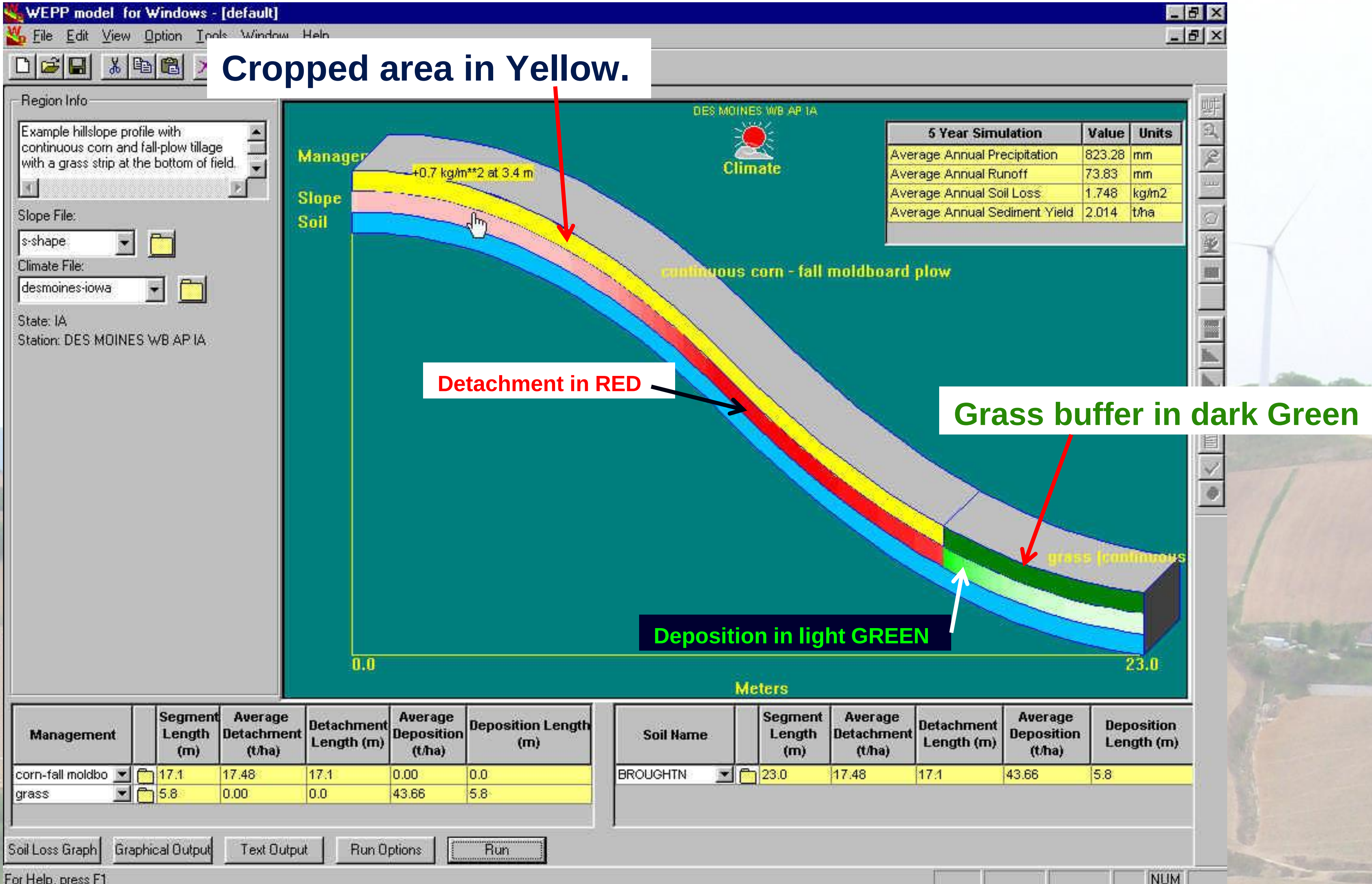
Spatially distributed parameters allow for:

- Simulation of non-uniform soils down a hillslope profile, or on different channel elements
- Simulation of non-uniform cropping and land management down a hillslope profile, or within different areas of a watershed. For example, strip-cropping or buffer strip impacts.
- Model outputs provide spatial soil loss and sediment deposition predicted, down a hillslope profile, as well as spatially within a watershed simulation.

Example – WEPP Grass Buffer simulation



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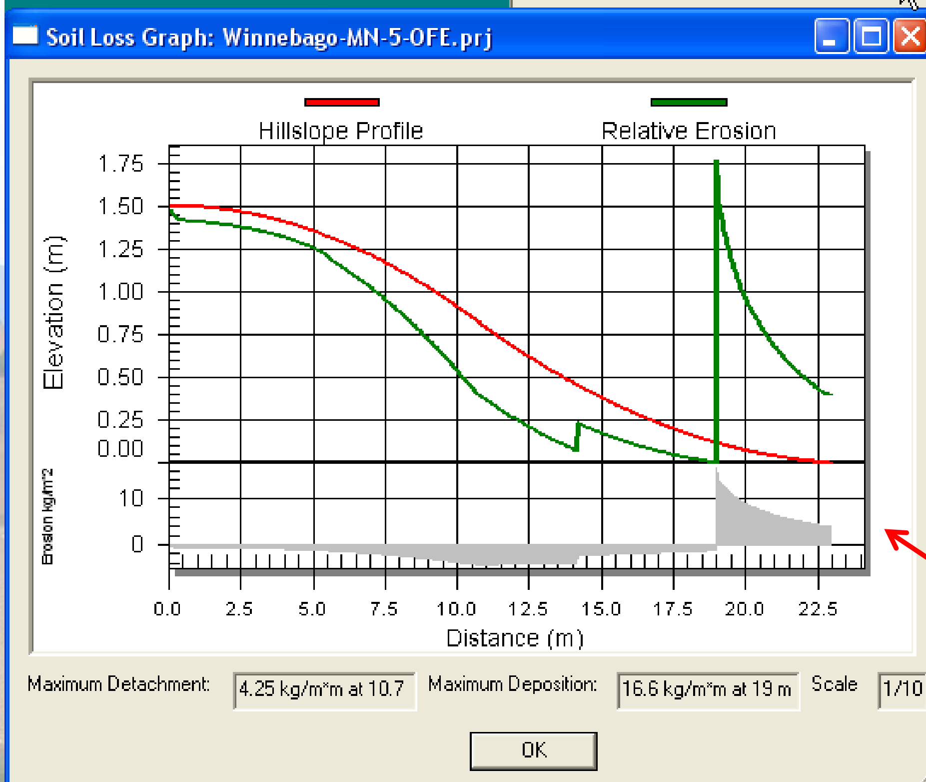
Continuous model simulations

- For long time periods, e.g. 100 years
- Allow for long-term interactions between climate, cropping / management, and soil factors
- Probability risk analyses can be conducted, and return period estimates for runoff and sediment losses can be estimated.
- Also provide a research tool to examine impacts of climate change on complex hydrologic and erosion processes.

Continuous WEPP model simulation outputs

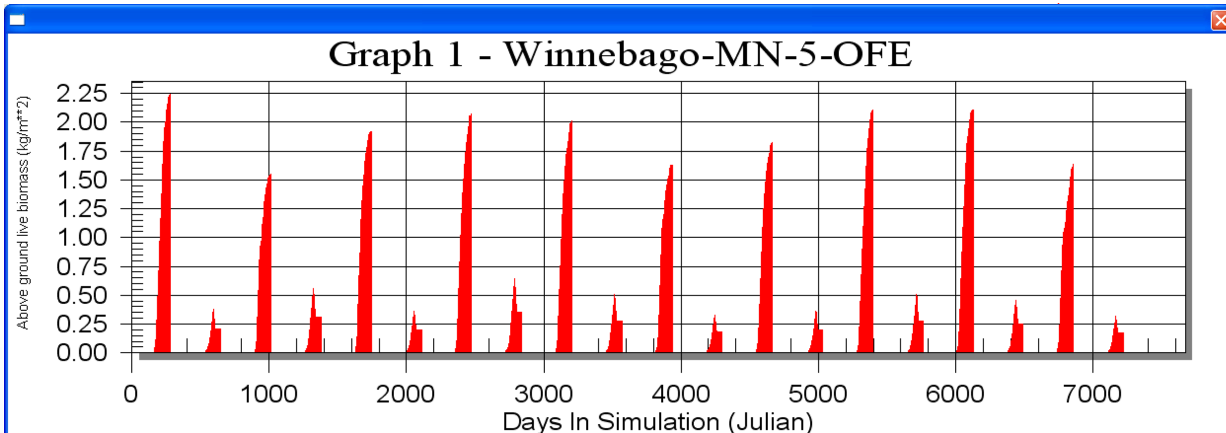
20 Year Simulation	Value	Units
Average Annual Precipitation	748.33	mm
Average Annual Runoff	137.72	mm
Average Annual Soil Loss	2.159	kg/m2
Average Annual Sediment Yield	5.070	t/ha

Average annual precipitation, runoff, soil loss, and sediment yield from the profile. Here you can see that the average annual soil loss on the eroding area of the slope was over 21 tonnes/ha, but sediment yield for the entire profile was only 5 tonnes/ha, due to the sediment deposited in the grass strip.

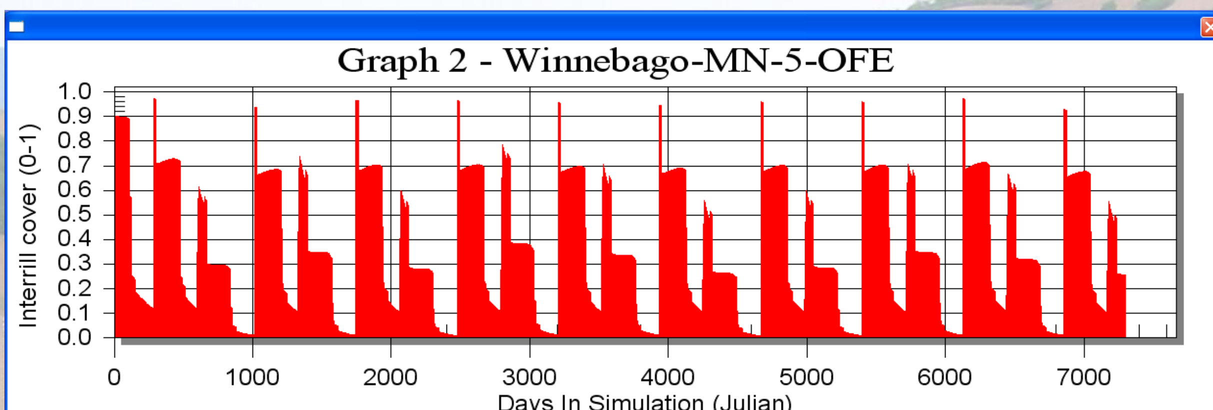


Graphical representations of spatial soil loss and deposition. Here detachment is occurring on the steep upslope cropped portion of the profile, and deposition on the concave region at the bottom that has a grass buffer strip.

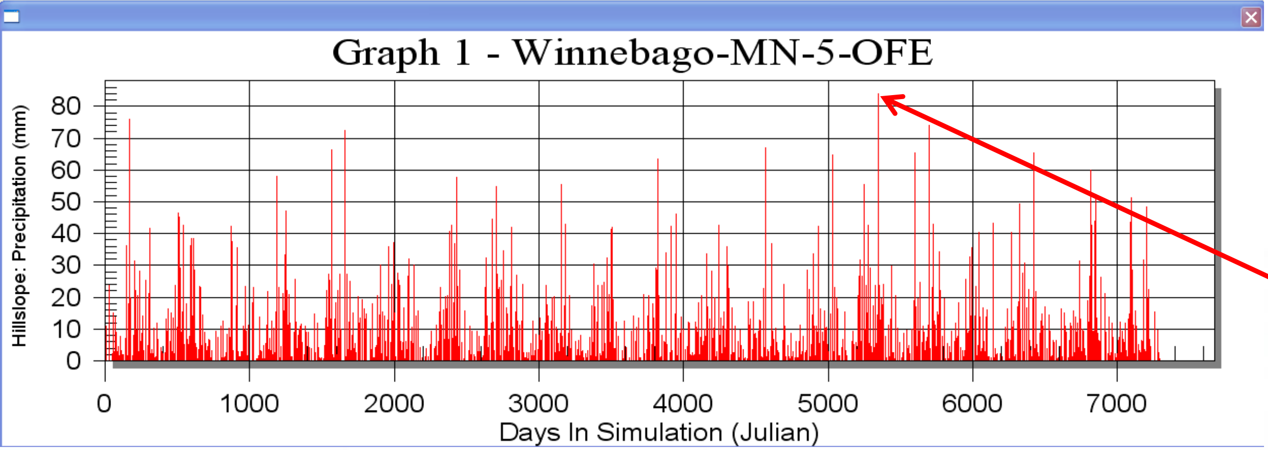
Graphical model outputs



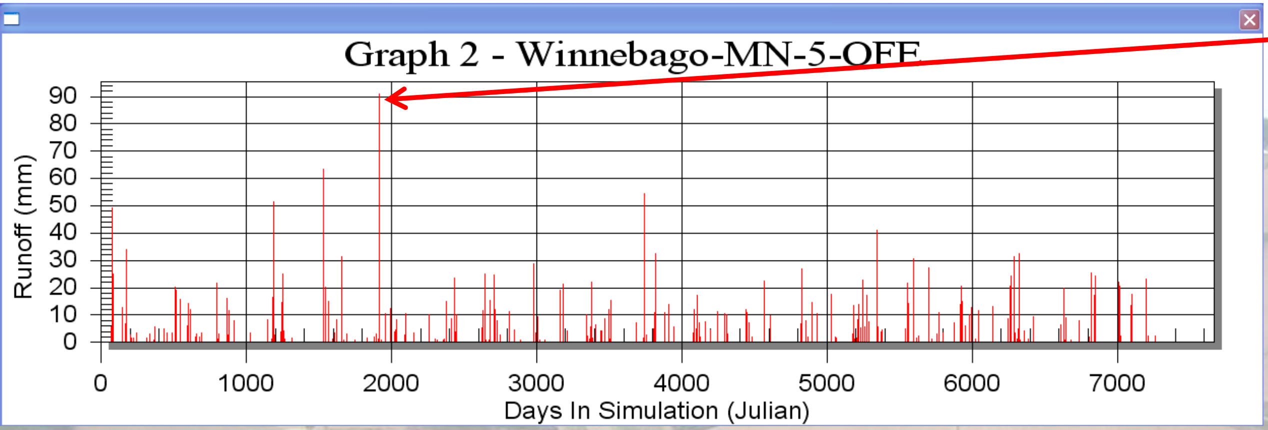
User can plot over 90 variables versus time (or each other). Here you can see above ground live biomass (kg/m^2) versus time in the simulation. Note the corn (higher) and soybean (lower) amounts of biomass. Also the variability caused by weather and soil conditions.



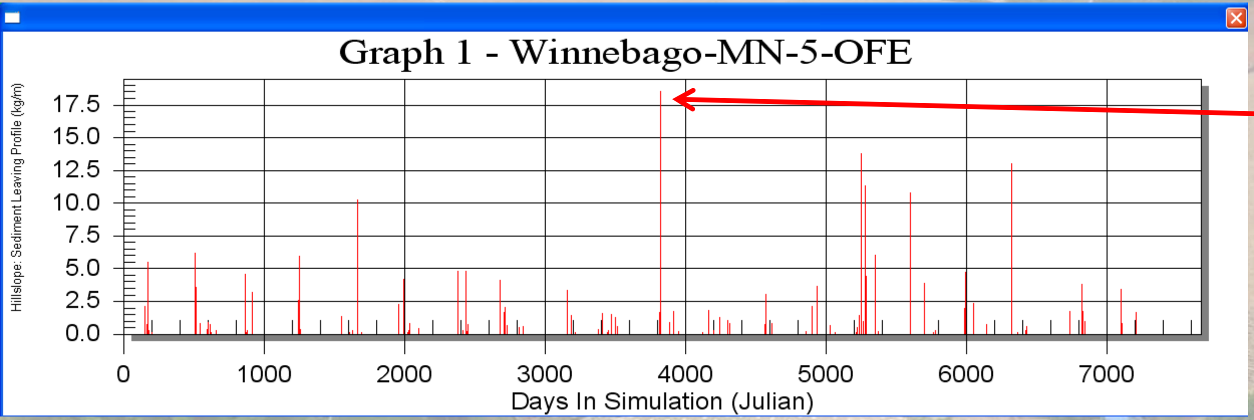
Ground cover versus time. Here you can see how residue cover on the ground changes through time. A lot of cover goes on the ground right after harvest, but then a fall chisel tillage operation occurs soon after that. Further spring tillage decreases ground cover further.



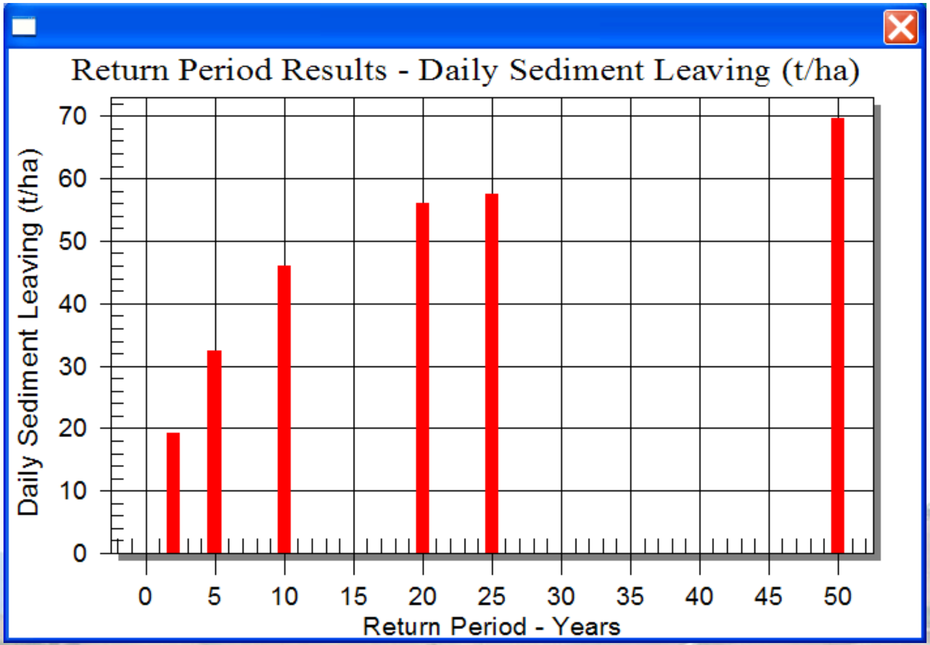
Greatest rainfall does not always produce greatest runoff!



And greatest runoff does not always produce greatest sediment loss!

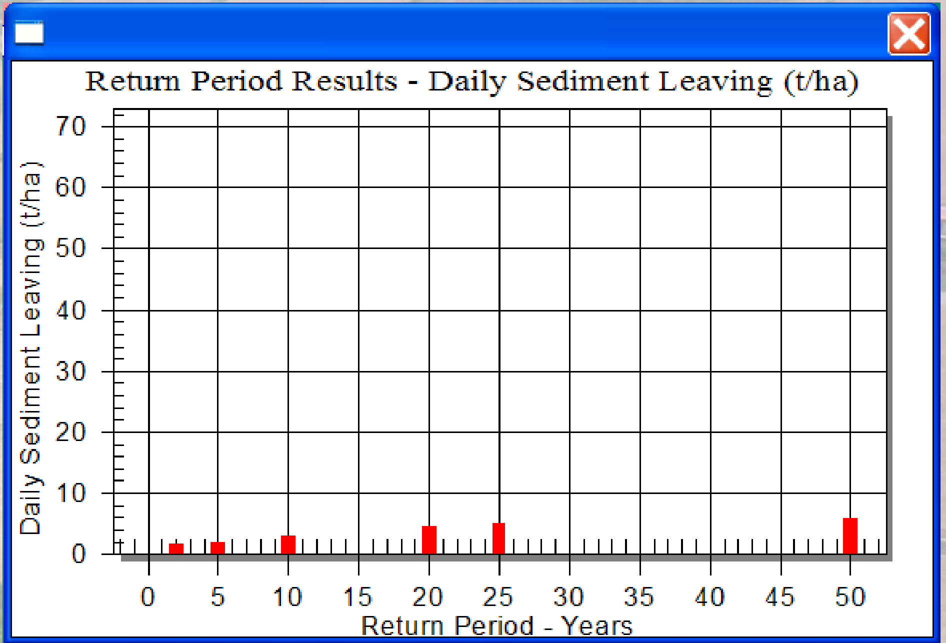


Another example - Return Period comparison



For **Conventional Tillage**, daily sediment leaving another profile was predicted to exceed 19 tonnes/ha at least once every 2 years, and 57 tonnes/ha at least once every 25 years.

For **No-till cropping management**, daily sediment leaving the profile was predicted to only exceed 1.5 tonnes/ha once every 2 years, and 5.1 tonnes/ha once every 25 years!



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WEPP for use on PC’s

- Desktop or laptop use
- Original software designed to be a stand-alone system, consisting of the FORTRAN science model and user interface (DOS, Windows)
- New WEPP applications still for use on a PC, but now may need only an internet connection to run a web-browser interface.
- Future development may progress into handheld device “apps”

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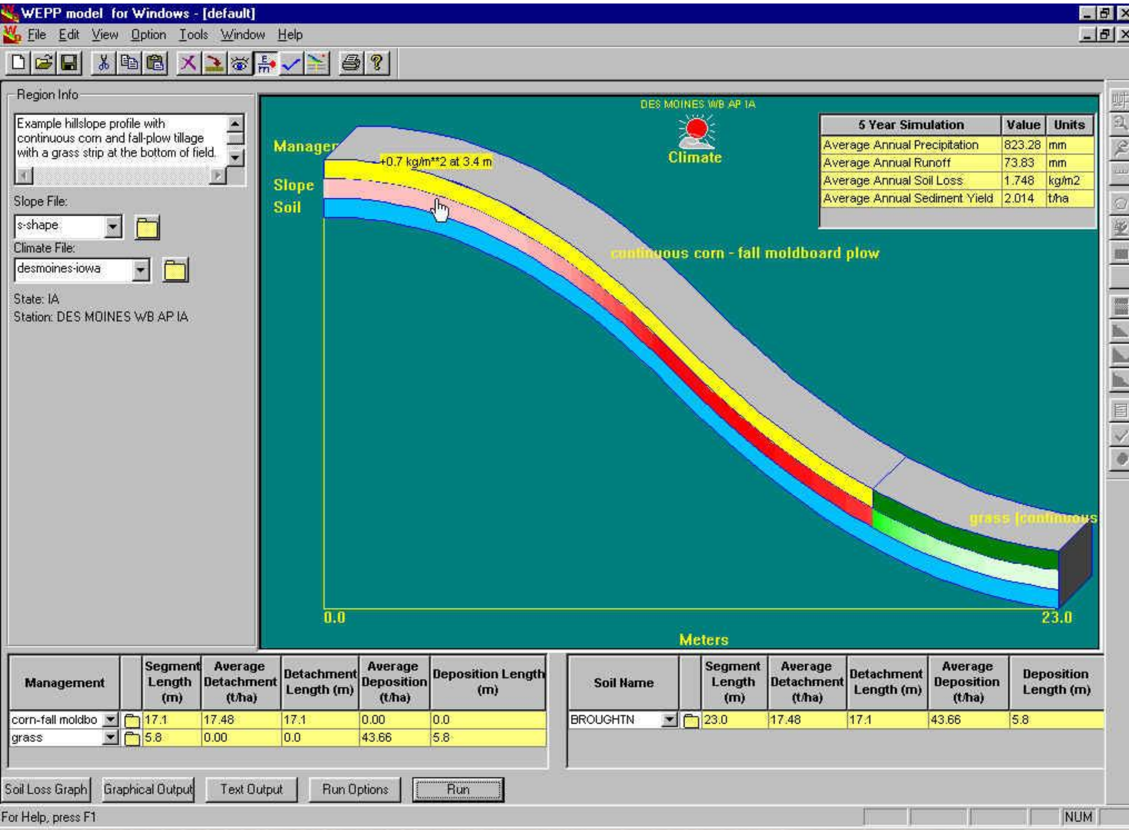
WEPP Interfaces Developed

- DOS interface (1992-95)
- Windows stand-alone interface (1996-1999)
- GeoWEPP extension to ArcView / ArcGIS (2001 – present)
- Web-based interfaces
  - USDA-Forest Service-Rocky Mtn. Res. Station (2000-present)
  - USDA-ARS National Soil Erosion Res. Lab. (2002-present)
  - Iowa State University – Daily Erosion Project (2002-present)

Windows Interface – Hillslope Profiles

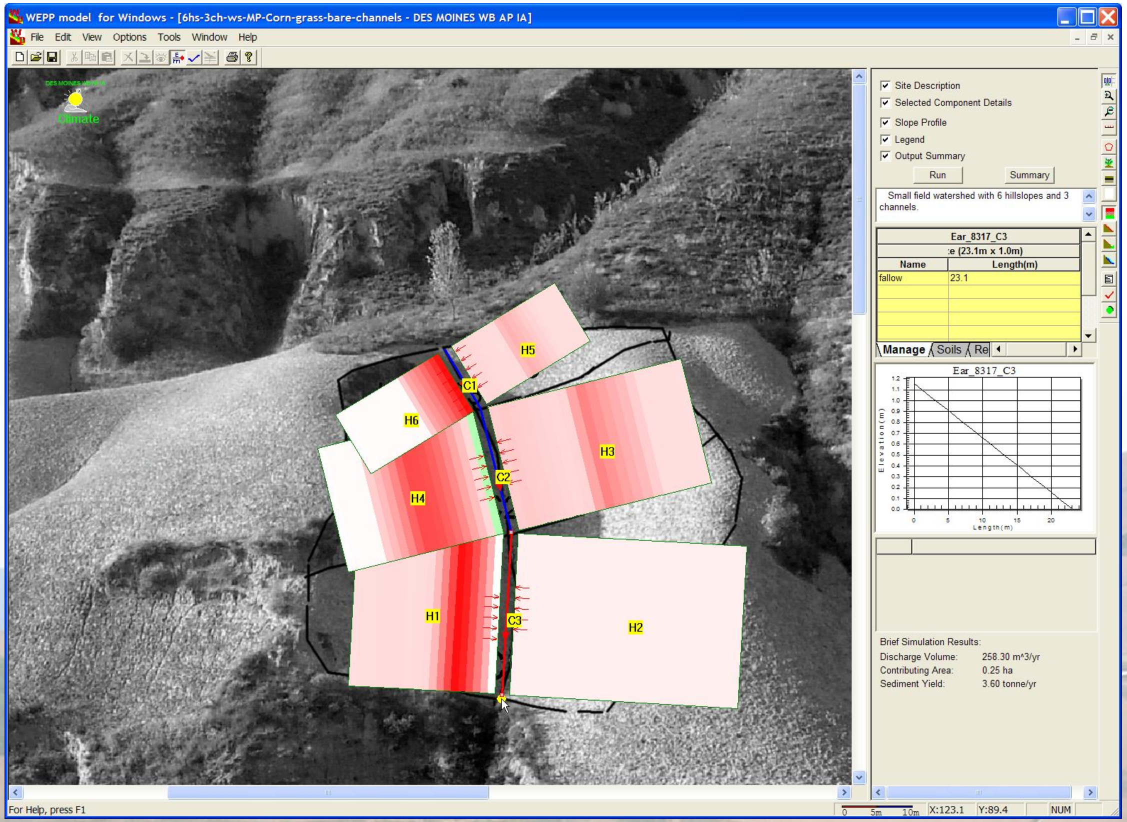


- **Profile depicted graphically in 2-D/3-D.**
- **Graphic image is "hot" and allows viewing & editing of underlying parameters.**
- **Can copy, cut, paste, & delete soil or mgmt. regions.**
- **Erosion & deposition rates shown in shades of red & green in center profile layer.**

Full flexibility to modify <u>any</u> model input parameter!

Extensive model text and graphical outputs, to assist in debugging, creation of new input sets, model calibration and validation exercises.

Windows Interface – Watersheds



- Top view of hillslopes, channels and impoundments.
- Graphic image is "hot" and allows viewing & editing of underlying components and their input parameters.
- Can import a background image (aerial photo, soil survey page, etc.), and scale to known distances.
- Erosion & deposition rates shown in shades of red & green on each hillslope profile.

Full flexibility to modify <u>any</u> model input parameter!

Clicking on an individual element (hillslope region, channel element, impoundment) will bring I/O info to forefront in the right side of the screen.

Procedures in all WEPP Geospatial Interfaces

- Extract channel network from DEM with TOPAZ (Garbrecht and Martz, 1997) program.
- Select outlet point of watershed.
- Delineate watershed boundary and subcatchments, using TOPAZ.
- With flowpath output from TOPAZ delineation, determine representative hillslope profiles using custom NSERL software (Prepwepp).

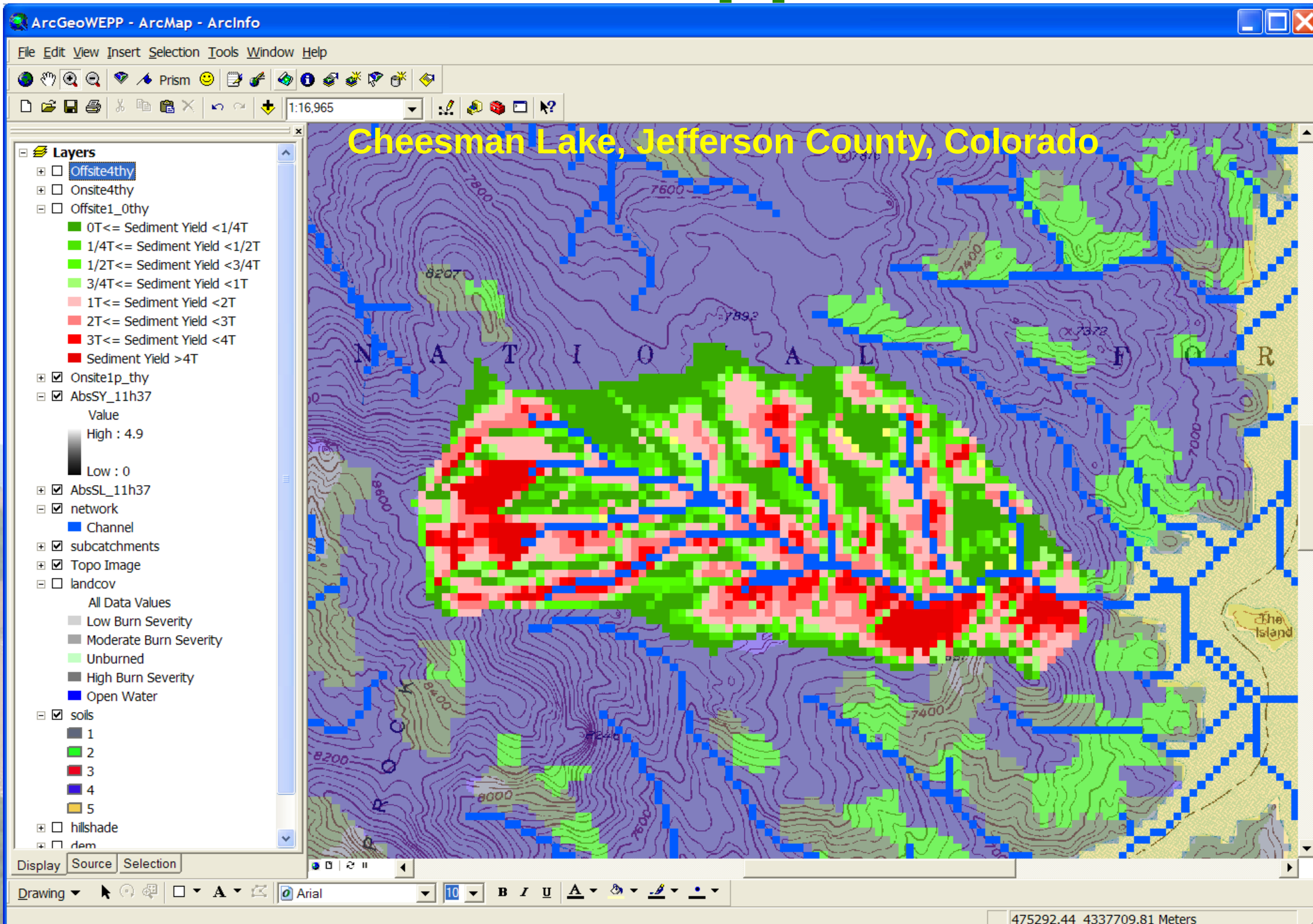
Procedures in all WEPP Geospatial Interfaces (cont.)

- Topographic analysis also provides channel slope information.
- Set up WEPP model simulations (Prepwepp handles this). User can specify soil & landuse for watershed, or can use GIS layer info to define.
- Run WEPP for all flowpaths, and for representative hillslopes and channels.
- Map output from WEPP to GIS layers to display.

GeoWEPP

- Originally an ArcView 3.2 extension
- Allows user to access and import commonly available data from the Internet (DEM, soils, landuse).
- Also allows user to import their own unique and detailed data.
- Can be difficult for a GIS-novice to understand and apply.
- Has been updated to ESRI ArcGIS 10.x

GeoWEPP Application

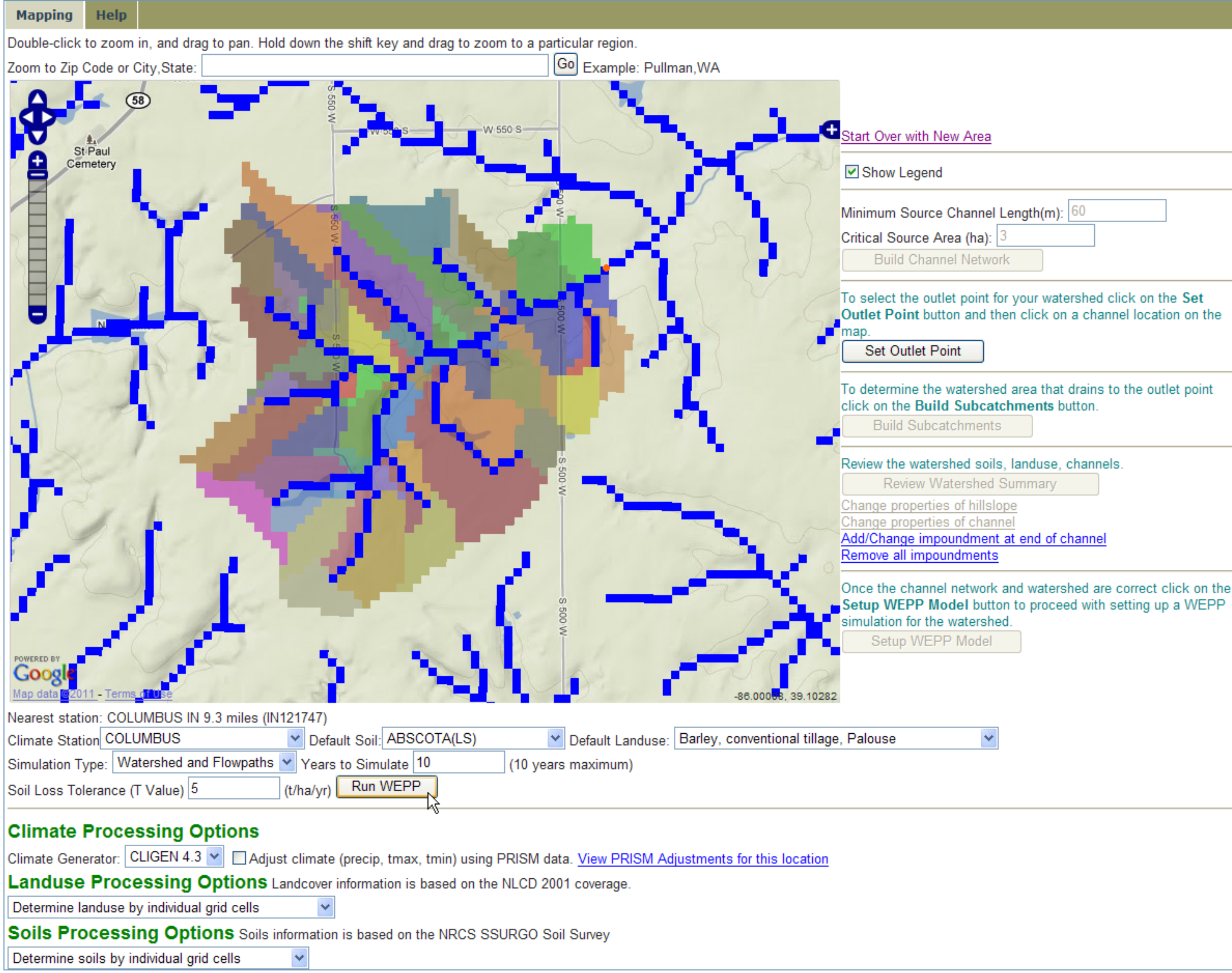


Web-based Geospatial WEPP Interface

- Same general procedures described earlier and implemented in GeoWEPP used.
- PHP, HTML and JavaScript languages used to write main user interface.
- OpenLayers package used to display image layers in geo-referenced space.
- Connects to external GIS data servers using Web Mapping Services.
- MapServer software converts GIS data into images and reprojections compatible with Google Maps image layers.

Web-based Geospatial WEPP Interface (cont.)

- Custom programs used to:
  - Clip the DEM data to the screen view
  - Call the TOPAZ topographic analysis program
  - Process the TOPAZ outputs for:
    - Channel delineation
    - Watershed delineation
    - Subcatchment delineation
    - Flowpath delineation.
  - Invoke the WEPP model simulations
  - Process the WEPP runoff, soil loss, and sediment yield outputs for display in the GIS.



Watershed delineated, flowpaths determined, subcatchments determined, representative hillslopes determined, channel slope inputs determined, spatial land use data can be used, spatial soil properties data can be used, nearest climate can be used. Ready for WEPP model simulations.

WEPP spatial soil loss results

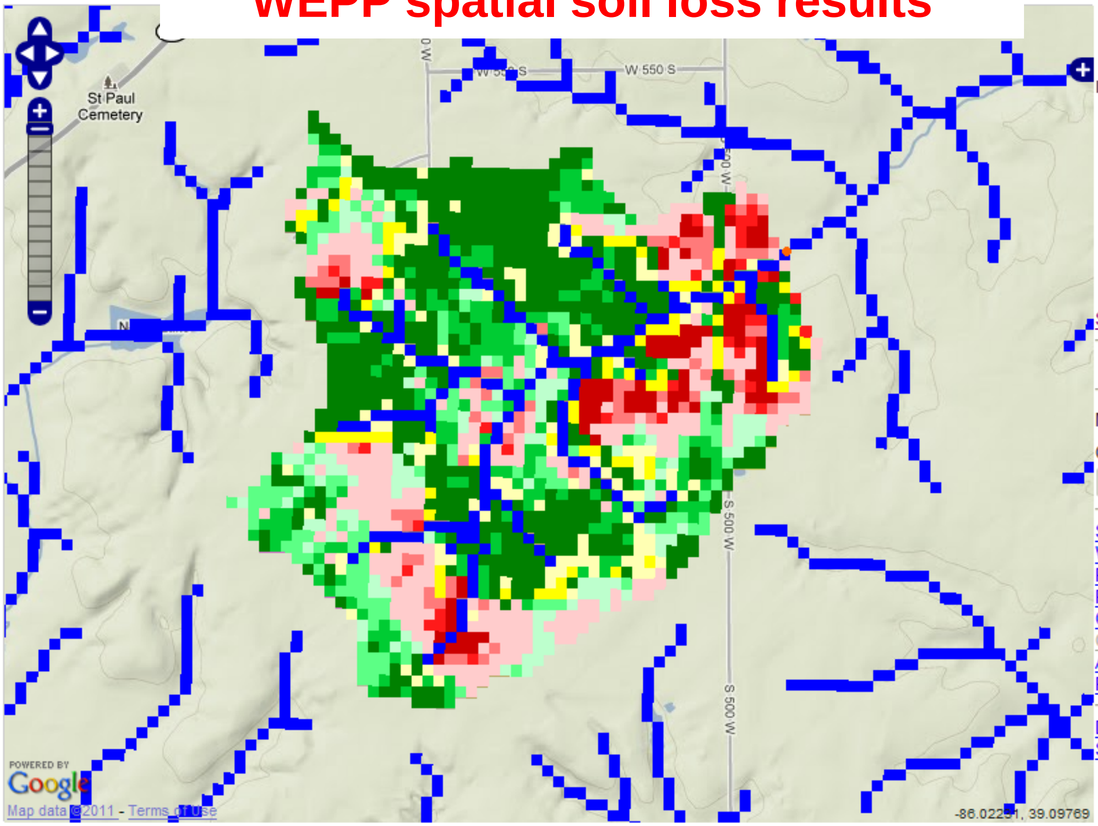
WEPP Watershed
Online GIS Interface

January 2011

Mapping | 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



Hillslope Soil Loss

- Soil Deposition > 5 t/ha/yr
- Soil Deposition 5 - 0.0001 t/ha/yr
- Soil Loss 0 - 1.25 t/ha/yr
- Soil Loss 1.25 - 2.5 t/ha/yr
- Soil Loss 2.5 - 3.75 t/ha/yr
- Soil Loss 3.75 - 5 t/ha/yr
- Soil Loss 5 - 10 t/ha/yr
- Soil Loss 10 - 15 t/ha/yr
- Soil Loss 15 - 20 t/ha/yr
- Soil Loss 20 - 1000 t/ha/yr

Start Over with New Area

☑ Show Legend

Minimum Source Channel Length(m): 60

Critical Source Area (ha): 3

Build Channel Network

Summary of Simulation Results
WEPP Model Text Output
Reclassify Output Maps
Review Watershed
Change properties of hillslope
Change properties of channel
Add/Change impoundment at end of channel
Remove all impoundments

Download Watershed Project
Save Watershed Project

Nearest station: COLUMBUS IN 9.3 miles (IN121747)

Climate Station COLUMBUS | Default Soil: ABSCOTA(LS) | Default Landuse: Barley, conventional tillage, Palouse

Simulation Type: Watershed and Flowpaths | Years to Simulate 10 (10 years maximum)

Soil Loss Tolerance (T Value) 5 (t/ha/yr) Run WEPP

Climate Processing Options

Climate Generator: CLIGEN 4.3 ☐ Adjust climate (precip, tmax, tmin) using PRISM data. View PRISM Adjustments for this location

Landuse Processing Options

Landcover information is based on the NLCD 2001 coverage.

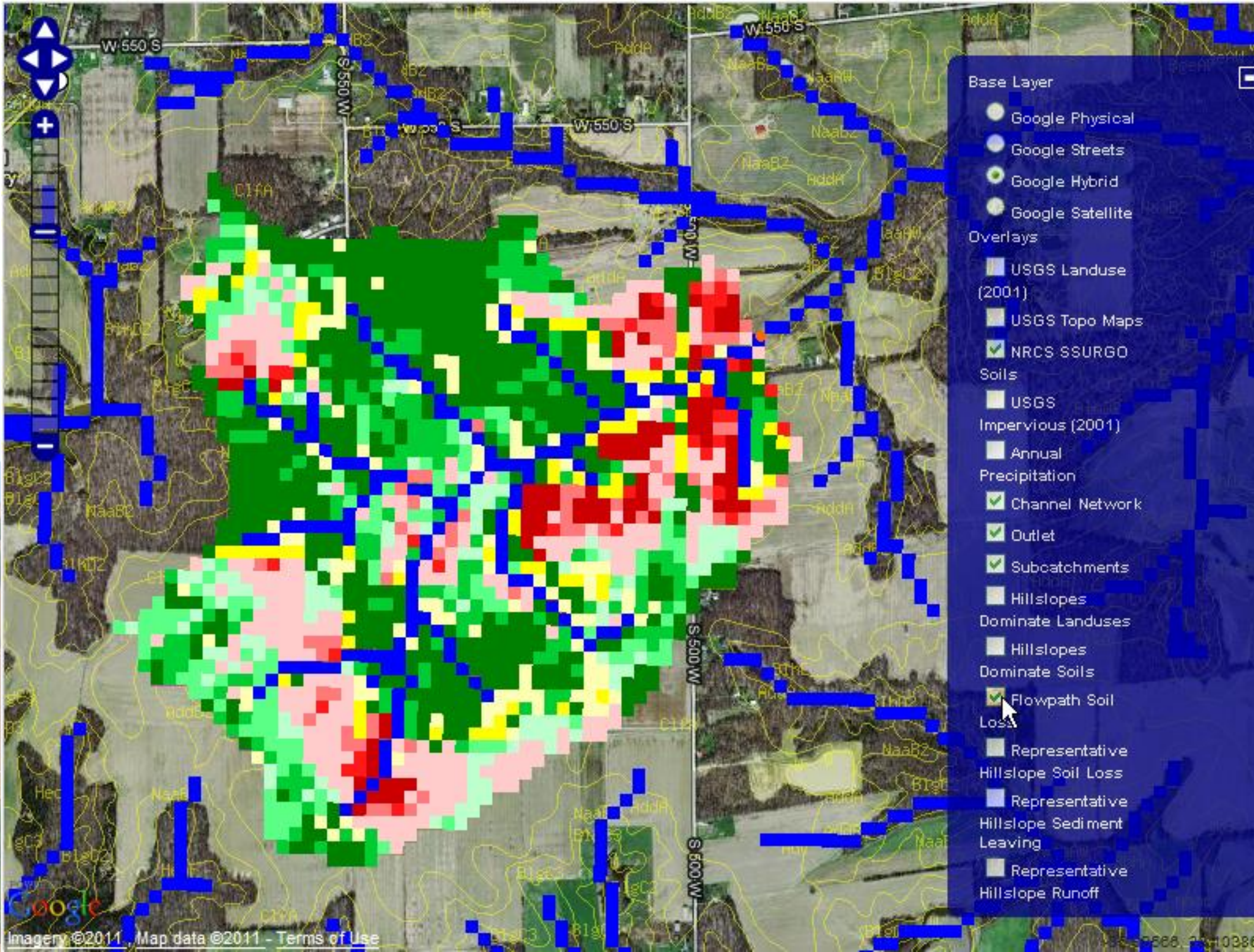
Determine landuse by individual grid cells

Soils Processing Options

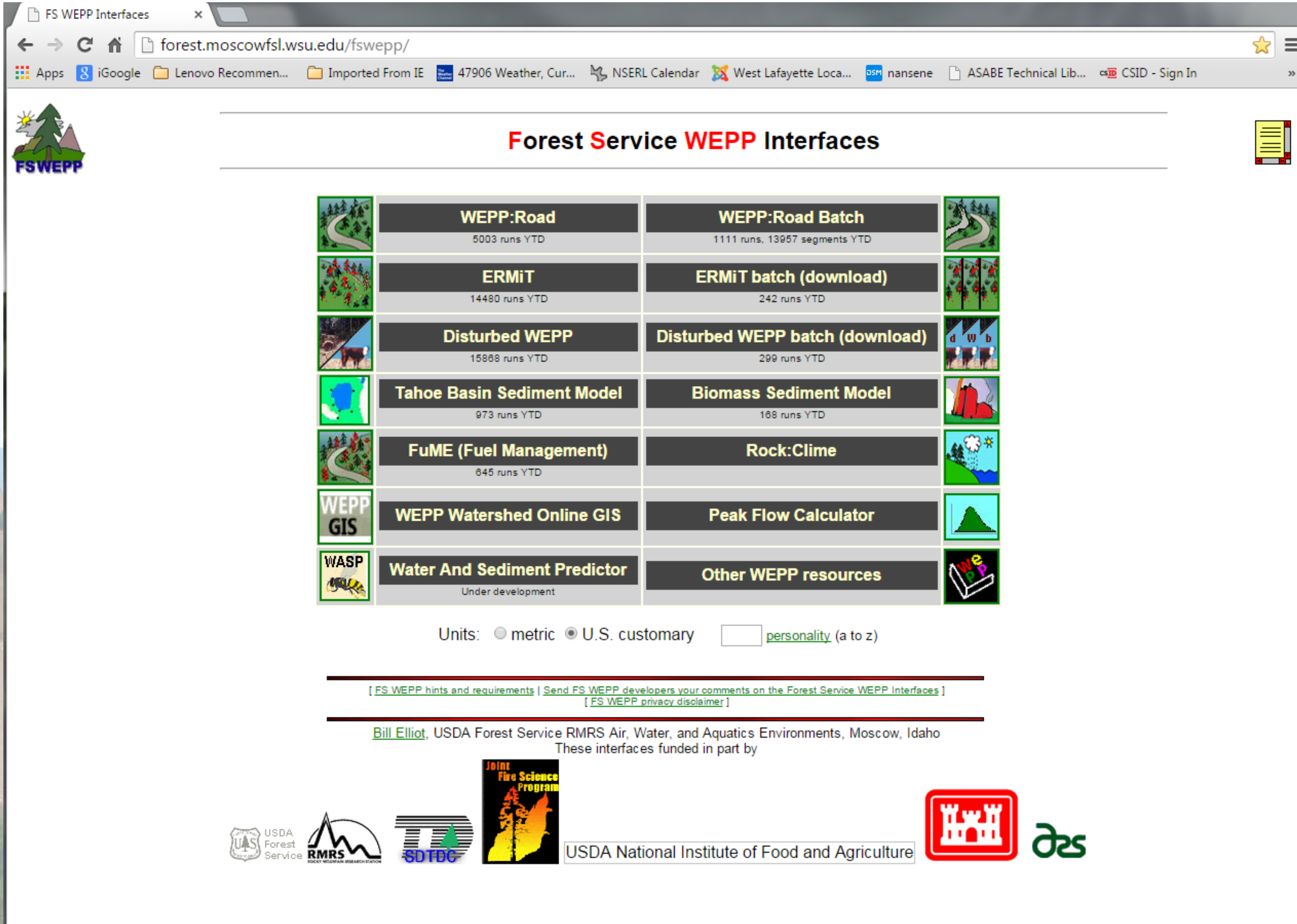
Soils information is based on the NRCS SSURGO Soil Survey

Determine soils by individual grid cells

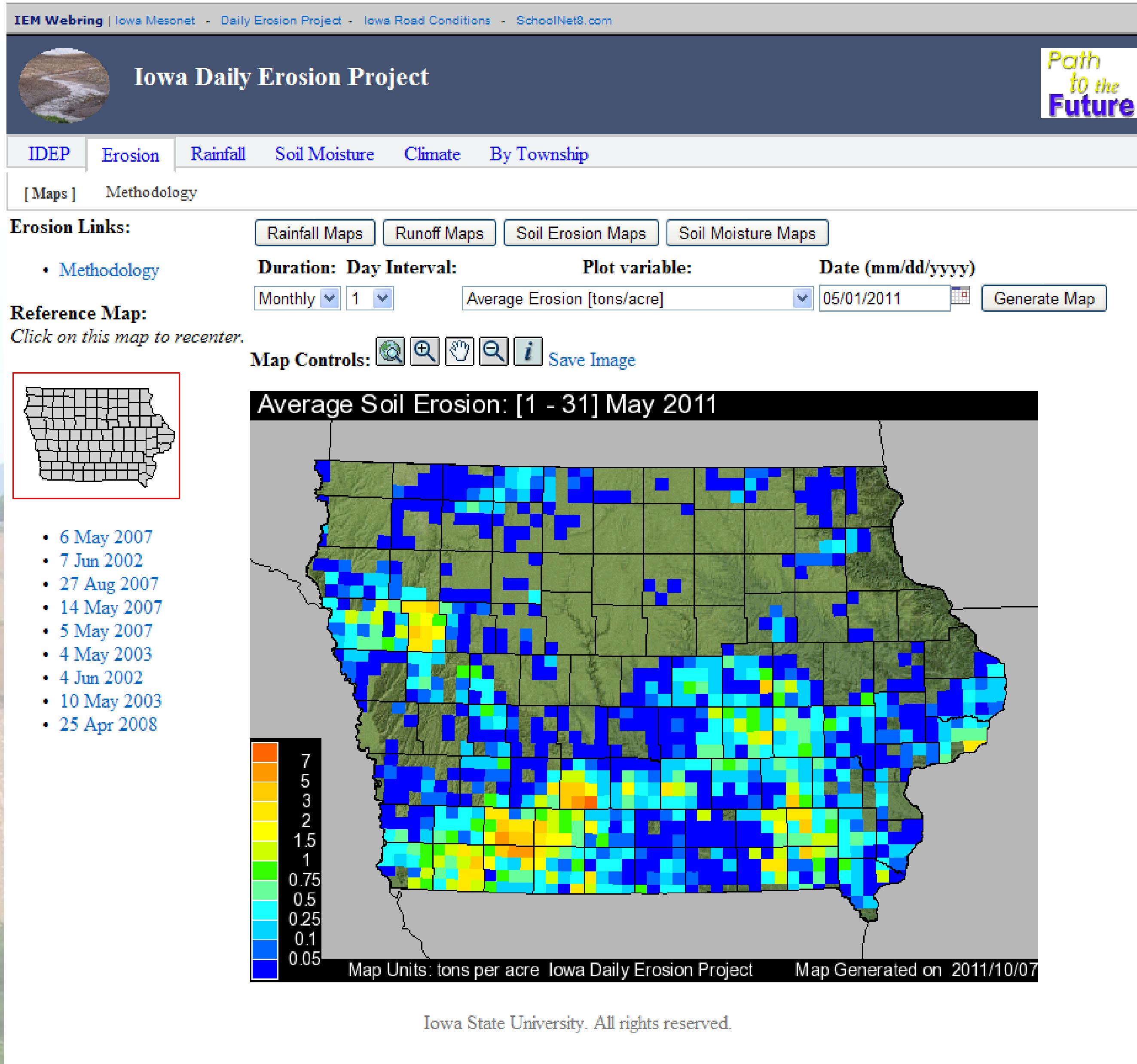
Output – Average Annual Soil loss by pixel – and other display options



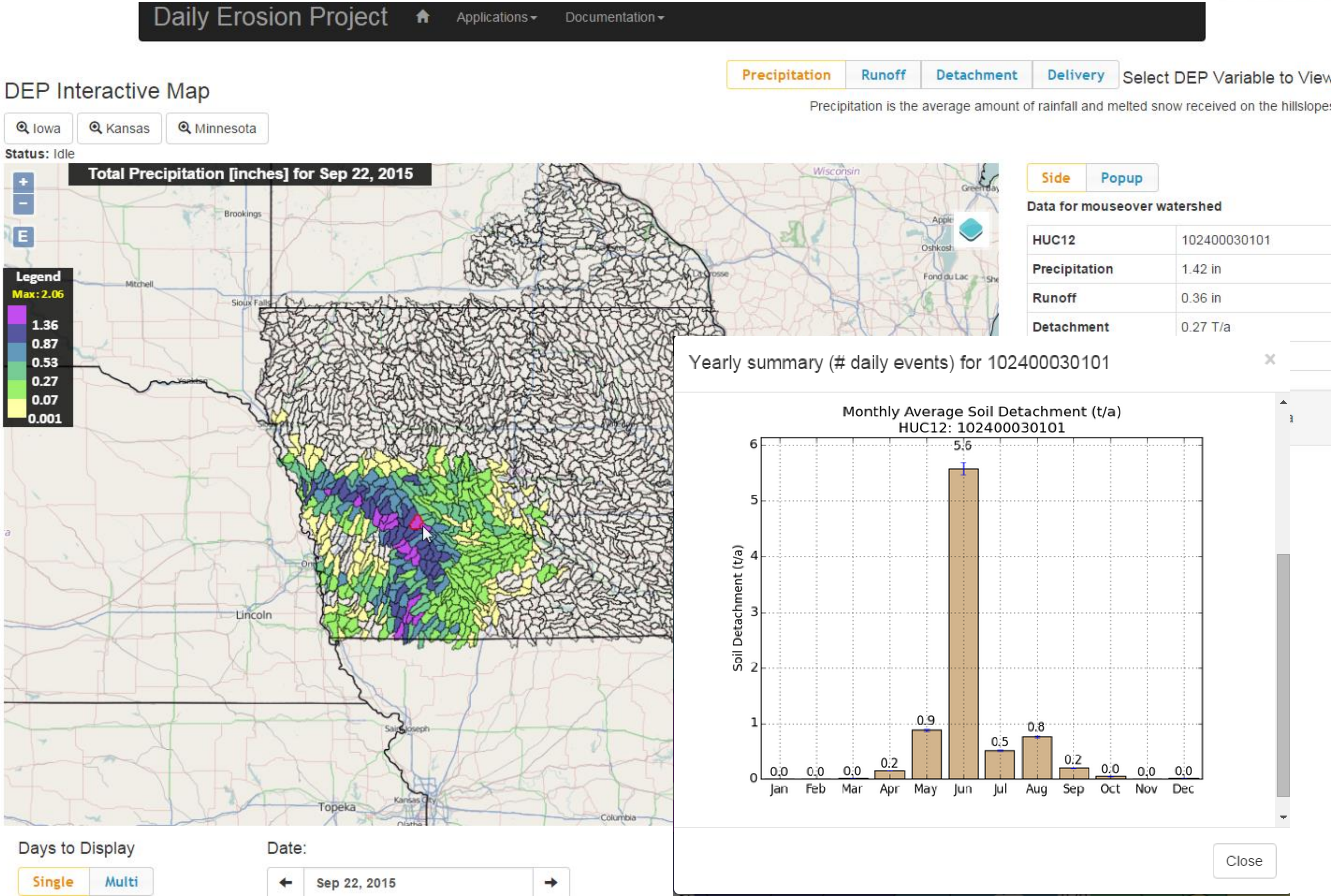
Other web-based WEPP interfaces - FS



Other web-based WEPP interfaces – Iowa Daily Erosion Project v1
http://idep-legacy.agron.iastate.edu/



Other web-based WEPP interfaces – Iowa Daily Erosion Project v2
http://dailyerosion.org



Status - 2015

- Current model version is v2012.8
- An updated model version should be released within the next 12 months.
- A major effort in the past year has been updating of the CLIGEN weather station database (to 1974 – 2013 information).
- Also, major effort with NRCS to develop software and utilize NRCS databases to allow for WEPP model simulations via web-based tools.

Current Projects

- Implementation of WEPP by USDA-NRCS to allow for model simulations of erosion and sediment loss in fields and small watersheds.
- Cooperative efforts with USDA-FS to create targeted web-based GIS watershed interfaces.
- Addition of water quality components to WEPP to allow nutrient and pesticide simulations at hillslope and watershed scales.
- Project with SWAT developers to incorporate WEPP erosion as option, as well as develop a global SWAT/WEPP web watershed GIS tool.
- Cooperative efforts with Iowa State University on Daily Erosion Project there.

Summary & Conclusions

- Process-based models allow simulation of important physical processes controlling soil erosion, as well as interactions.
- WEPP model is a powerful tool for estimating runoff, soil loss and sediment delivery from hillslope profiles and small watersheds.
- Geospatial interfaces allow for much more rapid, consistent, and unbiased WEPP application.
- Work continues to expand WEPP applications with the USDA-FS and NRCS.

The End

Any Questions?