DEVELOPMENT OF WEB-BASED GIS INTERFACES FOR APPLICATION OF THE WEPP MODEL

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Abstract
The Water Erosion Prediction Project (WEPP) model is a process-based, distributed parameter, continuous simulation erosion prediction tool. Work in the past 5 years has included linkage of WEPP with Geographic Information Systems (GIS) and utilization of digital elevation data for automatic creation of topographic inputs. This paper describes creation of Web-browser based GIS interfaces that allow similar functions as stand-alone products (such as GeoWEPP under ArcView). The Web GIS software allows users to specify an area of interest to model with WEPP, and then a Digital Elevation Model (DEM) for the area is sent to topographic parameterization software to delineate watersheds, channels and hillslopes. All computations to process the DEM are conducted on the server side, and then images of the delineated watershed and hillslopes are passed to the client's screen. WEPP model simulations of representative hillslope profiles and channels, and/or all flowpaths in the watershed, are also conducted on the server. Then the predicted soil erosion results in graphical format are sent as images to the client machine. Subsequent model simulations using different land management practices can help to show the impact of use of conservation practices on runoff, soil erosion and sediment yields.

Additional Keywords: soil erosion prediction, internet

Introduction

Erosion prediction is becoming increasingly more important as concerns over water quality and watershed health grow. Process-based prediction tools, such as the Water Erosion Prediction Project (WEPP) model (Flanagan and Nearing, 1995) can provide detailed spatial and temporal estimates of soil detachment and sediment deposition, as well as sediment delivery from a hillslope profile or small watershed. WEPP requires detailed inputs on daily climate, soil properties, cropping and management, and topography (Flanagan and Livingston, 1995). The model was designed to predict erosion and sediment delivery from hillslopes and small watersheds (<500 ha).

For simple applications of the WEPP model on single hillslope profiles (similar to a simple Universal Soil Loss Equation (USLE) application (Wischmeier and Smith, 1978)), USDA-ARS has developed a user-friendly Windows interface (Flanagan *et al.*, 1998) and a Web-browser interface (http://octagon.nserl.purdue.edu). The Windows interface can also be used to set-up and run simple watershed simulations. However, for more complex situations, the task of building, structuring and describing inputs for all necessary components can be difficult and time-consuming. To remedy this, development of a WEPP GIS interface began in 1996 (Cochrane and Flanagan, 1999), and culminated in the GeoWEPP software (Renschler *et al*., 2002; Renschler, 2003), which is an extension under ESRI ArcView 3.x. GIS tools require Digital Elevation Models (DEMs) and other spatial data for the watershed region.

While GeoWEPP is a significant advancement in applying WEPP to complex watersheds using commonly available data and the GeoWEPP wizard greatly simplifies a user's tasks to conduct watershed simulations, there are still disadvantages to this approach. First, GeoWEPP is an extension to the ESRI ArcView 3.2 GIS and also requires ESRI Spatial Analyst to run. ESRI software is commercially available at a significant cost (~$3000 US for ArcView plus Spatial Analyst). A second disadvantage is that when running an ArcView extension, the full GIS program and all functions are available for use or misuse. Many target WEPP users may have limited or no expertise with a GIS, so ArcView can be quite confusing. Another disadvantage is that users must gather the necessary elevation, land use and soil data for their area of interest and assemble it for use in the desktop GIS and GeoWEPP. The tasks of preparing the data for use often require specific GIS skills that many WEPP users may not have. Finally, stand-alone GIS programs and data take up significant system resources in terms of personal computer (PC) memory, disk space and CPU time.

The goal of the work described here, therefore, was to develop a Web-based GIS system that allows for the functionality of the GeoWEPP program without the need for a stand-alone desktop GIS.

Materials and Methods

The initial idea of running the WEPP model using an Internet based GIS was formulated after looking at various Web-based hydrologic modeling tools (http://pasture.ecn.purdue.edu/~watergen) developed at Purdue University (Choi *et al*., 2002; Choi *et al*., 2003). There, one of the Web-based decision support systems was developed to assess the impact of present and future land use on hydrology and water quality. It contains the ability to access commonly available digital elevation model (DEM) data (initially for only the state of Indiana), as well as other commonly available data such as soils and land use.

Both the Purdue system and this project use the open source MapServer environment from the University of Minnesota (http://mapserver.gis.umn.edu) as the basic Web GIS. However, WEPP has many more inputs to set-up, much more output to process and is more computationally intensive. The WEPP watershed delineation uses the TOPAZ (TOpographic PArameteriZation, Garbrecht and Martz, 1997) digital landscape analysis tool, which includes flow-vector and subcatchment information that is critical for setting up the model simulation runs. Also, the WEPP scale is for small watersheds, and it thus requires photos and/or digital raster graphs (DRGs) for users to correctly locate their area of interest.

The WEPP model and GIS server hardware is comprised of a dual processor Athlon system running Linux, 2GB of memory and 250GB of disk space. The prototype system has been initially designed to support a small number of concurrent users (about 25).

The commonly available data on the server used as the basis for the WEPP inputs are the following:

- National Elevation Dataset from USGS (http://gisdata.usgs.gov/NED/default.asp), 30 m coverage for US. This data was pre-processed and clipped by state boundaries with a 1KM buffer.
- National Land Cover Dataset from USGS (http://landcover.usgs.gov/nationallandcover.asp), the current dataset being used is from 1992. When the 2001 coverage is complete, that data will be used.
- STATSGO Soils Data from USDA Natural Resources Conservation Service – This is at a regional scale with the SOILS5 ID linking to existing WEPP soils data. Some areas have more detailed SSURGO (http://www.ncgc.nrcs.usda.gov/branch/ssb/products/ssurgo) data. In the future, SSURGO would be better to use with all WEPP simulations.
- Climate Data – The daily climate inputs are generated with CLIGEN (Nicks et al., 1995), which is the weather generator program for WEPP. The geographic location of the user's watershed determines the closest CLIGEN station data to use. A better approach to potentially use in the future would be to interpolate parameters from all nearby stations and use PRISM (http://www.ocs.orst.edu/prism) to account for elevation differences.

Users locate the area where the WEPP watershed model is to be applied by viewing topographic map images (digital raster graphs) and orthophotos. This data is not kept on the local NSERL server, but is instead retrieved on demand from TerraServer USA (http://terraservice.net) using the Web Mapping Services protocol. Other data such as roads, rivers, and county boundaries are kept on the local server and are also used for orientating the user. This image data is not used in running a WEPP simulation.

The current system is comprised of five major pieces of software (Figure 1). As a user zooms into an area of interest to model with WEPP, data for display is obtained from the TerraServer site and from local spatial data on the NSERL server. The MapServer software sends image data to the client's Web-browser and handles requests for zooming and panning. When the exact location of interest is identified, the TopazPrep software handles extracting an area of the DEM to process with TOPAZ. TopazPrep is custom software written in C++ and PHP. PHP is a widely-used open source scripting language well suited for Web development and can be easily inserted into HTML (HyperText Markup Language).

The first run of TOPAZ delineates the channel network, and then from the channel network the user selects a watershed outlet point. The second run of TOPAZ defines the watershed and subcatchments from the outlet. The current system limits the area the user can model to 0.25 degrees latitude by 0.25 degrees longitude, in order to ensure that TOPAZ can handle the extracted DEM and to allow for a reasonable response time. If the watershed delineated is acceptable, the WeppPrep program is executed which generates WEPP inputs from the extracted DEM, land use, soils and TOPAZ watershed structures. WeppPrep is also custom software written in C++ and

PHP. The WEPP model is then run on the various subcatchments and/or flowpaths and WeppPrep interprets the results and produces maps which are sent to the client using MapServer.

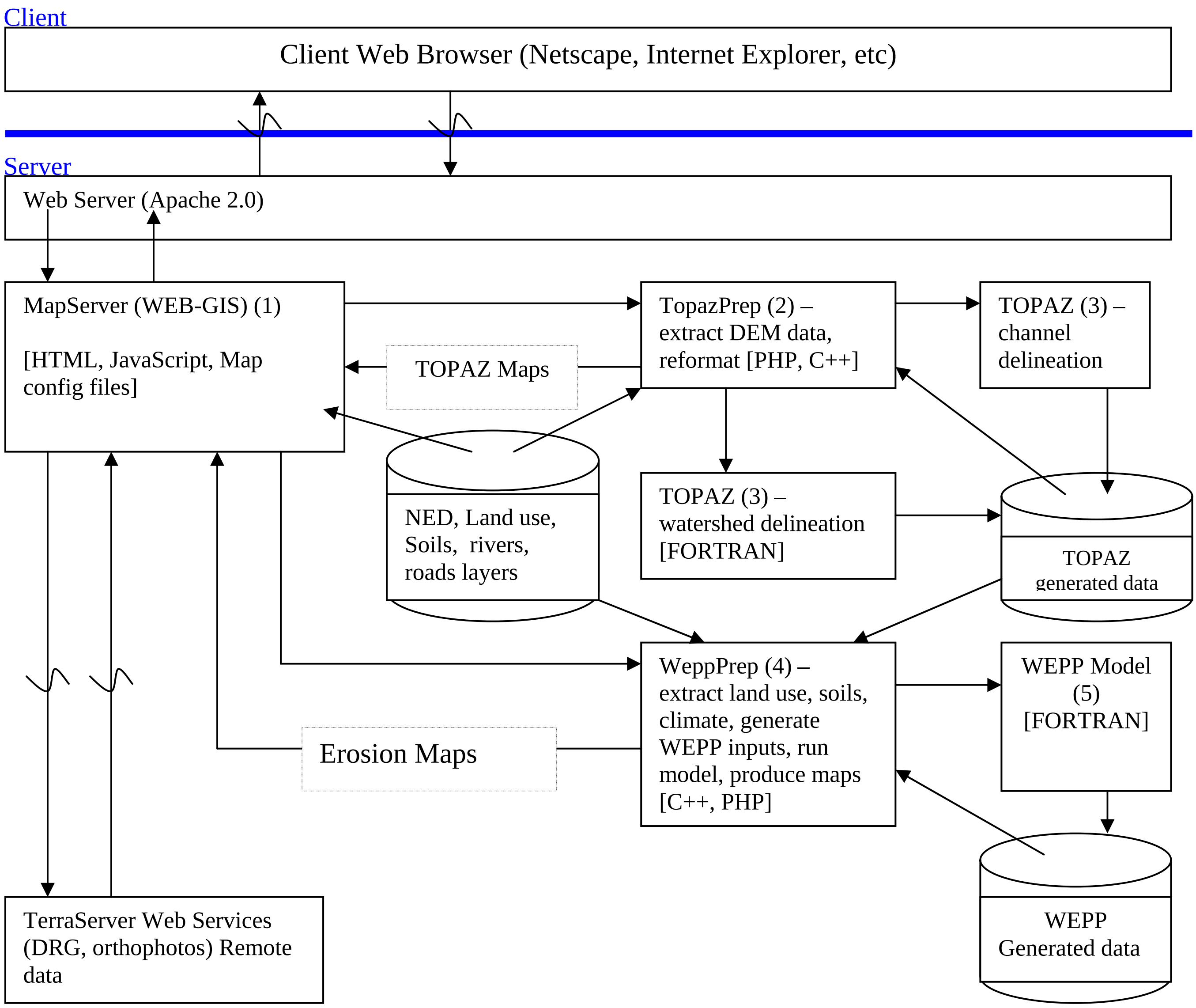

Figure 1. Schematic of WEPP Web-based GIS system

Data from TOPAZ and WEPP simulations along with maps generated on the server side are catalogued in subdirectories for each user, which are managed by using the PHP session information.

Results and Discussion

The software developed to this point is extremely fast and functional. Any location within the contiguous United States can be selected, and digital elevation data accessed. The TOPAZ program has been linked and can rapidly delineate the watershed boundaries, hillslope regions and channels, as well as all flowpaths within the watershed.

An example application of the prototype system for a location in Tippecanoe County, Indiana will be shown in this section. The new web site for the WEPP Web-based GIS system is at the URL http://milford.nserl.purdue.edu. After connecting to this location with a Web-browser, the user would select "WEPP GIS" from the choices listed. The next step is to click on the desired state and zoom in to the area of interest. Layers can be turned on showing the DRG images and/or orthophotos from the TerraServer, as well as roads, rivers, soils, land use and the DEM (Figure 2).

Once an area of interest that is recognizable to the user has been found, the next step is to continue on and delineate the channel network, through utilization of TOPAZ. Figure 3 shows the screen in which the minimum source channel length and critical source area can be entered. These settings impact the delineated channel network.

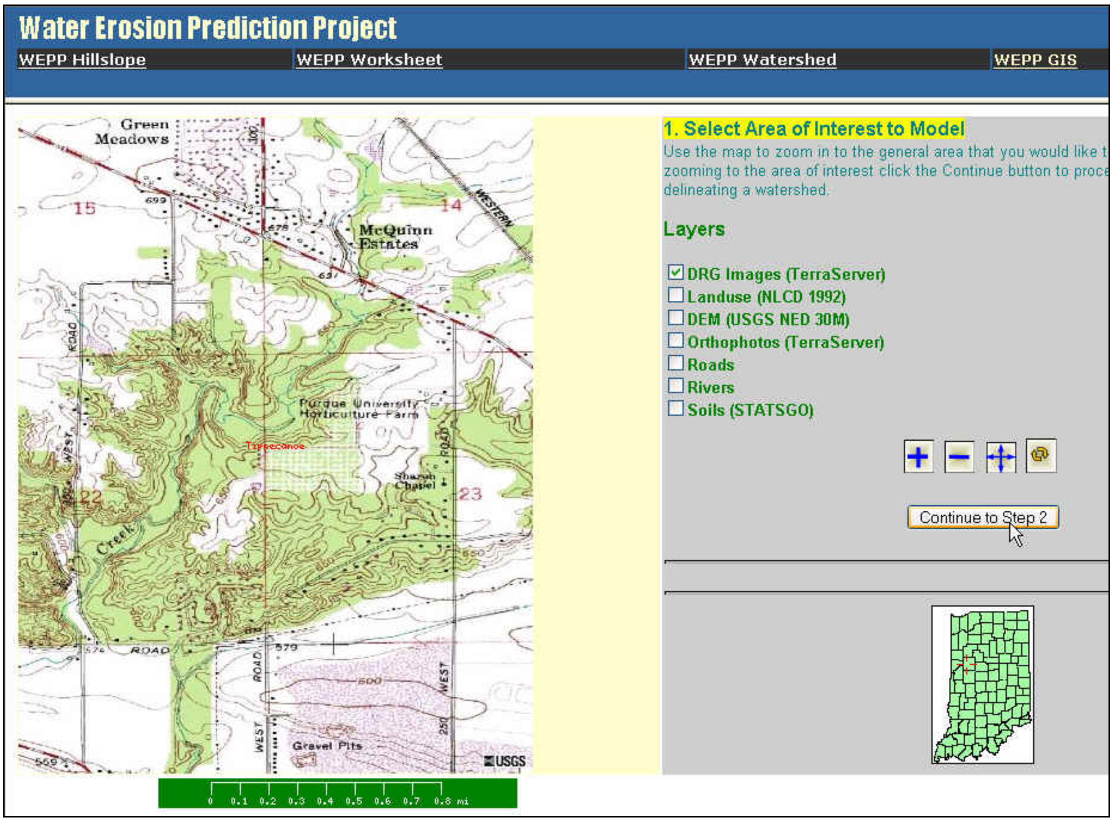

Figure 2. Screen capture of prototype Web-based WEPP GIS program, showing general area of interest in Tippecanoe County, Indiana.

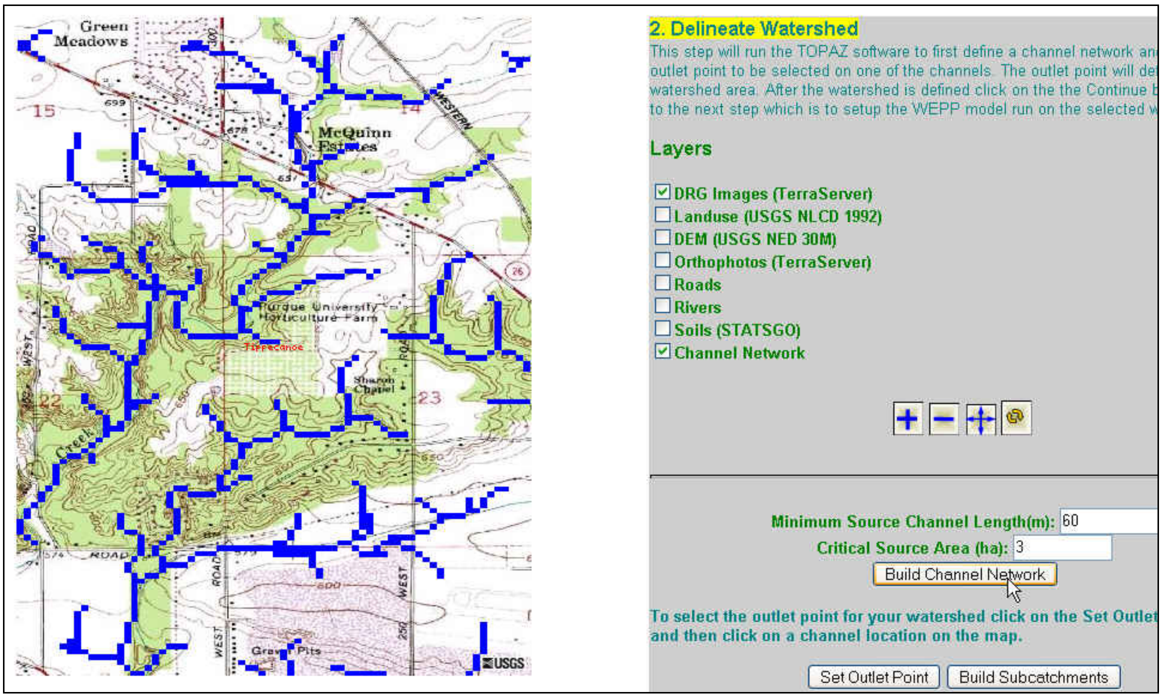

Figure 3. Screen capture of prototype Web-based WEPP GIS program, showing second step, to build the channel network with TOPAZ based upon user-entered values for minimum source channel length and critical source area.

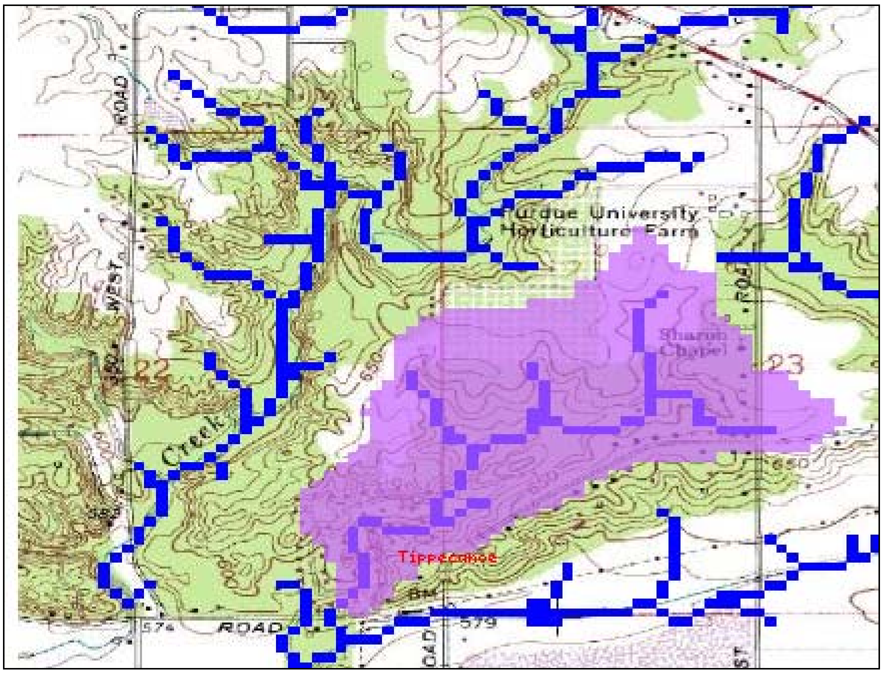

Figure 4. Screen capture of prototype Web-based WEPP GIS program, showing delineated watershed boundary after selecting a cell on the channel network.

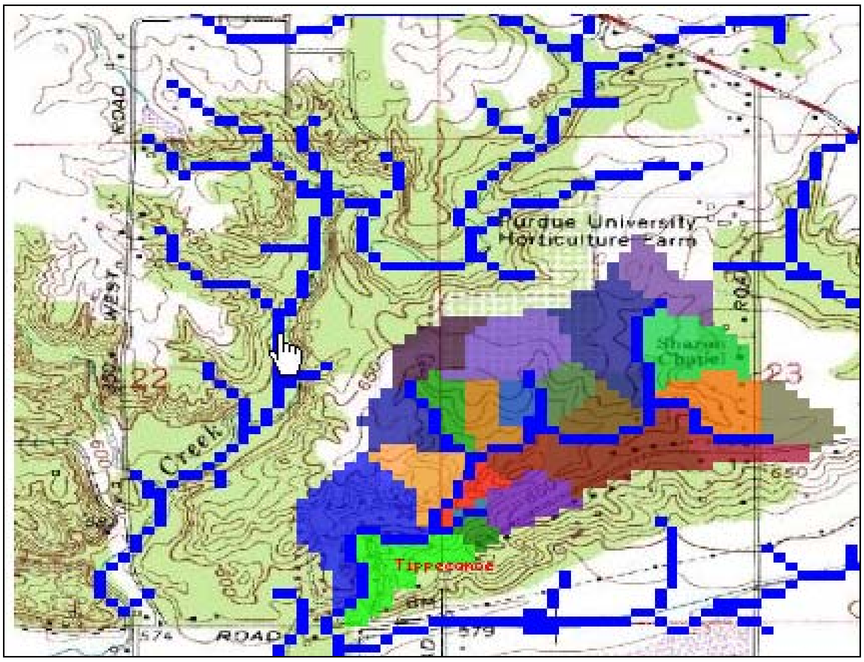

Figure 5. Screen capture of prototype Web-based WEPP GIS program, showing delineated watershed, channels and subcatchments (hillslope regions).

Once the channel network has been delineated, users set the desired outlet point for their watershed by clicking on the "Set Outlet Point" button, clicking on a point on a channel with the left mouse button, then clicking on the "Build Subcatchments" button. These steps will result in the TOPAZ software being run again, to delineate the entire watershed boundary (Figure 4) as well as all of the subcatchments (Figure 5) that are then used as WEPP hillslope regions.

The internal logic of the software to convert TOPAZ flowpath information into representative hillslope profile slope inputs for WEPP is described by Cochrane and Flanagan (1999, 2003). Users can optionally associate specific WEPP soil and management datasets with soil and land use classifications from the GIS layers. Channel parameters are selected by the user. There are two modes of simulation: (1) Representative hillslopes and channels, and (2) Flowpaths. In the first approach, slope characteristics of all flowpaths within each subcatchment are used to create a representative slope profile input for each hillslope region. In the flowpath approach, WEPP hillslope simulations are run on all flowpaths within all subcatchments, then the spatial estimates of soil loss on each flowpath are merged to produce a map of soil loss and deposition predictions (Figure 6a). If the watershed exhibits excessive soil loss, subsequent simulations using alternative management approaches can be tried to identify systems that may reduce soil loss to acceptable levels.

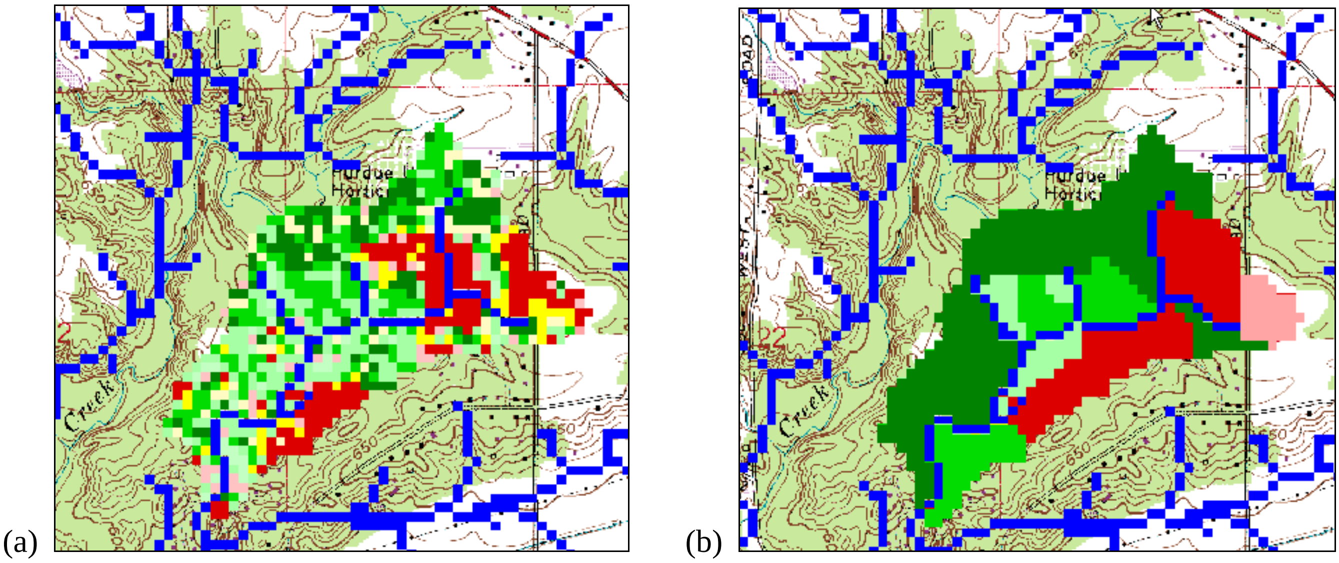

Figure 6. Screen captures of prototype Web-based WEPP GIS program (a) showing spatial soil loss (shades of red and green) and deposition (shades of yellow) from flowpath simulations and (b) representative hillslope results for sediment yield by subcatchment.

Conclusions

The work described here is ongoing, with a fully functional prototype expected before the end of 2004. This Web-based approach for application of the WEPP model should provide a powerful tool for users interested in erosion assessment of small watersheds. Also, the procedures and system developed should be useful for possible expansion to other ARS erosion prediction tools.

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