Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

A single raindrop is all it takes to begin the process of erosion.
Credit: USDA Natural Resources Conservation Service (NRCS).

Tapping into Technology and Information Resources to Assess Erosion Risk

Summary

Just over 50 years ago, predicting soil erosion was a time-consuming manual process. These methods have evolved over time and now include models such as the Water Erosion Prediction Project (WEPP), which helps simulate the important physical processes that result in soil erosion by water. It was the goal of this study to build on the WEPP model to create a multi-scale software tool that could provide fire and fuel managers with access to the geographic data and detailed images they needed to predict soil erosion after wildfire and fuel-reduction treatments. The new tool, known as the Geo-spatial interface for WEPP (GeoWEPP), digitally enhances WEPP simulations by linking with Geographic Information Systems (GIS) and tapping into digital sources of information such as digital elevation models and topographic maps. With GeoWEPP, fire managers can locate where a fire is burning and plug this data into a program that helps estimate problems in watersheds.

Key Findings

- Modifications to the Water Erosion Prediction Project (WEPP) model provide users with an improved ability to model steep forest watersheds and shallow soils.
- Enhancements to the perennial vegetation routines in WEPP enable users to better model forest and rangeland vegetation.
- Access to online data, digital elevation models and topographical parameterization software help represent current conditions more effectively, resulting in more accurate erosion prediction.
- The latest version of GeoWEPP, the Geo-spatial interface for WEPP, tutorials and documentation can be found at: www.geog.buffalo.edu/~rensch/geowepp/.

A natural process with destructive potential

Erosion has continually shaped the earth's surface, using wind or water to wear away agricultural fields and to sculpt canyons, stone arches and limestone cliffs. A complex process, erosion not only has the power to create stunning natural formations, but the power to destroy, and is considered one of the top environmental concerns in our world today.

Fluvial erosion, or erosion by moving water, comes in the form of rainfall, traveling over land and in streams and removing the material from one location and depositing it at another location. When this happens, valuable nutrients are stripped from agricultural fields and land is reduced along rivers and streams. Powerful storms can produce mudslides and floods, damaging ecosystems, and destroying manmade structures and life. Even more devastating is the impact erosion can have on water supplies, by introducing more sediment into the water channel network and contaminating reservoirs.

Typically, undisturbed forests experience little erosion, with vegetation and litter protecting the soil and allowing a high rate of water infiltration. But when the land and soil properties are altered, erosion can take effect. Years of total fire exclusion create high intensity fires that make soils temporarily hydrophobic and therefore severely limit the infiltration of water. That impacts how water flows across the landscape and where soil is eroded and deposited, potentially causing mass erosion and mudflows.

Once soil has been disturbed, time to assess erosion risk is limited. That's why fire, fuel and land managers need effective tools that can help them evaluate potential hydrologic effects in advance with greater speed and accuracy so they can determine the appropriate next steps before taking action.

The evolution of erosion prediction

For more than half a century, scientists have been studying erosion and developing models to better understand and predict the process. In 1936, H. L. Cook identified three factors that may contribute to soil erodibility by water, including the soil's susceptibility to erosion, the potential for erosion as a result of rainfall and runoff, and soil protection due to vegetative cover. In 1940, two additional factors—slope steepness and slope length—were added. Over time, more factors were included and observed, such as support practices, cropping systems and soil management, with an increasing emphasis on slope.

Erosion of a granite dome in North Carolina. Credit: Jeff Kauffman.

Earlier methods were manual, time-consuming and limited, making it difficult for researchers to capture the true variability of the landscape and changing weather conditions. The erosion prediction process continues to evolve as prediction models become more sophisticated and as new resources are available. Computers have had a dramatic impact, providing fire and fuel managers with access to the latest digital images and innovative technologies, thus improving decision-making and response time.

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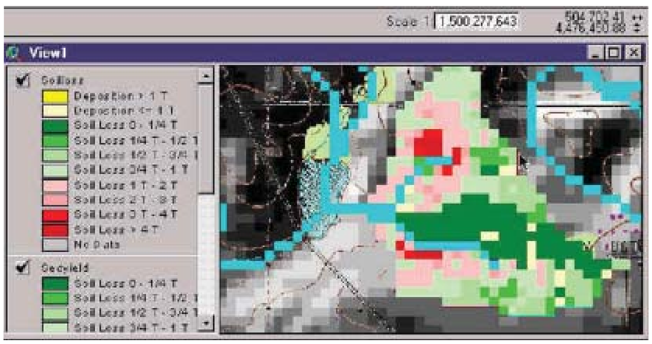
One relatively new erosion prediction technology, the Water Erosion Prediction Project (WEPP) model, was developed by the U.S. Department of Agriculture and released in 1989. A process-based model, WEPP incorporates climate, hill slope, hill length, and management, vegetation and soil information to help predict soil erosion, with the ability to model a single hill or an entire watershed. WEPP can also simulate small watersheds and hillslope profiles within those watersheds to assess water and soil conservation management options for rangeland, forest, and agricultural sites.

Since its release, the WEPP interface has undergone many improvements, helping to increase the tool's accuracy and ability to accommodate a wider range of conditions. WEPP was also modified to create simulations from digital information sources by linking with Geographic Information Systems (GIS). The Geo-spatial interface for WEPP, known as GeoWEPP, provides a more accurate spatial distribution and uses digital geo-referenced information to begin site-specific water and soil conservation planning for small watersheds. GeoWEPP is intended for users with varying levels of GIS knowledge and enables access to commonly available geographic data and databases online. Together, WEPP and GeoWEPP are able to provide users with the prediction and visualization capabilities needed to best determine which areas in a watershed are most vulnerable to erosion.

According to Chris Renschler, Principal Investigator, "GeoWEPP is a continuous model that allows users to assess spatial and temporal changes in managing watersheds, also known as cumulative watershed effects analysis."



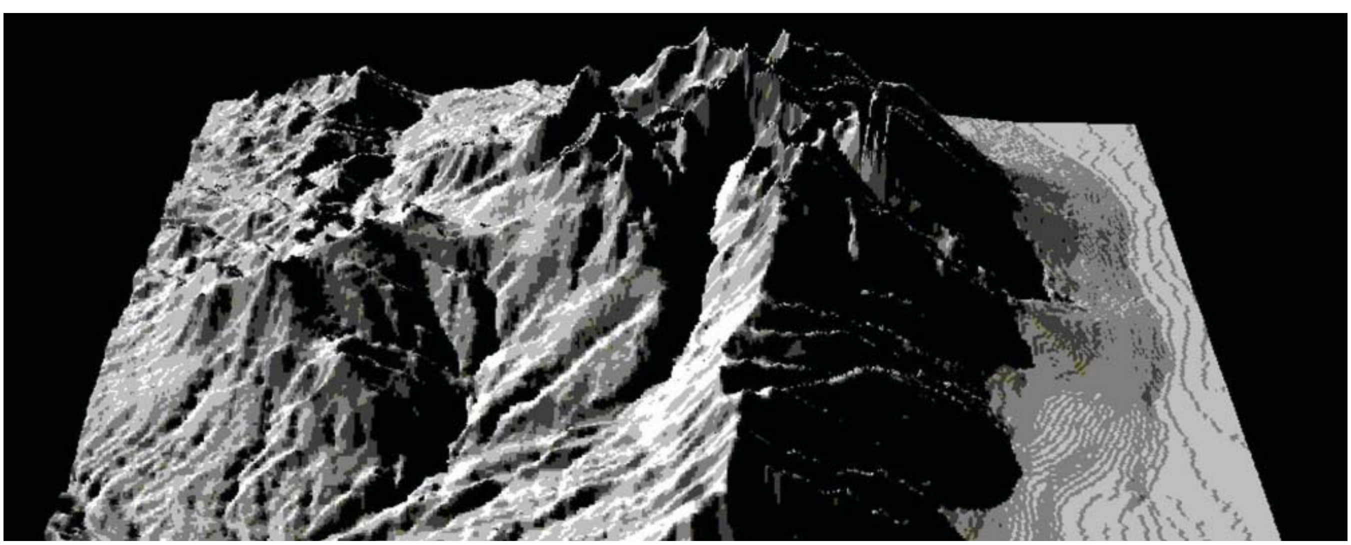
In GeoWEPP, soil loss is simulated for each pixel of a watershed (target value T represents 1 t/hectare/year, with 1 hectare equivalent to 2.471 acres).

Using technology to mimic real life

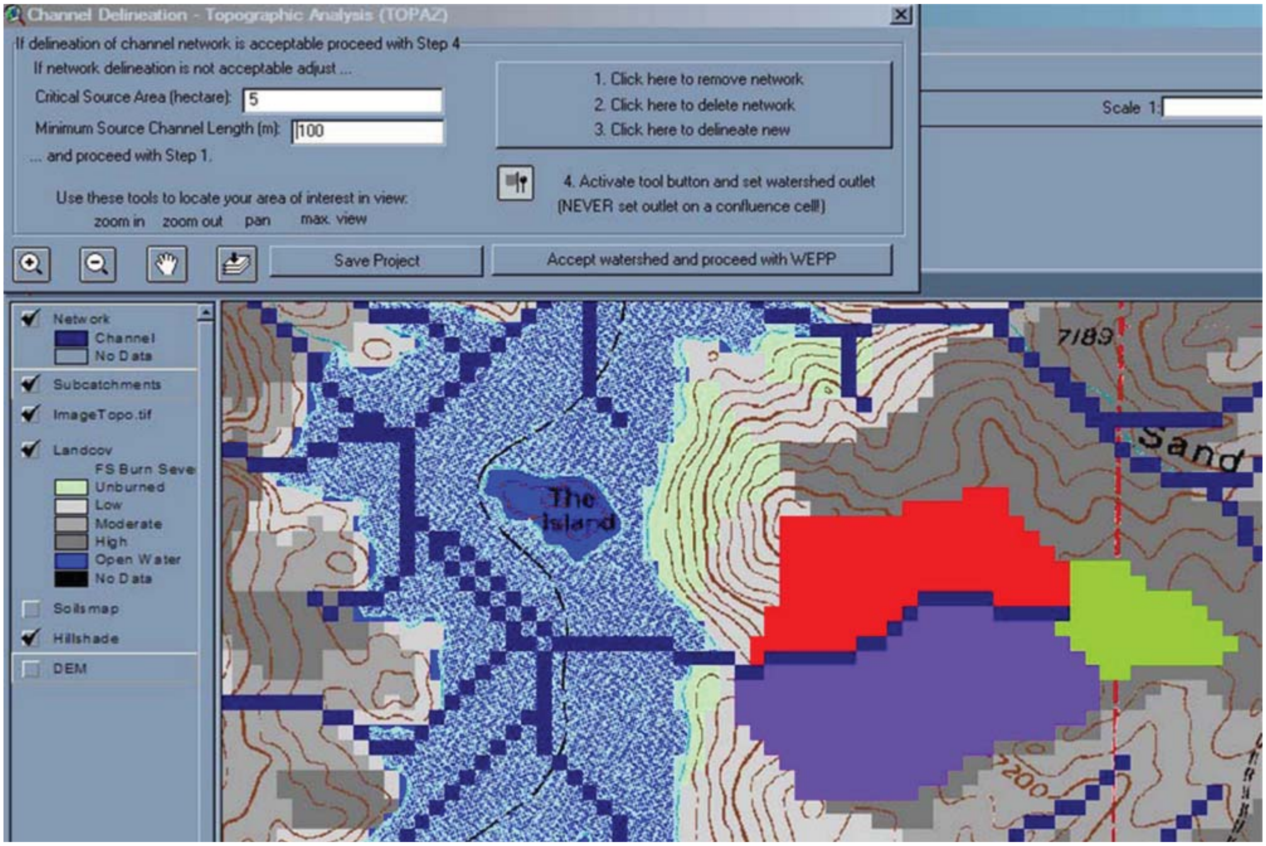
In this study and a previous study, researchers performed an extensive amount of work to strengthen GeoWEPP's ability to assess erosion risk and simulate erosion events by representing the real world as closely as possible. In addition, researchers focused on erosion risk as a result of wildfire and fuel management activities. Throughout this process both the WEPP model and the GeoWEPP technology have undergone numerous modifications, with WEPP being revised to model steep forest watersheds with shallow soils more precisely and the GeoWEPP technology being rewritten and converted.

Researchers also recognized the need to tap into the wealth of information provided by the Internet and other technology tools. Therefore, it was important to modify GeoWEPP to successfully use and integrate these different types of information. GIS provide a series of interfaces to help users with varying levels of GIS knowledge to access the data they need, whether it's GIS data, GPS databases and/or free, nationwide data sets. GIS are especially helpful when managers need to perform advanced modeling in areas that are complex, spatially variable and difficult to access. GeoWEPP also provides access to commonly available data sources on location and climate, such as the Digital Raster Graph (DRG), created by the U.S. Geological Survey (USGS), and the Climate Generator (CLIGEN), developed by the Agricultural Research Service.

In addition to acquiring geographic data, being able to precisely represent the topography of the land is key to assessing erosion potential. Physical characteristics of a slope such as slope length, shape and gradient can influence how water flows across the surface, and ultimately affect how and where the soils erode. In a GIS, the digital elevation model (DEM) is a digital file that consists of



This sample DEM represents a portion of Blanco Peak, CO and is known as a 2-arc-second DEM, a standard product of the National Mapping Program of the USGS. DEM's like these are produced as a by-product of cooperative partnerships with the Defense Mapping Agency, the Forest Service and the Bureau of Land Management (BLM). Credit: USGS Rocky Mountain Mapping Center.



Based on a specified outlet point, TOPAZ creates the subcatchments. Each channel within the watershed will have up to three subcatchments, one that represents the source and two that represent the contributing areas on the left and right sides of the channel. In the simple watershed indicated here, only three subcatchments are created. However, as the complexity of a watershed increases, so will the number of subcatchments. Credit: Martin Minkowski.

terrain elevations for ground positions at regularly spaced horizontal intervals, which helps represent topography, hydrological flow and connectivity. To run GeoWEPP, users must plug their own DEM into the program but must be aware that the resolution of the DEM will impact the clarity and accuracy of the results.

Next, a channel network is created within GeoWEPP using TOPAZ, a topographical parameterization software. TOPAZ is the essential link needed to provide a detailed analysis of a specific topography and visually delineates the drainage network within that landscape. When a DEM is used, TOPAZ and the DEM work together to produce a predicted channel network based on user-defined parameters. As a result, users are better able to understand the nuances of the terrain and thus more accurately predict erosion and runoff at the hillslope and watershed scale.

Quicker response to emergency situations

Being able to take action and stop erosion immediately after a wildfire is the primary goal of a burned area emergency response (BAER) team. Once a fire has been extinguished, a BAER team surveys the burned area to determine where to implement soil management and erosion prevention plans. Once surveyed, the BAER team can inhibit destructive mudflows and rehabilitate the burned area by creating structures, moving large fallen trees, planting grasses and distributing ground cover material. To help speed this process, BAER teams have used GeoWEPP. For example, in 2004, GeoWEPP helped the BLM analyze the Andrews Fire in the wildland urban interface of Reno, Nevada. The analysis highlighted the main risk as runoff, not erosion, and was proven to be correct on December 31, 2004, when a major flood event caused significant property damage on one of the burned watershed outlets. GeoWEPP was also used in 2005 to help a BAER team assess a substantial fire which burned 50,000 acres in the Umatilla National Forest, located in the Blue Mountains between Washington and Oregon. The BAER team used GeoWEPP to model ten watersheds within the fire area to help identify the watersheds that were of the greatest interest and determine the burn severity of each hillslope. GeoWEPP was also helpful in estimating hillslope parameters for use with the Erosion Rehabilitation Management Tool (ERMiT), providing the BAER team with a greater understanding of what rehabilitation method was needed and where it should be applied.

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The Forest Service Interagency Joint Fire Science Program (JFSP) recognizes the importance of having a tool that enables faster response times as well as provides more precise visualization and prediction of erosion patterns and sediment yields. As a result, the organization continues to invest in and support GeoWEPP's ongoing development.

A Boise National Forest Hydrologist uses water to test the effects of fire on the soil. Credit: Tina Boehle, BLM.

The evolution continues

Due to the extensive work performed in this study and a previous study, GeoWEPP has an improved ability to predict erosion and support fuel management and wildfire rehabilitation activities. By providing users with access to a multitude of digital image and data resources, they gain a clearer picture of the real-life topography and conditions of a given area, which ultimately enables better decision making, erosion assessment and overall land management. Beyond fuel management and rehabilitation, GeoWEPP can also be used by other disciplines to help manage natural resources, for example, at construction sites or developing ski areas.

But with any complex objective, there is still more work to be done. Validation of the GeoWEPP software is ongoing and continual improvements are being made as technology and erosion prediction evolves. Various agencies such as the Forest Service, BLM, Natural Resources Conservation Service (NRCS), and universities have received technical support and education on how to apply the products. And further progress is being made to integrate GeoWEPP with the following data resources:

- Geospatial Data Gateway, NRCS
- Digital Orthophoto Quadrangle, USGS
- Parameter-elevation Regressions on Independent Slopes Model, Oregon State University
- Geographical Coordinates and Elevation, Precision Farming with Global Positioning System
- Soil Survey Geographic database, NRCS
- Land Cover Characterization Program, USGS
- Cropland Data Layer, National Agricultural Statistics Service

Management Implications

- Users can access and incorporate available geographic information into GeoWEPP via Geographic Information Systems, Global Positioning Systems and other data sets.
- BAER teams can use GeoWEPP to develop effective erosion prevention and management plans, resulting in more rapid response and implementation.
- Managers can now use either the ArcView or ArcGIS version of GeoWEPP to perform their analyses.
- New soils and vegetation databases are available in the WEPP model.
- GeoWEPP now provides the ability to incorporate risk into watershed erosion prediction by allowing users to analyze precipitation, runoff, soil loss and sediment delivery events.

Further Information: Publications and Web Resources

GeoWEPP Web site: www.geog.buffalo.edu/~rensch/geowepp/index.html

New York Times. 2003. "What's Next: Mapping Technology Speeds Help to Fire-Scarred Land": http://www.nytimes.com/2003/08/07/technology/what-s-next-mapping-technology-speeds-help-to-fire-scarredland.html?scp=1&sq=What%27s+Next%3A+Mapping+Technology&st=nyt

U.S. Geological Survey, Rocky Mountain Mapping Center Web site: http://www.usgs.gov

Scientist Profile

Associate Professor of Geography and a Research Scientist of the National Center for Geographic Information and Analysis (NCGIA) at the University of Buffalo, Dr. Chris Renschler is Director of the Landscape-based Environmental System Analysis & Modeling (LESAM) laboratory. The LESAM lab's mission is the development and implementation of integrated, user-friendly analysis and modeling techniques using GIScience, Remote Sensing, Environmental Modeling, and readily available data sets to support rapid, practical and effective decision-making in managing natural resources and extreme events. Chris Renschler earned a PhD in Natural Sciences from the University of Bonn, Germany and a Master's Degree in Geoecology from the University of Braunschweig, Germany. Dr. Renschler has written various peer-reviewed articles, received numerous competitive and non-competitive extramural research grants and awards and has contributed to countless research projects (both completed and ongoing).

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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