

An ArcGIS Toolkit to Assist in Using Digital Soil Data for BAER Erosion Hazard Ratings

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abstract

After a wildfire, understanding a landscape's response to precipitation is essential. Land that has been stripped of its vegetation and soils that inhibit infiltration create a situation that can have disastrous effects, including severe erosion and landslides. Increased sediment in streams from soil erosion can result in fish kills and degraded water quality. Soil scientists play a key role in post-wildfire assessments and rehabilitation. The formal team assigned to assess post-fire landscape damage is known as a BAER (Burned Area Emergency Response) team. BAER teams must complete their assessment within 7 d of a fire's containment, and having soil survey data available makes the job much easier. One of the tasks for soil scientists on BAER teams is to assess the potential for erosion in areas damaged by the fire. The Smokey BEHR (BAER Erosion Hazard Rating) Toolkit for GIS isolates soil survey data within the fire perimeter and distills some of the most important soil attributes from SSURGO (Soil Survey Geographic) data into a readily usable format. Combined with burn severity information from a Burned Area Reflectance Classification (BARC) raster layer, areas with high erosion hazard can be quickly identified and targeted for treatment.

In the western United States, large, damaging wildfires occur every year. In 2008, more than 5 million acres of U.S. wildlands burned, and nearly 40% of those acres were on Federal lands (National Interagency Fire Center, 2009). These fires can be tens of thousands of acres in size and burn for weeks or months. Because the storms that follow the fire season can cause increased erosion and sediment in the streams, as well as mudslides, the many communities adjacent to the large areas of recently burned wildlands have cause for concern. Soil scientists play an important role in assessing the potential hazard across such areas and recommending treatments to prevent soil movement and protect resources and private property.

When the acreage of a fire on Federal land exceeds 300 acres, a BAER team may be called in to assess the need for post-fire treatment. BAER teams vary in size according to the size of the fire and the availability of personnel, but usually include a soil scientist and hydrologist. On larger fires, assessment often begins before the fire is fully contained, leading to technical challenges in accessing a site, assessing post-fire conditions in areas recently burned, as well as updating post burn conditions as the fire continues to grow. However, because the final BAER team report is required within 7 d of a fire's containment, the post-fire emphasis is on rapid assessment of conditions and proposed burn area mitigation treatments. Ideally, implementation of treatments will begin before the first damaging storm, a feat that can be challenging with late summer fires, which are frequently exacerbated by dry conditions. In

addition, the timeframe between fire and storm can be short, making quick, accurate landscape assessment highly desirable.

Since soil scientists often travel to fires in locations with which they are not familiar, one key to rapid assessment is having soils data readily available. With such data, soil scientists can begin to target areas with a higher potential for erosion and sedimentation problems and focus the limited field time available on areas of highest concern. Often there are hardcopy soil reports available, but although better than having no information at all, these are of no use in a Geographic Information System (GIS), where much of the other pertinent BAER information (e.g., fire perimeter) exists. While digital, spatial data are available from the Soil Data Mart for many surveys, making the link to the soil attribute data is cumbersome and challenging to access for many with only basic GIS skills.

GIS has become an important tool in the BAER rapid assessment process (USDA Forest Service, Remote Sensing Applications Center, 2009). Maps are created to assist with field surveys. Mileages and acreages are calculated to determine the extent of the fire's impact and assist with calculating costs of potential treatments. The BARC raster layer is used in conjunction with other locational data, such as roads, streams, and topography. Also, the ability to overlay and query many datasets takes much of the guesswork out of the tabulations required in the final BAER report.

Having soil survey data in GIS greatly improves the efficiency of the soil scientist in determining potential erosion hazard because areas of moderate or high burn severity can be linked directly to soil map units and their properties. However, GIS specialists are often unfamiliar with complexities and many-to-many relationships in SSURGO data (USDA-NRCS Soil Survey Staff, 2009). Many soil scientists, who understand the data and their needs, lack the GIS experience to perform the complex joins and analyses required to make the data accessible. The Smokey BEHR Toolkit bridges that knowledge gap and gives the soil scien-

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U.S. Forest Service soil scientist Dave Young measures infiltration as part of a BAER team onsite assessment following a wildfire.

tist better access to the data needed. It does not calculate the erosion hazard and take the place of the soil scientist, whose expertise in interpreting the data is still required for the tools to perform the analysis.

Data Requirements

There are four data requirements for the Toolkit to run in its entirety. First, soil data in SSURGO format must be available. Datasets are available from the Soil Data Mart (<http://soildatamart.nrcs.usda.gov/>) or the Geospatial Data Gateway (<http://datagateway.nrcs.usda.gov/>). Both sites are maintained by the USDA-NRCS. The spatial data are delivered via ftp in ESRI shapefile format (Environmental Systems Research Institute, 2009). The tabular data are delivered as .txt files, which are then loaded into a Microsoft Access template. NRCS provides comprehensive documentation for accessing SSURGO data at the Soil Data Mart website. Once the soil data have been acquired and the tabular data imported into Access, additional steps must be taken to make them fully accessible in a GIS and usable in the Toolkit.

Second, since the focus of the Toolkit is BAER work, the Toolkit asks for a fire perimeter to limit the data analysis extent. In reality, any polygon would work (e.g., watershed). In the initial analysis phase, the tool does not clip the data but selects soil map units that intersect the fire area (Fig. 1a). The rationale for not clipping the data at the outset is that it allows the soil scientist to see how far a map unit extends outside the burned area and qualitatively assess how that might influence their analysis and subsequent treatment recommendations. Although not necessary for determining the erosion hazard rating, it is considered a benefit to the rapid assessment process in that it provides a bigger picture of the surrounding landscape (USDA Forest Service, Region 5. Dave Young, Brad Rust, ongoing personal communications, January 2008 to October 2009).

Third, a key element in determining the potential erosion hazard rating is vegetative cover. The U.S. Forest Service Remote Sensing Applications Center provides a satellite-derived raster image of a fire known as a BARC layer (Fig. 1b). The Center compares near and mid-range infrared values from both pre- and post-fire imagery and creates a layer that approximates burn severity (USDA Forest Service, Remote Sensing Applications Center (2009). The layer is classified, before delivery to the user, into four classes: unburned, and low, moderate and high burn severity. Users can change the predefined classes if better information is



The Oregon fire burns outside the town of Weaverville, California in 2001. Photo courtesy of Wayne Moss.

available from onsite examination. When the BAER team is satisfied with the BARC layer, it is reclassified into the four severity classes with values from 0 to 3. The layer then serves as a proxy for vegetative cover change when erosion hazard is assessed.

The fourth and final data element requirement is a table generated by the soil scientist based on soil attributes, field investigation, and professional expertise. It requires knowledge of how erosion is affected by attributes such as slope, surface texture, and hydraulic conductivity. In addition, a site assessment of fire-induced hydrophobicity allows the soil scientist to adjust the erosion hazard rating parameters to more accurately reflect local conditions. In California, many soil scientists have adopted the methodology put forth by the California Soil Survey Committee (1990) for computing erosion hazard ratings. The components for the calculation include erodibility, runoff, slope, and cover factors. The toolkit provides the user with many of the attributes required to make an informed assessment of these factors, but leaves the rating process up to the individual preferences and expertise of the soil scientist. The table the soil scientist generates (by whatever process) gives an erosion hazard rating to each soil map unit under each of the four potential burn severity classes.

The Toolkit

The Toolkit has four tools that can be used in stepwise fashion to aid the soil scientist in determining the erosion hazard potential in a post-fire rapid assessment situation. The tools append the tabular soil data to the selected spatial layer, export the data, combine the soil and burn severity layers, and output an erosion hazard rating layer based on user input (Fig. 2). They are designed to work together but, to some extent, they can be used independently. The documentation provided with the Toolkit download explains each tool's purpose, requirements, and output. The user has a great deal of flexibility in naming conventions and data output locations, but because the Toolkit uses standardized data, there is little to no ability to format the data itself to one's preferences. The Toolkit requires ESRI ArcMap 9.3 GIS software, was written with ModelBuilder, and is delivered

-  **EHR Tools**
-  **1 - Create Soil Data Layer**
-  **2 - Export Data to Table**
-  **3 - Merge Soil and BARC4 Layers**
-  **4 - Create EHR Layer**

Fig. 2. Tools provided by the Smokey BEHR Toolkit.

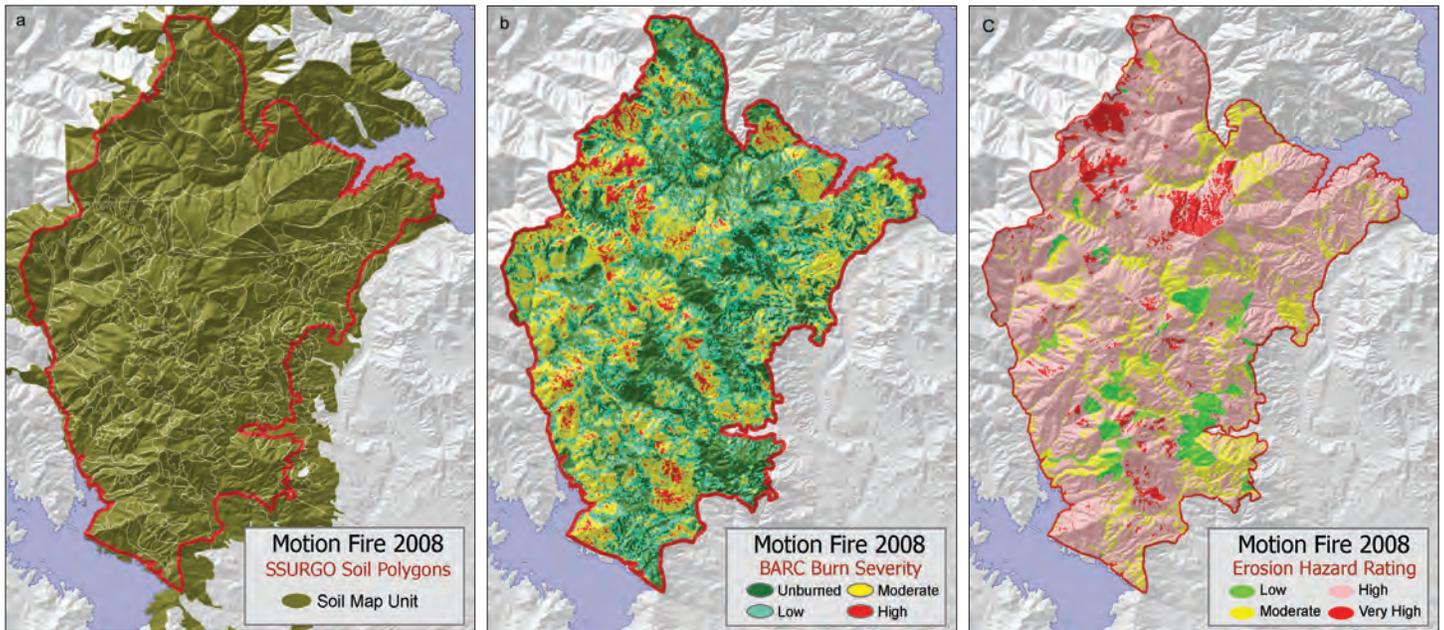


Fig. 1. (a) Soil map units which intersect the fire are selected and attributed with the “Create Soil Data Layer” tool. (b) BARC raster layer provided by USDA Forest Service Remote Sensing Applications Center depicting burn severity and used as a proxy for vegetative cover when determining erosion hazard potential. (c) Erosion hazard rating layer produced by the “Create EHR Layer” tool.

as zipped file with four subfolders and the EHR Tools toolbox (Fig. 3). Documentation from NRCS on using SSURGO data, some sample data, and empty geodatabases to get the user started are also included.

The Tools

Create Soil Data Layer

The “Create Soil Data Layer” tool selects soil map units within the fire perimeter and appends selected soil attributes to the polygons. The attributes were chosen because they offer useful information about the soil map unit that the soil scientist can use to help determine the ero-

sion hazard rating (USDA Forest Service, Region 5. Dave Young, Brad Rust, ongoing personal communications, January 2008 to October 2009). Compared to the complexity of the SSURGO database and the many-to-many nature of soil survey data, the output of this tool is decidedly spartan but aims to offer enough information to give the user a “quick look” at certain soil properties. Three categories of data are attached to the soil polygons, each with an increasingly tighter view of the soil map unit qualities. The first category is map unit level data. These include the soil survey area (areasymbol), map unit symbol (musym), and the map unit name (muname). The second category is major component level data and these attribute names are preceded in the table with “mc_” (e.g., mc_name is the name of the major component). When a map unit

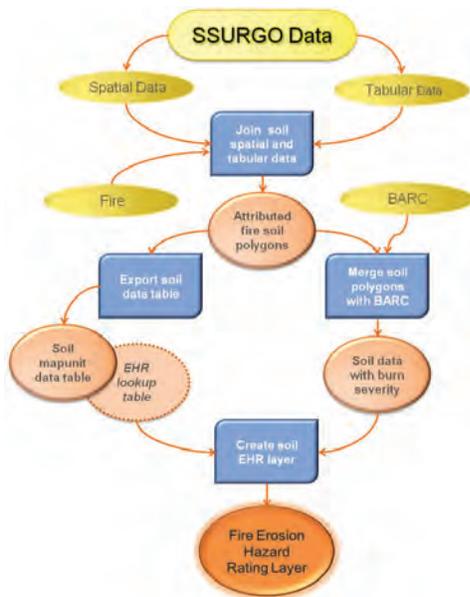


Fig. 3. General process of the Smokey BEHR Toolkit for creating an Erosion Hazard Rating GIS layer after a wildfire.

Table 1. Data elements appended to the spatial data layer by the “Create Soil Data Layer” tool.

Column name	Description
ObjectID	OID created by ArcGIS
Shape	Type of features
AreaSymbol	Soil survey area
SpatialVer	Spatial data version
Musym	Soil map unit symbol
Mukey	Key that links tabular data to soil polygon
Muname	Soil map unit name
Mc_pct	Percentage of the major component in the map unit
Mc_name	Name of the major component in the map unit
Mc_loslp	Low slope of the component (percent)
Mc_hislp	High slope of the component (percent)
Mc_runoff	Runoff category of the component
Mc_drncls	Drainage class of the component
Mc_hydgrp	Hydrologic soil group of the component
Mc_taxon	Taxonomic classification of the component
H1_depth	Depth of the first horizon of the major component
H1_loksat	Low ksats value of the first horizon
H1_hiksat	High ksats value for the first horizon
H1_frag_wt	Percentage by weight of > 2mm fraction of the first horizon
H1_fragvol	Percentage by volume of > 2mm fraction of the first horizon
H1_texture	Surface horizon textural modifier and class
Shape_length	Perimeter of the polygon
Shape_area	Area of the polygon

has more than one major component (as with a complex or association), the major component with the highest percentage in the map unit is used. The final category is horizon level data and focuses on the surface horizon. These attributes are preceded in the table by “h1_”. The attributes extracted are shown in Table 1. No attempt was made to determine if data elements were unpopulated at the SSURGO level so columns may be blank or populated with zeros in the output feature class.

Export Data to Table

The “Export Data to Table” tool simply exports the soil tabular data described above to a dBase file that can then be viewed in Excel or other spreadsheet programs. The purpose of the tool is to make the attribute data more accessible by making it available outside of ArcGIS but its use is not required. The data can be exported using any of the native ESRI functions or not exported at all if the user prefers to assess the attributes within GIS. To facilitate ease of use, the tool allows the user to eliminate certain columns in the output table so that unnecessary data export is minimized.

Merge Soil and BARC4 Layers

The “Merge Soil and BARC4 Layers” tool clips the soil layer to the fire perimeter and then combines this information with the BARC raster layer. The result is a layer that shows the burn severity by each soil map unit within the fire perimeter. The tool calculates acres for each of the soil map unit–burn severity combinations as long as the coordinate system unit is meters (e.g., UTM). The BARC grid is converted to a feature class before it is merged with the soil polygon layer. The conversion does not simplify the polygons so the output maintains the square polygon “grid look.”

Soil scientists may use the output for assessments other than erosion hazard rating. For example, the BAER specialist’s report requires a number of acreage assessments by burn severity, and the output from this tool provides the ability to categorize soil map unit acres by the burn severity classes. This allows the user to see selected map units that may or may not be affected by high burn severity or only an acre or two of a map unit that falls into a moderate or high burn severity class. Such specific information can help the soil scientist focus time and analysis on map units with the highest potential for landscape stability problems. The user may want to run this tool and create a summary table before creating the EHR lookup table for the next step. In the rapid assessment process, knowing which map units are only lightly affected and which require a harder look can speed the process along considerably.

Create EHR Layer

The “Create EHR Layer” tool derives the EHR layer from the merged soil–BARC layer and a lookup table created by the soil scientist. It looks for each of the map unit–burn severity combinations and then attributes the polygons with the appropriate EHR value. The result is drawn to the screen using symbology from a layer file provided with the Toolkit (Fig. 1c). The user must provide a lookup table showing each map unit’s erosion hazard rating under each of the four burn severity classes. The

ratings can vary from low to very high and are based on the soil scientist’s expertise, field observations, and evaluation of the soil properties provided by the soil data layer created with the first tool.

The output layer maintains the “Unburned” EHR value so it can be determined what, if any, effect the fire has had on the soil’s erosion hazard potential. Using ArcMap’s “Select by Attributes” function, users can select where the current EHR value is equal to the unburned EHR value to see where there has been no change. These areas represent a lower priority for treatment since the team’s focus is on soils that have been adversely affected by the fire.

Summary

In a post-wildfire assessment, soil scientists must work quickly to determine the extent to which the area has become susceptible to erosion. The process involves consulting existing soil information and burned area field examinations. Often the time for comprehensive examination is short, and the recommendations for treatments to mitigate the fire-induced effects must be delivered within days of a fire’s containment. In areas where SSURGO certified data are available, the Smokey BEHR Toolkit for GIS can greatly reduce the amount of time spent extracting soil attribute data and running burn severity analyses for soil map units. The tools perform some of the more complex GIS functions so the soil scientist can spend time and expertise determining the potential erosion hazard.

Looking Ahead

The Toolkit was tested on several fires in the summer of 2009 and received very positive feedback. Some suggestions for expansion include adding parent material (which can be somewhat problematic with soil series that occur on a variety of parent materials) and the unmodified surface texture. There is a potential improvement being discussed that would allow users to select a secondary component if the dominant component in the soil map unit is rock outcrop or another miscellaneous land type. Careful consideration must be made, however, to keep the tools simple and easy to use, lest they become more time consuming than useful.

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