PREDICTING WATERSHED IMPACTS OF FOREST FUEL MANAGEMENT WITH WEPP TECHNOLOGY

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Abstract A new interface has been developed to specifically aid forest managers in evaluating hillslope sediment yields of fuel management activities in forested watersheds. From a single input screen, twelve computer runs are carried out, and the run results and a narrative are generated to aid the user in incorporating the results into an environmental analysis document. This tool will simplify synthesizing the watershed impacts of forest fuel management activities.

INTRODUCTION

One of the main products of many forests is surface water. The main pollutant in most forest streams is sediment. Upland management disturbances including fuel management activities and forest roads can cause erosion, leading to increased stream sedimentation and reduced water quality. Forest managers need to evaluate the impact of most forest activities on stream sedimentation, including fuel management. Fuel management activities include thinning and prescribed fire. With ground-based thinning operations, a road network must also be maintained.

A suite of Internet interfaces were developed to assist users in predicting soil erosion from disturbed forest hillslopes and forest roads (Elliot, 2004). As users were shown how to use these tools, they found the final synthesis of the information difficult to complete. Road erosion was in kg (lbs) sediment from a road section, and hillslopes in Mg/ha (tons/acre) in the year of the disturbance. Also, road segments generated sediment every year, whereas wildfire would only cause erosion for a year or two following the fire. Erosion from thinning and prescribed fire occurs every few decades. A tool was needed to synthesize the results of numerous erosion predictions, and aid users in interpreting those predictions.

To meet this need, a computer Internet interface was developed to assist with synthesizing soil erosion rates associated with fuel management activities in forests, named “WEPP FuMe”. This interface estimates background erosion rates, and predicts erosion associated with mechanical thinning, prescribed fire, and the road network. The interface uses the Water Erosion Prediction Project (WEPP) model to predict sediment yields from hillslopes and road segments to the stream network. The WEPP model is a physically-based soil erosion model developed over the past 15 years to predict soil erosion and sediment yields for agriculture, rangeland, and forest conditions (Laflen et al., 1997). The simple interface has a large database of climates, vegetation files, and forest soil properties. The soil databases for roads and disturbed forested hillslopes are based on rainfall simulation and natural rainfall studies carried out over the past 20 years (Elliot and Hall, 1997). To simplify the coding, the vegetation input to the WEPP model for WEPP FuMe was set to have a constant ground cover (no vegetation growth, no residue decomposition). A preliminary analysis to compare the effects of fixed cover showed that the impacts of this on predicted erosion was minimal for highly disturbed conditions, but may lead to over prediction of low erosion rates.

For this application, the WEPP hillslope version was used to model a single strip of hillslope (Figure 1). It was assumed that the sediment generated from this hillslope from a number of disturbances was routed through the watershed. In the year of the disturbance, there is likely to be deposition of sediment from the disturbed hillslope in the stream network. This sediment is gradually routed through the watershed in subsequent wet years. If the years are dry, there is unlikely to be any sediment routed. As the disturbed hillslope recovers, erosion from that hillslope will gradually decline. This application assumes that road erosion occurs every year, with the magnitude dependent only the level of traffic and the weather during the year. As more than one hillslope may be disturbed during a given sequence of fuel management activities, users will likely carry out the analysis for numerous hillslopes, and combine the final results.

DESCRIPTION OF WEPP FUME

The WEPP FuMe interface carries out erosion prediction runs for seven forest conditions:

1. Undisturbed mature forest
2. High severity wildfire
3. Prescribed fire
4. Thinning
5. No traffic roads
6. Low traffic roads
7. High traffic roads

In addition to the above runs, WEPP FuMe carries out an additional five runs for moderate and low severity wildfire, higher and lower severity prescribed fire, and lower impact thinning, such as cable logging.

The climate, soil texture, topography, road density, wildfire return interval, prescribed fire cycle and thinning cycle are specified by the user.

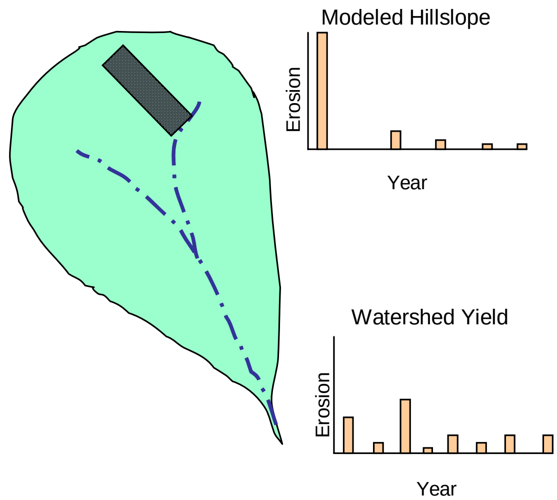

Figure 1. Diagram of a WEPP FuME hillslope within a watershed, and relationship of timing and magnitude of sediment generation from the hillslope and the watershed

<u>Assumptions in WEPP FuMe</u> The WEPP FuMe interface makes a number of simplifying assumptions for the twelve runs. Table 1 shows some of the assumptions for the first seven runs. The five additional runs aid the user in developing alternative management scenarios. If users wish to consider disturbances other than those presented in Table 1 or the additional runs for disturbed forests, such alternatives can be evaluated with the Disturbed WEPP interface (http://forest.moscowfsl.wsu.edu/fswepp/).

Table 1. Main assumptions for WEPP FuME runs

Run	Assumptions
Undisturbed forest	"20-yr forest" soil* Ground Cover 100 percent, including buffer All buffer slopes assumed to be half the hillslope steepness
Thinned forest	"5-yr forest" soil Ground cover 85% on treated hillslope, 100% on buffer
Prescribed fire	"Low Intensity Fire" soil Ground cover 85% on treated hillslope, 100% on buffer
Wildfire	"High Intensity Fire" soil Ground cover 30%, no buffer
No traffic road	Gradient = 1/10 of hillside slope, road length = 300 ft, width is 13 ft Treatment is insloped vegetated ditch, vegetated surface, no traffic Fillslope length is 30 feet, and steepness is twice the hillslope steepness Buffer length and steepness as specified
Low traffic road	Gradient = 1/10 of hillside slope, road length = 300 ft, width is 13 ft Treatment is insloped vegetated ditch, native surface, low traffic Fillslope length is 30 feet, and steepness is twice the hillslope steepness Buffer length and steepness as specified
High traffic road	Gradient = 1/10 of hillside slope, road length = 300 ft, width is 13 ft Treatment is rutted, gravel surface, high traffic Fillslope length is 30 feet, and steepness is twice the hillslope steepness Buffer length and steepness as specified

*Soils refer the nomenclature associated with the Disturbed WEPP database (Elliot, 2004)

Mechanics From the online input screen, the input data files are formatted for the WEPP model for each of the seven runs. The WEPP model is then run on the server for each condition. The results of the runs are converted into common units of tons sediment delivered per square mile per year and presented in tables with an accompanying summary narrative.

For the road analysis, roads may deliver sediment to a stream crossing, or may have runoff and sediment diverted across the specified buffer before entering a stream. For "No Treatment," it is assumed that some roads will have no traffic, while others have low traffic, so the predicted sediment yield range is from no traffic with a buffer to low traffic with no buffer. For the treatment scenario, it is assumed that some of the roads will be low traffic and others will have high traffic with gravel. Therefore sediment yields will range from the lowest value from low traffic or high traffic with a buffer to the highest value from low traffic or high traffic with no buffer. The true road impact will be somewhere between these two values. Users who wish to make a more detailed analysis of road sediment generation can use either the WEPP:Road or WEPP:Road Batch interface (http://forest.moscowfsl.wsu.edu/fswepp/).

Background Sediment Frequently "background sediment" is considered sediment eroded from undisturbed forests. Numerous studies on forests with even low levels of disturbance have shown that erosion rates from areas of minimal disturbance are near zero (Covert, 2003). Generally, background rates measured at watershed scale are in the order of 10 t/ sq km (25 ton/sq mi). Some have attributed these numbers to landslides in the watershed, others to stream channel erosion. The WEPP FuMe technology attributes much of this sediment to the routing of sediment stored in watersheds following the last major wildfire. Following a wildfire, upland erosion rates can exceed the transport capacity of forest streams, causing an accumulation of sediments in upland channels. During the decades following the wildfire, this sediment is gradually routed the stream network. There will be high rates of sediment transport in years of higher runoffs, and low to no sediment transported during years of low runoff. An "average" background number can be estimated by dividing the estimated erosion following wildfire by the number of years between wildfire events, called the "fire return interval."

Currently, most forest watersheds have a significant network of roads. In the past, it was assumed that sediment from these roads was beyond any "background" value, and thus must be considered as excess sediment associated with any watershed planning. This assumption does not address the current realities, that the citizens expect to be able to access public lands. This means that at least a part of the current road network on public is now permanent, and managers may wish to incorporate sediment from the permanent network into the "background" sediment. The road network will contribute sediment to the stream network every year.

Scope of WEPP FuMe The WEPP FuMe interface can be used anywhere within the U.S. using the existing climate database. It is intended to provide an overview of the sources of sediment on a given fuel management site. Users who want more detailed analysis will have to use more complex interfaces available online (http://forest.moscowfsl.wsu.edu/fswepp/) or standalone windows (USDA, 2004) or GIS interfaces (Renschler, 2004).

Sediment predictions from WEPP FuMe are for surface erosion only. In some watersheds, landslides may be a significant source of sediment, and in others, stream channels may be sources of sediment. Users will need to obtain estimates for these potential sources of sediment from local specialists.

Data Input Needs The WEPP FuMe input screen has several input fields for selecting climate and soil, and specifying road density, hillslope and buffer lengths, hillslope steepness, wildfire return interval and frequencies of proposed treatments.

Climate Database The climate database includes the statistics from over 2600 weather stations. In addition, the monthly precipitation estimates for every 4-km grid in the conterminous U.S. is also online (Scheele et al., 2001). Users also have the option of using their own monthly temperature and precipitation data.

Soil The soil texture field contains four USDA soil textures, sandy loam, silt loam, clay loam, and loam. In the database behind the input screen, each of these textures includes the erodibility properties for each soil disturbance condition ranging from a native surface road to a wildfire and an undisturbed forest. Once a texture is selected, the appropriate erodibility values for that texture are used for all the soil components of the twelve runs. Research has found that small differences in texture are much less important than the nature of disturbance in determining forest soil erodibility (Robichaud et al., 1993).

Road Density The road density is the length of road per unit area of forest. Typical values range from 0.8 to 2.4 km/sq km (2 to 6 miles/sq mi) of road in managed forests. In some cases, roads may be on ridge tops. Ridge top roads, greater than about 100 m (300 ft) from ephemeral channels, are unlikely to contribute sediment to the stream system. Users may wish to ignore these roads.

Topography In the topography fields, the user is asked to input values for a typical horizontal slope length and steepness. Slope lengths and steepnesses can be obtained from field surveys or contour maps. Users may also have access to GIS topographic analysis tools to aid in estimating these values, providing average values, or determining a range of topographic values to consider. A special tool has been developed to obtain details of individual hillslopes developed by the GeoWEPP wizard (Renschler, 2004) for entering into the WEPP FuMe interface. Users also enter the horizontal length of any buffer strips of undisturbed forest between the treated areas and the stream system. These buffers are ignored for the wildfire run, and are the default distances used for the road erosion runs for the buffer estimates. Users may wish to evaluate several different buffer widths to determine the optimal width for their conditions. They may also wish to evaluate several different slope lengths or steepnesses to evaluate a range of conditions and determine which sites are likely to generate more sediment. In some of the wetter climates, the buffers may not reduce sediment delivery because they may become sources of sediment.

Disturbance Return Periods Hillside disturbances do not happen every year. The user must specify the wildfire return interval, and the frequency of thinning and prescribed fire. The wildfire return interval will likely range from 20 years with low elevation, dry forests, to 200 years with high elevation moist forests, to 300 years with very wet forests on the west slopes of the Cascades or the Coastal ranges (McDonald et al. 2000). Prescribed fire return periods can vary from 2 to 40 years, or more, and thinning periods from 10 to 80 years.

WEPP FuMe OUTPUT

Once the twelve WEPP runs are complete, and the data are adjusted to common units, the input and output tables (Table 2) and narrative (Figure 2) are presented on the output screen. Details of all twelve runs are presented after the narrative. The user may wish to print this page, save it, or copy all or part of it for pasting into a spreadsheet or word processor.

On the output table (Table 2), the results from each of the four hillslope erosion runs are presented as average annual erosion rates, converted to tons/mi^2. The erosion rates for each of these hillside disturbances are divided by the frequency of the disturbances to get an average annual sediment yield expected from a watershed. The three road runs are summarized on a low access range (for no traffic and low traffic) and a high access range (for low traffic and high traffic with gravel). Road erosion is assumed to occur every year.

The narrative that follows (Figure 2) can serve as a basis for a report of the analysis. Users will likely want to incorporate information from some of the additional runs, carry out runs for other hillslopes or different buffer widths and modify the narrative to reflect what is learned from those runs within a final report. Users may wish to add a value for sediment from landslides or from stream channel erosion to background or treatment values.

Table 2. Results table from a WEPP FuMe run for a climate in the Bitterroot National Forest.

Source of sediment	Sediment delivery in year of disturbance (ton mi^{-2})	Return period of disturbance (y)	"Average" annual hillslope sedimentation (ton mi^{-2} y^{-1})
Undisturbed forest		1	83.2
Wildfire	7622.4	40	190.6
Prescribed fire	1075.2	20	53.8
Thinning	147.2	20	7.4
Low access roads	2.0 to 14.5	1	2.0 to 14.5
High access roads	4.2 to 14.5	1	4.2 to 14.5

Additional Information Details of inputs and outputs from the twelve runs are summarized at the end of the output page. The user can use these as guidelines to get additional information for any of the runs by clicking on the run description. Information includes surface runoff and probabilities associated with different amounts of erosion or sediment yield. The output information can also serve as a guide for the variables to enter into the Disturbed WEPP or WEPP:Road online interfaces so the user can use these interfaces to do a similar run, or to explore the sensitivity of the predicted sediment yields to the input variables.

The additional five runs can be used to present alternative options or outcomes, with the existing discussion serving as a guide for incorporating the results into an environmental analysis document. For example, the user may wish to present as an alternative to severe wildfire, a lower intensity wildfire plus impacts from the proposed fuel management activities. Another example might be to use the low impact thinning as an indication of the erosion associated with a cable thinning operation to compare to the erosion predicted from the assumed tractor logging operation in the main output to see if the extra costs associated with the cable operation are justified by reducing sediment generation.

VALIDATION

It is not possible to carry out an extensive validation of the predicted values. Validation of both the WEPP Road and Disturbed WEPP interfaces have been carried out (Elliot and Foltz, 2001). For example, the erosion rate presented in Table 1 for the Bitterroot National Forest can be converted to 27 t/ha for wildfire, and 4 t/ha for prescribed fire. These values can be compared to observed values in the Bitterroot National Forest of 31 Mg/ha (Spigel, 2002) following wildfire, and no erosion in the dry year (1994) following a prescribed fire (Covert, 2003). Running the prescribed fire scenario from the output screen showed that there was a 28 percent chance that there would be no erosion following wildfire.

Contents of Narrative

Background sedimentation.
Wildfire + Undisturbed Forests
With and without roads

Thinning effects.
With and without roads
Impacts on wildfire occurrence or severity

Prescribed fire effects.
Without roads
Impacts on wildfire occurrence or severity

Combined thinning and prescribed fire effects.
With and without roads
Impacts on wildfire occurrence or severity

Road Impacts
Effects of road design and management
Benefits of road removal

Multiple Hillslopes

Details of Inputs and Outputs for all 12 Runs

Figure 2. Outline of contents of the narrative section of the WEPP FuMe output.

SUMMARY

A new interface has been presented that was designed specifically to aid forest managers in evaluating watershed impacts of fuel management activities. From a single input screen, twelve computer runs are carried out, and the run results and a narrative are generated to aid the user in incorporating the results into an environmental analysis document.

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