Erosion Risk Management Tool (ERMiT) – A Probability-based Erosion Prediction Model

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After wildfires, land managers must assess the potential for increased flooding, erosion, and sedimentation, and the increased threat these effects may pose to people, structures, and valued resources. A Web-based Erosion Risk Management Tool (ERMiT) has been developed to predict surface erosion from postfire hillslopes, and to evaluate the potential effectiveness of various erosion mitigation practices. The model uses a probabilistic approach that incorporates temporal and spatial variability in weather, soil properties, and burn severity for forests, rangeland, and chaparral hillslopes. Using multiple runs of the Water Erosion Prediction Project (WEPP) model, ERMiT provides event-based erosion rate probabilities-with and without treatments-for five post-fire years.

Keywords: *post-fire modeling, erosion prediction, resource management, erosion control, BAER treatments, straw mulch, contour-felled logs, seeding*

Post-fire rehabilitation efforts continue to be a major land management activity due to the increase in the number, size, and intensity of wildfires in the western United States during the past decade. The threat of future wildfire damage to resources and property is creating a demand for effective erosion mitigation strategies as well as improved modeling tools on which to base treatment decisions. Post-fire rehabilitation treatments cannot prevent erosion, but they can reduce overland flow amounts, site soil loss, and sedimentation for some rainfall events. Thus the risk of postfire damage to water quality, habitat, roads, and other structures cannot be eliminated, but it can be reduced. It is useful to do risk assessments-balancing the increased risk of erosion, flooding, and other hazards against the risk reduction expected from specific treatments-when making postfire treatment decisions. The Erosion Risk Management Tool (ERMiT) (Robichaud et al. 2006, 2007; Robichaud et al. [in press]) has been developed to provide a risk assessment (i.e., probability-based) approach to post-disturbance erosion modeling and rehabilitation treatment effectiveness.

ERMiT provides probabilistic estimates of single-storm postfire hillslope erosion by incorporating variability in rainfall characteristics, soil burn severity, and soil characteristics into each prediction. ERMiT uses WEPP technology as the runoff and erosion calculation engine. WEPP simulates both inter-rill and rill erosion processes and incorporates the processes of evapo-transpiration, infiltration, runoff, soil detachment, sediment transport, and sediment deposition to predict runoff and erosion at the hillslope scale (Flanagan and Livingston 1995). Through the ERMiT interface, stochastic weather files generated by CLImate GENerator (CLIGEN) (Nicks et al. 1995) are selected for use in WEPP. Users may customize climate parameter files using the integrated Rock:Clime web interface (Scheele et al. 2001).

ERMiT users specify: 1. climate parameters based on location with adjustments made through Rock:Clime (Elliot 2004); 2. vegetation type – forest, range, chaparral; 3. soil type – clay loam, silt loam, sandy loam, loam-and rock content; 4. topography – slope length and gradient; and 5. soil burn severity class – low, moderate, high. These input choices are similar to other WEPP-based interfaces (Elliot 2004) (Figure 1). However, the incorporation of variability in these parameters and the probability-based output are unique to ERMiT.

The general process by which ERMiT incorporates parameter variability is to: 1) determine the range of possible parameter values; 2) select representative values from the range; and 3) assign an "occurrence probability" to each selected value such that the sum of assigned occurrence probabilities adds to 100 percent. Thus, all possible parameter values are represented in the model by the four to five selected values. The specific processes are:

Climate variability: Using a 100-year climate record generated by CLIGEN, WEPP is run for 100 years and the rain events with the greatest runoff from each year are rank ordered by runoff amount. The years and rain events with the 5th, 10th, 20th, 50th, and 75th ranked runoff amounts are selected for further analysis (Figure 2). Occurrence probabilities for the five rain events associated with the selected runoff events are 7.5, 7.5, 20, 27.5, and 37.5 percent, respectively.

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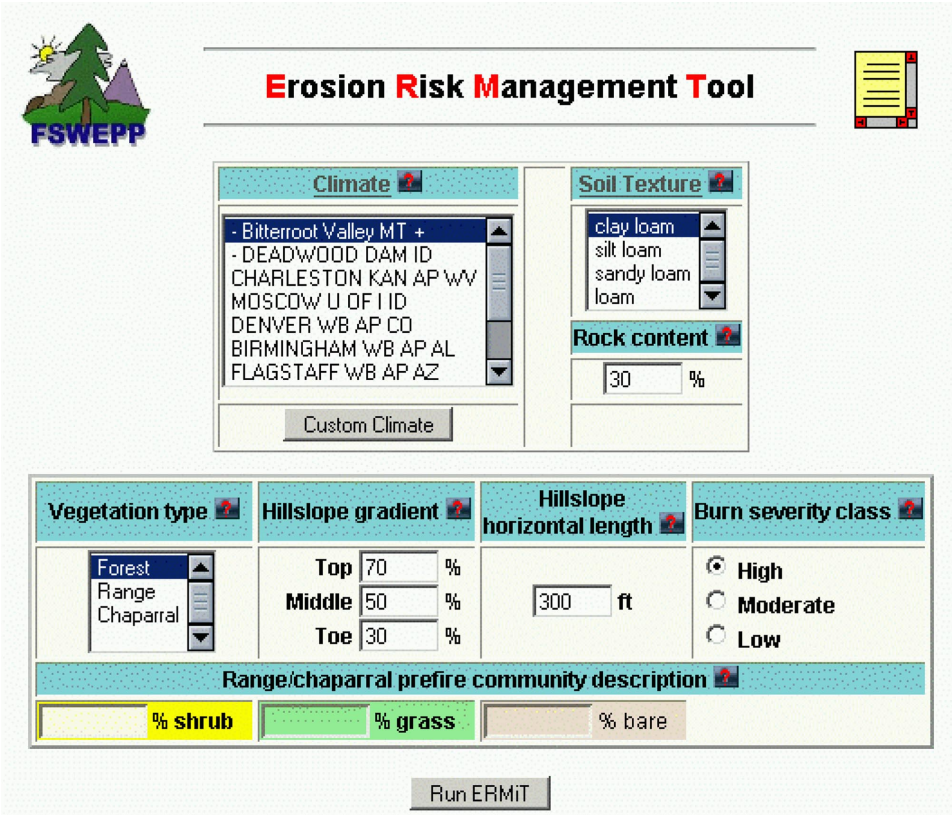

Figure 1. Example Erosion Risk Management Tool (ERMiT) user input screen accessed at http://forest.moscowfsl.wsu.edu/fswepp/.

Soil parameter variability: The variable effects of postfire ground cover, soil water repellency, and soil erodibility are modeled by variability in inter-rill erodibility, rill erodibility, effective hydraulic conductivity, and critical shear. Selected values, which vary by soil texture and soil burn severity, are grouped in five soil parameter sets from least erodible to most erodible. Thus, there are ten soil parameter sets for each soil texture-five for high soil burn severity and five for low soil burn severity. The five soil parameter sets (Soil 1, Soil 2, Soil 3, Soil 4, and Soil 5) are assigned occurrence probabilities of 10, 20, 40, 20, and 10 percent, respectively.

Soil burn severity spatial variability: WEPP models each hillslope in three sections, and in ERMiT each hillslope section can be either High or Low. Based on the user-designated soil burn severity input (high, moderate, or low), four spatial arrangements of High (H) and Low (L) sections, each with an assigned occurrence probability, are used. For example, a user designation of high soil burn severity will use four spatial arrangements of H and L for the three sections of hillslope (HHH, LHH, HLH, and HHL), which are assigned occurrence probabilities of 10, 30, 30, and 30 percent respectively.

Temporal variability: The changes in soil parameter values over time, due to recovery, are modeled by increasing the assigned occurrence probabilities of the lower erosion soil parameter sets and decreasing the occurrence probabilities of the higher erosion soil parameter sets. Also, the four spatial arrangements of hillslope sections are adjusted to include fewer high soil burn severity soil sets and more low soil burn severity soil sets with each year of recovery.

Through ERMiT, WEPP is run for each permutation of input parameters. Thus, every combination of the five selected rainfall events, five soil parameter sets, and four soil burn severity spatial arrangements is run to produce 100 event sediment delivery predictions. For each permutation, the product of the three component occurrence probabilities is the occurrence probability attached to the sediment delivery prediction. The probable erosion prediction output can be viewed in graphical (Figure 3) or tabular (Figure 4) form, with output data available for import into spreadsheets.

The interactive box in the tabular output screen allows users to delineate the level of risk (probability of exceedence) for potential erosion and then compare the relative effectiveness of various treatments to non-treatment as well as to one another (Figure 4).

ERMiT can also provide probabilistic estimates of the erosion reduction to be expected for three treatments-seeding, straw mulching, and contour-felled log or straw wattle erosion barriers. Data from rain simulation, sediment fence, and paired catchment studies are being used to calibrate the erosion reduction and sediment trapping

Figure 2. Example ERMiT climate output screens. (a) Generated precipitation and runoff information for input parameters. (b) Selected rainfall events used for the ERMiT erosion predictions.

a

Erosion Risk Management Tool

Bitterroot Valley MT +

Modified by RockClime on January 10, 2003 from STEVENSVILLE MT 247584 0
T MAX 20.71 27.48 36.30 47.41 55.81 63.12 72.63 71.19 59.76 47.01 31.26 22.44 deg F
T MIN 4.64 9.19 14.45 20.59 27.27 33.85 36.59 35.13 28.06 20.44 13.08 6.94 deg F
MEAN P 4.58 3.54 3.75 2.86 3.54 2.87 1.26 1.91 1.80 2.00 3.03 3.67 in
WET 9.34 7.09 7.36 7.33 8.86 9.58 5.71 5.96 6.43 6.44 8.18 8.74

clay loam soil texture, **30%** rock fragment

70% top, 50% average, 30% toe hillslope gradient

300 ft hillslope horizontal length

high fire severity on **forest**

100 - YEAR MEAN ANNUAL AVERAGES

35	**in**	annual precipitation from	9182	storms
2.2	**in**	annual runoff from rainfall from	1242	events
4.2	**in**	annual runoff from snowmelt or winter rainstorm from	1812	events

b

Ranking of event (return interval)	Storm Runoff (in)	Storm Precipitation (in)	Storm Duration (h)	tp (fraction)	ip (ratio)	10-min peak intensity (in h^{-1})	30-min peak intensity (in h^{-1})	Storm date
1	2.50	0.29	2.06	0.07	8.77	0.89	0.51	April 5 year 46
5 (20-year)	1.81	1.26	7.05	0.03	29.96	3.84	2.22	March 27 year 44
10 (10-year)	1.38	0.00	0.00	0.01	0.00	N/A	N/A	April 5 year 42
20 (5-year)	1.13	1.37	1.98	0.07	3.55	2.14	1.65	June 21 year 4
50 (2-year)	0.81	1.06	1.91	0.03	1.01	0.56	0.56	October 18 year 43

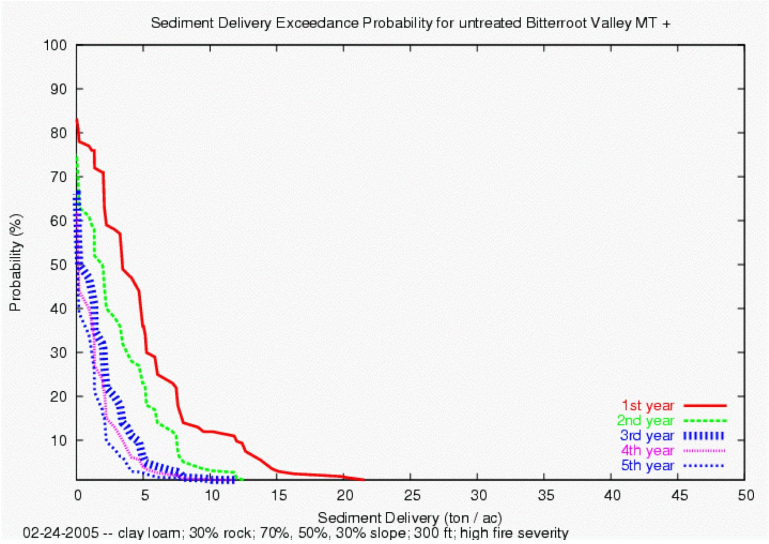

Figure 3. Example ERMiT graphical output for sediment delivery exceedence probability for five postfire years in the area being modeled.

Target chance event sediment delivery will be exceeded 10 % go	Event sediment delivery (ton ac^{-1})				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	11.98	7.51	4.51	3.45	2.25
Seeding	11.98	4.51	3.45	2.25	2.25
Mulch rate 0.2 ton ac^{-1}	5.9	4.93	4.51	3.45	2.25
Mulch rate 0.4 ton ac^{-1}	3.27	3.78	4.51	3.45	2.25
Mulch rate 0.7 ton ac^{-1}	2.24	3.66	4.51	3.45	2.25
Mulch rate 0.9 ton ac^{-1}	1.7	3.27	4.51	3.45	2.25
Logs & Wattles go Dia. 1 Sp. 10	xxx	xxx	xxx	xxx	xxx

Figure 4. Example ERMiT tabular output with predicted sediment delivery (ton ac^{-1}) for untreated, as well as seed, mulch (four rates provided), and erosion barrier (barrier specifications are determined by the user) treated hillslopes. Predictions for five postfire years are included.

efficiency (sediment stored by a contour-felled log divided by the sediment leaving the hillslope) of these treatments. Based on these data, straw mulch lowers predicted first-year erosion rates due to increased ground cover, more than the other treatments. Predicted erosion rates for erosion barriers vary by rainfall intensity (less erosion reduction occurs with high-intensity rainfall events) as well as estimated sediment storage capacity already filled.

Validation of ERMiT predictions by various users is ongoing. New data from treatment effectiveness studies and postfire erosion measurements will expand and refine the number of postfire rehabilitation treatments that can be modeled in ERMiT. Land managers who have used the model find the probability-based erosion predictions particularly useful when applied to risk-based management decisions, such as where to apply postfire rehabilitation treatments to get the most benefit for the cost.

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