ERMiT Results and Interpretation for the Bull Run Watershed

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Summary

Fire activity in the Western Cascades has increased in the recent years, as evidenced by the 2017 Eagle Creek Fire and the 2020 Oregon Fires (e.g. Riverside, Beachie Creek, Lionshead, Holiday Farm Fires). While these fires have not reached the Bull Run Watershed, they raised awareness to the watershed's vulnerability to fire and the potential risk to Portland's drinking water supply. Hydrologic and erosion models can help understand not only the risks of increased sediment delivery from burned areas on water quality but also how potential mitigation efforts might reduce these risks. Additionally, models can be used to prioritize mitigation treatments while at the same time considering both the costs and the potential benefits of such treatment.

The Erosion Risk Management Tool (ERMiT; Robichaud et al. 2007) is a post-fire erosion prediction tool based on the Water Erosion Prediction Project (WEPP) technology and is currently used by land and water managers in the U.S. to assess the effectiveness of hillslope treatments (e.g. seeding, mulching) for post-fire rehabilitation efforts.

We have previously run both undisturbed and disturbed simulations with the WEPP model, specifically with the WEPPcloud interface (https://wepp.cloud/weppcloud/), and have provided model results, such as surface runoff and sediment yield by watershed and hillslope: (https://wepp.cloud/weppcloud/portland-municipal/).

To assess the effectiveness of potential post-fire treatments in watersheds from Bull Run, we ran the ERMiT model for each hillslope within the seven watersheds that were previously modeled by WEPPcloud. Since the two models, WEPPcloud and ERMiT, have their own input file databases for soils, managements, and climates, we attempted to minimize the differences in results between the two models by matching the input files, whenever possible.

This document provides a brief overview of the ERMiT model, a description of the input data and output data with an example of results interpretation for the Bull Run near Multnomah watershed, and a summary of the results averaged across all watersheds.

Model inputs

The ERMiT model inputs are: soil texture, hillslope area, % rock, vegetation type, hillslope gradient, horizontal slope length, and soil burn severity class (Unburned, Low, Moderate, and High) (Robichaud et al. 2007). All this information was downloaded from the WEPPcloud interface using the "*Download the ERMiT and Disturbed WEPP batch processing spreadsheets*" option for each watershed. For this analysis we have only used the WEPPcloud model results based on the Norse Peak Fire Soil Burn Severity (SBS) predicted map.

Additionally, the ERMiT model, which is run from an Excel spreadsheet, requires a weather file. The weather file can be added from the CLIGEN database to a personal database and will be associated with the user's computer from the server.

This can be done from the main ERMiT page (https://forest.moscowfsl.wsu.edu/fswepp/) by selecting the options: Custom Climate → state of Oregon → Display Climate Stations → Hood River Exp Sta, OR → add to Personal Climates (Fig. 1).

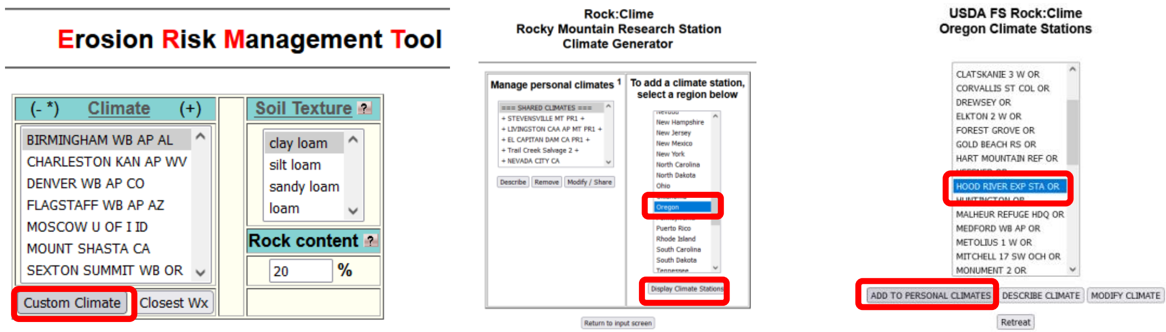

Fig. 1. Adding a CLIGEN climate station (Hood River Exp Sta OR) to personal climates.

Both ERMiT and WEPPcloud are using the CLIGEN model and its database to generate the climate files. For the simulations with the WEPPcloud interface we used the gridMET climate database to extract daily precipitation, and minimum and maximum temperature; all the other weather parameters needed by the model (rainfall peak intensity, time to peak intensity, storm duration, solar radiation, wind speed and direction) were stochastically generated with the CLIGEN model based on a criterion that involved elevation and distance to the watershed outlet. In WEPPcloud, the closest weather stations to the modeled watersheds, as determined by CLIGEN, are Bonneville Dam and Headworks. However, the ERMiT model is using an older version of the CLIGEN model and is missing these two stations. Therefore, we selected the Hood River Experimental Station for all watersheds. The Hood River station receives less than half the amount of annual average precipitation (1981-2010, Table 1) compared to the Boneville Dam and Headworks stations, and it could underestimate the ERMiT results. In ERMiT, all weather parameters, including precipitation and temperature, are stochastically generated by CLIGEN based on monthly statistics derived from long-term climate records at the respective station.

Table 1. NCDC 1981-2010 Climate Annual Normals

Climate station	Mean Max. Temp (F)	Mean Temp (F)	Mean Min. Temp (F)	Mean Precipitation (in)	Elevation (m)
HOOD RIVER EXP STN	62	51.3	40.7	31.29	152
BONNEVILLE DAM	61.8	53.5	45.2	77.52	18.9
HEADWORKS PORTLAND	59.7	51.6	43.5	78.29	228

https://wrcc.dri.edu/cgi-bin/cliNORMNCDC2010.pl?orhood
https://wrcc.dri.edu/cgi-bin/cliNORMNCDC2010.pl?or0897
https://wrcc.dri.edu/cgi-bin/cliNORMNCDC2010.pl?or3770

Model outputs and example of results interpretation

The ERMiT model provides probabilistic WEPP model output results for 1 to 5 years after the fire and for 5 post-fire forest treatment scenarios: seeding, and mulch at 1, 2, 3.5, and 4.5 t ha^{-1} rates. These results are organized in several spreadsheets (tabs) within the Excel document. Below is an example of model results interpretation for the Bull Run near Multnomah Watershed.

Summary Results - Year 1

This spreadsheet shows the year 1 sediment delivery rate statistics for different target probabilities, which are divided in four probabilities: 10, 30, 50, and 75%. The first column in each probability table shows the average sediment delivery by treatment category.

There is a 10% probability that the average erosion rate for the first year after the fire will be 29.52 t ha^{-1} if untreated, and 10.82 tons/ha if treated with mulch at 1 t ha^{-1}. This scenario is not very likely to occur. We recommend not using a probability below 20%.

There is a 75% probability that the average erosion rate for the first year after the fire will be 1.49 t ha^{-1} if untreated, and 0.37 t ha^{-1} if treated with mulch at a rate of 1 t ha^{-1}. Erosion rate is reduced by 75% if treated with 1 t ha^{-1} mulch.

Seeding does not appear to reduce erosion in the first year after the fire. This is expected as it will usually take one full growing cycle year before we observe reduction in sediment due to seeding.

Columns 2–5 in each probability table shows the hillslopes with the minimum and maximum erosion rate by treatment category. For example, for the 50% probability, hillslopes 2 and 11 do not erode while hillslope 854 will generate the maximum erosion under all treatments.

Results by Hillslope - Year 1

If we randomly select hillslope 259, there is a 50% probability that mulching at a rate of 1 t ha^{-1} will reduce erosion from 9.14 t ha^{-1} to 1.14 t ha^{-1}. Mulching at 2 t ha^{-1} reduces erosion to 1.09 t ha^{-1}. We do not observe a significant reduction in erosion for applying mulching at rate greater than 2 t ha^{-1}. However, it is practical and more economical to apply mulch at 1 t ha^{-1}. Some hillslopes might not need treatment. For example, for hillslope 791, there is a 60% probability that this hillslope will not erode. Even for the 30% probability, the erosion rate is 3.15 t ha^{-1}, which is much smaller than the erosion for the previous hillslope. From the Inputs spreadsheet, we can see that the two hillslopes both burned at a moderate severity fire, however, hillslope 259 is smaller, steeper at the toe of the slope, longer, and has a silt loam soil compared to hillslope 791, which has a sandy loam soil.

Results - Out Years

This spreadsheet allows us to compare the sediment delivery by specific probabilities, treatments, and years since fire. We are comparing 25, 50, and 75% probabilities for untreated and treated conditions with mulch at a rate of 1 t ha^{-1}.

From the previous spreadsheet, we saw that for hillslope 259 there is a 50% probability that left untreated, the hillslope will generate 9.14 t ha^{-1}. In the current spreadsheet, we can see that for the same hillslope, there is a 50% probability that the sediment delivery will decrease to 2.07 t ha^{-1} in the second year after fire, which reduced to 1.02 t ha^{-1} with mulching at 1 t ha^{-1}. By year 5, sediment delivery will decrease to 0.25 t ha^{-1} regardless of if treated or not.

Results - Erosion Barriers

This analysis assumes that managers are applying log erosion barriers on the hillslope for reducing the sediment delivery.

In this example we are testing several scenarios: for the first and fifth year after the fire, with log spacing of both 1.5 and 25 meters, and log diameters of 0.25 and 1 m. A spacing of 1.5 m might not be practical but we are using it here as an example. If we are considering hillslope 259 as in the previous examples, the results of this analysis suggest that adding logs on the contour will eliminate erosion even in the first year after the fire, except when the log spacing is 25 meters, in which case soil erosion would still be reduced from 9.14 t ha^{-1} (see spreadsheet "Results by Hillslope - Year 1") to 3.88 t ha^{-1}. The scenarios that assume log diameters of 1 m, are unlikely because fire crews could not move a 1 m diameter log to be placed on the contour. The largest practical diameter would be about 0.25 m diameter log that can be moved and anchored to the ground (so it does not roll down hill). The simulations for the 5th year post disturbance generated on average 0.25 t ha^{-1}. This is because the efficiency of the log performance in reducing erosion decays with time. Observational studies suggest that sediment often will go under or around the logs with time, as the logs settle and decay.

Results - Rainfall

This spreadsheet summarizes the rainfall events from the weather file, which was used for all hillslopes. Hillslope number (1134) is irrelevant as the same climate file is used for all hillslopes. The events are sorted based on the runoff amount and not rainfall, though. The largest runoff event was 56.4 mm, which was produced by an 80.9 mm rainfall event with a duration of 3.94 hours with a 10-minute peak rainfall of 97.18 mm/hr. Thus, this runoff was likely generated from a snowmelt event on March 10, year 21. Same for the last two events in the table.

Results – Treatment

This spreadsheet displays the simulated sediment delivery, total sediment, and % of total sediment by hillslope for various probabilities selected by the user for 1–5 years post-fire. For example, for a 58% probability (probability which better matched the results from the WEPPcloud model), for the 1st year after the fire, for hillslope 259, the model predicted 147.62 tons of total sediment loss or 4.48 t ha^{-1} for an area of 32.94 ha, which represents 0.2% of all sediment for the entire watershed. With treatment, total sediment drops to 30.93 t ha^{-1} for mulching at a rate of 1 t ha^{-1}. Increasing mulching to rates greater than 2 t ha^{-1} does not provide significant benefits. As mentioned before, it is practical to apply mulch at a rate of 1 t ha^{-1}. Thus, there is a 58% probability that applying 1 t ha^{-1} of mulch will reduce total sediment yield from 147.62 to 30.93 t ha^{-1} at the base of hillslope 259 in the first year after the fire.

In columns V–X we calculated % reduction in sediment yield following a 1 t ha^{-1} treatment for 25, 50, and 75% probability for the first-year post-fire. These results are further displayed in the "Viz-WEPPcloud_with_ERMiT" tool for each watershed. We also calculated the average % reduction in sediment for each probability (Table 2).

Table 2. Average percent reduction in sediment for the first-year post fire after applying 1 t ha^{-1} mulch.

Watersheds	% reduction		
	Probab. 25%	Probab. 50%	Probab. 75%
Fir Creek	84	97	97
North Fork	78	92	92
South Fork	85	97	98
Little Sandy	85	95	96
Blazed Alder	85	96	98
Cedar Creek	84	96	98
Bull Run	81	96	95

Results in Table 2 indicate that even when considering a 25% probability, the minimum percent reduction in sediment yield is greater than 78%, however, it can be as high as 98%. This highlights the effectiveness of the mulching treatment, even at a rate of 1 t ha^{-1}.

Viz-WEPPcloud_with_ERMiT

This tool displays the results from the ERMiT model by watershed and hillslope (Fig. 2) and can be found at:

https://cdeval.shinyapps.io/Viz-ERMiT/

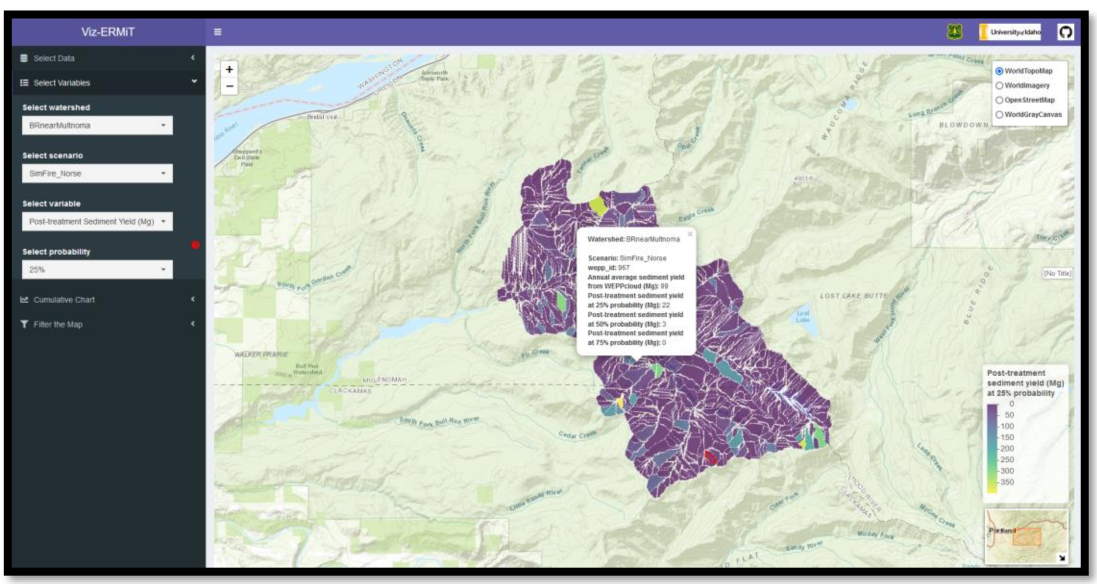

Fig. 2. Sediment yield reduction for the Bull Run near Multnomah Watershed at 50% probability.

Visualizing the sediment reduction by hillslope allows for easily identifiable hillslope with low and high erosion reduction potential (Fig. 2). Selecting a hillslope will display the name of the watershed, the WEPP ID number, simulated sediment yield from WEPPcloud (SdYd_kg_ha), and % reduction in sediment simulated with ERMiT for three probabilities (sed_reduc_at_25, 50, 75 probab) (Fig. 2). One important aspect in interpreting these results is that the % reduction in sediment yield was computed from the ERMiT model as sediment yield after mulching minus sediment yield for untreated. However, in the Viz-WEPPcloud_with_ERMiT tool we are displaying the WEPPcloud untreated sediment yield. Therefore, we recommend interpreting the results more in relative terms, rather than absolute terms. The WEPPcloud results are providing more realistic results as the model is using a wide array of soils and climates for each hillslope, while the ERMiT model is using four default soils based on soil texture and one climate file for all watersheds. Nevertheless, the main point is that mulching is highly effective at reducing the erosion.

Other information could be inferred from the ERMiT model. For example, the benefit from mulching is less on the southerly aspect slopes (40–60% reduction in sediment) of the Bull Run near Multnomah Watershed compared to the northerly aspect slopes (80–100% reduction in sediment). This could be a result of the soil burn severity. The Soil Burn Severity Map created based on the Norse Peak Fire shows that the south-facing slopes were predicted to burn on average at a moderate severity while the north-facing slopes had a larger percent of the area burned at high severity fire likely due to greater fuel loads on the wetter north-aspect slopes (Fig. 3). Therefore, the mulching had a greater benefit in reducing the erosion on slopes burned at a higher severity.

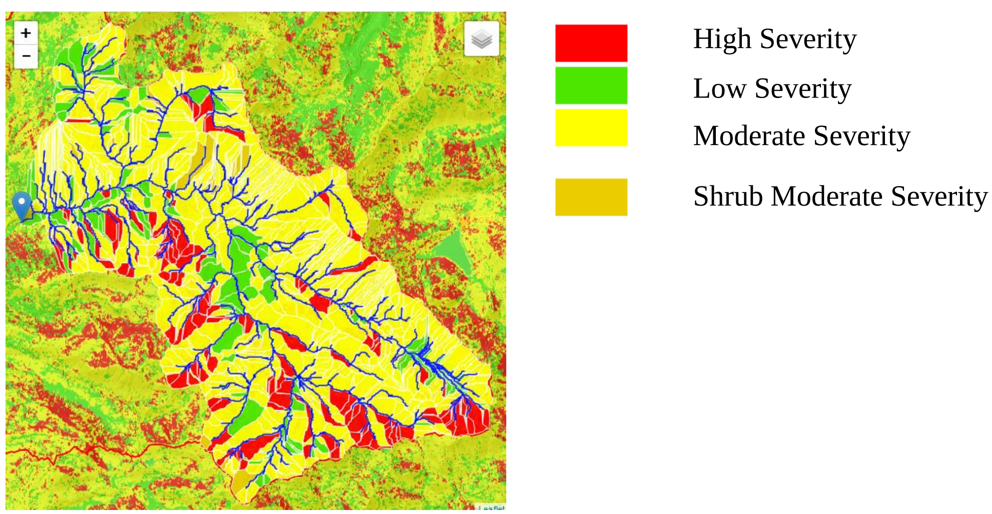

Fig. 3. Soil Burn Severity map for the Bull Run near Multnomah Watershed.

WEPPcloud vs ERMiT comparison

Both WEPPcloud and ERMiT are using the same WEPP model to perform hydrologic and erosion simulations but with slightly different input files. The slope length, hillslope area, soil texture, and soil burn severity are the same for both models. However, the climate and soils files are different. WEPPcloud uses Soil Survey Geographic Database (SSURGO) soils while ERMiT selects soils from a default database of four soils based on texture. Similarly, the WEPPcloud interface, creates a weather file based on 40 years of observed gridMET weather data and the CLIGEN model by adjusting the precipitation and temperatures with elevation, while the ERMiT model uses 30 years of climate generated entirely with the CLIGEN model, and the same weather file is used for all hillslopes. Lastly, some of the soil parameters in the WEPPcloud interface, such as the saturated hydraulic conductivity of the underlying geology was calibrated based on the maps of landslide susceptibility, while no modifications were made in the ERMiT model. Despite these differences, the two models provide results within the same order of magnitude (Table 2, Fig. 4). Table 2 shows the comparison between WEPPcloud and ERMiT by watershed. We altered the ERMiT % probability between 35 and 70 % to roughly match the WEPPcloud results. A 50% probability in ERMiT is roughly equivalent to model results that are expected to occur every two years, while the WEPPcloud model provides average annual results. Therefore, the two models cannot accurately be directly compared. However, the results in Table 2 gives us confidence that the two models can provide relatively comparable results.

Fig. 3 shows a visual comparison between the two models by hillslope. The main point is that, at least in terms of magnitudes, the two models perform similarly. However, Fig. 3 also shows the importance of accurately representing the soils and climate in simulating soil erosion.

Watersheds	WEPPcloud (tonnes)	ERMiT (tonnes)	WEPPcloud (tonne/ha)	ERMiT (tonne/ha)	ERMiT probability (%)
Fir Creek	8936	8844	3.90	5.50	45
North Fork	2401	2383	0.70	1.00	70
South Fork	23682	23029	4.00	4.80	41
Little Sandy	14460	15254	2.20	2.30	56
Blazed Alder	5891	10138	2.00	3.30	57
Blazed Alder*	5891	5978	2.00	2.80	57
Cedar Creek	19124	19145	5.30	7.20	35
Bull Run	60969	61915	3.60	4.00	58

** Without hillslope 157*

Table 2. Comparison between WEPPcloud and ERMiT annual average sediment yield for untreated conditions.

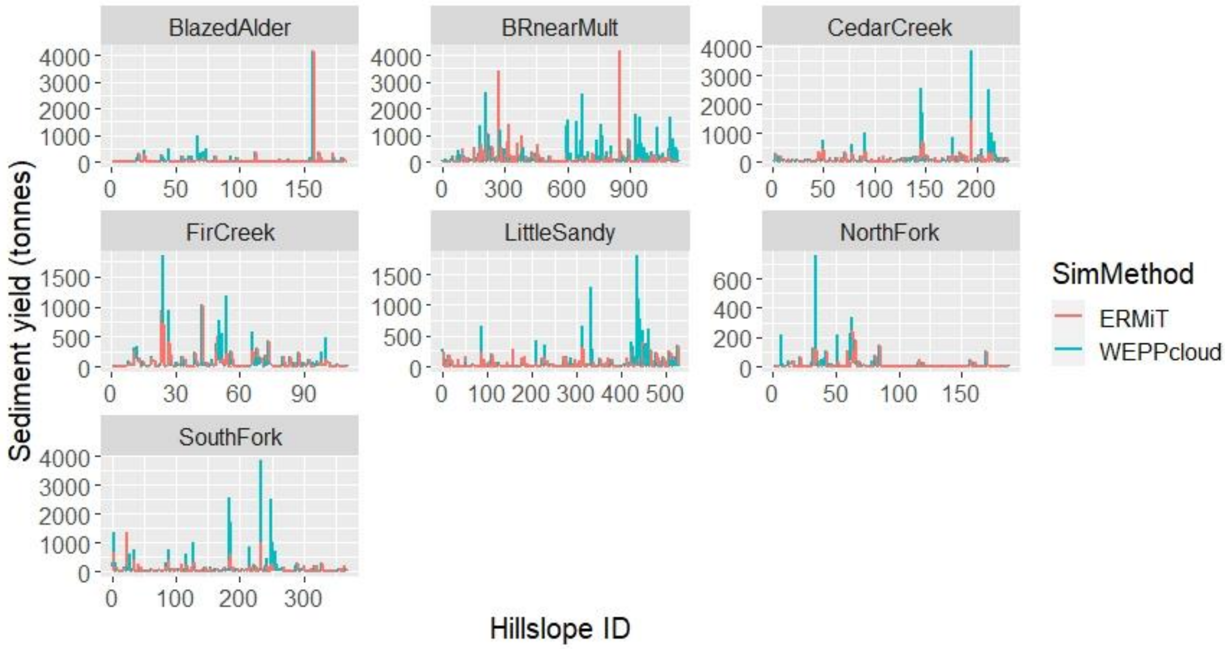

Fig. 4. Comparison between WEPPcloud annual average, and ERMiT sediment yields for untreated conditions and their probabilities from Table 2.

Conclusion

Overall, we demonstrated based on the results from the ERMiT model that the effectiveness of a post-fire mulching treatment at a rate of 1 t ha^{-1} can reduce the sediment yield by over 78% for the first years after disturbance in all sub-watersheds of the Bull Run Watershed. Despite the two models simulating different sediment yield when analyzed by individual hillslopes, the overall magnitudes are very comparable. Both WEPPcloud and ERMiT models provide simulation results based on a series of input files that often contain default parameters determined based on observations generalized for specific regions, soil types, or elevations. As a result, the accuracy of the model results will depend on the accuracy of the input data. For these reasons, management decisions based on any model results should be made while also accounting for the expertise and knowledge of the managers who are interpreting the model results.