16 Risk-Based Erosion Assessment: Application to Forest Watershed Management and Planning

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This chapter discusses conditions where risk-based erosion modelling may be appropriate in forested watersheds. It then describes four modelling approaches for risk-based erosion modelling using WEPP-based erosion technology.

16.1 Background

In many applications of erosion modelling, the vegetation condition to be modelled is relatively similar year after year, as in continuous agriculture or grazing lands. In other cases, a known sequence of surface conditions occurs over a period of several years, like agricultural systems with fixed crop rotations or short rotation forestry. In such cases, describing erosion with an average annual value is usually an adequate approach to conservation planning.

In some conditions, however, erosion processes are dominated by extreme disturbance events followed by a prolonged period of minimal disturbance, like unmanaged forests or rangelands in fire-driven ecosystems (Fig. 16.1), or managed forests that experience a major harvesting or thinning operation only once every few decades. In these cases, erosion is minimal prior to the disturbance, potentially high immediately following the disturbance, and then returns to a relatively low erosion risk within a few years. Wildfires can cause soils to become water repellent for a few years, increasing the risk of runoff and erosion immediately after fire. The repellency, however, dissipates in subsequent years on many soils (Doerr *et al*., 2000; Robichaud, 2000). For example, Table 16.1 shows three different studies in which erosion rapidly declined during the three years following wildfires in all but one year in one study.

One characteristic of these highly disturbed conditions is a high spatial variability of the disturbance. The disturbance rather than soil properties dominates the erodibility of the soils (Robichaud *et al*., 1993). The distribution of the disturbance following wildfires is seldom uniform or predictable (Robichaud *et al*., 2007) as is the case with agricultural conditions. There will be sites following wildfire where the fire burned at a higher severity, leading to a complete loss of surface cover and most likely the generation or augmentation of a water repellent soil condition. There will be other sites where the fire burned very little, or not at all, resulting in an area of minimal erosion risk. There is often considerable spatial variability in erodibility on a hillslope. For example, in a study of hillslope erosion after a wildfire in the Bitterroot Valley, Montana, US, the four plots were within a 100-m wide hillside, yet sediment delivered from the 15 July 2001 storm ranged from 0.13 to 18 Mg ha^{-1} (Table 16.2).

The weather in the years following the disturbance is crucial in determining the erosion

Handbook of Erosion Modelling, 1st edition. Edited by R.P.C. Morgan and M.A. Nearing.

Fig. 16.1 Scientist inspects the erosion occurring after a wildfire in northern California, US 2(photography courtesy of Natalie Copeland 2008).

Table 16.1 Observed annual erosion rates for three years following wildfires on three sites in the western US.

Site	Year of fire	Type of plot	Erosion (Mg ha^{-1})		
			Year 1	Year 2	Year 3
Wallowa-Whitman National Forest, Oregon[a]	1994	Silt fence	1.9	0.1	0.03
Bitterroot National Forest, Montana	2000	Silt fence[b]	29	0.8	0.07
		Small watershed[c]	0.64	0.93	0.09

[a]Robichaud & Brown (1999); [b]Robichaud *et al.* (2008a); [c]Robichaud *et al.* (2008b).

Table 16.2 Observed erosion rates (Mg ha^{-1}) from 20 m long plots in 2001 following the 2000 Bitterroot Valley Fire in Montana (Robichaud *et al.*, 2008a).

Plot	15-Jul	21-Jul	30-Jul	14-Sep	Total
A	2.9	20.9	0.09	0.06	23.9
F	17.9	–	0.08	0.03	18.0
I	0.33	8.4	0.23	0.08	9.0
N	0.13	15.8	0.25	0.02	16.2
Average	5.30	15.01	0.16	0.05	16.8
Pcp, mm[a]	6.6	15.7	22.1	3.8	
I-10, mm h^{-1} [b]	19.8	39.6	7.6	13.7	

[a]Total storm precipitation; [b]maximum 10-minute precipitation intensity of storm.

rate. If the precipitation is moderate, then erosion will probably be minimal. If the weather has storms or snowmelt rates that are above normal, then erosion can be severe. In the study summarized in Table 16.2, maximum precipitation intensity was more important than total precipitation amount at causing erosion. In other studies (e.g. Robichaud *et al.*, 2008b), total precipitation amount was more important than intensity in causing erosion.

In order to address erosion for disturbance-dominated conditions, an average annual value is of limited utility since the disturbed conditions are not average, and erosion following the disturbance is dependent upon the degree of the disturbance, the distribution of the disturbance, the weather immediately following the disturbance and the rate of vegetation and soil recovery. For these disturbed conditions, a risk-based approach is more appropriate. For example, one interpretation of the data in Table 16.2 is that the average erosion rate in the year following a wildfire is 16.8 Mg ha^{-1}. A more meaningful interpretation of these data might be that on one of these plots there is a 1 in 4 chance that the total erosion will exceed 23.9 Mg ha^{-1} from the four large storms in the year following the wildfire (Plot A total), and a 1 in 4 chance that erosion will exceed 20.9 Mg ha^{-1} from the largest single erosion event in the year following the wildfire (21 July on Plot A).

With risk-based erosion modelling, the modeller must estimate the probability distribution for a given set of conditions, and from that distribution, determine the probability of a given erosion rate occurring. Probability distributions should account for climate, soil properties and distribution of disturbance.

16.2 Risk-based Approach

This chapter will consider four different tools to use for risk-based erosion modelling, using interfaces developed for the Water Erosion Prediction Project (WEPP) model (Flanagan & Livingston, 1995). The interfaces are the Windows Interface (Flanagan *et al*., 1998), the online Disturbed WEPP Interface (Elliot, 2004), the online Erosion Risk Management Tool (ERMiT; Robichaud *et al*., 2007), and the GeoWEPP GIS wizard (Renschler, 2003).

An example application for each of these interfaces will be given to assist in understanding the technology. All examples will apply to an analysis of erosion following a high severity wildfire that occurred in forested mountains of the Bitterroot Valley in Western Montana, US, in July 2000. The soils in this area are gravelly sandy loam over granitic colluvium, with slopes typically from 20% to 50% (Robichaud *et al*., 2008a). For the hillslope examples, a horizontal slope length of 20 m with a maximum steepness of 61% will be used, similar to the silt fence plots installed by Robichaud *et al*. (2008a). The ground cover is assumed to be 5%, as was observed on these plots. In order to generate a climate for this remote area, the climate statistics of a nearby low-elevation weather station were modified with an online interface (Scheele *et al*., 2001; Elliot, 2004). Monthly precipitation amounts were modified with data from a nearby high-elevation snow monitoring station, and the number of wet days was increased by half the proportionate increase in precipitation. The monthly maximum and minimum temperatures were decreased from the valley station by the adiabatic lapse rate (Scheele *et al*., 2001). Observed erosion rates from Robichaud *et al*. (2008a) are presented for comparison with values predicted by the examples (Tables 16.1 and 16.2).

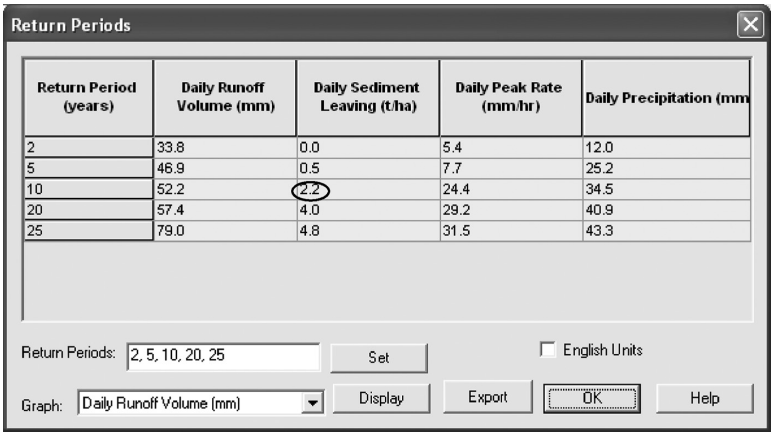
16.3 WEPP Windows

The weather file that drives the WEPP model contains daily data, and so WEPP predicts runoff and erosion on a storm-by-storm basis. All runoff events predicted by WEPP are stored in a single file. WEPP Windows accesses this file and determines the probability of exceeding a given amount of daily precipitation, daily runoff, peak runoff rate, or daily sediment delivery using a Weibull plotting formula (WEPP Help screen).

Example 16.1 To model the Bitterroot Valley site in the WEPP Windows interface, the following were selected from the downloaded databases and menus: a 50-yr stochastic weather file; a sandy loam, high-severity fire soil; the described topography; and the Return Period Analysis option. The management file was calibrated to ensure approximately 5% ground cover for every year of simulation.

The 'Return Period Analysis' output screen from this model run (Fig. 16.2) shows an estimate that for any given storm there is a 10% probability that erosion will exceed 2.2 Mg ha^{-1}. As a comparison, the 'Average' value predicted by this WEPP run was 0.55 Mg ha^{-1}.

In this example, the 10-year sediment delivery may or may not have been associated with the 10-year rainfall or 10-year peak runoff rate or


Return Periods

Return Period (years)	Daily Runoff Volume (mm)	Daily Sediment Leaving (t/ha)	Daily Peak Rate (mm/hr)	Daily Precipitation (mm
2	33.8	0.0	5.4	12.0
5	46.9	0.5	7.7	25.2
10	52.2	2.2	24.4	34.5
20	57.4	4.0	29.2	40.9
25	79.0	4.8	31.5	43.3

Fig. 16.2 Return period analysis output screen from WEPP Windows interface for Example 16.1.

volume, as WEPP considers daily conditions of the vegetation and soil water content before making runoff and erosion predictions. A detailed examination of the WEPP output for this sediment delivery event showed that it occurred on 2 August, year 32, when 43.3 mm of precipitation resulted in 4.5 mm of runoff. This storm was the 25-yr return period precipitation event, but the 24-h runoff depth was less than that for a 2-yr event (Fig. 16.2). The peak runoff rate predicted for the storm was 29.2 mm h^{-1}, the value for the 20-y return period peak runoff rate. Since the WEPP simulations show that there were no major runoff events in the four months prior to this storm, the hydrology was driven by the large precipitation event only.

If model users wish to consider the risk of exceeding a given level of erosion for an entire year, as a function of the variability in weather, then the user can request the detailed annual output from the WEPP model, and note the annual erosion rates for 50 or more years. These can either be analysed using a return period analysis technique, or simply ranked, with the year with the highest value serving as an estimate for the erosion with a probability of occurrence of one in the length of run, and the second largest value having a probability of occurrence of two in the length of run, and so on. This process has been programmed into the online Disturbed WEPP Interface (Elliot, 2004).

16.4 Online Interfaces

Two online interfaces have been developed that incorporate risk-based erosion prediction for forest conditions (Elliot, 2004), and they can be accessed at http://forest.moscowfsl.wsu.edu/fswepp. One interface, Disturbed WEPP, provides both the average annual runoff and erosion estimates, and the annual return period values for precipitation, runoff, upland erosion, and sediment delivery.

Example 16.2 The climate, soil, topography and vegetation cover conditions described for Example 16.1 were entered into the online input screen for Disturbed WEPP. A 50-year run was selected and the recommended cover calibration was carried out (Elliot, 2004). The model was then run and the output screen presented (Fig. 16.3).

The return period analysis (top part of Fig. 16.3) shows that following a wildfire, there is a 1 in 10 chance that annual sediment delivery from this hillslope will exceed 13.0 Mg ha^{-1}. The second output from Disturbed WEPP (bottom of Fig. 16.3) is that there is an 82% probability that there will be sediment delivered in the year following a wildfire. The average predicted erosion rate is 4.3 Mg ha^{-1}.

The predicted erosion rate is greater than the value predicted in Example 16.1 because it is for a full year and not a single storm, and maybe because there are different versions of WEPP

**Return period analysis
based on 50 years of climate**

Return Period	Precipitation (mm)	Runoff (mm)	Erosion ($t\ ha^{-1}$)	Sediment ($t\ ha^{-1}$)
50 year	1212.40	79.98	39.32	39.3155
25 year	1068.60	34.90	23.80	23.8010
10 year	979.30	20.26	13.01	13.0085
5 year	947.20	14.77	6.29	6.1110
2.5 year	899.90	7.31	3.46	3.0960
Average	874.39	9.33	4.31	4.3100

**Probabilities of occurrence first year following disturbance
based on 50 years of climate**

Probability there is runoff	84 %	
Probability there is erosion	82 %	
Probability there is sediment delivery	82 %	

Fig. 16.3 Return period analysis from the Disturbed WEPP online interface output screen for Example 16.2.

associated with these interfaces (WEPP Windows was version 2008.907 and Disturbed WEPP version 2001.100) and differences in input files describing vegetation. Figure 16.3 shows that the average predicted erosion rate for these conditions is 4.3 Mg ha^{-1}, compared with 0.55 Mg ha^{-1} from the WEPP Windows interface. Because of the skewed distribution of erosion events, observations of erosion rates need to be interpreted with care as erosion rates well below an average value are likely to be observed, while it is still possible to observe a greater than average erosion rate (Robichaud, 2005). As burned sites can quickly recover, only data collected the first year following a wildfire should be used to compare with these predicted values (Table 16.1).

The second online interface that incorporated probability into erosion prediction is the Erosion Risk Management Tool (ERMiT) (Robichaud *et al.*, 2007). ERMiT predicts the probability of exceeding a given sediment delivery amount following a wildfire for a single event, and also estimates the benefits of several practices to reduce erosion risk. ERMiT considers not only variability in climate, but also variability in severity of fire and the distribution of that severity on the hillslope (Robichaud *et al.*, 2007).

Example 16.3 What is the erosion rate from a single event that would probably be exceeded once in ten years for the conditions described in Examples 16.1 and 16.2? The data were entered into the ERMiT input screen, and a high-severity wildfire specified.

The ERMiT output screen presents two tables and a figure. The first table (Fig. 16.4) shows the individual runoff events selected for the analysis. The 10-year runoff depth is 18 mm, from 40.9 mm of precipitation, occurring on 15 May. The second output from ERMiT is an erosion exceedance graph showing the probability associated with a given erosion rate for each of five years following the wildfire (Fig. 16.5). The figure shows that there is a 10% probability that sediment delivery from a single event will exceed approximately 2.5 Mg ha^{-1} in the year following a wildfire. The final table on the ERMiT output screen is interactive, allowing the user to enter the desired exceedance probability. Once entered, the table displays the associated sediment delivery rate for each year following the wildfire and how that rate is impacted by common erosion mitigation treatments (Fig. 16.6). This table confirms the observation in Fig. 16.5, that there is a 10% probability that erosion will exceed 2.5 Mg ha^{-1} on the example hillslope. It also shows that erosion risk drops quickly in the following years, similar to observed data presented in Table 16.1, and that mulching can be effective at reducing sediment delivery rates.

The ERMiT model predicted erosion rates similar to those observed on a small watershed (Table 16.1) and lower than those observed from silt fence plots (Table 16.1 silt fence plots, and Table 16.2) and predicted by the Disturbed WEPP interface. This is probably because the silt fence plots were located on a site where there were only high-severity fire conditions, and examples 16.1 and 16.2 modelled those conditions. ERMiT, however, considers a hillslope as a mosaic of fire severity, and internally is designed to consider a range of hillslope severity conditions in its

Rainfall Event Rankings and Characteristics from the Selected Storms

Storm Rank based on runoff (return interval)	Storm Runoff (mm)	Storm Precipitation (mm)	Storm Duration (h)	10-min Peak Rainfall Intensity ($mm\ h^{-1}$)	30-min Peak Rainfall Intensity ($mm\ h^{-1}$)	Storm Date
1	34.1	3.4	2.05	N/A	N/A	January 31 year 91
5 (20-year)	23.2	2.1	3.96	N/A	N/A	January 28 year 100
10 (10-year)	18	40.9	7.42	71.10	52.49	May 15 year 49
20 (5-year)	14.6	34.5	1.85	66.28	47.57	May 1 year 39
50 (2-year)	6.5	26.2	3.40	39.30	30.32	July 13 year 46
75 ($1\frac{1}{3}$-year)	4	20.4	8.50	50.37	32.49	July 15 year 77

Fig. 16.4 Runoff events selected for analysis with the ERMiT interface for Example 16.3.

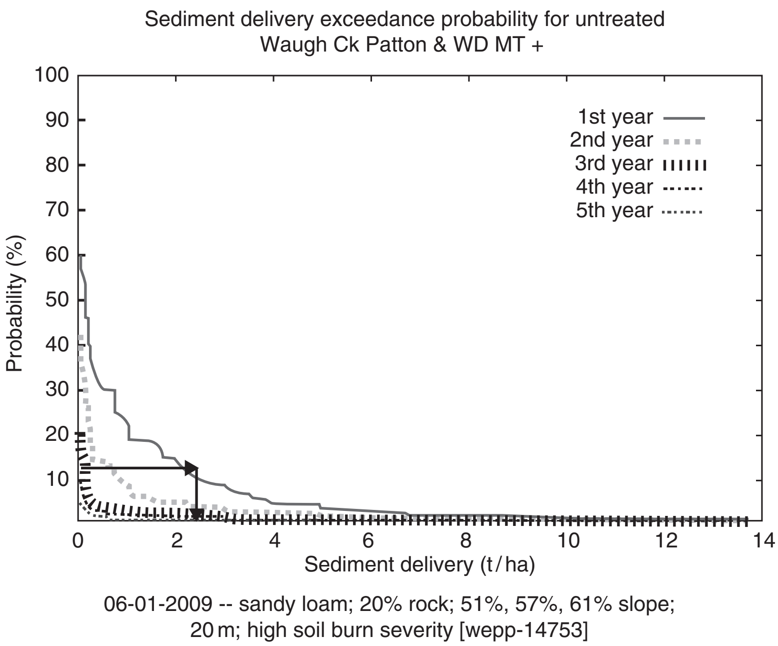


Fig. 16.5 Probability versus sediment delivery for the five years following a wildfire predicted by the ERMiT interface for Example 16.3.

Mitigation Treatment Comparisons					
Probability that sediment yield will be exceeded 10 % go	Event sediment delivery ($t\ ha^{-1}$)				
	Year following fire				
	1st year	2nd year	3rd year	4th year	5th year
Untreated	2.5	0.86	0.15	0.05	0
Seeding	2.5	0.25	0.15	0	0
Mulch (1 $t\ ha^{-1}$)	0.22	0.2	0.15	0.05	0
Mulch (2 $t\ ha^{-1}$)	0.09	0.2	0.15	0.05	0
Mulch (3.5 $t\ ha^{-1}$)	0.07	0.2	0.15	0.05	0
Mulch (4.5 $t\ ha^{-1}$)	0.06	0.15	0.15	0.05	0
Erosion Barriers: Diameter 0.05 m Spacing 25 m go					
Logs & Wattles	2.5	0.86	0.15	0.05	0

Fig. 16.6 Erosion exceedance value and effectiveness of mitigation treatment comparison for the first five years following a wildfire predicted by the ERMiT interface for a 10% exceedance probability for Example 16.3.

sediment delivery prediction (Robichaud *et al.*, 2007). Hence the ERMiT-predicted erosion rates are lower than those observed on silt fence plots ($2.5\ Mg\ ha^{-1}$ vs. $17\ Mg\ ha^{-1}$) and more typical of the values observed on the larger areas (Table 16.1, small watershed, $<1\ Mg\ ha^{-1}$). For some of the selected events, ERMiT predicts more runoff than precipitation (20-year event, Fig. 16.4). This is due to melting snow contributing to runoff for these events. Erosion events in this area are frequently associated with large runoff events from rain falling on a snow pack (Tonina *et al.*, 2008), and such events are included in all the WEPP predictions.

16.5 GIS Interface

The GIS interface for WEPP technology is GeoWEPP (Renschler, 2003). GeoWEPP builds the stream network from a digital elevation model (DEM). The user selects the outlet for each sub-watershed of interest, generally limiting watershed areas to under 500 ha for a 30-m DEM. As with the WEPP technology, the user can either use GeoWEPP to predict average annual erosion values, or can use it for risk analysis. GeoWEPP can be run in two modes, 'Watershed' or 'Flowpath' (Cochrane & Flanagan, 1999). The watershed mode is useful in determining sediment delivery to points of interest downstream from a major watershed disturbance. In Watershed mode, GeoWEPP predicts sediment delivery, surface runoff, and lateral flow from hillslope polygons, and routes the delivered sediment through the stream network (Dun *et al.*, 2009). In Flowpath mode, GeoWEPP determines distinct flow paths throughout the watershed, and determines the distribution of erosion along each flow path, estimating the erosion rate for each pixel in the analysis. The flowpath mode is useful for determining the location of the greatest risks of erosion within a watershed, so that erosion mitigation treatments can be targeted to those areas. With a 30-m DEM, there are usually two or three flow paths generated per hectare. For the example GeoWEPP flowpath run (Fig. 16.7), there were 286 flow paths identified on a 140-ha watershed.

Elliot *et al.* (2006) presented methods for applying risk-based erosion modelling to post-wildfire

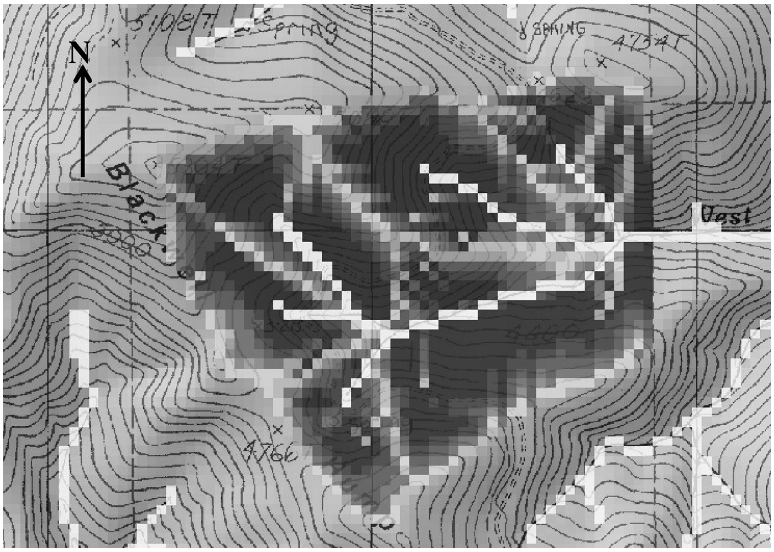


Fig. 16.7 Distribution of on-site erosion as predicted by GeoWEPP for Example 16.4, for a year with the 10-year sediment yield event. The stream network is white, and the darker the area, the greater the predicted erosion. The darkest areas have a predicted hillslope erosion rate exceeding 200 Mg ha^{-1}, and the lightest erosion less than 12.5 Mg ha^{-1}. Pixel size is 30 m and the watershed area is 140 ha.

Table 16.3 Return period analysis from GeoWEPP for Example 16.4. The watershed area was 140 ha.

Return period (years)	Sediment leaving (Mg)	Peak runoff rate (m^3 s^{-1})	Daily precipitation (mm)
1	2339	14.8	20
2	3164	18.7	24
5	4618	25.7	27
10	7505	36.2	33

conditions in forested watersheds. For the watershed analysis, one of the GeoWEPP output options is a return period analysis (e.g. Table 16.3). Carrying out a return period analysis with the flow path method is more complicated because the output is limited to hillslope polygon summaries of average annual erosion rates. The approach by Elliot *et al.* (2006) to apply probabilities to the flow path method was to determine from a hillslope (or watershed) return period analysis (Fig. 16.2 or Table 16.3) either the precipitation, runoff or sediment delivery amount for the desired return period, and then inspect the WEPP or GeoWEPP output event files to determine what year the event occurred. Once the year was known, then a custom input climate could be developed containing only the year of interest. Because of carry-over of snow pack from November or December in one year to the next, if the event of interest is during spring snowmelt, then it may be necessary to include both the year with the event and the previous year in the climate file, and run the flowpath method for those two years only (Example 16.4). The ERMiT tool uses this approach, running both the year of interest (Fig. 16.4) preceded by the year before.

Example 16.4 The DEM for a steep forested watershed near the Bitterroot Valley, Montana, was obtained, and a small upland watershed was identified within that forest for post-wildfire erosion risk analysis. The watershed vegetative cover was assumed to average 30% following the wildfire for this example. Two runs were carried out for the same climate and soil texture as in the previous examples. The first analysis was a 50-year run for the entire watershed, using the 'Watershed' option in GeoWEPP.

The return period analysis from the watershed run (Table 16.3) predicted that the 10-year return period sediment yield was 7505 Mg. The area was determined by GeoWEPP to be 140 ha, leading to an erosion rate for the 10-year return period of 54 Mg ha^{-1} for the 10-yr return period sediment yield event. A review of the GeoWEPP 'Events' file showed that this event occurred on 9 April in year 15, a day when there was no precipitation, so it was a runoff event from snowmelt only. The stochastic climate file was then truncated to contain only years 14 and 15, and GeoWEPP was run for the same watershed with the 'Flowpath' option for those two years. The results of the flowpath run with the average annual erosion rate for two years, one of which contained the 10-yr event, are shown in Fig. 16.7. The erosion rate for the darkest pixels exceeded 200 Mg ha^{-1}, and on the lightest pixels it was less than 12.5 Mg ha^{-1}.

The GeoWEPP predictions were greater than the observed values or other predictions because the slope lengths were greater, averaging 200 m. The flowpath method showed that the areas with greater predicted sediment yields were the areas immediately adjacent to the streams, while the ridge tops had lower predicted erosion rates. It also showed that the more westerly-facing slopes were at a higher risk of erosion than the east-facing slopes (Fig. 16.7). If additional information about the spatial distribution of the severity of wildfire were known, this could also be incorporated into GeoWEPP by altering the soil properties and/or ground cover on each hillslope polygon to match the conditions determined by remote sensing or ground survey as described by Elliot *et al.* (2006).

16.6 Discussion

Four different predictive tools, all based on WEPP technology, have been presented. The results of each method are summarized in Table 16.4, for a ten-year return period erosion event. The ERMiT tool estimated a higher precipitation value, probably because it uses 100 years of stochastic weather whereas only 50 years were used for the other examples. The ERMiT tool and WEPP Windows predicted the lowest sediment delivery rates. This is probably due to the fact that ERMiT considers a number of different surface and soil conditions even for high severity, whereas all of the other tools considered a single high-severity condition. The WEPP Windows prediction may be lower than Disturbed WEPP because WEPP Windows modelled cover as perennial, whereas the Disturbed WEPP interface was developed when this feature was not available, and thus may have limited vegetation cover early in the spring when significant rain-on-snow events occur. Also, the estimate for Disturbed WEPP was for an entire year that included several events, whereas ERMiT and WEPP Windows predictions were for single events. The GeoWEPP flowpath method predicted a much higher erosion rate, probably due to the much longer slope lengths.

Table 16.4 Summary of risk-based predictions for a 10-year event. All data are daily values except Disturbed WEPP.

Interface	Precipitation (mm)	Runoff (mm)	Sediment yield (Mg ha^{-1})
WEPP Windows	34.5	52.2	2.2
Disturbed WEPP (annual)			13.01
ERMiT	40.9	19.0	2.5
GeoWEPP Watershed	33.4	99.1	53.6

The output files portray another modelling challenge: many of the large runoff events were a combination of rainfall and snowmelt. This is especially evident when runoff exceeded precipitation for the 20-year runoff event for ERMiT (Fig. 16.4), and the 10-year event for the watershed example when the entire event was snowmelt and there was no precipitation. Because of the importance of snowmelt processes in this climate, traditional precipitation-based risk tools may not work as well as models that account for snowmelt processes.

16.7 Applicability to Climate Change

The WEPP model is the physically-based engine behind the interfaces that have been described. The climate input into the WEPP model includes daily precipitation amounts and maximum and minimum temperatures. These files are generally generated with a stochastic climate generator CLIGEN (Nicks *et al*., 1995) that is accessed by all of these interfaces. This interface allows incorporation of future climate scenarios into any WEPP technology.

The general approach to incorporate future climate scenarios for all of these applications is through the online 'RockClime' interfaces (Scheele *et al*., 2001). This interface allows users to access current climate station data from the CLIGEN database containing about 2600 stations, modify that climate for remote areas within the US using the PRISM monthly precipitation database (Daly *et al*., 1994), and further adjust the maximum and minimum temperatures, monthly precipitation amount, and number of wet days in a month to match future climate scenarios. Future temperatures and precipitation values are readily available from numerous sources (e.g. http://forest.moscowfsl.wsu.edu/climate/). Research is ongoing to determine the distribution of wet days in future climates.

It is generally predicted that future climates will be warmer, and in many areas, wetter in the winter months. This means that snowpack in the northern hemisphere will be less developed, and snowmelt or rain-on-snow events less severe, whereas runoff associated with large precipitation events may increase. Warmer summers will also likely lead to increased evapotranspiration and lower soil water contents, resulting in lower runoff from summer storms, unless those storms are more severe. Whatever the effect, the altered climate coupled with the WEPP technology will be able to predict the risk of a given amount of erosion from a single event, or from a year for any current or future climate. The biggest limitation is the ability to describe the future climate. The WEPP technologies are already providing average annual predictions and single storm predictions for these future scenarios (e.g. Nearing *et al*., 2005; Elliot, 2006; see also Chapter 15).

16.8 Summary

This chapter described the need for risk-based modelling to predict soil erosion associated with forest management disturbances and wildfires. It presented four different WEPP interfaces and demonstrated how they could be used for erosion risk analysis following a wildfire. These included a Windows interface, two online interfaces, and a GIS interface. In the examples provided, the online ERMiT tool, which considers a range of fire severities, and the WEPP Windows interface, estimated lower erosion rates than the Disturbed WEPP interface, which could only provide an annual estimate and not a single storm prediction. Each of the models predicted erosion rates within the wide range of those measured in field experiments in the modelled area. The WEPP model is well suited for making such risk-based predictions for current and future climate scenarios.

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