Evaluation of Post-Wildfire Runoff and Erosion on Semiarid Ecological Sites

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Abstract—*Field studies are being conducted to quantify runoff and erosion rates following wildfires in semiarid rangelands. Rainfall simulator experiments were conducted on two grassland sites and one oak woodland site in Southern Arizona immediately following wildfires in 2002 and 2003. The experiments applied a range of rainfall intensities between 50 and 180 mm/h. Infiltration, runoff, and erosion rates were measured for each application rate. The post wildfire runoff and erosion responses are much higher on the oak woodland site and show much more variability than the responses from the two grassland sites. The results from this and other field studies will be used to determine model input parameters for a post-wildfire erosion risk tool.*

Introduction

Land managers and Burned Area Emergency Rehabilitation (BAER) teams need to be able to quickly assess the effects of wildfires on runoff and erosion processes on semiarid rangelands to determine the potential on and offsite risks. However, post wildfire runoff and erosion rates on semiarid rangeland ecological sites are not well known. Currently in southeastern Arizona, peak runoff and erosion rates following a rangeland fire are typically estimated by the USFS using TR55 (USDA-NRCS 1986) and Universal Soil Loss Equation (ULSE) (Wischmeier 1959). Although these methods are robust, they may not be applicable in the Southwest where high intensity thunderstorm rainfall dominates the runoff and erosion processes. Both these methods have uncertainties in parameter estimation and questions regarding their applicability to semiarid rangelands.

Field experiments using a variable intensity rainfall simulator are being conducted immediately following wildfires to quantify post-wildfire runoff and erosion rates over a two year period to monitor the recovery. This paper presents post-wildfire results from three Natural Resource Conservation Service (NRCS) Ecological Sites. In April 2002, the Ryan Fire burned two grassland sites, a Loamy Upland Ecological Site (Post Canyon) and a Limey Slopes Ecological Site (East Mesa) on the Audubon Research Ranch near Elgin, Arizona. An oak woodland site (A-Bar), dominated by manzanita, burned in May 2003 as a result of the A-Bar fire near the San Rafael Valley. This site is also mapped as a Loamy Upland Ecological Site.

Methods

The rainfall simulator experiments were conducted immediately following the fires and before the onset of the summer monsoons. The Walnut Gulch Rainfall Simulator, an oscillating boom, variable intensity rainfall simulator (Paige et al. 2003a) was used to apply a range of rainfall intensities (50 to 180 mm/h) on 2 m by 6 m plots installed at the three sites. Two plots were installed at the grassland sites on "uniform" hillslopes. Four plots were installed at the A-Bar site—two on shrub interspace areas and two on interspace (no shrub mounds) areas. All plots had a dry run, 60 mm/h for 45 minutes, at initial soil moisture conditions followed by a wet run one hour after the cessation of runoff from the dry run. For the wet run, a sequence of application rates from 25 to 177 mm/hr in increasing increments was used. The application rates were changed after runoff had reached steady state for at least five minutes. Runoff was measured at the down slope outlet of the plot using a pressure depth gage attached to a pre-calibrated flume. Sediment samples were taken during the runs using grab samples, dried, and weighed to compute sediment concentrations. Plot cover characteristics, canopy and ground, were measured at 400 points per plot using the point intercept method.

Results and Discussion

Results from the rainfall simulator experiments were analyzed using data collected from the wet runs. Ratios were used to account for the different amounts of water applied on the plots. The runoff ratio, the total runoff (Q) divided by the total amount of water applied (I), was used to quantify the differences in runoff. The sediment yield ratio was computed as the total sediment yield (SY) divided by the total runoff (Q) amount times the plot slope (So) to account for the range of slopes (8-15%) at the sites. The total amount of applied rainfall and the runoff and erosion measurements from the wet runs are presented in table 1 along with the runoff and sediment yield ratios. A comparison between runoff and sediment yield

Table 1—Total rainfall (I), runoff (Q), and sediment (SY) amounts and runoff (Q/I) and sediment yield (SY/Q S_0) ratios for the wet runs.

Site	Plot	I mm	Q mm	SY T/ha	Q/I	SY/QSo T/ha/mm
East Mesa	EM2	85	58	6.50	0.69	0.74
	EM3	106	52	5.58	0.50	0.89
Average:					0.59	0.81
Post Canyon	PC1	94	48	2.53	0.50	0.66
	PC2	94	58	3.21	0.62	0.61
Average:					0.56	0.64
A-Bar	AB1	64	40	16.43	0.63	3.98
	AB2	84	62	16.11	0.74	2.84
	AB3	90	65	2.11	0.72	0.40
	AB4	84	68	4.42	0.81	0.66
Average:					0.72	1.97

ratios from the burned grassland ecological sites with similar unburned ecological sites showed increases in runoff from 5 to 74% and significant increases in erosion (399 to 2,200%) on the burned sites (Paige et al. 2003b). The results from the oak woodland site are much greater than those from the burned grassland sites, especially for the sediment yield (table 1). The runoff ratio from the A-Bar site is 18 to 22% greater than the two grassland sites, and the sediment yield is 58 to 68% higher. There is more variability in the runoff results from East Mesa and Post Canyon (22 and 15%) than for the A-Bar site (10%). However, there is much greater variability in the erosion (88%) from the A-Bar site than the East Mesa and Post Canyons Sites (13 and 5%).

Comparing the results from the A-Bar site, the sediment discharge rate as a function of runoff rate is much higher on plots 1 and 2 (figure 1). Concentrated flow was observed on plots 1 and 2, the shrub interspace plots, at the higher intensities. Multiple flow paths developed on plot 1, while plot 2 developed a single flow path down the center of the plot. Plots 3 and 4 displayed uniform sheet flow similar to the flow observed on the burned grassland sites.

Differences in the runoff and erosion responses for the full range of rainfall intensities from the three burned sites are illustrated in figure 2. The responses for the East Mesa and Post Canyon grassland sites show strong relationships between measured runoff and sediment discharge rates with R^2 values of 0.99 and 0.95, respectively. The runoff and erosion responses from the A-Bar oak woodland site show much more variability and a much greater range in sediment discharge rates for similar runoff rates. However, the response from plots 3 and 4 from the A-Bar site, which did not have shrub mounds, is very similar to Post Canyon grassland sites. Both sites are mapped as a Loamy Upland Ecological Site. This preliminary evaluation of the data from three wildfire burn sites indicates (1) that there is a range of runoff and erosion responses that can occur due to variable intensity rainfall and (2) that there appear to be significant differences between oak woodland and grassland responses immediately following wildfires.

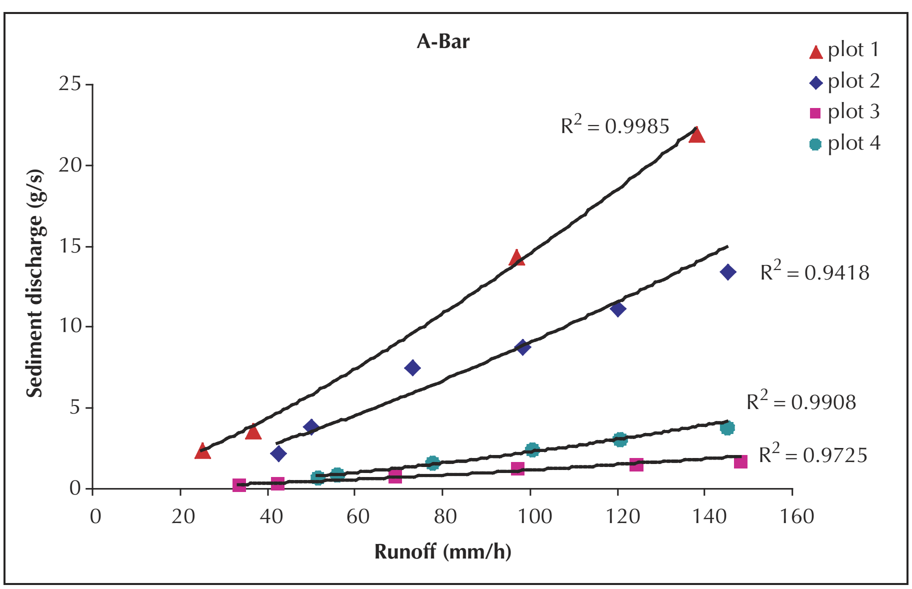

Figure 1—Comparison of sediment discharge rate as a function of runoff rate from the four plots at the A-Bar site.

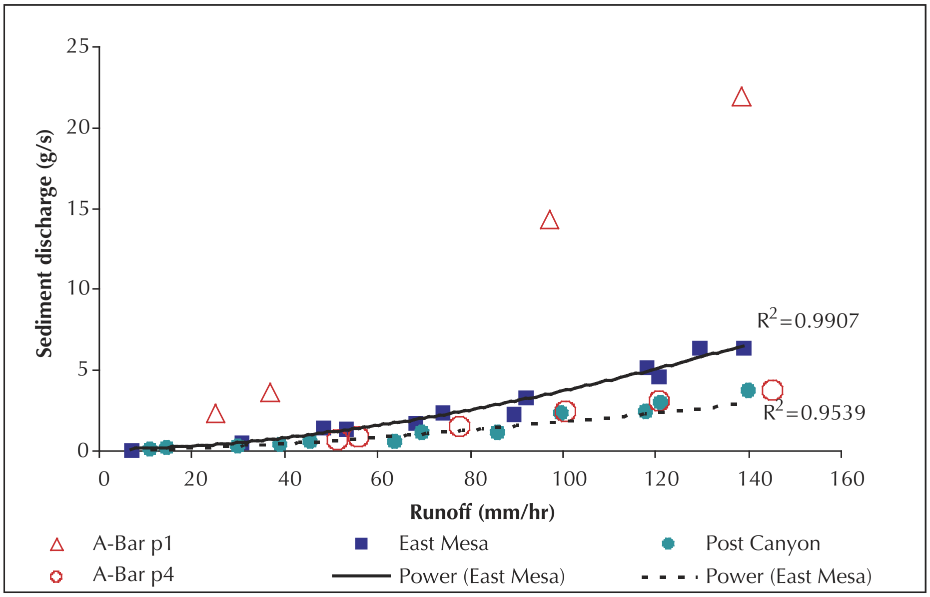

Figure 2—Sediment discharge rate as a function of runoff rate from the East Mesa and Post Canyon grassland sites and plots 1 and 4 from the A-Bar site. The erosion response from plot 4 (A-Bar) is very similar to the response from the Post Canyon Site.

Next Step

The post-wildfire runoff and erosion measurements from this and future field studies will be used to develop parameters for semiarid rangelands that can be used in Disturbed WEPP (Elliot et al. 2000) to evaluate runoff and erosion risks following wildfires. The model is being implemented within an erosion risk management tool (ERMiT http://forest.moscowfsl.wsu.edu/cgi-bin/fswepp/ermit/ermit.pl) in the Great Basin region (Elliot et al. 2001). The model is easy to use and parameterize and has an extensive database for the soil-vegetation complexes considered in the Great Basin. WEPP has the potential to be more applicable than TR55 and USLE to conditions in the Southwest because the hydrology and erosion components account for rainfall intensity and spatial characteristics of overland flow.

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