POST WILDFIRE RUNOFF AND EROSION RESPONSE ON GRASSLAND AND OAK WOODLANDS IN SOUTHEASTERN ARIZONA.

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ABSTRACT

Very little research has been conducted on the effect of wildfires on changes in runoff and erosion on grassland and oak woodland ecosystems in southeastern Arizona. As a result, land use managers and Burned Area Emergency Response teams face a high degree of uncertainty in evaluating post fire effects. Experiments using a rainfall simulator are being conducted after wildfires to measure runoff and erosion with the objective to develop methods for post fire evaluations. Data from four grassland and two oak woodland sites are presented and compared. The results for each vegetation community show that the increase in runoff ranges from no difference for grasslands to 20% for the oak woodlands while the increase in erosion is 350 to 500% for grassland and oak woodland respectively. Although the change in runoff is similar for both vegetation types, the increase in erosion is much greater for the oak woodland sites. This difference in erosion between the vegetation types is attributed to a change in the dominant erosion process from one that is primarily due to raindrop detachment for pre-fire conditions to one which is dominated by rill erosion immediately after a fire. For those sites with multiple years of data after the fire, both runoff and erosion appear to approach pre-fire conditions within two to three years.

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 and over a four year period to monitor the recovery. This paper presents post-wildfire runoff and erosion results from two oak woodland fires, ABar and Antonio, and three grassland fires, Ryan, Tank, and Empire. All of the fires were located in southeastern Arizona and were low to moderate severity burns. Characteristics of the sites are listed in table 1.

METHOD

The rainfall simulator experiments were conducted immediately following the fires and before the onset of the summer monsoons. Simulations were also conducted on the same site for an unburned condition and are being conducted during the recovery period for a period of four years. The Walnut Gulch Rainfall Simulator, an oscillating boom, variable intensity rainfall simulator (Paige et al., 2003) was used to apply a range of rainfall intensities (50 to 180 mm/h) on four small (0.75 m^2) and four large (2x6 m) plots installed at the sites. The small plot data were used to quantify erosion by rain drop detachment and the large plot data were used to quantify runoff and the integrated erosion response of rain drop detachment, flow detachment, sediment transport, and deposition. All plots had a dry run with a rainfall intensity of 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 rainfall intensities were applied from 25 to 177 mm/hr in increasing increments. 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 point 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 and are presented as the average for grassland sites and oak woodland sites. 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 (8-30%) at the sites. The runoff ratios immediately after the fire were not significantly different for the grassland sites but significantly increased for the oak woodland sites (figure 1a) by about 20% immediately after the fire. In contrast with the runoff ratios, the sediment ratios were significantly larger after the fire for both vegetation communities, ranging from about 350% for the grassland sites to 500% for the oak woodland sites (figure 1b). However, the oak woodland sites had post fire ratios about 2.5 times larger than the post fire ratios for the grassland sites. For those sites with two years of recovery data, the sediment ratios are not significantly different than the pre-fire ratios for both vegetation communities.

The difference in sediment ratios between the oak woodland and grassland sites can be attributed in part to the dominant erosion process active at the sites. In the following discussion, we assume that rain drop detachment of soil is the same on the small and large plots and that the difference, if any, in sediment discharge between the two size plots is due to the dominant erosion process on the large plots. Theoretically if the small plot sediment discharge is larger than the large plot discharge, then there is deposition of rain drop detached sediment on the large plot. If the small plot sediment discharge is smaller than the large plot discharge, then flow detachment should be occurring on the large plot. If the sediment discharge on both plots is the same, then all that is being detached by rain drop impact is being transported off the large plot. Comparisons of small and large plot steady state sediment discharge versus steady state runoff discharge times slope for pre-fire and immediately after the fire for both communities are shown in figures 2 and 3. The curves in the figures are best fit log-log regression lines. For the grassland sites, the pre-fire small plot relationship is larger than the large plot relationship (figure 2a) indicating deposition on the large plot. After the fire (figure 2b) both the small and large plot relationships are the same, meaning that all that is being detached by rain drop impact is being transported off the plot. In contrast, for the oak woodland sites, the pre-fire relationship for the small and large plots is the same (figure 2a) while for the post fire, the large plot relationship is larger than the small plot (figure 2b). These figures suggest that for pre-fire conditions, the dominant erosion process is rain drop detachment on both vegetation communities but that the oak woodlands is on the threshold of flow detachment. After a wild fire, the dominant erosion process approaches flow detachment on the grasslands but transitions to flow dominated detachment on the oak woodlands. The difference between pre-fire and post fire response was primarily due to a loss of canopy and ground cover slightly increasing rain drop detachment but significantly increasing transport capacity. The difference in sediment yield between the vegetation communities is hypothesized to be due to a higher transport capacity caused by differences in microtopography. Flow on the grassland sites generally is obstructed by grass plants, litter, and rocks so that the surface roughness is high and the flow path is sinuous, particularly at the lower flow rates. Thus, there is greater opportunity for deposition of detached sediment. In contrast, the microtopography on the oak woodland sites consists of topographic high areas (mounds) under the oaks and manzanita shrubs and topographic low areas (interspace) populated by grasses. At both the oak woodland sites, these interspace areas were continuous in the downslope direction and concentrated runoff during the simulations. These continuous concentrated flow areas appear to be more efficient at transporting sediment off the site.

SUMMARY

Rainfall simulator experiments are being conducted after five wildfires on oak woodlands and grassland sites in southeastern Arizona. Results from the experiments show that runoff does not significantly increase for the grassland sites and slightly increases for the oak woodland sites. Erosion increases dramatically for both vegetation communities immediately after a fire, with the oak woodland having the largest increase. The increase in erosion is attributed to a change in the dominant erosion process from rain drop detachment to a threshold flow detachment for the grassland sites and a threshold flow detachment to flow detachment for the oak woodland sites. Both vegetation communities appear to be approaching pre-fire erosion rates two years after the fire.

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Table 1. Site characteristics

Site	Fire (year of fire)	Ecological Site	Vegetation Community	Average Slope (%)
ABar	ABar (2003)	Loamy Upland	Oak	8
Antonio	Antonio (2005)	Loamy Upland	Oak	16
Empire	Empire (2005)	Loamy Upland	grass	16
East Mesa	Ryan (2002)	Limey Slopes	grass	12
Post Canyon	Ryan (2002)	Loamy Upland	grass	8
Tank	Tank (2004)	Clay Loam Upland	grass	30

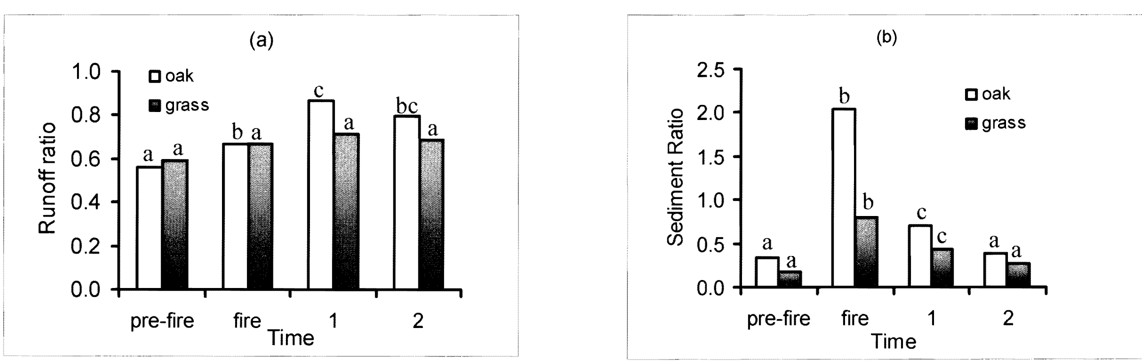

Figure 1. Vegetation community average (a) runoff ratios and (b) sediment ratios for pre-fire, immediately after the fire, and during the 1st and 2nd year after the fire. Bars for the same vegetation community followed by the same letter are not significantly different at $p \leq 0.05$.

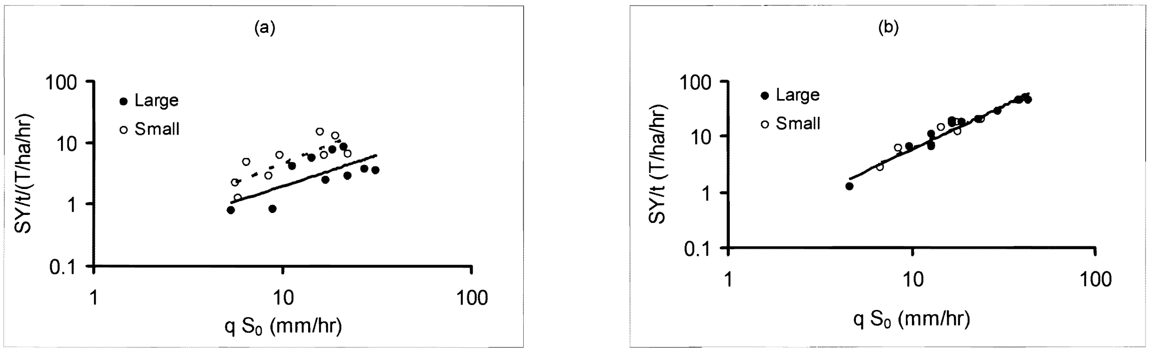

Figure 2. Comparison of small and large plot steady state sediment discharge (SY/t) versus steady state runoff discharge times slope (q S_0) for the grassland sites for (a) unburned and (b) burned conditions.

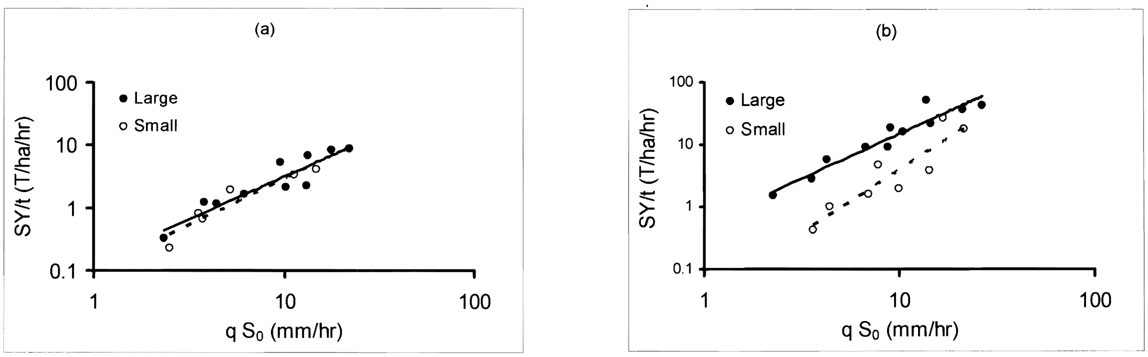

Figure 3. Comparison of small and large plot steady state sediment discharge (SY/t) versus steady state runoff discharge times slope (q S_0) for the oak woodland sites for (a) unburned and (b) burned conditions.