PRESCRIBED FIRE AND SIMULATED EROSION EFFECTS ON A SOUTHERN ARIZONA GRASSLAND: FIRST-YEAR RESULTS

Mary O'Dea[1] and D. Phillip Guertin[1]

Within an ecosystem, plant and soil processes interact to affect surface hydrology through their influence on surface roughness, soil structure, and evaporation, and through their relationship with soil biota. In the Southwest, decreases in perennial grass cover and erosion of uplands can initiate a decline in watershed condition. We know from both explicit research and intuition that the processes that characterize the watershed, such as geomorphology, hydrology, soil, and vegetation, are linked together. But what is not well known are the linkages and drivers that can advance the disruption of this integrated system.

The goal of this study is to identify and quantify the role of edaphic linkages between plant and surface hydrologic processes, specifically those that are dependent upon the physical, chemical, and biological features of the upper soil surface layer. The objective of this paper is to present first-year results in sediment yield, soil, and vegetation properties following a prescribed fire and simulated monsoon rainfall event on a perennial grassland community.

Materials and Methods

The study area is a small watershed located in Elgin, Arizona. This perennial grassland community contains native grasses, including plains lovegrass (*Eragrostis intermedia*), blue (*Bouteloua gracilis*), black (*B. eropida*), hairy (*B. hirusta*), and side-oats (*B. curtipendula*) gramas, other grama species, and *Muhlenbergia* spp. Mimosa (*Mimosa biuncifera*), rabbitbrush (*Chrysothamnus nauseosus*), various cacti, mesquite (*Prosopis velutina*), oaks, and juniper are also present.

The soil series at the site is a White House gravelly loam, whose parent material is an alluvium derived from andesite, rhyolite, limestone, and quartzsite. These soils are fairly deep with moderate to slow (0.06–0.2 in/hr) permeability and a high shrink/swell potential within the surface layer (SCS Soil Survey for Santa Cruz County, and parts of Cochise and Pima Counties, Arizona).

The study is a randomized complete block (block = replicate) with a split-plot design. Six blocks each containing four permanent runoff subplots were established, measuring 3 m wide by 10 m long with a 3-m buffer between plots. Each subplot was walled to disallow run on. Four treatments were randomly applied: an erosional rainfall event, a prescribed fire, a fire and erosion event, and a control. Twelve permanent sampling points were established systematically within each subplot.

A prescribed fire in early summer was applied following plot establishment and baseline data collection. The prescribed burn was planned for late spring–early summer to simulate the historic timing of fires in this area when lightning storms may occur.

Following the application of the burn treatment, assigned plots were forced into a visibly eroded state using a rotating-boom rainfall simulator. The assigned plots were treated at a rate of 2.5 inhr^{-1} for 40 minutes; ponding occurred after 3.5 minutes. All sediment was captured in a pan at the foot of the plot.

One hundred percent of the vegetation within each quadrat was surveyed for frequency of species occurrence, basal diameter, and percent total canopy cover. In addition, total percent cover of cryptogams, rocks, annuals, and bare ground was also noted.

Samples were taken in the top 10 cm of soil because these layers are the most influential on infiltration rates in semi-arid soils (Dunne et al. 1991). Aggregate stability (Kemper and Rosenau 1986), particle-size distribution (Gee and Bauder 1986), and bulk density (Blake and Hartge 1986)

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[1] School of Renewable Natural Resources, University of Arizona, Tucson 85721

were measured. A disk permeameter (infiltrometer) was used to measure changes in infiltration rates (Sullivan et al. 1996).

Tests for significant differences among treatments followed experimental design. Treatment effects on soil and plant parameters were analyzed with analysis of variance and covariance techniques.

Results and Discussion

Prior to treatment application there were no significant differences in mean percent cover for perennial grasses or herbaceous plants, cryptogams, rocks, or bare ground. Following the first growing season after treatment application, both perennial grass and herbaceous cover changed significantly ($p \leq 0.05$), reflecting treatment effects (Table 1). Significant decreases in perennial grass cover within the burned plots, and significant increases in herbaceous cover within the simulation and burn treatment, lead to questions regarding the stability of the highly disturbed communities (Figure 1).

There were also significant ($p \leq 0.05$) decreases in plant basal area among the burned plots (Table 1). There was little difference in basal area among the control and simulated erosion treatments. With the nearly 40 percent more total rainfall than the control plot, it was not unreasonable to expect a large accretion of biomass in the simulated erosion treatment. The large differences in basal area between the simulation and burn treatment with the other treatments illustrates not only the destructive nature of the treatment interaction, but also the variability among the treatments (Figure 2).

From field observation of the burned plots, the most notable characteristic of the perennial grass community is that both live and relic clumps remained on site following the first monsoon season. So although the relics may present physical barriers to overland flow this season, their presence in future years may be in question. These results therefore lead to questions regarding the possibility of an increased presence of annual species over the perennial ones within the highly disturbed sites, as well as a decrease in adequate barriers to overland flow in the future.

Following the first monsoon season there were no significant ($p \leq 0.05$) treatment effects on soil properties in either particle size distribution or percent stable aggregates (aggregate stability). Both the bulk soil and the sediment had highly variable particle size distributions, which included a large and variable clay fraction (30–60%). The number of percent stable aggregates (PSAs) did not significantly differ among treatments. Given that the PSAs were 0.3 mm or smaller, the wet-sieving method used to evaluate aggregate stability may not be appropriate to detect differences.

The burn treatments showed significant differences ($p \leq 0.05$) in both bulk density and surface infiltration rates compared to the unburned. Burned plots had significantly ($p \leq 0.05$) higher bulk density for the top 10 cm of the soil profile than the control. The simulation and burn treatment had significantly ($p \leq 0.05$) greater bulk density at the 6–10 cm depth compared to the surface 5 cm (Figure 3). Within the simulated erosion treatment, bulk density did not change significantly with depth. However, although the top 5 cm of the profile was not significantly different from the other treatments, the lower profile (6–10 cm) was significantly ($p \leq 0.05$) higher than the same depth in the control. Given the changes in the bulk density measurements it was not surprising to see similar patterns in the results for surface infiltration rates. As expected the burned treatments had significantly ($p \leq 0.05$) lower rates than the unburned treatments (Figure 4).

Changes in surface hydrology were expected, given the changes within the plant community and soil structure. Using total runoff and total

Table 1. First-year comparison of land cover among treatments.

	Percent Cover (%)					
Treatment	Basal Area (cm^2)	Perennial Grass	Cryptogams	Rocks	Herbs	Bare Ground
Control	254.8^a	20.4^b	0.5^a	0.7^a	0.9^b	77.5^b
Burned	185.3^{ab}	9.0^c	0.6^a	0.9^a	1.9^{ab}	87.7^a
Simulated erosion	319.8^a	29.8^a	0.5^a	0.8^a	1.9^{ab}	67.0^c
Simulation and burn	24.7^b	11.2^c	0.5^a	1.0^a	3.2^a	84.1^{ab}

Signifcant differences ($p \leq 0.05$) among means are denoted by different letters.

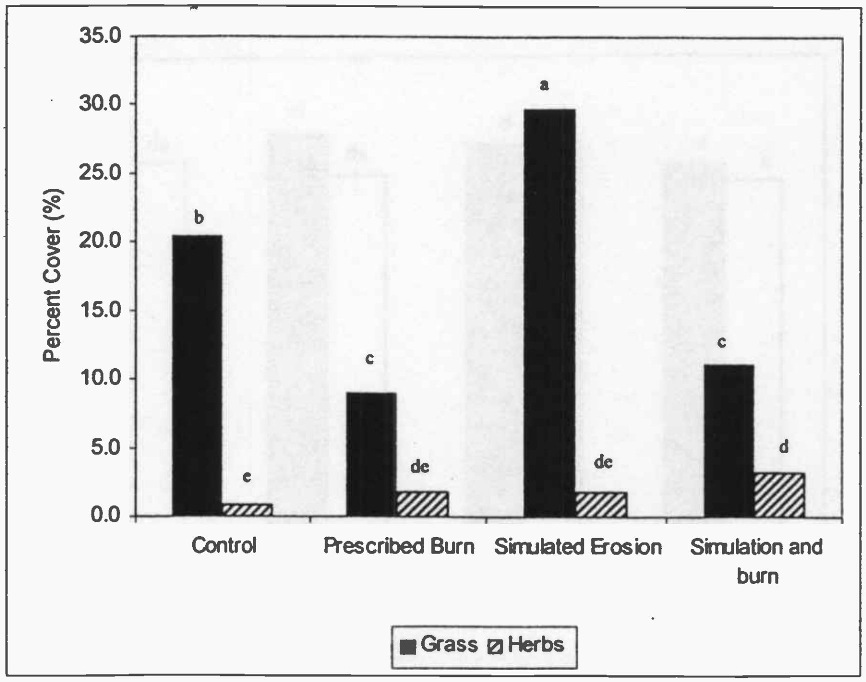

Figure 1. Comparison among treatments: Percent cover of perennial grass and annual herbaceous plants. 1 = Statistical comparison is within plant classes. 2 = Significant differences ($p \leq 0.05$) among means are denoted by changes in lettering.

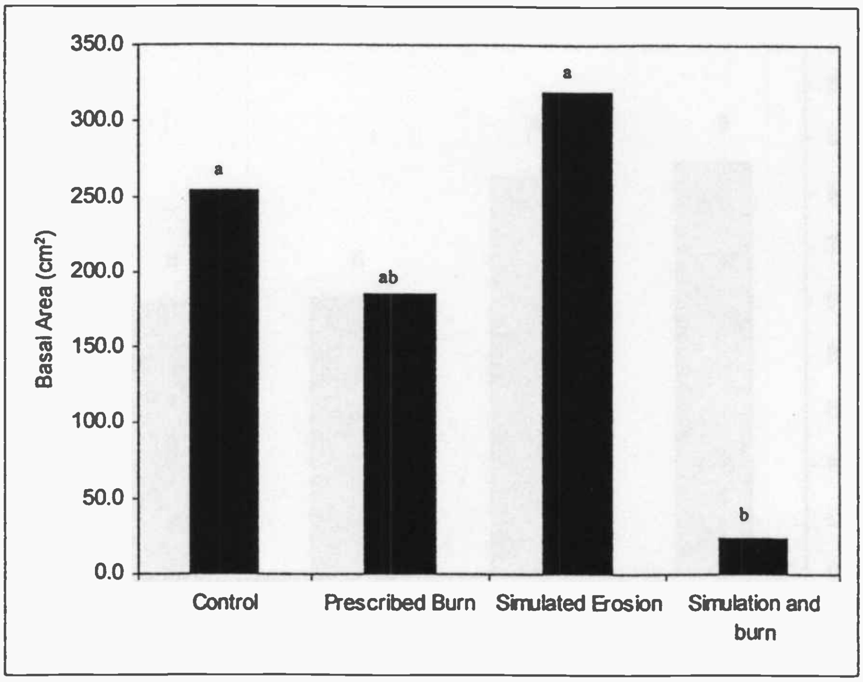

Figure 2. Comparison among treatments: Basal area of perennial grasses.

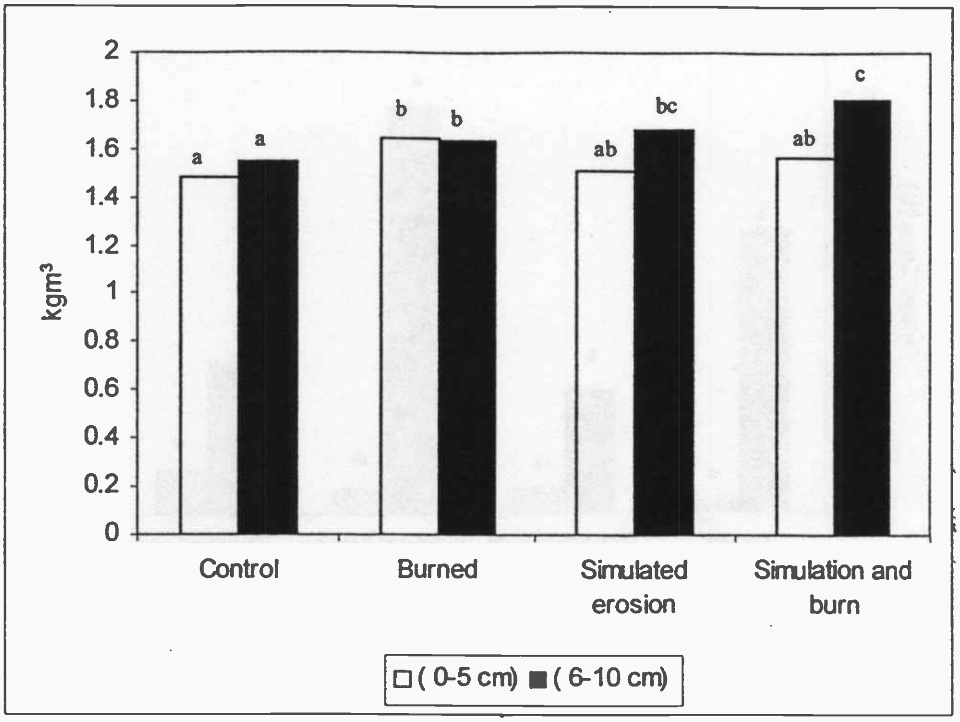

Figure 3. Comparison among treatments: Changes in bulk density with depth. Statistical comparisons are within depth classes.

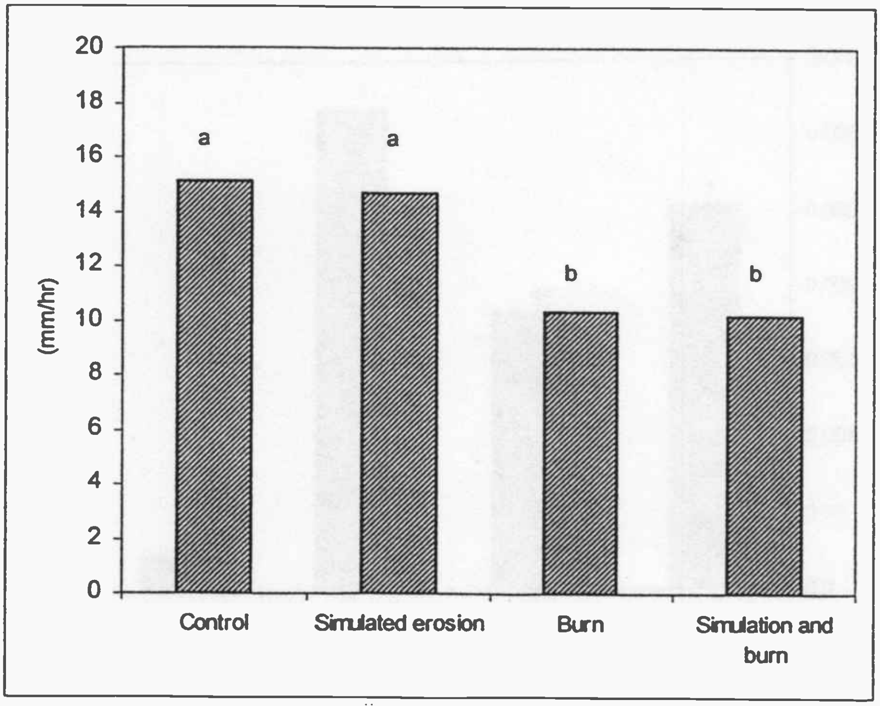

Figure 4. Comparison among treatments: Surface infiltration rates.

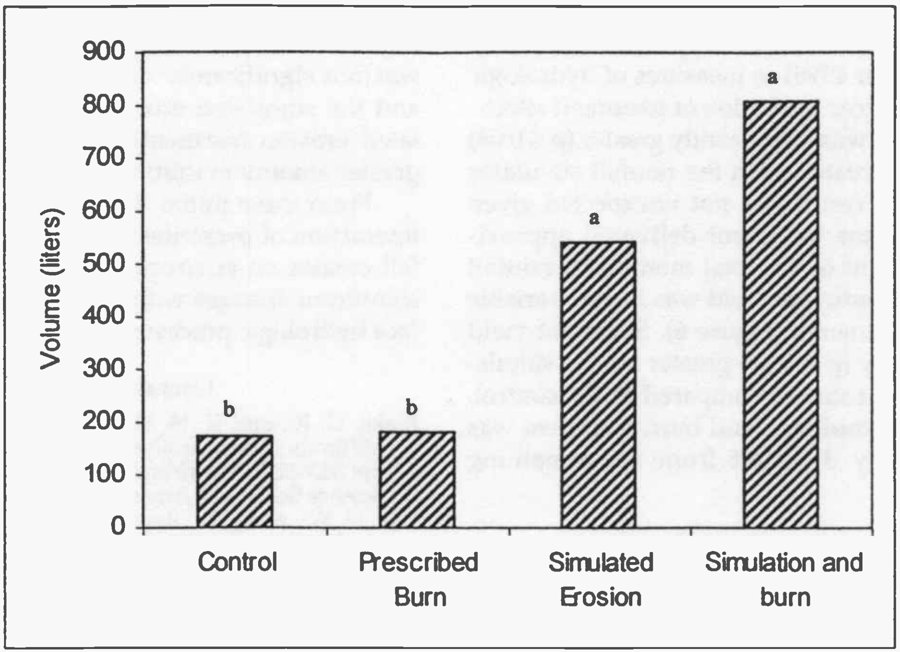

Figure 5. Comparison among treatments: Total runoff volume from 1 July 1998 to 1 October 1998 captured within the sediment pan. The values do not take into account losses due to evaporation or pan leakage.

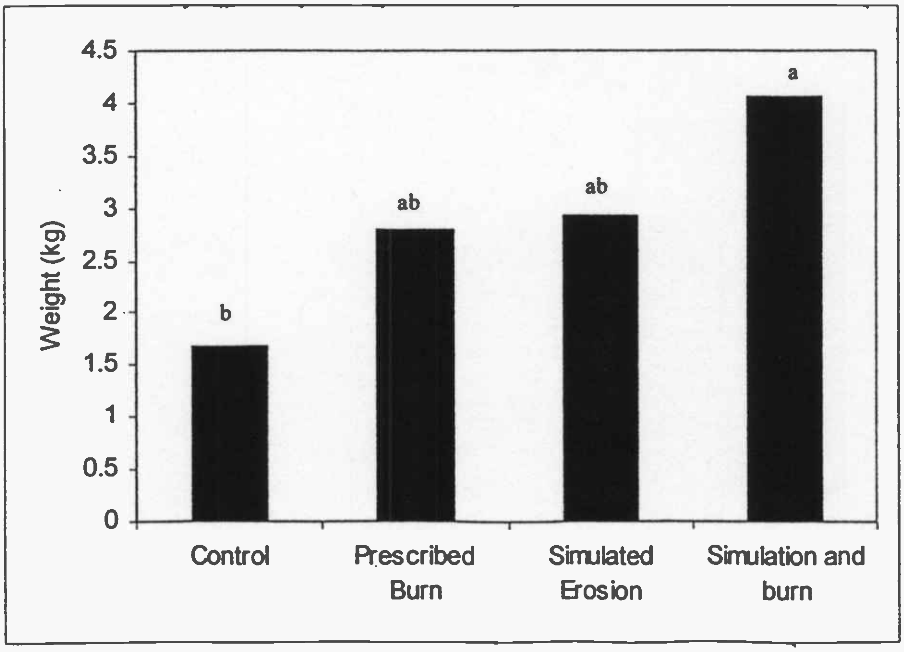

Figure 6. Comparison among treatments: Total sediment yield between 1 July 1998 and 1 October 1998.

sediment yield (in the sediment pans) captured during the monsoon season (approximately 1 July 1998 to 1 October 1998) as measures of hydrologic change gives a clear indication of treatment effect.

Total runoff was significantly greater ($p \leq 0.05$) from the plots treated with the rainfall simulator (Figure 5). This result was not unexpected given that the simulator treatment delivered approximately 40 percent of the total monsoonal rainfall for 1998. Total sediment yield was highly variable among the treatments (Figure 6). Sediment yield was significantly ($p \leq 0.05$) greater for the simulation and burn treatment compared to the control. However, the simulation and burn treatment was not significantly different from the remaining treatments.

Conclusion From First-Year Results

Burned plots showed the most dramatic changes in the first year following treatment application. These plots had lowered perennial plant cover and basal area, with a shift to increased annual cover. In addition, these plots had the highest values for bulk density, with the simulation and burn treatment having a significant change with depth. Moreover, these treatments displayed the slowest values for surface infiltration rates. Sediment yield was also greatest within the burn treatments. It is important to note that although the sediment yield was not significantly different between the burn and the simulated erosion treatments, the simulated erosion treatment had been subjected to a greater amount of rainfall (approximately 40%).

From these initial findings it appears that the interaction of prescribed fire and monsoonal rainfall creates an environment in which potentially significant changes within the plant, soil, and surface hydrologic processes may occur.

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