The Affect of Wildfire on Rangeland Sustainability in the San Rafael Valley
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Introduction

Wildfire can be a catastrophic event in some situations; it could also be beneficial in other situations. This depends on how the land is being used, and what sort of vegetation is present. Because rangelands often have different types of vegetation on them, burning is likely to have some effect on the interrelation between plant types. It is clear that if the vegetation is removed by fire, the land will not be good for grazing animals on for some time. But for how long should animals be kept off of the land?

If the vegetation is significantly reduced, the manner in which the land erodes will also change. For undisturbed conditions the dominant erosion mechanism for rangelands is due to raindrop impact. After a fire, overland flow becomes the dominant erosion mechanism. Fire causes a shift in the sediment transport regime due to this change in the dominant erosion mechanism. Understanding this shift is important to land managers so that they can decide on an effective rehabilitation strategy after a fire.

Objectives

The objectives of this study were to use a multi-intensity rainfall simulator to characterize the sediment transport regimes for both burned and unburned conditions in grassy and shrubby areas. To determine how long it takes for land to recover to after a fire. And to relate sediment transport regimes to the type of vegetation present on the landscape. In particular, because the study areas were located on a landscape that included both woody shrub areas and grassy areas, the dynamic between the mounds that formed at the bases of shrubs and the adjacent grassy interspace areas were investigated.

Experimental Design

A scheme for determining the dominant sediment detachment mechanism was created under the following assumptions:

If the experimental plot size is small, then the sediment that runs off of the plot is due to the raindrop splash detachment exclusively. However, if the experimental plot size is much larger, then sediment detachment can occur by either raindrop splash or overland flow. Also on larger sized plots sediment that has detached can re-deposit onto the plot, as well as runoff.

Sediment transport regimes would then be determined as follows. If a small plots regression model of sediment discharge vs. runoff yielded significantly larger sediment discharges than the large plots, this would mean that sediment detachment is due only to raindrop impact. Because the sediment yield from the large plots is less than the small plots in this case, it is assumed that
under this condition that there is sediment is re-deposition on the plot. This state is called Net Deposition. When the sediment yields from the two different sized plots are not significantly different, this state would be called Net Transport. This would mean that all erosion processes are at work. It is assumed that because the small plots are yielding as much sediment discharge as the large plots, raindrop splash is the dominant detachment mechanism. And also because the sediment yield is not significantly different between the plot sizes, it is assumed that the sediment that is detached is also transported off of the plot. In the case where the large plots yield more sediment discharge than the small plots, raindrop splash detachment is no longer the dominant detachment mechanism. This would imply that overland flow is the dominant erosion mechanism. The larger sediment yield from the large plots would mean that the sediment that has been detached would flow off of the plot. This state would be called Net Detachment.

Experiment

The oscillating boom multi-intensity rainfall simulator was placed over the experimental plot from which discharge data was to be collected. An initial rainfall simulation was conducted at an intensity of approximately 65 mm/hr for forty five minutes in order to establish uniform soil moisture. After a forty five minute hiatus, rainfall was again initiated at 65mm/hr to begin the data collection run.

Data collection involved monitoring discharge through a flume at the outlet of the plot in order to determine when steady state runoff was achieved. The flow through the flume was determined by a depth to discharge relationship that had been previously determined by calibration. Once steady state runoff was reached, hand samples of the outflow were taken at the flume. This process was repeated for the steady state runoffs created by 100, 130, 160 and 180 mm/hr rainfalls generated by the simulator.

At a later time, sample bottles were weighed, allowed to settle, decanted, dried in an oven (95°F) for more than twenty four hours, and then weighed again to determine the relative mass of sediment to mass of water. These sediment discharge and flow discharge data points were used to create linear regression models. A total sediment yield was also calculated for each plot so that a multi-linear regression model could be created to determine if any of the vegetation, canopy cover, or ground cover characteristics were significantly related to the sediment discharge.

This experiment was conducted at two field sites in the San Rafael Valley, one was called Abar, and the other San Antonio.
Analysis

Runoff and sediment yield ratios are described by equations 1 and 2.

\[
Q = \frac{Q}{P} \quad \text{eq(1)} \quad SY = \frac{SY}{A \cdot P \cdot S_0} \quad \text{eq(2)}
\]

Where \( Q \) = runoff amount (mm), \( P \) = rainfall amount (mm), \( SY \) = sediment yield (g), \( A \) = plot area (m\(^2\)), \( S_0 \) = plot slope (m/m)

These ratios were used to get a quick idea of how the different types of plots behaved at the different sites.

Charts 1,2

Charts 3,4

Observation of the relations shown in charts 1-4 showed that the major response to burning was seen in the sediment yield ratio during the year of the burn.

**Determination of Sediment Transport Regime**

\[
q_s = a \cdot (qS_0)^b \quad \text{eq(3)}
\]

Where \( q_s \) = steady state sediment discharge rate (g/s/m\(^2\)), \( q \) = steady state runoff discharge rate (mm/hr). The data was logarithmically transformed from a power relation to better fit the model.

\[
\ln q_s = a + b \cdot \ln(qS_0) \quad \text{eq(4)}
\]
For the unburned condition the regressions were similar for all plots. There was no significant difference between interspace, mound or small plots at the Abar site, and that there was no difference between small and interspace plots at San Antonio, but mound plots were significantly different from small plots at the San Antonio site. This indicated that the land was in the net transport sediment regime at Abar, and that at San Antonio interspace areas were in net transport and mound areas were in net detachment.

During the year of the fire both types of large plots were discharging more sediment than the small plots, indicating that the land was in a net detachment state. At both sites, the mound plots yielded more sediment discharge than the interspace plots.

The data from the fourth year after the fire showed that the small plots were yielding more sediment discharge than the both of the large plot types. Because the small plots were discharging more sediment than the large plots, the land was in a net deposition state.
Relating Sediment Transport Regimes to Vegetative Cover

It was determined that the amount of bare soil was the only significant variable used to predict the sediment yield from a plot. Bare soil vs. sediment yield was then plotted for both interspace and mound plots on the same graph. Information relating sediment yields to sediment transport regimes was used to relate sediment transport regimes to the degree of bare soil.

Chart 11

Discussion

The comparison of interspace and mound plots after a fire yielded some interesting results. In the unburned condition, the mound plots averaged a little more sediment yield than the interspace plots, but the behavior was not very different. Raindrop splash was the dominant erosion mechanism at this time for all plots except for a mound plot at San Antonio, which was in a net detachment state.

In the year of the fire there is a significant difference in the behavior of the two different kinds of plots. Mound plots discharged much more sediment than the interspace plots for same degree of bare soil. This was because the overland flow, which was the dominant erosion process, was focused between the shrub mounds. This created a more intense flow that preferentially eroded the mounds.

By the fourth year after the fire, there was little difference in how much sediment was being removed from the interspace and mound plots. This was because raindrop splash was once again the dominant erosion mechanism. The important difference to notice between this period and the initial unburned condition is the degree of bare soil. Because there was less bare soil, there must have been that more vegetation. In the unburned condition, the sediment transport regime was net transport, what was detached was carried off of the plot. At the time four years after the fire, with the new vegetation present, what sediment was detached by raindrop splash was re-deposited back onto the plot. This indicated that the land was once again suitable for grazing.

After a fire, the areas that have developed a micro-topography that supports shrub growth changed in a way that promoted grass growth. This lead to a state where erosion was lessened because the sediment that comes apart from the land did not travel far because it was caught by the vegetation. This indicated that fire plays a part in the sustainability of range lands.