Effects of Fire and Emergency Seeding on Hillslope Erosion in Southern California Chaparral

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Abstract

Catastrophic wildfires can set the stage for massive postfire erosion and sedimentation in southern California chaparral ecosystems with the onset of heavy winter rainstorms. As a mitigation measure, land managers have typically used grass seeding as a standard emergency rehabilitation technique. However, the effectiveness of grass seeding as a watershed protection practice remains uncertain. To address this problem, we conducted field experiments on southern California chaparral-covered hillsides involving burning and seeding to quantify the magnitude of postfire hillslope erosion and the effect of annual ryegrass (*Lolium multiflorum*) for erosion control. After fires in chaparral, there is a dramatic increase in both dry season and wet season sediment production, resulting in hillslope erosion up to 100 times greater than prefire amounts. Hillslope erosion generally takes 2 to 4 years to return to prefire levels, after which it may actually dip below the baseline. After a wildfire, the erosion response of a recently burned site was similar to that after the original prescribed fire, but lower in amplitude than a previously unburned companion site. Seeding with annual ryegrass may reduce postfire hillslope erosion on some sites in southern California chaparral ecosystems, but only after erosion has dropped to baseline levels.

Introduction

Chaparral in California is a shrub-dominated plant community that covers about 11 percent of the state (Barbour and Major 1988). Chaparral appears to be adapted to periodic burning, and fire may be necessary for ecosystem perpetuation (Barro and Conard 1991). However, these same fires may render the postburn landscape susceptible to massive erosion, flooding, and sedimentation. Many of these brushfields occur at the urban/wildland interface, where burgeoning population centers in the lowland valleys have encroached on adjacent foothills and steep mountain fronts. Consequently, the societal impacts of wildfire and accelerated erosion in chaparral are disproportionately large relative to its area.

The general patterns of postfire erosion on chaparral hillslopes have been well-documented (Rice 1974, Wells 1981, Wells 1986, Wells 1987). Fires remove the protective vegetation and organic litter from the hillsides and can destabilize surface soils on steep slopes. During and immediately after a fire, surface erosion increases by raveling or gravity sliding, as organic barriers are incinerated (liberating trapped sediment) and soil structure in the upper horizons is disrupted. With the onset of the rainy season, surface erosion again increases, as the denuded hillsides are exposed to raindrop impact and associated surface runoff. Moreover, the production of a fire-induced, near-surface water repellent soil layer (DeBano 1981) alters hillslope hydrology by restricting soil water infiltration. This can generate extensive overland flow capable of eroding considerable quantities of soil material. Erosion generally remains elevated for several years after a fire, gradually decreasing over time as the area revegetates, and watershed erosion returns to prefire levels within 5 to 10 years (Rowe and others 1949).

The potential for extensive damage and expensive cleanup costs associated with accelerated erosion and flooding in fire-prone chaparral ecosystems is enormous. Land managers and protection agencies have undertaken a variety of postfire emergency rehabilitation measures to protect downstream life and property. Although many possible options for erosion control are available (USDA Forest Service 1992), conventional wisdom maintains that it is most cost-effective and realistic to attempt to reduce erosion at the hillside source areas (Rice and others 1965).

Seeding treatments seek to rapidly establish a dense ground cover on burned hillslopes that will hold the soil in place until the area revegetates. By 1950 annual ryegrass (*Lolium multiflorum*) had become the species of choice for postfire seeding in chaparral ecosystems: it germinated quickly; produced an extensive root system; was inexpensive and readily available; and could be easily applied to large areas from the air (Barro and Conard 1987).

Although a variety of postfire rehabilitation strategies have been employed over the years, the effectiveness of the treatments has not been adequately monitored. Most projects were evaluated qualitatively or subjectively, perhaps with a photo series to document the degree of postfire ground cover. Rigorous quantification of hillslope erosion has been lacking (Barro and Conard 1987). The few studies that have measured surface erosion and compared postfire treatment effects suffered from inadequate sample sizes (Blankenbaker and Ryan 1985) or were confounded by factors such as severe animal disturbance (Taskey and others 1989) or extremely low precipitation in the first postfire winter (Rice and others 1965).

Another difficulty of working in chaparral ecosystems is the huge spatial and temporal variability in hillslope erosion response (Wells 1981, Wohlgemuth 1986). Thus, the results of individual sites from single years may reflect local site characteristics and/or postfire weather patterns rather than general fire responses or treatment effects.

This paper discusses burning and seeding field experiments to investigate postfire hillslope erosion and the effect of annual ryegrass for emergency watershed protection on chaparral sites in southern California.

Field Studies

Our experimental design initially called for the establishment of three study sites in each of four regions within coastal central and southern California (Peninsular Ranges, central Transverse Ranges, western Transverse Ranges, and southern Coast Ranges; fig. 1). All sites were located in areas that were targeted for burning by Federal, State, or county agencies as part of fuel hazard reduction programs. Unfortunately, only one site in each geographic area was burned and the four study sites burned in three different years: Belmar in 1988, Bedford and Vierra in 1990, and Buckhorn in 1994 (fig. 1). However, the Belmar site and a previously unburned companion site burned in a wildfire in 1993, yielding results from a total of five different fires. Physical site characteristics of the five burn sites have been previously described

(Wohlgemuth and others [In press]). Despite the implementation problems, this project, using identical methodologies over a wide variety of sites and conditions, represents the definitive hillslope erosion and seeding study to date in chaparral ecosystems.

California

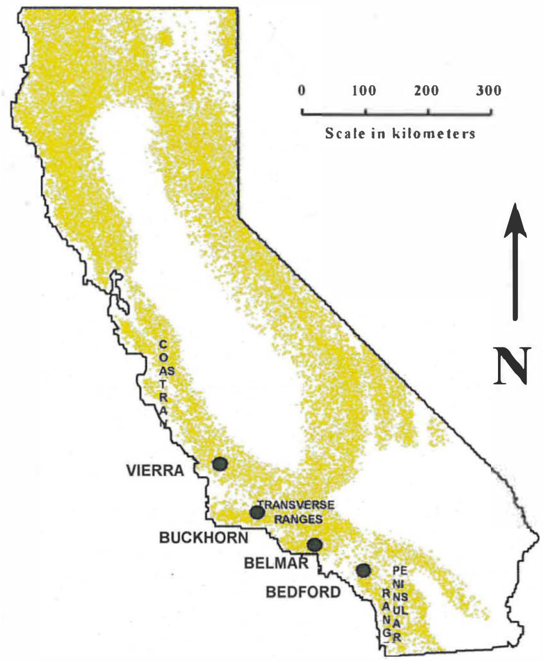

Figure 1. *Chaparral study sites of postfire hillslope erosion in the coastal central and southern California mountains.*

We established 70 erosion plots in mature, mixed chaparral at each site. Each erosion plot consisted of a set of five sheet metal sediment traps with a 30-cm aperture (Wells and Wohlgemuth 1987). These unbordered plots were situated at midslope positions, with the potential contributing area extending to the hillslope crest. We measured both wet and dry season hillslope erosion for 1 to 4 years before burning. At each site, 10 of the 70 plots were established outside the firelines to serve as unburned controls. The rest were burned in high intensity prescribed fires intended to mimic wildfire conditions. Partially burned plots were discarded, reducing the number of usable burn plots from the original 60 to as few as 36 and as many as 57. Half of the burn plots were randomly selected for seeding with annual ryegrass. Seed was applied in the late fall with hand-spreaders at a rate of 9 kg/ha (about 475 seeds per square meter), comparable to aerial seeding operations (Barro and Conard 1987). Sticky paper was deployed to check the application rate. Eroded material was collected from the traps, then transported to the laboratory where it was dried and weighed. Postfire erosion was measured with decreasing frequency for up to 5 years at each site, and erosion data were aggregated into wet and dry season collection periods, based on the rainfall patterns. Differences in erosion resulting from the seeding at a site were evaluated using a two-sample randomization technique (Manly 1991).

This study is unique in its combination of several design features. First, by physically capturing soil and sediment in collector traps, we were able to measure hillslope erosion directly, rather than relying on ocular estimates or indirect techniques such as erosion pins (Haigh 1977) or erosion bridges (Ranger and Frank 1978). Second, by using a large sample size, we were able to overcome the large spatial variability inherent in hillslope erosion that has undermined previous studies. Third, by using prescribed burns to simulate wildfires, sites were established before burning, enabling us to measure prefire erosion then capture the complete postfire erosion record for the exact same location, rather than using uncalibrated controls. Fourth, by establishing sites over a large geographic area and in different years, we were able to quantify erosion response over a wide variety of conditions. Fifth, one of our sites fortuitously burned in a wildfire 5 years after the original prescribed fire, enabling us to quantify the effects on hillslope erosion of a recent reburn.

Results and Discussion

Erosion data from the control plots were used in conjunction with the prefire data from the burned plots to calculate a baseline level of erosion for each sample location. This baseline is an estimate of the amount of erosion over time that would have been produced by a plot if it had not been burned. The baseline erosion varies over time, generally increasing in response to greater rainfall, but the magnitude of the fluctuations is very small compared to the change in erosion after fire. Postfire erosion was compared to the calculated baseline to quantify the effects of both the fire and the grass seeding on hillslope sediment movement. A generalized pattern of erosion response was determined on the basis of data from our study sites (Wohlgemuth and others [In press]; fig. 2).

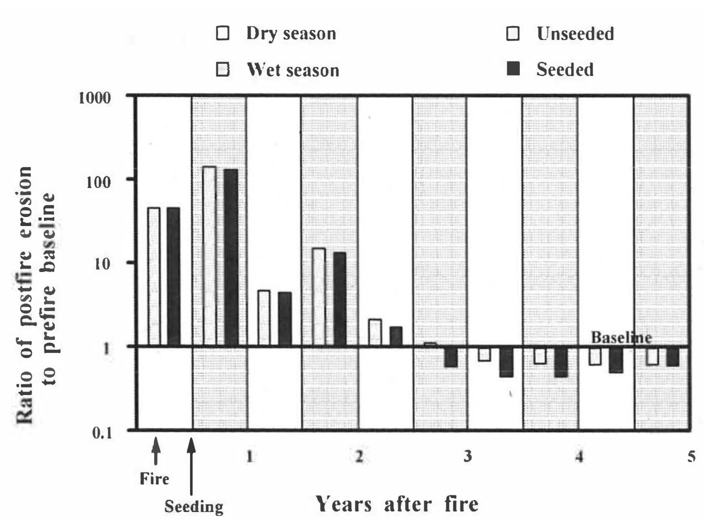

Figure 2. *Generalized pattern of postfire hillslope erosion and the influence of ryegrass seeding in chaparral. The values shown are indicative only and do not represent an actual site. The horizontal line is the baseline (prefire) erosion. The ratio of postfire erosion to baseline erosion is plotted on a logarithmic scale.*

Erosion increased dramatically after the fire at each site, confirming the observations of previous investigators (Rice 1974, Wells 1981). Accelerated erosion in the form of dry ravel starts during and immediately after the fire as the surface material on the hillslopes adjusts to a new equilibrium state. A second pulse of accelerated erosion is generated with the onset of the winter rains, as the hillslopes adjust to another equilibrium state governed by surface runoff. Generally, surface erosion in the first postfire winter is more pronounced in wet years (or years with very high intensity rains) than during normal or sub-normal rainfall years. In the case of drought years, dry season erosion can actually exceed surface transport during the wet season (Wohlgemuth and others [In press]).

Accelerated postfire surface erosion eventually recovers to prefire levels, as hillslope sediment supply is depleted and the site revegetates. On our sites, when postfire vegetation cover was sparse, recovery took as long as 4 years. However, recovery occurred in as little as 2 years on other sites where vegetation regrowth was rapid (Wohlgemuth and others [In press]). Three to 5 years after the fire, measured erosion actually dropped below the calculated baseline, similar to the pattern observed by Wells (1981).

Seeding with ryegrass to reduce erosion produced mixed results. On two of the sites (Belmar and Buckhorn), there was no treatment difference in surface erosion. On the other sites (Bedford and Vierra), significantly more ($p < 0.05$) postfire hillslope erosion was generated on the unseeded plots than the seeded plots for several of the seasonal collection periods (Wohlgemuth and others [In press]). However, this difference was not achieved until erosion was at, or below, the baseline levels (fig. 2).

The wildfire at the Belmar sites provided a valuable opportunity to compare a variety of burn responses for essentially identical site characteristics. The 1993 wildfire burned under much more severe weather conditions than did the original 1988 prescribed burn. Consequently, the reburn site burned with higher fire intensity than it did in the prescribed burn, while the previously unburned vegetation was completely consumed. Both sites had elevated erosion levels in the first postfire winter rains, but while the reburn erosion response was comparable to the original prescribed fire, the previously unburned site was an order of magnitude greater (Wohlgemuth and others [In press]). Recovery to preburn erosion levels was almost immediate on the reburn site, while erosion on the previously unburned site remained elevated. It is unclear to what degree these measured erosion responses reflect the relative importance of the fire characteristics, the vegetation regrowth, or the depletion of hillslope sediment supply.

Conclusions

In southern California chaparral-covered uplands, hillslope erosion is inevitable. Fire increases the background hillslope erosion by one to two orders of magnitude. Much of the postfire erosion occurs in the dry season on these steep hillsides, although accelerated erosion by gravity processes immediately after the fire is superseded by hydrologic processes with the onset of winter rains. Hillslope recovery to preburn erosion levels is remarkably rapid, occurring within 2-4 years after the fire. Grass seeding as a postfire emergency rehabilitation measure does little to reduce erosion until it has already dropped to baseline levels. Thus, it is unrealistic to expect that seeding can ever be more than a partial solution to the management problems associated with accelerated postfire erosion.

Each of these study locations was unique in terms of the combination of site characteristics, fire characteristics, and postfire rainfall that governed vegetation regrowth, erosion response, and seeding treatment effectiveness. Although we have been able to make some qualitative comparisons and note general trends, more study sites with better replication will be necessary before postfire hillslope erosion patterns are thoroughly explained.

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