The Effectiveness of Aerial Hydromulch as an Erosion Control Treatment in Burned Chaparral Watersheds, Southern California

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Abstract

High severity wildfire can make watersheds susceptible to accelerated erosion, which impedes resource recovery and threatens life, property, and infrastructure in downstream human communities. Land managers often use mitigation measures on the burned hillside slopes to reduce postfire sediment fluxes. Hydromulch, a slurry of paper or wood fiber that dries to a permeable crust, is a relatively new erosion control treatment. Delivered by helicopter, aerial hydromulch has not been rigorously field tested in wildland settings. Concerns have been raised over its ability to reduce watershed erosion along with its potential for negative effects on postfire ecosystem recovery. Since 2007 we have compared sediment fluxes and vegetation regrowth on plots treated with aerial hydromulch versus untreated controls for three wildfires in southern California. The study plots were all on steep slopes with coarse-textured soils that had been previously covered with mixed chaparral. Sediment production was measured with barrier fences that trapped the eroded sediment. Surface cover was repeatedly measured on meter-square quadrats. The aerial hydromulch treatment did reduce bare ground, and at least some of this cover persisted through the first postfire winter rainy season. Aerial hydromulch reduced hillslope erosion from small and medium rainstorms (peak 10-minute intensities of <30 mm/hr), but not during an extreme high-intensity rain event (peak 10-minute intensity of >70 mm/hr). Hydromulch had no effect on regrowing plant cover, shrub seedling density, or species richness. Hence, in chaparral watersheds, aerial hydromulch can be an effective postfire erosion control measure that is environmentally benign with respect to vegetation regrowth.

Keywords: wildfire, erosion control, hydromulch

Introduction

Wildfires can increase flooding and accelerate erosion in upland watersheds, adversely affecting natural resources and downstream human communities. Burned watersheds coupled with heavy winter rains can produce floods and debris flows that may affect riparian refugia of endangered species. They may also threaten life, property, and infrastructure (roads, bridges, utility lines, communication sites, pipelines) some distance from the fire perimeter. Land managers often use mitigation measures on the burned hillside slopes to reduce postfire sediment fluxes as the first step in ecosystem restoration and to protect human developments. Some of these rehabilitation treatments are costly but have not yet been proven to reduce erosion in wildland settings and may have serious consequences for postfire watershed recovery.

The physical landscape in southern California reflects the balance between active tectonic uplift and the erosional stripping of rock and soil material off the upland areas, along with the delivery of this sediment to the lowlands. Fire is a major disturbance event in southern California chaparral shrublands, and much of the erosion occurs immediately after burning. The postfire landscape, with the removal of the protective vegetation cover, is susceptible both to dry season erosion—ravel—and to wet season erosion—raindrop splash, sheetflow, and rilling (Rice 1974). Moreover, fire alters the physical and chemical properties of the soil—bulk density and water repellency—reducing infiltration and promoting surface runoff (DeBano 1981). The enhanced postfire runoff can remove additional soil material from the denuded hillsides and can mobilize sediment deposits in the stream channels

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to produce debris flows with tremendous erosive power (Wells 1987). Postfire erosion rates decline as the regrowing vegetation canopy and root system stabilizes the hillslopes, providing critical watershed protection (Barro and Conard 1991). In the southern California foothills, erosion is driven by winter cyclonic storms. Summer thunderstorms are rare, and snowmelt runoff is virtually nonexistent, except at the highest elevations.

Hydromulch, a slurry of paper or wood fiber that dries to a permeable crust and is used to increase groundcover, is one treatment option for reducing postfire erosion. Hydromulch has been used extensively on road cut slopes and construction sites. For burned areas with steep slopes with no road access, the hydromulch needs to be applied by fixed-wing aircraft or helicopter. The aerial hydromulch used in southern California is a wood and (or) paper mulch matrix with a non-water-soluble binder, often referred to as a bonded fiber matrix (BFM) (Hubbert 2007). The BFMs are a continuous layer of elongated fiber strands held together by a water-resistant, cross linked, hydrocolloid tackifier (bonding agent) that anchors the fiber mulch matrix to the soil surface (Hubbert 2007). BFMs provide a thicker cover than ordinary hydromulch and are recommended for steeper ground and areas frequented by high intensity storms. BFMs largely eliminate direct rain drop impact onto the soil, have high water holding capacity, are sufficiently porous not to inhibit plant growth, and will biodegrade completely. Breakdown of the product does not occur for up to 6–12 months through multiple wetting and drying cycles (Hubbert 2007).

Aerial hydromulch is a relatively new erosion control treatment that has not been extensively tested under field conditions in burned upland areas. Its ability to reduce erosion has not been quantitatively demonstrated, while its effects on regrowing vegetation are virtually unknown (Robichaud et al. 2000). The objectives of this study are to quantify the ability of aerial hydromulch to reduce postfire hillslope erosion and to document its effect on vegetation regrowth.

Study Sites

Aerial hydromulch has been used on three large wildfires located on National Forest lands in southern California in close proximity to the wildland/urban interface since 2007 (Figure 1). In each case a U.S. Department of Agriculture Forest Service Burned Area Emergency Response (BAER) team determined that there were significant threats to life, property, and infrastructure in the downstream human communities and recommended aerial hydromulch as a postfire erosion control treatment.

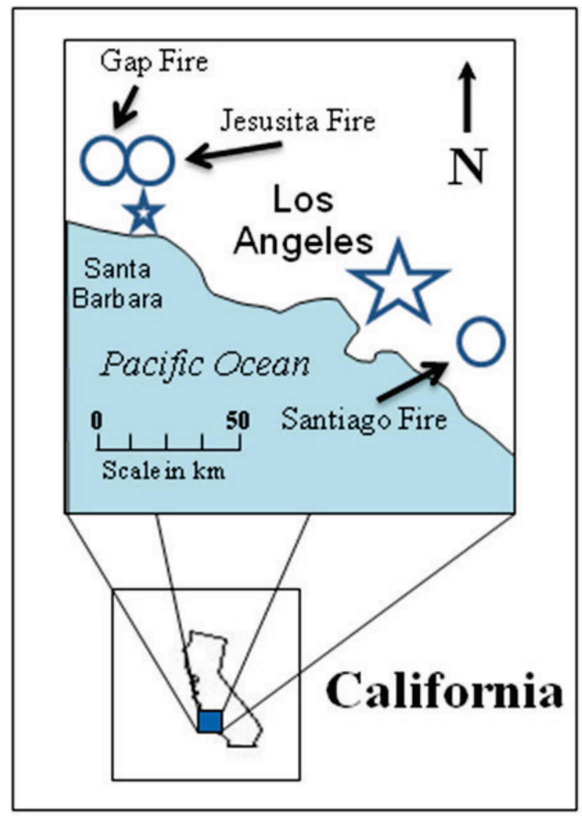

Figure 1. Location map of the study areas.

The Santiago Fire burned over 11,300 ha in Santiago Canyon, northeastern Orange County, CA (Figure 1). The burned area is a deeply dissected mountain block underlain by sedimentary and metamorphic rocks that produces a rocky, highly erosive soil (Wachtell 1975). The area was covered with thick chaparral vegetation, with some areas having no previous record of burning. Approximately 500 ha were treated with aerial hydromulch at a total cost of just under $5 million.

The Gap Fire burned nearly 3,850 ha in the Santa Ynez Mountains in Santa Barbara County, CA, in July 2008 (Figure 1). The burned area consists of the upper half of the coastal face of a linear mountain range underlain by sedimentary rocks that produce an erosive coarse-grained soil (Shipman 1981). Prior to the fire, the area was covered with mixed chaparral. Nearly 625 ha were treated with aerial hydromulch at a total cost of just under $5 million.

The Jesusita Fire burned roughly 3,540 ha in the Santa Ynez Mountains, Santa Barbara County, CA, in May 2009 (Figure 1). The burned area included the middle to lower slopes and canyons of the coastal face of a linear mountain range underlain by sedimentary rocks that produce an erosive coarse-grained soil (Shipman 1981). Nearly identical in site characteristics (topography, geology, soils) to the Gap Fire, the area was also covered with mixed chaparral vegetation prior to the fire. Over 80 ha were treated with aerial hydromulch at a total cost of $640,000.

Methods

Sites were operationally treated with aerial hydromulch, and plots were established on uniform slope facets. Companion control plots were established in nearby untreated areas, ideally within a few hundred meters of the treated plots with similar site characteristics. A minimum of four raingages were deployed at each study site to measure precipitation amounts and intensities. County gages within 5 km of the sites provided long-term data to put the measured rainfall in historical context. The studies were funded to measure erosion and vegetation regrowth for 3 years after each fire.

Hillslope erosion was measured using barrier fences constructed of high tensile strength nylon landscape fabric wired to t-posts (Robichaud and Brown 2002). The sediment fences were arranged in discrete clusters on the Santiago and Gap sites and along a series of adjacent interior spur ridges at the Jesusita site. On the Gap and Jesusita sites, the sediment fence plots were bounded by an upper trench, creating an area 15–20 m in length. The plots on the Santiago site were unbounded, averaging about 55 m in length. The fences built for these studies were approximately 5 m wide and 1 m high, with the capacity of the fence determined by its height, width, and hillslope gradient. Sediment captured by the fences was cleaned out using shovels and buckets after each rainstorm or series of storms. The sediment from each fence cleanout was weighed in the field and subsampled for moisture, and the field weights were corrected to account for the weight of the water.

Cover was measured in 1 m × 1 m quadrats using a grid frame and a pointer. The pointer was lowered at 100 points in a 10 cm × 10 cm grid within each quadrat. Hits were recorded for the various classes of cover and were converted to a percentage. Groundcover categories consisted of hydromulch, organic material (stumps, wood, live plant bases, litter), and bare soil including gravel and rocks. If the aerial hydromulch covered pieces of rock or wood, it was counted as mulch. Aerial cover from the regrowing vegetation was tallied separately from groundcover provided by plant bases. Two quadrats were initially sampled after site establishment just upslope of each sediment fence. An additional five quadrats were established for each fence in the first postfire spring season. These latter quadrats were placed from 4 to 20 m from the fence along vertical transects at the edges of each fence contributing area. Aerial plant cover was recorded by species. Surveys were conducted 2–3 times during the first postfire year, then annually in the spring. Indicators of postfire vegetation response include the amount of aerial plant cover (as opposed to groundcover), the density of shrub seedlings (the eventual climax vegetation), and a measure of species diversity or richness.

Results and Discussion

Initially, aerial hydromulch greatly reduced bare ground on the treated plots compared to the controls (Tables 1–3), presumably affording a greater level of watershed protection. Treatment cover of 17–24 percent persisted through the first postfire winter (over 65 percent on the Santiago site), but the hydromulch was less than 5 percent by the end of the second or third year after the fire. Cover of organic matter, less than 10 percent at the time of site establishment, reflected differences in rainfall as well as inherent site characteristics. Organic cover accumulated slowly on the Santiago site (which experienced a postfire drought) compared to the spectacular regrowth on the Jesusita site.

Total annual rainfall (and percent of long-term normal from nearby county gages), peak 10-minute rainfall intensity, and hillslope erosion aggregated to annual totals for treated and untreated plots are arrayed in Tables 4–6. The 64–84 percent reduction in first-year sediment yield compared to the untreated controls suggests that the aerial hydromulch was effective in controlling erosion on the Gap and Jesusita sites. At the Santiago site, initial storms of small and moderate amounts and intensities showed a reduction in hillslope erosion on the treated plots similar to the two Santa Barbara sites. However, an unusual short-duration but very high-intensity thunderstorm (>70 mm/hr) at the end of May completely overwhelmed the site, causing massive erosion to treated and untreated plots alike. Sediment fences were overtopped and the differences in first-year erosion (Table 4) are minimum values and merely reflect the differences in fence capacity. Thus, while aerial hydromulch can reduce hillslope erosion from small and medium rainstorms, it was ineffective during an extreme high-intensity rainfall event.

The hydromulch treatment caused no substantial differences in the amount of aerial plant cover, shrub seedling density, or species richness (Tables 7–9). There was no evidence that any species were eliminated or suppressed by the presence of the hydromulch. Thus, apart from minor differences attributed to inherent site characteristics, the aerial hydromulch was environmentally benign with respect to vegetation regrowth.

Conclusions

Resources on public lands need wise management while human development requires prudent hazard protection. Both are threatened by accelerated erosion in the aftermath of wildland fire. Aerial hydromulch is a relatively new erosion control technique that was previously untested in southern California watersheds and had raised concerns about unwanted environmental side effects. A recent series of wildfires and the application of aerial hydromulch as a BAER treatment prompted this study to evaluate the effectiveness of the mulch in reducing erosion and its affect on regrowing chaparral vegetation.

The aerial hydromulch does increase groundcover, some of which persists through the first postfire rainy season. The aerial hydromulch reduced hillslope erosion by 64–84 percent compared to untreated controls for small and moderate rainstorms, but not for an extreme rainfall event (>70 mm/hr). Moreover, the aerial hydromulch appeared to have no affect on postfire vegetation cover or species richness. Thus, in southern California chaparral watersheds, aerial hydromulch appears to be an effective postfire erosion control treatment from all but the largest storms and is environmentally benign with respect to vegetation regrowth.

Table 1. Average groundcover—Santiago Fire.

Survey	Hydromulch (n=10) (%)	Control (n=10) (%)
	Site establishment	
Treatment	66.0	0
Organics	0.8	2.1
Bare soil	33.2	97.9
	Year 1	
Treatment	65.7	0
Organics	3.1	2.8
Bare soil	31.2	97.2
	Year 2	
Treatment	18.4	0
Organics	27.8	20.5
Bare soil	53.8	79.5
	Year 3	
Treatment	3.6	0
Organics	64.0	41.7
Bare soil	32.4	58.3

Table 2. Average groundcover—Gap Fire.

Survey	Hydromulch (n=10) (%)	Control (n=6) (%)
	Site establishment	
Treatment	87.8	1.7
Organics	1.2	2.4
Bare soil	11.0	95.9
	Year 1	
Treatment	24.9	0
Organics	21.0	17.0
Bare soil	54.1	83.0
	Year 2	
Treatment	0.6	0
Organics	72.6	83.7
Bare soil	26.8	16.3

Table 3. Average groundcover—Jesusita Fire.

Survey	Hydromulch (n=10) (%)	Control (n=9) (%)
Site establishment		
Treatment	80.6	0
Organics	10.2	11.0
Bare soil	9.2	89.0
Year 1		
Treatment	17.7	0
Organics	66.7	62.6
Bare soil	15.6	37.4

Table 4. Average hillslope erosion—Santiago Fire.

Collection period	Hydromulch (n=10)	Control (n=10)
Year 1		
TAR	275 (59%)	
I_{10}	70.1	
HE	20.67*	26.1*
Year 2		
TAR	336 (64%)	
I_{10}	38.6	
HE	6.4	8.6
Year 3		
TAR	547 (93%)	
I_{10}	58.8	
HE	10.3	10.8

TAR, total annual rainfall (mm) (percent of normal)
I_{10}, peak 10-minute intensity (mm/hr)
HE, hillslope erosion (Mg/ha)
*Minimum value (fences overtopped)

Table 5. Average hillslope erosion—Gap Fire.

Collection period	Hydromulch (n=10)	Control (n=6)
Year 1		
TAR	469 (54%)	
I_{10}	59.4	
HE	7.8	21.5
Year 2		
TAR	1,055 (113%)	
I_{10}	27.4	
HE	2.8	5.1

TAR, total annual rainfall (mm) (percent of normal)
I_{10}, peak 10-minute intensity (mm/hr)
HE, hillslope erosion (Mg/ha)

Table 6. Average hillslope erosion—Jesusita Fire.

Collection period	Hydromulch (n=10)	Control (n=9)
Year 1		
TAR	554 (87%)	
I_{10}	41.1	
HE	5.3	33.7

TAR, total annual rainfall (mm) (percent of normal)
I_{10}, peak 10-minute intensity (mm/hr)
HE, hillslope erosion (Mg/ha)

Table 7. Average vegetation response—Santiago Fire.

Survey	Hydromulch (n=10)	Control (n=10)
Year 1		
APC	13.1	20.9
SSD	NA	NA
SR	1.7	3.2
Year 2		
APC	95.0	99.5
SSD	2.6	2.7
SR	4.1	5.5
Year 3		
APC	141.5*	115.4*
SSD	NA	NA
SR	8.4	10.5

APC, aerial plant cover (percent)
SSD, shrub seedling density (seedlings per quadrat)
SR, species richness (species per quadrat)
*overlapping plant cover can exceed 100 percent

Table 8. Average vegetation response—Gap Fire.

Survey	Hydromulch (n=10)	Control (n=6)
	Year 1	
APC	75.3	47.0
SSD	6.9	6.4
SR	6.2	3.2
	Year 2	
APC	160.4*	143.9
SSD	4.8	5.3
SR	9.8	6.8

APC, aerial plant cover (percent)
SSD, shrub seedling density (seedlings per quadrat)
SR, species richness (species per quadrat)
*overlapping plant cover can exceed 100 percent

Table 9. Average vegetation response—Jesusita Fire.

Survey	Hydromulch (n=10)	Control (n=9)
	Year 1	
APC	155.3	158.7*
SSD	7.5	3.2
SR	7.4	8.4

APC, aerial plant cover (percent)
SSD, shrub seedling density (seedlings per quadrat)
SR, species richness (species per quadrat)
*overlapping plant cover can exceed 100 percent

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