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 that may impede resource recovery and threaten life, property, and infrastructure in downstream human communities. Land managers often use mitigation measures on the burned hillside slopes to control post-fire sediment fluxes as the first step in ecosystem restoration and to protect human developments. Aerial hydromulch, a slurry of paper or wood fiber that dries to a permeable crust, is a relatively new erosion control treatment that has not been rigorously field tested in wildland settings. Concerns have been raised over the ability of aerial hydromulch to reduce watershed erosion along with its potential for negative impacts on post-fire ecosystem recovery. Since 2007 we have measured sediment fluxes and vegetation development on plots treated operationally with aerial hydromulch and compared them to untreated controls after three separate wildfires in southern California. These study plots, located on steep slopes with coarse upland soils previously covered with mixed chaparral, were monitored with silt fences to trap eroded sediment and meter-square quadrats to measure ground and vegetation cover. We found that aerial hydromulch did reduce bare ground on the treated plots and that some of this cover persisted through the first post-fire winter rainy season. Aerial hydromulch reduced hillslope erosion from small and medium rainstorms, but not during an extreme high intensity rain event. Hydromulch had no effect on regrowing plant cover, shrub seedling density, or species richness. Thus, in chaparral watersheds, aerial hydromulch appears to be an effective post-fire erosion control measure that is environmentally benign.

Keywords: (wildfire, erosion control, hydromulch)

Introduction

Wildfire increases flooding and accelerated erosion in upland watersheds that can adversely affect natural resources and downstream human communities. Burned watersheds coupled with heavy winter rains can produce floods and debris flows that may threaten riparian refugia of endangered species as well as 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 control post-fire sediment fluxes as the first step in ecosystem restoration and to protect human developments. Some of these rehabilitation treatments are costly, yet to be proven to reduce erosion in wildland settings, and may have serious consequences on post-fire 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 environments that drives much of the surface erosion. The post-fire 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 post-fire runoff removes even more soil material from the

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denuded hillsides and can mobilize sediment deposits in the stream channels to produce debris flows with tremendous erosive power (Wells 1987). Post-fire accelerated erosion eventually abates 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 non-existent.

Aerial hydromulch, a slurry of paper or wood fiber that dries to a permeable crust and is used to increase ground cover, is one of the post-fire erosion control treatment options available to land managers and hazard protection agencies. The aerial hydromulch typically used in the 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 BFM's 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). BFM's provide a thicker cover than ordinary hydromulch, and are recommended for steeper ground and areas frequented by high intensity storms. They can eliminate direct rain drop impact onto the soil, have high water holding capacity, are porous enough not to inhibit plant growth, and will biodegrade completely. Breakdown of the product does not occur for up to six to twelve months through multiple weather cycles including rain (Hubbert 2007).

Aerial hydromulch is a relatively new erosion control treatment that has not been extensively tested under field conditions in burned upland areas. Uncertainty remains about its ability to reduce erosion, while its impacts on re-growing vegetation are virtually unknown (Robichaud et al. 2000). These concerns prompted this study to evaluate the performance of the aerial hydromulch treatment in wildland settings.

Study Sites

Since 2007 aerial hydromulch has been used on three large wildfires located on National Forest lands in close proximity to the wildland/urban interface. 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 post-fire erosion control treatment.

Santiago Fire

In October 2007 an arson incident triggered a wildfire in Santiago Canyon, in northeastern Orange County, California (Figure 1), consuming the vegetation on over 11,300 hectares. The Santiago Fire area consists of a deeply dissected mountain block underlain by sedimentary and metamorphic rocks that produces an erosive soil with considerable coarse, rocky fragments (Wachtell 1975). The area was covered with heavy chaparral vegetation, some of which had no recorded fire history. Approximately 500 hectares were treated with aerial hydromulch at a total cost of just under $5 million.

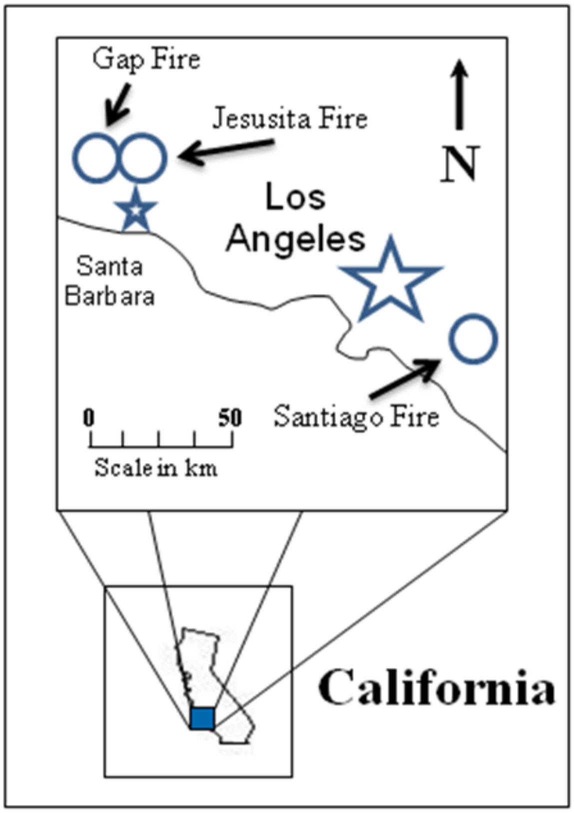

Figure 1. Location map of the study areas.

Gap Fire

In July 2008 an accidental fire start generated a wildfire in the Santa Ynez Mountains, in Santa Barbara County, California (Figure 1), burning nearly 3850 hectares. The Gap Fire 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). The area was covered with heavy mixed chaparral vegetation prior to the fire. Nearly 625 hectares were treated with aerial hydromulch at a total cost of just under $5 million.

Jesusita Fire

In May 2009 an accidental fire start produced another wildfire in the Santa Ynez Mountains, in Santa Barbara County, California (Figure 1), burning roughly 3540 hectares. The Jesusita Fire area consists of 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 to the Gap Fire, the area was also covered with heavy mixed chaparral vegetation prior to the fire. Over 80 hectares were treated with aerial hydromulch at a total cost of $640,000.

Methods

Hillslope erosion was measured using silt fences constructed of high tensile strength nylon landscape fabric wired to t-posts (Robichaud and Brown 2002). The fences built for these studies were approximately 5 meters wide and 1 meter high, with the capacity of the fence determined by its height and the slope gradient of the hillside. On the Gap and Jesusita sites, the silt fence plots were bounded by an upper trench, creating an area 15 to 20 meters in length. The plots on the Santiago site were unbounded, averaging about 55 meters in length. Sediment captured by the silt fences was cleaned out after each rainstorm or series of storms. Cleanouts were performed by hand using shovels and buckets along with a portable balance to measure field weights. Subsamples were taken from each fence, moisture determinations were made in the laboratory for the subsamples, and the field weights were corrected to account for the weight of the water. The silt 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. A raingage was deployed at each fence cluster or spur ridge to measure precipitation amounts and intensities. Nearby county flood control gages yielded long-term average rainfall patterns.

Cover was measured in 1 meter by 1 meter quadrats using a grid frame and a pointer. The pointer was lowered at 100 points in a 10 cm by 10 cm grid within each quadrat. Hits were recorded for the various classes of cover and were converted to a percentage. Aerial cover from the re-growing vegetation was tallied separately from ground cover provided by plant bases. Ground cover categories consisted of hydromulch treatment, organic material (stumps, wood, live plant bases, litter), and bare soil – including gravel (mineral pieces ranging in size from 1 to 7.5 cm) and rock (fragments greater than 7.5 cm in size). If the aerial hydromulch covered pieces of rock or wood, it was counted as mulch. Two quadrats were initially sampled after site establishment just upslope of each silt fence. An additional five quadrats were established for each fence in the first post-fire spring season. These latter quadrats were placed from 4 to 20 meters along vertical transects at the edges of each silt fence contributing area. Aerial plant cover was recorded by species. Surveys were performed 2-3 times during the first post-fire year, then annually in the spring for up to three years after the burn.

Results

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. Some treatment cover persisted through the first post-fire winter (a substantial amount on the Santiago site), but the hydromulch was essentially gone by the end of the second or third year after the fire. Cover of organic matter, small at the time of site establishment, was undoubtedly affected by differences in rainfall as well as by inherent site characteristics. Organic cover accumulated slowly on the Santiago site (which experienced a post-fire drought) compared to the spectacular re-growth on the Jesusita site.

Total annual rainfall (and percent of long-term normal from nearby county gages), peak ten-minute rainfall intensity, and hillslope erosion aggregated to annual totals for treated and untreated plots are arrayed in Tables 4-6. The large 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. The lack of reduction on the Santiago site can be explained by the pattern of first-year rainfall. Initial storms of small and moderate amounts and intensities in fact 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 at the end of May completely overwhelmed the site, scouring treated and untreated plots alike. Silt fences were overtopped and the differences in first-year erosion (Table 4) merely reflect the differences in silt 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.

Indicators of post-fire vegetation response include the amount of aerial plant cover (as opposed to ground cover), the density of shrub seedlings (the eventual climax vegetation), and a measure of species diversity or richness (Tables 7-9). None of these categories show substantial differences between treated and untreated plots for any of the study sites. No species were eliminated or suppressed by the presence of the mulch. Thus, apart from minor differences attributed to inherent site characteristics, the aerial hydromulch was environmentally benign.

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 is untested in southern California watersheds and has 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 re-growing chaparral vegetation.

Our findings show that the aerial hydromulch does increase ground cover, some of which persists through the first post-fire rainy season. The aerial hydromulch reduced hillslope erosion compared to untreated controls for small and moderate rainstorms, but not for an extreme rainfall event. Moreover, the aerial hydromulch appeared to have no affect on several indicators of post-fire vegetation response: aerial plant cover, shrub seedling density, and species richness. Thus, in southern California chaparral watersheds, aerial hydromulch appears to be an effective post-fire erosion control measure that is environmentally benign.

Table 1. Average ground cover – Santiago Fire.

Survey	**Hydromulch** (n=10)	**Control** (n=10)
Site establishment	-----------Percent----------	
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 ground cover – Gap Fire.

Survey	**Hydromulch** (n=10)	**Control** (n=6)
Site establishment	-----------Percent----------	
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 ground cover – Jesusita Fire.

Survey	**Hydromulch** (n=10)	**Control** (n=9)
Site establishment	-----------Percent----------	
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 ten-minute intensity (mm hr^{-1})
HE – Hillslope erosion (Mg ha^{-1})

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		1055 (*113 %*)	
I_{10}		27.4	
HE	2.8		5.1

TAR – Total annual rainfall (mm) (*Percent of normal*)
I_{10} – Peak ten-minute intensity (mm hr^{-1})
HE – Hillslope erosion (Mg ha^{-1})

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 ten-minute intensity (mm hr^{-1})
HE – Hillslope erosion (Mg ha^{-1})

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

Table 7. (cont.)

Survey	**Hydromulch** (n=10)	**Control** (n=10)
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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