Effects of Three Mulch Treatments on Initial Postfire Erosion in North-Central Arizona[1]

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Abstract

Mulching after wildfires is a common treatment designed to protect bare ground from raindrop impact and reduce subsequent erosion. We tested the effectiveness of three mulching methods on the Indian Fire near Prescott, Arizona, USA. The first method felled all fire-killed trees, chipped the logs and limbs, and spread the chips across the hillslope with a mobile self-feeding chipper. The second treatment spread compressed, tackified straw pellets that expand when wetted and release a soil flocculant. The third treatment was rice straw applied at 4.5 Mg ha^{-1} (2 tons ac^{-1}). Each treatment was applied to a small catchment with a silt fence sediment trap at the mouth. Sediment yield from an untreated (control) catchment was also measured. The treatments were tested by three erosion-causing summer rain events. The chipping treatment and the pellets reduced sediment yield by 80 to 100 percent compared to the control in the first two storms. In the third event, a multi-day storm followed by an intense thunderstorm, the pellets and straw reduced sediment yield 42 and 81 percent, respectively. The effectiveness of the chip treatment could not be completely assessed because of partial failure of the sediment fence. Vegetation cover was low on all sites; ground cover from pellets decreased more than did straw or chips by mid-October, probably accounting for the lower effectiveness in reducing erosion compared to straw.

Introduction

Applying mulch to protect bare ground is regarded as one of the most effective methods for reducing post-fire erosion (Bautista and others 1996, Miles and others 1989, Robichaud and others 2000). Rice or cereal straw is most commonly applied by hand to hillslopes above high-value assets such as roads, streams or reservoirs. Hand-application makes this method relatively labor-intensive and expensive to employ (Miles and others 1989, Robichaud and others 2000).

There is a great deal of interest in developing mulch methods that can be applied more easily or use on-site materials. We initiated a project to use two relatively new mulch treatments – on-site whole tree chipping and compressed straw pellets – on a 2002 wildfire site in north-central Arizona. This paper evaluates the initial erosion-control effectiveness of these treatments compared to a standard method—hand-applied rice straw—and an untreated control.

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Methods

The May 2002 Indian Fire burned approximately 550 ha (1,340 ac) of ponderosa pine (*Pinus ponderosa*) forest with scattered oaks (*Quercus emoryi*) on the Prescott National Forest, just southwest of Prescott, Arizona, USA. A large portion of the fire area, including the location used for this project, was rated as high burn severity, with complete or nearly complete consumption of tree foliage and total removal of ground cover.

The study site was located approximately 4 miles south of Prescott on an east-facing slope at an elevation of 1,800 m (5,900 ft) in the Indian Creek drainage. Soils on the site are classified as lithic ustorthents, derived from granitic parent material. Average annual rainfall in nearby Prescott is 487 mm (19.2 in). Different mulch treatments were applied to small (0.34 to 0.48 ha [0.83 to 1.20 ac]) zero-order watersheds with similar slope geometry situated adjacent to each other. Slope angles increased from less than 10 percent at the bottom to 30 to 40 percent in the upper portions of each watershed.

Each of the three mulch treatments was applied to one small watershed, with a fourth watershed left untreated as a control. A 10 to 15 m wide silt fence was installed at the base of each watershed, where slope angle was less than 10 percent, to serve as a sediment catchment basin, following the method of Robichaud and Brown (2002). A second silt fence was installed below the first to serve as a back-up in case of sediment overflow or fence failure. Silt fence material (supplied by GeoTK LLC, Vancouver, WA, USA) was supported on standard steel fence posts (T-posts) spaced approximately 1.5 m apart. The fences were approximately 1.3 m tall. After installing the fences, the floor of each basin was covered with a layer of construction marking chalk. This facilitated finding the bottom of the basin when digging out sediment for measurement. Mulch treatments were applied as equipment and materials became available. Silt fences were installed as near as possible to the time treatments were applied.

Two tipping-bucket recording rain gauges (Onset Computer Corp., Bourne, MA, USA) were installed on the site; each tip recorded 0.25 mm (0.01 in.) of rain. Data were periodically downloaded from the rain gauges to office computers for analysis via an Onset HOBO Shuttle™ and BoxCar Pro™ software. Rain gauge output was used to calculate total precipitation as well as 10-, 30- and 60-minute maximum rainfall intensities for each storm event.

The "chips" treatment consisted of felling all killed (pine) and top-killed (oak) trees in the catchment with a track-mounted feller-buncher, followed by chipping all logs smaller than 35 cm with a tracked whole-tree chipper. The discharge chute of the chipper could be rotated, allowing a certain degree of control over the distribution of the chips. Most chips produced were 1 to 2 cm wide by 2 to 5 cm long and about 1 cm thick, but they ranged in size up to 10 to 15 cm across and several cm thick. Depth of the chips varied considerably, from a few cm to several dm in isolated areas. Cover was originally nearly 100 percent. Chips were applied in mid-July 2002. The upper 10 to15 m of the watershed contained an archaeological site (largely rocks) that had to be excluded from treatment; this affected less than 10 percent of total watershed area.

The "pellets" treatment was applied on July 16. The pellets (supplied by Pelletized Straw, LLC, Manteno, IL, USA) were made of a highly compressed, pasteurized straw product bound with "Silt Stop," a proprietary polyacrylamidefamily linear polymer soil flocculant/tackifier. Pellets were 1.9 cm diameter and chopped to an average of 0.6 cm in thickness to prevent rolling after application; they are designed to expand 4-fold or more upon wetting and to be held in place by the tackifier. Pellets were hand-spread to produce 50 percent cover when dry in an effort to provide 100 percent cover upon wetting and expansion. Silt fences on the pellet catchment were installed August 1. One significant rain event occurred after treatment but before installation of the silt fences.

Rice straw ("straw" treatment) was spread the week of August 5 at a rate of 4.5 Mg ha^{-1} (2 T ac^{-1}), based on findings of Edwards and others (1995) that an application rate of 4 Mg ha^{-1} was optimum for minimizing erosion. Fences were installed the following week.

After each precipitation event that resulted in significant erosion in the catchments, we removed and weighed collected sediment from behind the silt fences. Stratification of the sediment was visually assessed, and the proportion of each class of sediment–fine, wet, ashy sediment near the fence to coarse, sandy, dry material upstream–was estimated. The sediment was then subsampled for moisture content, with the number of samples taken from each class based on the proportion of the total sediment estimated to be in the class. Wet sediment was weighed on an electronic balance to the nearest 0.1 kg and then discarded downslope of the edges of the silt fences. After sediment was removed to the original contour of the basin, a new layer of chalk was applied in preparation for the next event. Moisture subsamples were returned to the lab, weighed, and dried to constant weight in a forced air oven at 105°C. The moisture content of the subsamples and the contributing area of each catchment were used to convert the measured wet weight of sediment to mass of dry sediment per ha.

Ground cover by straw pellets, pellet remnants, rock, woody debris, ash, and bare soil was visually estimated in nine randomly placed 1 m^2 quadrats in the pellet catchment on August 1, after a rainstorm when the pellets had expanded and their cover was presumably maximal. Ground cover was estimated in all catchments on August 15, 2002 and again on October 28 by placing 1 m^2 quadrats every 5 m along three 50 m transects. Transects were roughly parallel and ran upslope in the middle and on each side of the catchment. Percentage cover was visually estimated in categories that included bare ground, mulch materials, rock, litter, live vegetation, woody debris, and so forth. Casual observation of the state of the mulches was also made at each site visit.

Results

Precipitation prior to installation of the first silt fences in July was light and did not cause sediment movement. Typical monsoon thunderstorms occurred on July 24 and August 4, 2002 (*fig. 1*). Each of these storms produced approximately 10 mm of rain (average of the two rain gauges) and measurable erosion (*table 1*). The maximum 10-minute rainfall intensity of each storm corresponded to a recurrence frequency of 1 year (Bonnin and others 2004); intensities calculated for 30 and 60 minutes had similar recurrence frequency (data not shown).

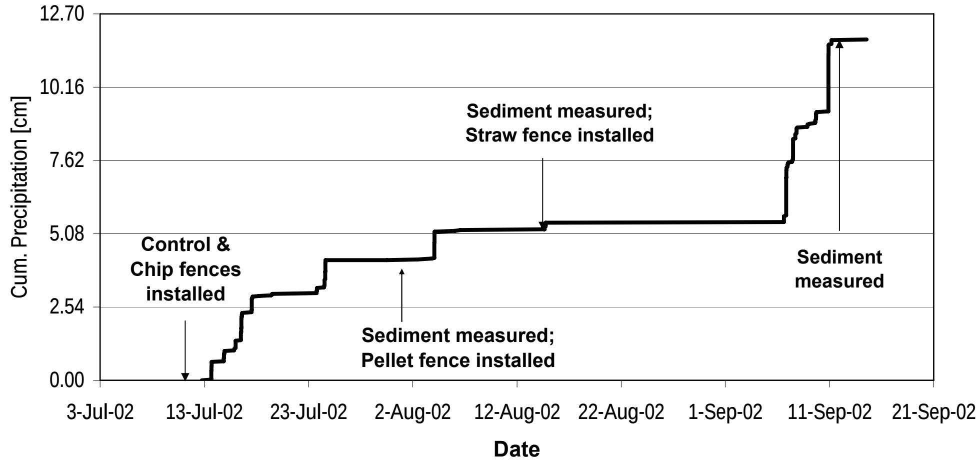

Figure 1—Cumulative precipitation (cm) and dates of silt fence installations and clean-outs at the Indian Fire study site near Prescott, AZ.

An extended rain event from September 6–9 yielded 38 mm of precipitation. We arrived at the site September 10 to find considerable deposition in all sediment basins and standing water accumulated behind several of the fences due to fine silt plugging the fencing material. That evening a thunderstorm produced 23 mm of rain in approximately 30 minutes. The maximum 10 minute rainfall intensity corresponded to a 10 yr recurrence frequency (Bonnin and others 2004) (*table 1*), but the 30 and 60 minute intensities were lower (2 yr recurrence; data not shown).

Following the late-July storm, at which time only the chip and control fences were installed, the chip catchment yielded 0.42 Mg ha^{-1} of sediment and the control 6.4 Mg ha^{-1} (*table 1*). While the pellet fence had not yet been installed, the treatment was inspected during the visit. The pellets were observed to have absorbed rainwater, expanded and released the soil flocculant, which was highly visible. Cover estimates of the pellets/flocculant ranged from a low of 60 percent in one plot, which had 20 percent rock and 5 percent litter cover, to a high of 95 percent in another plot. The remaining seven plots measured each had 85 or 90 percent pellet cover and 0 to 10 percent bare ground.

After the second rain event on August 4, at which time the pellet fences had been installed, we collected 10.8 Mg ha^{-1} of sediment from the control catchment, zero from the chip treatment, and 2.2 Mg ha^{-1} from the pellet treatment (*table 1*). Ground cover of the mulch materials averaged 81, 62, and 75 percent for the chips, pellets and straw, respectively, on August 15 (*table 2*), which was shortly after the second storm.

Because we were unable to clean the basins and measure the sediment (a multi-day task) between the two September storms, sediment yields from the two events were combined. Pressure from the runoff and sediment during the September 10 thunderstorm caused partial failure of the wood chip silt fence by tearing the material in the upper fence and collapsing a portion of the backup fence, allowing some sediment overflow and loss downstream. The combined rain events yielded a total of 48.4 Mg ha^{-1} of sediment from the control catchment, more than 15.5 Mg ha^{-1} from the chips treatment, 28.2 Mg ha^{-1} from the pellet treatment, and 9.1 Mg ha^{-1} from the straw catchment (*table 1*).

Table 1—*Dry weight of sediment and precipitation information for the Indian Fire site, Prescott, AZ, summer 2002. The September 14 value for the Chips treatment is an underestimate because some sediment was lost when the silt fences partially failed. Precipitation intensity recurrence interval was determined from Bonnin and others (2004).*

Cleanout Date:	**7/30/2002**	**8/14/2002**	**9/14/2002**
Treatment Watershed	Sediment yield in Mg ha^{-1} (T ac^{-1})		
Control	6.4 (2.8)	10.8 (4.8)	48.4 (21.6)
Chips	0.42 (0.18)	0 (0)	>15.5 (>6.9)
Pellets	N/A	2.2 (0.96)	28.2 (12.6)
Rice Straw	N/A	N/A	9.1 (4.1)
Total storm precipitation mm (in)	9.2 (0.36)	9.1 (0.36)	61.0 (2.4)
Maximum 10-min intensity mm hr^{-1} (in hr^{-1})	22.9 (0.9)	38.1 (1.5)	117.3 (4.62)
Intensity recurrence interval (years)	1	1	10

Table 2—*Average percent ground cover of mulches and bare ground on two sampling dates in 2002.*

Sampling Date:	**8/15/2002**		**10/28/2002**	
	Ground cover (pct)			
Treatment Watershed	Mulch	Bare	Mulch	Bare
Control	--	58	--	38
Chips	81	5	58	3
Pellets	62	9	27	25
Rice Straw	75	13	51	25

Discussion

Summer precipitation in the Prescott area is dominated by monsoon thunderstorms of variable frequency, beginning early- to mid-summer. While often of limited areal extent, these storms can be of considerable intensity, capable of causing significant postfire erosion. Three such erosion-causing storms occurred at the study site after the Indian Fire in 2002.

The wood chip treatment appeared very effective in reducing erosion during the late July and early August storms, with sediment yields 93 and 100 percent less, respectively, than in the control catchment. The storm intensities were typical of what could be expected every year in this area. Unfortunately the straw treatment was not applied in time for these two storms, so no comparison of the chips to the standard postfire mulch application can be made. The continuous and thick layer of cover provided by the wood chips undoubtedly accounted for the ground protection afforded during these relatively mild summer storms.

After the early August storm, the pellets were observed to have further dispersed, and flocculant was no longer obvious on the surface of the soil. Straw from the pellets had dispersed to fine chaff widely distributed across the ground surface, which would seem unlikely to have much impact in reducing erosion.

Nonetheless treatment effectiveness appeared very good, with sediment yield 80 percent less than the control. This decrease could be a result of the presence of soil flocculant in addition to extra ground cover provided by the chopped straw. For this second mild storm, the pellets were only slightly less protective than the wood chips.

The more intense September storm series provided the first test of the rice straw treatment. Sediment yield was 81 percent less than from the control catchment, confirming earlier studies that have shown good effectiveness for rice straw (Bautista and others 1996, Miles and others 1989), compared to a 42 percent reduction for the pellets. Although data are incomplete for the chips catchment, the treatment produced more sediment than the straw. Because this was the first storm after application of the rice straw, ground coverage may have been more even than in the other two treatments, which had been affected by earlier rains, at least during the first of the two September storms. We did note that the big event caused significant movement of straw, with substantial exposure of bare ground and clumping of straw, and rills formed between the clumps (compare cover on October 28 to August 15 in *table 2*).

Similarly, substantial movement of the wood chips was observed in September, especially on the upper, steeper portion of the catchment, and accumulation of chips atop the sediment in the basin was noted before the September 10 thunderstorm caused the fence failure. This indicates that wood chips are susceptible to being "floated" off a hillslope under conditions of sufficient overland flow. Lower chip cover in October (*table 2*) confirms the loss of material.

The two alternative mulch materials protected the ground effectively during the "typical" thunderstorms earlier in the summer, but they did not appear to perform as well as the freshly-applied standard treatment, straw, during the more intense late-summer storms. Thus there would seem to be no reason to use either instead of straw. The September 10 thunderstorm was a 10-year event in terms of its 10-minute rainfall intensity, however; thus not every postfire site would be subject to those conditions, and the use of straw pellets or wood chips could be justified if they had some other advantage over straw.

Both treatments differ from straw in that they cannot introduce weed seeds onto a burn site (the chopped straw in the pellets is pasteurized). Mulched areas can have greater abundance of nonnative species (Kruse and others 2004). In areas where rice straw, which contains few terrestrial weed seeds, is not available, these treatments could have an ecological advantage over mulching with ordinary cereal or pasture straw, which often contain weed seeds, despite lower expected erosion reduction effectiveness during intense thunderstorms. Also, the rapid decrease in cover of the pellet treatment (*table 2*) could make it preferable for use in areas where recovery of sensitive plant species after fire is a concern.

The effectiveness of these treatments will be monitored for additional years in this study. Wood chips would be expected to persist on the hillslope longer than either pellets or straw, and relative erosion control effectiveness of treatments may change in the future. The first year after fire is generally the most significant in terms of erosion, however, when soil protection is most needed (Robichaud and others 2000). The impact of mulches on vegetation recovery may also vary through time. Use of straw mulch after fire is increasing, particularly aerial application (Faust, this volume). It remains to be seen whether wood chips or straw pellets have substantial merit as postfire mulches that would recommend their use in place of straw.

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References

Bautista, S.; Bellot, J.; Vallejo, V.R. 1996. Mulching treatment for post-fire soil conservation in a semiarid ecosystem. Arid Soil Research and Rehabilitation 10: 235–242.

Bonnin, G.; Todd, D.; Lin, B.; Parzybok, T.; Yekta, M.; Riley, D. 2004. Precipitation frequency atlas of the United States. NOAA Atlas 14, volume 1, Version 3.2. Silver Spring, MD: National Weather Service.

Edwards, L.M.; Burney, J.R.; Dehann, R. 1995. Researching the effects of mulching on cool-period soil erosion in Prince Edward Island. Journal of Soil and Water Conservation 50: 194–197.

Faust, R. *This volume*. Aerial mulching techniques—Trough Fire. In: M.G. Narog, technical coordinator. Proceedings of the 2002 fire conference on managing fire and fuels in the remaining wildlands and open spaces of the southwestern United States; 2002 December 2–5; San Diego, CA. Gen. Tech. Rep. PSW-GTR-189. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture.

Kruse, Renee; Bend, Eric; Bierzychudek, Paulette. 2004. Native plant regeneration and introduction of non-natives following post-fire rehabilitation with straw mulch and barley seeding. Forest Ecology and Management 196(2-3): 299–310.

Miles, S.R.; Haskins, D.M.; Ranken; D.W. 1989. Emergency burn rehabilitation: cost, risk, and effectiveness. In Berg, N.H., technical coordinator. Proceedings of the symposium on fire and watershed management, October 26–28, 1988, Sacramento, CA. Gen. Tech. Rep. PSW-GTR-109. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 97–102.

Robichaud, Peter R.; Beyers, Jan L.; Neary, Daniel G. 2000. Evaluating the effectiveness of postfire rehabilitation treatments. Gen. Tech. Rep. RMRS-GTR-63. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture; 85 p.

Robichaud, Peter R.; Brown, Robert E. 2002. Silt fences: an economical technique for measuring hillslope soil erosion. Gen. Tech. Rep. RMRS-GTR-94. Fort Collins, CO: Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture; 24 p.

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