An ASABE Meeting Presentation

Paper Number: 078046

Field Testing of Wood-based Biomass Erosion Control Materials on Obliterated Roads

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Written for presentation at the
2007 ASABE Annual International Meeting
Sponsored by ASABE
Minneapolis Convention Center
Minneapolis, Minnesota
17 - 20 June 2007

Abstract. *Woody biomass erosion control products are increasing in popularity as an alternative to agricultural straw in forested areas. Applications of two wood-based products, wood strands and wood shreds, plus agricultural straw were investigated in this study. All three investigated mitigation treatments significantly reduced soil loss during both the snowmelt and summer seasons on coarse-grained soil. Mitigation treatments did not significantly reduce soil loss from the fine-grained soil, although the untreated plot produced two to six times as much sediment as the treated plots. A significant amount of mitigation material was lost from the shreds and straw plots over the course of the first year. Wood strands maintained their original cover over this time period. All mitigation treatments reduced plant revegetation on the fine-grained soil; however, wood strands did not inhibit revegetation on the coarse-grained soil.*

Keywords. Erosion control, Road obliteration, Wood strands, Wood shreds, Mitigation.

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Introduction

Agricultural straw is one of the most widely used materials for erosion mitigation. Foltz and Dooley (2003) estimated that over 250,000 Mg of agricultural straw are used in the United States annually. Of that amount, 12,500 Mg were applied to forested lands in 2002. It is perceived as inexpensive, readily available, relatively easy to apply, and effective in reducing soil erosion. Applications in forested settings may result in the introduction of undesirable weeds (Robichaud et al. 2000) and chemical residues from agricultural pesticides (Michel and Doohan 2006). Kruse et al. (2004) found that areas with straw mulch applications had a significantly higher occurrence of nonnative species and no indication of facilitated recovery of the native plant community. Kullman et al. (2002) report that dust liberated during field application produces a health risk to workers. While application of agricultural straw is a popular erosion control technique and has been widely used in road obliteration projects, the opportunity for an alternative erosion control material exists.

One alternative erosion control material for forest environments would be a woody biomass product derived from native forest materials. A study conducted by Foltz and Dooley (2003) evaluated the performance of wood strands, a byproduct of veneer manufacturing specifically engineered to optimum dimensions for soil loss mitigation. The optimum dimensions were found to be two lengths of 60 and 100 mm, width of 6 mm, and thickness of 3 mm. These dimensions are controlled in the manufacturing process. Unlike agricultural straw, wood strands are inherently weed and chemical free and are not likely to carry fine dust particles. Additionally, they are manufactured from what have been considered either waste materials or low value hog fuels. Foltz and Dooley (2003) found that wood strands were as effective as agricultural straw in reducing runoff and soil loss. Yanosek et al. (2006) investigated the efficacy of wood strands on various slopes and soil textures and concluded that when compared to straw, wood strands were equally effective in reducing soil loss from coarse-grained soils and superior on fine-grained soils. They also reported that the unique three-dimensional layering of the wood strands provided a highly stable matrix which assisted in reducing soil loss and preventing rill formation.

Wood shreds may provide another woody biomass product that would reduce soil loss. Groenier and Showers (2004) suggested the use of wood shreds for soil loss reduction. The authors reported that small-diameter trees removed from road rights-of-way, trees cleared during road construction, and woody debris from forest thinning for fuel reduction could be shredded into a mulch-like material. Typically, these materials would have to be burned or chipped to reduce fire hazard, therefore, shredding them for soil loss control creates a more valuable use. An additional advantage to using wood shreds was that they could be derived from on-site forest materials, especially during road construction or at fire rehabilitation sites, thus reducing transportation costs. They are similar to wood strands in that they are derived from forest materials. Unlike wood strands, however, wood shreds are not manufactured to specific dimensions. The manufacturing process, wood recycling grinders, produces a material with a range of sizes from fines less than 25 mm to branches larger than 200 mm in length. Widths and thickness exhibit a similar degree of variability. Foltz and Copeland (in review) tested wood shreds using laboratory scale plots and simulated rainfall. They reported that wood shreds were as effective as agricultural straw in reducing soil loss from both a coarse and fine grained soil.

The studies by Foltz and Dooley (2003), Yanosek et al. (2006), and Foltz and Copeland (in review) were conducted on small 5.7 m^2 plots and validated the utility of wood-based biomass for soil loss control. The next step would be field scale testing of the materials. This paper reports on the status of a study of wood strands, wood shreds, and agricultural straw at the field scale (60 m^2) on obliterated roads. The objectives of this study were to determine the effects of agricultural straw, wood strands, and wood shreds on 1) soil loss, 2) erosion mitigation, 3) reduction in treatment cover, and 4) revegetation.

Methods

Two locations, one with a fine-grained soil and one with a coarse-grained soil, were chosen to represent the range of soils across forest lands. The fine grained soil was on the Payette National Forest in Idaho and is known as Mud Creek. Annual precipitation is 600 mm per year. Watershed elevations range from 1160 to 1900 m. The soil is a gravelly loamy sand (Typic Cryosammet) soil derived from Columbia River basalt and Idaho Batholithic granite parent material. The Mud Creek watershed is dominated by a subalpine fir/paxistima habitat (USDA Forest Service, 2003).

The coarse grained soil location was on the Kanisku National Forest in Washington and is known as Willow Creek. Average annual precipitation ranges from 1140 to 1440 mm. Watershed elevations range from 1100 to 1400 m and hillslopes are typically 20 to 60%. The predominant geologic parent material is composed of glacial till and soils are heavily influenced by volcanic ash. Soils are shallow and poorly developed in some areas. The surface layers are mostly silt loam. The dominant habitat types surrounding Willow Creek are western red cedar and subalpine fir (USDA Forest Service, 2004).

Sediment collection plots of approximately 64 m^2 were located on freshly obliterated road sections with the long dimension (10 m) parallel to the former road centerline. A sediment collection tank was buried near the former fill slope. Three sides of the plots were bordered with sheet metal while the upslope side of the plot near the former top of the cutslope was left open to receive overland flow from the undisturbed forest. All plots were installed within a month following road obliteration. Each treatment at Mud Creek had four replications and each at Willow Creek had three replications.

Each mitigation treatment was applied by either representatives from the principal supplier or by USFS district personnel. Wood strands were applied by Forest Concepts, LLC and wood shreds were applied by Missoula Technology Development Center. Amount and uniformity were left to the discretion of the suppliers. Straw cover was targeted at 60 percent, but measured coverages averaged 67 percent. Wood strands and wood shreds were targeted at 50 percent and both averaged 48 percent.

Sediment was removed from plot collection tanks in June 2006 following the snowmelt period and again in September 2006 following the summer thunderstorm season. Sediment mass was corrected for water content.

Soil loss per unit area was calculated by dividing the total mass by the area of each plot. A one-way ANOVA was used to determine if soil loss per unit area was different among treatments for each cleanout interval. All pairwise contrasts between wood strands, wood shreds and agricultural straw were investigated. Significance from statistical tests are reported at the $\alpha = 0.05$ level.

Mitigation for each plot was calculated using equation 1 below

$$Mitigation = \frac{(treatment - bare)}{bare} * 100 \qquad 1$$

where *treatment* was the average mass of sediment removed from all treatment plots and *bare* was the average mass of sediment removed from all bare plots. Each location was treated separately.

Treatment cover was determined from vertical photographs taken immediately following plot installation in June 2006 and again in September 2006. Seven locations in each plot were randomly selected and photographed to determine initial treatment cover. Four non-overlapping measurements of cover were made on each of the photographs using a 48 point grid with a real world spacing of 30 mm between points. The June and September determinations were reduced to two randomly chosen locations in each plot with two non-overlapping measurements of cover on each photograph using the 48 point grid at the same 30 mm real world spacing.

Statistical analysis to assess whether treatment coverages were decreasing over time was performed using a mixed model two-way analysis of variance (ANOVA) with cleanout date considered a repeated measure and the within plot picture location considered a random variable. Least squares means were adjusted using Tukey's method to determine paired differences. Treatment effects on plant revegetation were also tested using a mixed model two-way ANOVA with cleanout date as a repeated measure and within plot picture location a random variable.

Results and Discussion

Tables 1 and 2 show precipitation depth and intensities for both locations. The total precipitation was less than the 30-year long term average at each location. During the snowmelt collection interval, October to June, the highest 1-hr, 30-minute, 15-minute, and 5-minute rainfall intensities were from a single spring storm in the spring at Mud Creek and a single fall storm at Willow Creek. During the summer collection interval, June to October, single storms at each location produced the highest intensities.

Soil loss

Soil loss from the first snowmelt season is shown in Table 3. The soil loss on the bare plots was 0.015 kg/m^2 on the fine-grained Mud Creek soil and 0.12 kg/m^2 on the coarse-grained Willow Creek soil. The bare plots had a higher coefficient of variation than any of the mitigation plots (i.e. wood strands, wood shreds, or agricultural straw) at both locations.

Soil loss from the first summer season is shown in Table 4. Similar to the snowmelt season cleanout, the fine-grained Mud Creek bare plots had a high coefficient of variation. Unlike the snowmelt season cleanout, the coarse-grained Willow Creek bare plot did not have a high coefficient of variation.

The annual soil loss on the coarse-grained bare soil plots (0.83 kg/m^2) was approximately that of a forest after a low severity fire (1 kg/m^2) as reported by Elliot (2002). The annual soil loss from the fine-grained soil plots (0.05 kg/m^2) was about half than that of harvested forest (0.1 kg/m^2) (Elliot, 2002).

There was no statistically significant difference in soil loss among any of the treatments (p-value = 0.14) on the fine-grained location, Mud Creek, for the snowmelt cleanout interval due largely to the high coefficient of variation (125%) on the bare plots. There was a statistically significant difference among the treatments (p-value = 0.003) on the coarse-grained location, Willow Creek. Tukey's method of multiple pairwise comparisons grouped all of the mitigation plots into a single group characterized by statistically lower soil loss than that from the bare plots. Thus, all of the mitigation treatments performed similarly on the coarse-grained soil.

Application of erosion control material on the coarse-grained soil made a statistically significant difference in soil loss for the snowmelt driven erosion. Again, there was no statistical difference among the mitigation treatments. Soil loss on the fine-grained soil was not statistically significant.

There was not a statistically significant difference (p-value of 0.11) in soil loss due to treatment effect on the fine-grained soil, Mud Creek, for the summer cleanout. As with the snowmelt cleanout, there was a high coefficient of variation on the bare treatment which made detection of differences difficult. There was a significant difference (p-value of 0.004) in soil loss due to treatment effect on the coarse-grained soil, Willow Creek, for the summer cleanout. Tukey's method of multiple pairwise comparisons grouped wood shreds and straw into a group having significantly more soil loss than the wood strands.

Erosion Mitigation

Table 5 presents the erosion mitigation for both cleanout intervals. The wood strand mitigation values are typically less than reported by Yanosek, et al. (2006) based on rainfall simulation from small plots (85 to 90 percent). Wood shred mitigation values are also less than those reported by Foltz and Copeland (in press) on small size, rainfall simulation plots (85 percent for both soil types).

Wood strands had the highest level of mitigation at 80 percent when both soil types were combined. Agricultural straw followed closely at 79 percent. Wood shreds were a distant third at 41 percent. All values are for a single season and additional years of data from these sites may change any conclusions drawn from the first year.

Reduction in Treatment Cover

Cover was re-measured following the snowmelt cleanout and after the summer cleanout (Table 6). There was a statistically significant reduction in cover among the three measurements for the shreds at both locations (p-values of <0.0001 and 0.04 for Mud Creek and Willow Creek, respectively) and for the straw at both locations (p-values of <0.0001 and 0.006 for Mud Creek and Willow Creek, respectively). The wood strands did not have a statistically significant change in cover among the three measurements at either location (p-values of 0.07 and 0.14 for Mud Creek and Willow Creek, respectively).

Both the straw and wood shreds lost a statistically significant amount of ground cover over the first year while the wood strands did not. The straw lost 29 percent of its initial ground cover over the first year. The wood shreds lost 36 percent of its initial ground cover over the first year. Wood strands maintained their original cover over the first year. These observations have important implications for long term erosion control when ground cover is needed for three to five years following disturbance until vegetation can reestablish. Road obliteration and burned areas are two such examples in the forest environment.

Revegetation

Plant cover was measured at the same two intervals as the mitigation treatment cover, i.e. after the snowmelt period and after the summer period. There was no plant cover on any of the plots immediately following plot installation. Table 7 shows the plant cover and coefficient of variation for each treatment at the two locations. Plant cover was highest on the bare plots regardless of soil type (location). A two-way ANOVA indicated that on the fine-grained soil, Mud Creek, there was an overall statistical difference (p-value of 0.001) among treatment effects, there was a statistical difference (p-value < 0.0001) between the two measurement intervals, and there was no statistical difference in revegetation trends over time among treatments (interaction p-value = 0.86). Tukey's method of multiple pairwise comparisons grouped all mitigation treatments on the fine-grained Mud Creek soil into one group having significantly lower revegetation over time than the bare plots. The results were similar from the coarse-grained Willow Creek soil which had a statistical difference (p-value = 0.02) among the treatment effects, a statistical difference (p-value = 0.004) between the cleanout periods; and no statistical difference (interaction p-value = 0.15) in revegetation trends over time. The only significant pairwise comparisons were between the bare plots and the wood strands plots.

Revegetation was highest on the bare plots and was increasing over time, regardless of soil type. On the fine-grained soil each of the mitigation treatments caused a significant reduction in revegetation, but there was no statistical difference in revegetation among the individual mitigation treatments. On the coarse-grained soil revegetation was unaffected on the wood strands plots but was significantly reduced on the straw and wood shreds treatments.

Conclusion

Three erosion control materials, wood strands, wood shreds, and agricultural straw were tested on the field scale for effectiveness in erosion mitigation. Testing was performed on obliterated road surfaces in two locations in Idaho, one having a coarse-grained soil and the other a fine-grained soil. Test plots were installed and mitigation treatments were applied in the summer of 2005. The sites were visited two times to collect soil loss data, once after the snowmelt season in 2006 and again after the summer rainstorm season in 2006.

Total precipitation was less than the 30-year long term average at each location. The highest rainfall intensities during the snowmelt season were from a single fall storm on the coarse-grained soil and a single spring storm on the fine-grained soil. Single storms at each location produced the highest intensities during the summer collection interval.

Average annual soil loss from the bare plots on the coarse-grained soil was 0.83 kg/m^2, which is on the order of what would be expected from a low severity fire (Elliot, 2002). Annual soil loss from the bare plots on the fine-grained soil was 0.05 kg/m^2, which is roughly half of what would be expected from a harvested forest area (Elliot, 2002).

During the snowmelt period there was a statistical difference in soil loss between the bare treatment and the mitigation treatments on the coarse-grained soil. There was no statistical difference among the individual mitigation treatments, indicating that all mitigation treatments provided the same amount of protection. There was no statistical difference in soil loss among the treatments on the fine-grained soil, including the bare control treatment. In other words, mitigation treatments provided no protection on the fine-grained soil during the snowmelt period. During the summer period there was a statistical difference in soil loss among treatments on the coarse-grained soil, with the wood strands treatment having significantly less soil loss than the straw and shreds treatments. As during the snowmelt period, there was no statistical difference in soil loss among the treatments on the fine-grained soil.

Mitigation from wood strand and agricultural straw treatments were near 80 percent for both soil types with wood shreds at 41 percent. All values were less than those reported from rainfall simulation studies on small plots.

Wood shreds and straw treatment plots lost enough cover material at both locations over this first year to significantly decrease material coverage from the initial percent cover applied at plot installation. Shreds treatments had an average decrease of 36% in initial ground cover and straw had an average decrease of 29%. The wood strands treatment did not have a significant change in cover over this time period.

Plant revegetation was inhibited regardless of the erosion mitigation treatment used. Revegetation was significantly higher from the wood strands than from the wood shreds and straw treatments on the coarse-grained soil, however. There was no difference in revegetation among mitigation treatments on the fine-grained soil.

All three investigated mitigation treatments significantly reduced soil loss during both the snowmelt and summer seasons on the coarse-grained soil. Mitigation treatments did not significantly reduce soil loss from the fine-grained soil, although the untreated plot produced two to six times as much sediment as the treated plots. A significant amount of mitigation material was lost from the shreds and straw plots over the course of the first year. Wood strands maintained their original cover over this time period. All mitigation treatments reduced plant revegetation on the fine-grained soil; however, wood strands did not inhibit revegetation on the coarse-grained soil.

Acknowledgements

The authors would like to thank Jim Dooley of Forest Concepts, LLC. for providing and applying the wood strands, Scott Groenier of Missoula Technology Center for providing and applying the wood shreds, and Jill Cobb of the Idaho Panhandle National Forest and Tom Crawford of the Payette National Forest for providing and applying the straw. The authors would also like to thank Ben Kopyscianski for design and installation of all of the plots and Tyler Oester for his assistance in the plot cleanouts and processing in the lab.

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Table 1. Precipitation depths.

Location	Total (mm)	Snowmelt collection interval (mm)	Summer collection interval (mm)
Mud Creek	504	413	91
Willow Creek	311	242	69

Table 2. Precipitation intensities

Location	Snowmelt collection interval				Summer collection interval			
	1-hr	30-min	15-min	5-min	1-hr	30-min	15-min	5-min
Mud Creek	5.0	8.1	16.3	45.7	6.6	12.2	20.3	36.6
	3/30	3/24	3/24	3/24	8/17	8/17	8/17	8/17
Willow Creek	4.3	5.1	7.1	12.0	16.5	19.8	38.6	51.8
	10/1	10/1	10/1	4/24	7/7	7/7	7/7	7/7

Table 3. Soil loss per unit area following first snowmelt season.

Treatment	Location	Soil loss (kg/m^2)	CV soil loss (%)
Bare	Mud Creek	0.0154	124
	Willow Creek	0.1202	56
Straw	Mud Creek	0.0031	50
	Willow Creek	0.0239	17
Wood strands	Mud Creek	0.0024	48
	Willow Creek	0.0170	14
Wood shreds	Mud Creek	0.0050	65
	Willow Creek	0.0245	15

Table 4. Soil loss per unit area following first summer season.

Treatment	Location	Soil loss (kg/m^2)	CV soil loss (%)
Bare	Mud Creek	0.0371	106
	Willow Creek	0.7154	33
Straw	Mud Creek	0.0088	54
	Willow Creek	0.1226	12
Wood strands	Mud Creek	0.0123	53
	Willow Creek	0.0723	12
Wood shreds	Mud Creek	0.0277	51
	Willow Creek	0.3774	103

Table 5. Sediment mitigation for both seasons.

Treatment	Location	Snowmelt mitigation (%)	Summer mitigation (%)	Combined mitigation (%)
Straw	Mud Creek	80.6	76.4	77.6
	Willow Creek	77.7	81.3	80.8
Wood strands	Mud Creek	84.5	66.5	71.8
	Willow Creek	84.7	89.3	88.6
Wood shreds	Mud Creek	65.7	20.7	33.9
	Willow Creek	77.7	42.7	47.6

Table 6. Changes in treatment cover over time.

Treatment.	Location	Initial		Snowmelt interval		Summer interval	
		Cover (%)	CV (%)	Cover (%)	CV (%)	Cover (%)	CV (%)
Straw	Mud Creek	66.9	24	52.1	11	38.5	28
	Willow Creek	68.3	23	70.7	12	57.9	19
Wood strands	Mud Creek	45.9	33	47.0	17	38.4	38
	Willow Creek	50.5	27	52.5	12	56.8	12
Wood shreds	Mud Creek	53.4	34	29.4	25	25.3	38
	Willow Creek	42.5	34	45.9	19	36.0	22

Table 7. Changes in plant cover over time.

Treatment.	Location	Snowmelt interval		Summer interval	
		Plant cover (%)	CV (%)	Plant cover (%)	CV (%)
Bare	Mud Creek	7.1	67	14.2	51
	Willow Creek	0.3	239	4.6	77
Straw	Mud Creek	3.9	147	8.0	57
	Willow Creek	0.2[a]	324	7.1	77
Wood strands	Mud Creek	2.9	107	7.8	73
	Willow Creek	1.8	210	6.2	82
Wood shreds	Mud Creek	3.8	92	7.5	37
	Willow Creek	0.9[a]	231	5.4	81

All treatments started at zero percent ground cover.
[a] – Not statistically different from zero.