EFFECTIVENESS AND COSTS OF OVERLAND SKID TRAIL BMPS

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ABSTRACT

Forestry Best Management Practices (BMPs) are designed to protect water quality; however, little data exists comparing the efficacy and costs of different BMP options for skid trail closure. Study objectives were to evaluate erosion control effectiveness and implementation costs of five overland skid trail closure techniques. Closure techniques were: waterbar only (Control), waterbar plus seed (Seed), waterbar plus seed and mulch (Mulch), waterbar plus hardwood slash (Hardwood), and waterbar plus pine slash (Pine). Techniques were replicated on four skid trails. Sediment traps were used to capture sediment for 13 months. Data indicated that Mulch was the most effective for controlling erosion (1.5 tons/acre/year), followed by Hardwood (2.3 tons/acre/year), Pine (2.4 tons/acre/year), Seed (6.1 tons/acre/year), and Control (10.8 tons/acre/year). Incorporating slash dispersal and compaction onto overland skid trails during harvesting activities may be the best option for reducing BMP costs and potential erosion, but all treatments may be appropriate for certain situations.

INTRODUCTION

Major sources of sediment associated with timber harvesting are haul roads, skid trails, and log landings (Megahan and Kidd 1972, Yoho 1980, Madej 2001). Large sediment yields result from timber harvesting with poor planning and execution, and water quality considerations are necessary when developing logging access (Yoho 1980). Kochenderfer (1977) found that roads, trails, and landings accounted for 10% of a skidder harvested area. Martin (1988) found similar numbers at harvest sites in New England where 8–18% of mineral soil was exposed. Jackson et al. (2002) found that roads, decks, and skid trails accounted for 25% of the area within a harvest in Bolivia. Litschert and MacDonald (2009) evaluated nearly 200 logging units from 2 to 18 years old and found that 83% of erosion features connected to stream channels originated from skid trails. State forestry BMP recommendations specify skid trail closure techniques that can be used to minimize erosion (Shepard 2006), but few studies have been conducted to show the actual amount of erosion prevented by specific treatments (Aust and Blinn 2004, Anderson and Lockaby 2011).

Costs to install BMPs are important to loggers, forest landowners, and the forest industry (Shaffer et al. 1998). Implementation time and associated BMP costs have been evaluated in the past through surveys and questionnaires (Shaffer et al. 1998, Montgomery et al. 2005, Bolding et al. 2010), literature reviews (Aust et al. 1996), and engineering approaches using available maps (Ellefson and Miles 1985, Lickwar et al. 1992). Ellefson and Miles (1985) found that loggers could lose as much as 60% of their net revenue when all BMPs are applied. Logging contractors in West Virginia also paid an average of $1,426 per employee for formal BMP training (Egan et al. 1996). Loggers directly incur most of the BMP costs in both the lumber and paper sectors of the forest products industry (Sun 2006), but these costs are typically passed to the land or timber owner through lower stumpage prices (Cubbage 2004). Montgomery et al. (2005) found that BMP implementation and compliance in Arkansas led to a 3.5% decrease in annual tonnage produced from 1998 to 2005. BMPs are the key to maintaining water quality and site productivity; therefore, understanding the most cost-effective implementation methods prior to harvest is a great advantage for operators (Shaffer and Meade 1997).

The primary objectives of this study were to evaluate the effectiveness and costs of five closure techniques on overland skid trails. Erosion rates were directly measured from different BMP treatments: 1) waterbar only, 2) waterbar plus grass seed, 3) waterbar plus grass seed and straw mulch, 4) waterbar plus pine slash, and 5) waterbar plus hardwood slash. Actual costs to install the BMP treatments were recorded and were provided cost estimates for skid trail closure.

METHODS

STUDY SITE

This study was conducted near Critz, VA at the Reynolds Homestead Forest Resources Research Center in the western Piedmont physiographic region. The topography of the area consists of rolling hills with sideslopes typically ranging from 10-30 percent. Average annual rainfall is 49.3 inches with additional snowfall accumulations of 10.5 inches annually (Patrick County, VA 2011). The principal soil series on the site is Fairview sandy clay loam (Fine, kaolinitic, mesic Typic Kanhapludults) (NRCS 2011).

To facilitate data collection, a timber harvest was conducted on a 29 acre stand. The forest stand was a combination of old-field Virginia pine (*Pinus virginiana*) on the ridgetops

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and mixed upland hardwoods with scattered Eastern white pine (*Pinus strobes L.*) on the sideslopes. Approximately 106 tons/acre were harvested and 4,997 feet of primary overland skid trails were established during the operation. The total area of skid trail was approximately 1.4 acres or 4.9% of the harvested area.

TREATMENTS AND DATA COLLECTION

After harvesting, four primary overland skid trails with similar soils and slope were selected for treatment with each trail representing a designed block. Five BMP closure treatments were randomly applied to each of the four trails (blocks) to provide 20 treatment plots or experimental units. The five treatments were: (1) waterbars only (Control); (2) waterbars plus lime, fertilizer, and seed (Seed); (3) waterbars plus lime, fertilizer, seed, and coverage with straw (Mulch); (4) waterbars plus coverage with pine slash (Pine); and (5) waterbars plus coverage with hardwood slash (Hardwood). The segment of skid trail between the crest of two consecutive waterbars formed a treatment area approximately 12 feet wide and 50 feet long.

A sediment collection system was designed for each experimental unit (20) using geotextile sediment traps known as Dirtbags® and PVC (ACF Environmental, Richmond, Virginia). The custom ordered Dirtbags® used in this study were approximately 4 feet wide and 6 feet long. To facilitate sediment flow, a gutter was constructed from a 20 foot piece of 6 inch Schedule 40 PVC by cutting out the top half of the circular piece of pipe. Three feet of the downslope end of the pipe remained intact to connect to the fill spout of the Dirtbag®. After harvest completion, a logging contractor was hired to apply pine slash and hardwood slash treatments to the respective experimental units. All logging slash used was on site from the recently completed timber harvest. A John Deere 648E rubber-tired grapple skidder was used to gather, place, and compact the slash in the treatment areas.

The Seed and Mulch treatments each had grass seed, lime, and 10-10-10 fertilizer applications. The grass seed, Contractor's Utility Mixture, consisted of 50% tall fescue and 50% annual ryegrass; a mixture that is commonly used for seeding skid trails in the area (Virginia Department of Forestry 2002). Grass seed was broadcast on Seed and Mulch treatments at a rate of 265 lbs/acre. Fertilizer was applied at the equivalent of 200 lbs/acre and lime was spread at the equivalent of one ton/acre per appropriate treatment area. These soil amendments are typically recommended to facilitate grass establishment on Piedmont skid trails (Virginia Department of Forestry 2002). The Mulch treatments received a complete coverage of wheat straw mulch, which generally required two square bales per treatment area. The grass seed, fertilizer, and lime were broadcast with a hand-crank spreader, and the straw mulch was spread by hand.

Erosion quantities from each of the 20 treatment areas were evaluated monthly from August 2009 through August 2010 for a total of 12 measurement periods; February 2010 was delayed due to snow cover. Each treatment sediment trap was detached from the gutter and weighed to the nearest 0.2 pounds with a digital, 1,200 lb capacity crane scale (Citizen Scales Inc., Edison, New Jersey). Monthly sediment weights were adjusted for soil moisture, bag moisture, and sediment trapping efficiency.

Costs for installations of the five BMP treatments to the four overland skid trails were recorded and compiled. The skid trail closure techniques were installed or directly supervised by the researchers; therefore, all time and expenses were recorded. Equipment and labor rates for slash treatments were based on the actual charges by the skidding contractor who placed and compacted slash on the appropriate treatments. The equipment rate was $50 per hour and the labor rate was $25 per hour. Expenses were then converted to a cost per mile basis to produce cost estimate tables for the particular BMP applications.

STATISTICAL ANALYSIS

Data from the overland skid trails were analyzed as a Randomized Complete Block Design with four blocks of five BMP treatments for a total of 20 treatment areas and 12 repeated measures in each treatment area. The twelve monthly measurement periods required the use of repeated measures within the design. Analyses were performed with Number Cruncher Statistical Systems software (Hintze 2001) using the GLM ANOVA Repeated Measures procedures and the Tukey-Kramer mean separation test to verify significant differences between treatments. All significant differences were based on an alpha level of 0.05.

RESULTS AND DISCUSSION

EROSION CONTROL

The sediment trap data indicated that erosion rates for the overland skid trail closure treatments were significantly different ($p < 0.0001$) (Figure 1). The Mulch (1.5 t/a/y), Hardwood (2.3 t/a/y), and Pine (2.4 t/a/y) treatments had similarly low erosion rates and were effective at minimizing skid trail erosion. The Control treatment had the highest erosion rate (10.8 t/a/y) followed by the Seed treatment (6.1 t/a/y). The Control and Seed treatments had significantly different erosion rates from all other treatments while the Mulch, Hardwood, and Pine treatments showed no significant differences from each other

Monthly soil erosion by treatment and precipitation are displayed in Figure 1. The soil remained relatively stable in all treatments during the first half of the study, even though some months had considerable rainfall. The November 2009 collection period received 8.35 inches of precipitation, but the soils still had low rates of displacement. Warmer spring temperatures, which thawed frozen soils, and intense rainfalls preceded an increase in soil erosion. Ferrick and Gatto (2005) demonstrated that freeze-thaw actions that disrupt soil structure, coinciding with high soil moisture following thaw, caused significant increases in soil erosion during runoff events. Another period of reduced soil erosion occurred in the early summer months of 2010 when precipitation totals were low. July and August 2010 experienced strong summer thunderstorm activity and erosion dramatically increased as rainfall totals approached 10 inches for the period.

The Mulch treatment had the lowest erosion rate and reduced soil erosion by 86% when compared to the Control. Erosion on the Mulch treatments remained low during the entire study. For the first six months, the highest monthly total was 0.06 tons/acre; then rates started to fluctuate due to monthly precipitation. Erosion patterns spiked during March 2010 and again in August 2010 when rainfall intensity increased (Figure 1). The average erosion rate for all Mulch treatments was 1.47 tons/acre/year. Grushecky et al. (2009) evaluated the influence of fiber mats on soil erosion from skid trails in West Virginia as compared to waterbars and seed and concluded that the cover provided by the mat reduced erosion by 88%. The Mulch treatment of this study provided very similar results, but the Fiber mats would be much more expensive.

The Hardwood and Pine slash treatments provided very similar erosion rates during the entire study period. Either form of logging slash added immediate cover to the soil which reduced erosion in a manner similar to Mulch. By compacting the slash, ground contact minimized sheet erosion underneath the slash. Logging slash on skid trails has been shown to significantly reduce soil erosion on volcanic soils in the west (McGreer 1981) and on harvest sites in New York (Schuler and Briggs 2000). The average erosion rate for Hardwood was 2.27 tons/acre/year and Pine was 2.41 tons/acre/year. The Hardwood and Pine treatments reduced erosion by 79% and 78%, respectively, as compared to the Control.

Grass cover on the Seed treatments never reached desired BMP establishment levels (70%) according to the Virginia Department of Forestry (2002) even though multiple reseeding attempts occurred. Erosion for this treatment averaged 6.06 tons/acre/year, or a 44% decrease in annual erosion when compared to the Control.

The overall average erosion rate for the Control was 10.82 tons/acre/year. The Control treatment had nominal erosion during the first six months, 0.31 tons/acre or less, even without any added soil protection. Soil loss dramatically increased after the freeze-thaw actions of winter had churned and loosened exposed soil layers. As expected, the greatest erosion coincided with the highest precipitation totals. The March 5, 2010 collection period received 9.18 inches of rainfall while soil loss averaged 2.35 tons/acre. The most erosion occurred during the final collection period; rainfall accumulations were 9.87 inches and soil erosion averaged 5.82 tons/acre (Figure 1). Soil erosion data collected by Quinton et al. (1997) also showed that variations in soil losses increase when bare soil is more prominent.

CLOSURE COSTS

Overland skid trail closure costs for the specific components of the installed BMPs are summarized in Table 1. Table 2 shows a more detailed analysis of costs for the 29 acre harvest site. These costs combine each component by treatment for the five closure techniques. The Control treatment of only water bars may be an adequate level of BMP compliance in some instances, and the Control was the least expensive treatment. It should be noted that waterbars were a component of all other treatments. Of the other treatments in the study, Slash (Hardwood and Pine) was the most expensive per mile followed by Mulch, Seed, and Control. Based on observations of other harvest operations, it was speculated that the Slash component could be four times more efficient if the transport of slash was incorporated into the harvest operation. The Integrated Slash treatment, including water bar construction, could be $2,970 per mile, or 51% less than our Slash treatment installed after harvest completion. A Slash treatment would only be cost effective when grapple skidders are used in the harvest operation and if slash is readily available, such as when operations use a mechanized or gate de-limber.

The logging contractor utilized 0.95 miles of skid trails to harvest 3,074 tons on the 29 acre site. The skid trail length was used to produce a cost by treatment for the harvest. While many factors are involved in skid trail layout, similar quantities were found by Kochenderfer (1977) when loggers averaged 1 mile of skid trail for every 22.3 acres harvested. Lickwar et al. (1992) calculated cost estimates for enhanced BMPs on Piedmont sites in the Southeast to be $32.33/acre (comparable to approximately $68 in 2010). At current prices on a small tract, we determined skid trail closure costs alone to be $137/acre for the Mulch treatment which is comparable to their enhanced BMP scenario. A treatment cost per ton of wood harvested was also calculated. The Slash treatments were the most expensive at $1.88/ton, followed by Mulch ($1.29/ton), Seed ($1.19/ton), and Integrated Slash ($0.92/ton). A combination of treatment efficacy and costs is shown Table 2. Logging slash is already being used as a protective cover for exposed soils on timber harvest sites, and our calculations show it to be the least expensive choice ($203/ton of erosion) for preventing erosion if integrated into the harvest operation. However, if slash is spread after harvesting, the Slash treatment becomes more expensive than either the Seed or the Mulch treatments.

SUMMARY AND CONCLUSIONS

Timber harvesting has a huge economic impact in Virginia and the southeastern United States, and BMP implementation costs can influence potential profits. The minimum BMPs typically considered for skid trails are waterbars, but waterbars may need to be supplemented with other practices when slopes exceed 5%. Of the four additional treatments evaluated, the Seed treatment had the lowest costs but was not the best option for minimizing erosion. The Mulch, Hardwood slash, and Pine slash treatments are effective at lowering soil erosion on overland skid trails but are expensive and labor intensive. The Integrated Slash approach is already being implemented by many logging contractors, and it may be the best option for expenses and long term effectiveness. Overall, it appears that all of the BMPs evaluated may be appropriate under certain conditions and final selection should be determined by landowner goals, operator capabilities, environmental sensitivity, and cost effectiveness.

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Table 1—Cost estimates for specific components of skid trail BMP treatments installed during 2009

Component	Information	Equipment - Supply Costs ($/mile)	Operator - Labor Costs ($/mile)	Total Installation Costs ($/mile)
Water Bar	$18.75/bar	$1,320	$660	$1,980
Seed	265 lbs/acre @ $1.11/lb	$442	$33	$475
Mulch	2 bales/50 feet @ $4.99/bale	$1,054	$ 220	$1,274
Lime	1 ton/acre @ $200/ton	$300	$33	$333
Fertilizer	200 lbs/acre @ $0.259/lb	$78	$33	$111
Slash	Cover 100 feet/hour	$2,790	$1,320	$4,110

Table 2—Cost estimates for skid trail closure techniques used for overland skid trails on a 29 acre site in the Virginia Piedmont during 2009

Treatment	Costs per mile	Costs for 29 acre site	Costs per ton of wood harvested	Costs per ton of erosion prevented (Year 1)
Mulch (WB,S,L,F,M)	$4,173/mi	$3,964	$1.29/ton	$262/ton
Slash (WB,X)	$6,090/mi	$5,786	$1.88/ton	$416/ton
Seed* (WB,S,L,F)	$3,849/mi	$3,657	$1.19/ton	$486/ton
Control (WB)	$1,980/mi	$1,881	$0.61/ton	NA
Integrated Slash (WB,X)	$2,970/mi	$2,822	$0.92/ton	$203/ton

WB = Water Bar; S = Seed; L = Lime; F = Fertilizer; M = Mulch; X = Slash
*The seed treatment includes costs for 3 seed applications.

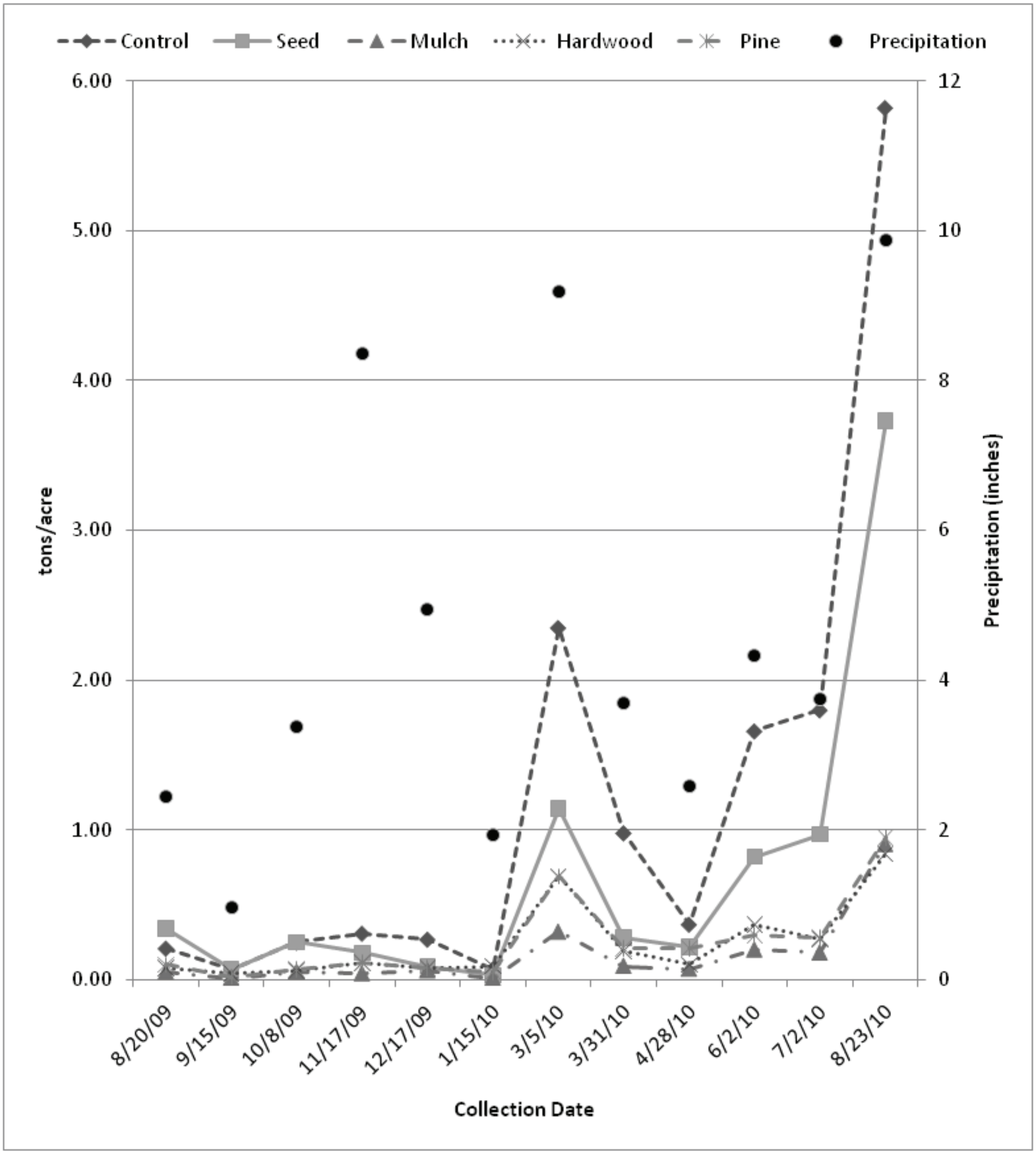

Figure 1—Average erosion and precipitation by treatment and collection period.