Evaluation of Bladed Skid Trail Closure and Cover BMPs for Erosion Control

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\textbf{ABSTRACT}

Sediment is one of the leading pollutants in our nation’s water bodies. Within a silvicultural operation the majority of sediment originates from areas that are highly disturbed including areas such as decks, roads, and skid trails. Forestry Best Management Practices (BMPs) have been developed to minimize sediment export. BMP implementation is particularly important on skid trails because trails are built to lower standards and present the potential for increased erosion. Typical trail closure BMPs include installing water bars, and seeding with or without the application of mulch. The goal of our study was to determine the effectiveness of the following five closure and cover BMPs for bladed skid trails: 1) water bar only (Control); 2) water bar and grass seed (Seed); 3) water bar, grass seed, and mulch (Mulch); 4) water bar and piled hardwood slash (Hardwood Slash); and 5) water bar and piled pine slash (Pine Slash). To capture and quantify the amount of sediment being produced, geotextile devices known as dirtbags\textsuperscript{®} were used. Bags were weighed after each major rainfall event or monthly, if no events occur, to assess the amount of erosion. In addition to field measurements, three soil erosion models were used to determine treatment effectiveness. The models used were the Universal Soil Loss Equation for Forestry (USLE), Water Erosion Prediction Project for Forest Roads (WEPP), and the Revised Universal Soil Loss Equation version 2 (RUSLE2). Preliminary results indicate significant treatment differences, with the Mulch, and Slash treatments being the most effective at reducing erosion.

\textbf{INTRODUCTION}

Sedimentation has clearly been identified as one of the most important sources of non point source (NPS) pollution in the United States (USEPA, 2003). Increased sedimentation can impair the natural functions of streams and rivers to a point where they become unsuitable for aquatic organisms (Virginia Department of Environmental Quality, 2007; Henley et al., 2000) and no longer can serve recreational needs (USEPA, 2003; Henley et al., 2000). Sedimentation derived from land uses such as agriculture, forestry, and urban development are the leading sources of NPS (USEPA, 2003; Yoho, 1980).

In response to the increased erosion potential from silvicultural operations, forestry Best Management Practices (BMPs) have been developed. Forestry BMPs mainly focus on highly disturbed areas within a silvicultural system that are most susceptible to erosion. These areas include roads, decks, and skid trails (Kochenderfer, 1977). BMPs are designed to reduce erosion by decreasing the amount and velocity of water thus decreasing its energy, and increasing the
stability of the soil. BMPs used for roads, skid trails, and logging decks include: 1) proper planning, construction, and location; 2) control of grade; 3) control of water; 4) surfacing; and 5) road or trail closure (Grace, 2005; Swift and Burns, 1999; Swift, 1985). Bladed skid trail closure is important because skid trails are typically built to lower standards than haul roads and have the potential to produce more sediment. Typical closure BMPs include installing water control structures and applying cover. Water control structures such as water bars are used to divert water flow from the roadway and dissipate it over the adjacent forest floor. The spacing interval of water bars is dependent on the slope of the trail, as the slope increases the distance between bars decreases. Cover BMPs such as seeding, and seeding and mulching often reduce the amount of erosion by providing stability to the soil (Grace, 2002). The cover provided also decreases overland flow velocity and causes deposition of sediment before it reaches a waterway. Mulching provides immediate cover while the effects of seeding are not evident until the seed germinates. Piling slash on skid trails can also be a means of providing immediate cover and is recommended in southeastern states’ BMP manuals (Georgia Forestry Commission, 2009; West Virginia Division of Forestry, 2009; North Carolina Division of Forest Resources, 2006; Virginia Department of Forestry, 2002); however there has been limited research into the effectiveness of slash as a soil stabilizer. One study conducted on volcanic soils in the western U.S. showed that piled slash reduced soil erosion by 99% when compared to bare mineral soil (McGreer, 1981).

To help land managers evaluate the effects of silvicultural activities on sedimentation, soil erosion models have been developed to predict erosion rates from both hillslopes and roads. Erosion prediction methods are also used to evaluate management practices and erosion control techniques (Elliot, 2004). Soil erosion models potentially provide a cost effective way to evaluate the performance of forestry BMPs. However, few erosion models have been calibrated for bladed skid trails.

The objectives of this study are to evaluate the performance of five closure and cover BMPs for the reduction of sediment production on bladed skid trails. The BMPs being evaluated are: 1) water bar only (Control); 2) applying grass seed (Seed); 3) applying grass seed with mulch (Mulch); 4) piling hardwood slash on trails (Hardwood Slash); and 5) piling pine slash on trails (Pine Slash). The treatment effectiveness is determined by both onsite field measurements and by use of soil erosion models. The soil erosion models being used are the Universal Soil Loss Equation for Forestry (USLE), the Water Erosion Prediction Project for Forest Roads (WEPP), and the Revised Universal Soil Loss Equation version 2 (RUSLE2).

METHODS

Study Site
The study site is located at Reynolds Homestead Research Center in the Piedmont physiographic region of Virginia. Reynolds Homestead is owned by Virginia Polytechnic Institute and State
University and is located in Patrick County. Patrick County is approximately 1,250 square kilometers and land is generally characterized by gently rolling terrain. The average temperature in January ranges from a high of 9°C to a low of -1.8°C. In July the average temperature ranges from a high of 29.7°C to a low of 17.8°C. The average precipitation is 151.9 cm with 125.2 cm being rainfall and the remaining 26.7 cm is snowfall (Patrick County, VA). The treatments are installed in a 5 hectare clearcut with side slopes of 15-20%. The dominant soil series on the site is Fairview sandy clay loam, fine, kaolinitic, mesic Typic Kanapludults. This soil is formed from residuum from mica schist and mica gneiss and is very deep, well drained, and has an erodibility index of 0.28 (NRCS Soil Survey, 2009).

**Experimental Design and Data Collection**

**Field Measurements**

Treatments were installed on segments of bladed skid trail. There were a total of six bladed skid trails built with five treatments per trail. The study was designed as a Randomized Complete Block Design with the trails being designated as the six blocks and having a total of thirty experimental units.

Experimental units were approximately 15.2 meters (50 ft) in length by 3 meters (10 ft) in width and have water bars installed at the head and base of the treatment slope. Berms were maintained along the sides of each unit to ensure that no runoff produced from the treatment escapes and that no runoff from outside the unit area enters. Treatments were randomly assigned to each experimental unit.

- The Control treatment only has water bars installed. This treatment represents a commonly used closure BMP. Water bars were installed roughly at a 45 degree angle to the treatment slope. A high degree angle is preferable when installing water bars to ensure that as runoff reaches the water bar and is diverted into the adjacent off road area it will carry enough velocity to reach the outlet. Treatment water bars were built 0.6 to 0.9 meters (2 to 3 feet) in height to ensure that water will not overtop them, thus rendering them useless.

- Seed treatments consisted of water bars built at the head and base of the treatment and an application of seed. The seed mixture used was provided by Plum Creek Timber Company, Inc and consisted of winter rye (35%), timothy (10%), orchard grass (10%), perennial rye (10%), medium red clover (20%), and annual rye (15%). This mixture is used by Plum Creek Timber Company, Inc to close out skid trails on their company land in West Virginia. To promote germination, lime was applied at a rate of 2.25 Mg/ha (1 ton/acre), and a 10-10-10 fertilizer was applied at a rate of 227 kg/ha (200 lbs/acre). Seed was applied at a rate to ensure establishment (minimum 70% coverage) and was reapplied as necessary on treatments where germination was inadequate.
• Mulch treatments consisted of water bars built at the head and base of the treatment and an application of seed and straw mulch. The application of seed was the same as the Seed treatments and lime and fertilizer were applied at the same rates. Straw was applied after the application of seed at a rate that ensured 100% coverage. On a 15.2 meter (50 ft) by 3 meter (10 ft) slope length this equated to two straw bales.

• The Hardwood Slash treatments consisted of water bars and an application of hardwood slash. The hardwood slash was generated by felling small pole size trees in adjacent stands and cutting them into random lengths. The trees were harvested during March and April of 2009. The diameter of the felled trees ranged from 2.5 cm (1 in) to 15.2 cm (6 in) and the lengths ranged from 1.2 m (4 ft) to 3 m (10 ft). A combination of species were used and included white oak (Quercus alba), scarlet oak (Quercus coccinea), hickory (Carya spp.) yellow poplar (Liriodendron tulipifera), American beech (Fagus grandifolia), sourwood (Oxydendrum arboreum) and red maple (Acer rubrum). Slash was applied, using front end forks mounted on an agricultural tractor, initially to a waist high depth and then trampled down by a bull dozer to break up the slash and ensure good ground contact.

• The Pine Slash treatments consisted of water bars and an application of pine slash. The majority of the pine slash originated from a previous study conducted at Reynolds Homestead in February and March of 2009 and was composed of loblolly pine (Pinus taeda). The remaining pine slash was cut on the property in May of 2009 and consisted of Virginia pine (Pinus virginiana) and white pine (Pinus strobus). The lengths and diameters of the pine slash were similar to the hardwood slash and the application was the same as that of the hardwood slash.

Sediment produced from treatments was captured by gutters installed in trenches at the base of the treatments and then transported into a geotextile device, known as a dirtbag®, where the sediment was filtered (Figure 1).

Figure 1. Dirtbags® installed on bladed skid trail.
Dirtbags® are designed to filter sediment from construction site retention ponds but have been adapted for our use. Similar devices were utilized by Smith and Fenton (1992) to measure sediment from skid trails in New Zealand. To assess the amount of erosion that has occurred, dirtbag® weights were recorded monthly. Weights were measured by a Citizen HA crane scale, that has a weight capacity of 544 kg (1200 lbs), mounted on a metal arm attached to the blade of a John Deere 450E dozer. During measurements the moisture of the sediment within the bags was recorded using a time domain reflectometer (TDR). The bags were then classified into moisture classes, 1) saturated; 2) moist; and 3) dry, that described the moisture content of the bag itself. Correction factors were developed for each moisture class based on the surface area of the bag. The recorded weights were then adjusted by the sediment moisture and the moisture class correction factor.

**Soil Models**

The three soil erosion models used were the Universal Soil Loss Equation for Forestry (USLE), the Water Erosion Prediction Project for Forest Roads (WEPP), and the Revised Universal Soil Loss Equation version 2 (RUSLE2). Model predictions were analyzed, as a Randomized Complete Block Design, in the same manner as the field measurements. There were a total of 6 blocks with 5 treatments per block for a total of 30 experimental units.

Onsite measurements were taken at the onset of the study to describe the site conditions for use in the soil erosion models. The collected data was used to directly derive variables in the USLE and also to derive management files for use in RUSLE2 and WEPP. For model predictions, treatments were broken into two segments and erosion rates were calculated for each and then summed together for a total treatment erosion rate (Figure 2). The first segment includes the area from the top of the water bar at the head of the treatment to the base of the water bar at the foot of the treatment. The second segment is the area from the top of the water bar at the base of the treatment to the base of the same water bar. Treatments were divided in this manner because the slopes of the two segments are very different, with the water bar slope generally being in excess of 25%.

![segment](image)

Figure 2. Treatment areas were separated into two segments and estimates were made for each segment and summed for a total erosion estimate
The equation that USLE uses to estimate erosion is as follows:

\[ A = R \times K \times LS \times CP \]

Where

- \( A \) = amount of erosion per unit area per year
- \( R \) = rainfall and runoff
- \( K \) = soil erodibility factor
- \( LS \) = slope length and steepness factor
- \( CP \) = cover and management factor

An R value of 175 was used for all treatments and was taken from isoerodent maps found in the USLE handbook (Dissmeyer and Foster, 1984). A K value of 0.28 was used for all treatments and was found in the Patrick County Soil Survey (NRCS Soil Survey, 2009). The remaining factors were based on treatment specific conditions. For each treatment, LS values were determined based on slope profiles derived from elevation data collected by a total station, and CP values were based on data collected along four equidistant transects across each treatment area. USLE measurements were taken several times throughout the study. Multiple measurements were useful to examine the effects of season and time on erosion rates. We captured the effects that grass development and subsequent die back, slash decomposition, and soil reconsolidation had on erosion rates. USLE measurements were taken twice. A weighted average was used to develop estimates with the weights reflecting time between measurements. Also estimates were made pre and post grass establishment on Seed and Mulch treatments. We assumed that grass establishment took thirty days and appropriate weights were assigned to pre and post conditions.

RULSE2 originated from the empirically based USLE but has some process based functions and WEPP is a completely process based model. Both models are similar to one another in the data that is needed for model runs. Both require four types of information: 1) climate file; 2) soil file; 3) slope file; 4) and management file. Both models offer databases where climate files, soil files, and management files can be downloaded. These database files can be utilized or can be manipulated for site or treatment specific conditions. Both programs offer an interface for the user to input slope steepness and length values to create a slope file. In this analysis, climate and soils files were downloaded for Patrick County and management files were altered for treatments and are outlined in the following table (Table 1).
Both field measurements and soil model estimates were set up as a Randomized Complete Block Design, with trails being designated as the blocking factor with five treatments per trail for a total of thirty experimental units. Analysis of variance (ANOVA) was used to determine whether or not there were significant treatment differences. If treatment differences were detected a Tukey Means separation test was used to determine where the significant differences occurred. For all tests significance was determined based on an alpha level of .05.

RESULTS and DISCUSSION

Dirtbag® weights have been measured ten times since the onset of this study, for a total of 60 weights per treatment. Soil erosion model estimates have been developed for each experimental unit and there are a total of 6 estimates per treatment per model. Treatment averages are shown in Table 2 and ANOVA results are shown in Table 3. ANOVA results indicate that significant differences exist in both field measurement results and all three soil erosion model estimates.

Table 1. Management file details for RUSLE2 and WEPP models

<table>
<thead>
<tr>
<th>Treatment</th>
<th>RUSLE2</th>
<th>WEPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Highly Disturbed Land/Blade Cut &amp; Highly Disturbed Land/Track Walking Operation</td>
<td>Forest Bladed Road</td>
</tr>
<tr>
<td>Seed</td>
<td>Control File &amp; Broadcast Seed Operation applying southern range grass</td>
<td>Control &amp; annual ryegrass was planted at a medium fertilization rate</td>
</tr>
<tr>
<td>Mulch</td>
<td>Seed File &amp; Highly Disturbed Land/Add Mulch Operation applying wheat straw: application rate based on coverage (=100%)</td>
<td>Seed File &amp; mulch residue addition of fescue at a rate of .788 kg/m² (=2 straw bales per treatment)</td>
</tr>
<tr>
<td>Hardwood Slash</td>
<td>Control File &amp; Highly Disturbed Land/Add Mulch Operation applying wood fiber. Response of wood fiber was changed to large woody debris and decomposition half life was increased to 1800 days (=4.85 yrs). Application rate was based on percent coverage provided by treatments.</td>
<td>Control file &amp; mulch residue addition of fescue. The application rate was based on the amount of slash applied to treatments.</td>
</tr>
<tr>
<td>Pine Slash</td>
<td>Same as Hardwood except that the decomposition half life was further increased to 3600 days (=19 yrs)</td>
<td>Same as Hardwood</td>
</tr>
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Table 2. Mean erosion rates for treatments for Field Measurements and Soil Erosion Models

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Field Measurements</th>
<th>USLE</th>
<th>RUSLE2</th>
<th>WEPP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>tons/acre/yr</td>
<td>Mg/ha/yr</td>
<td>tons/acre/yr</td>
<td>Mg/ha/yr</td>
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<tr>
<td>Control</td>
<td>67.5</td>
<td>151.9</td>
<td>48.6</td>
<td>109.4</td>
</tr>
<tr>
<td>Seed</td>
<td>18.0</td>
<td>40.5</td>
<td>32.8</td>
<td>73.9</td>
</tr>
<tr>
<td>Hardwood Slash</td>
<td>4.9</td>
<td>11.1</td>
<td>4.5</td>
<td>10.1</td>
</tr>
<tr>
<td>Pine Slash</td>
<td>3.5</td>
<td>7.8</td>
<td>1.8</td>
<td>4.1</td>
</tr>
<tr>
<td>Mulch</td>
<td>1.7</td>
<td>3.8</td>
<td>2.7</td>
<td>6.1</td>
</tr>
</tbody>
</table>
A tukey means separation test was used to determine treatment differences. Figure 3 shows the results from this test.

The results indicate that water bars alone are not always effective at preventing erosion and are not the best choice for trail closure in areas that are prone to erosion. Seed treatments offer some erosion control but are only slightly better than water bar alone. The amount of erosion control offered by seed applications depends on how much germination is achieved. In many cases applying seed alone achieves inadequate germination and very little erosion control is offered. The best erosion control was offered by the Hardwood Slash, Pine Slash, and Mulch treatments. In three of the four evaluation methods the Hardwood Slash, Pine Slash, and Mulch treatments differed very little. All methods except RUSLE2 showed the Slash and Mulch treatments to

<table>
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<th></th>
<th>F Value</th>
<th>Prob Level</th>
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<tbody>
<tr>
<td>Field Measurements</td>
<td>44.14</td>
<td>&lt;.0001</td>
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<tr>
<td>USLE</td>
<td>28.75</td>
<td>&lt;.0001</td>
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<tr>
<td>RUSLE2</td>
<td>303.13</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>WEPP</td>
<td>286.97</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

Figure 3. Treatment averages per evaluation method. Treatments with the same label are not significantly different
have erosion rates less than 10 Mg/ha/yr. When the small area of skid trails (generally < 10%) is weighted with the total harvest area, the sediment contribution becomes similar to agriculture.

CONCLUSION

In silvicultural operations it is very common to see trail closure consisting only of water bar installation and water bars are a commonly prescribed treatment in state BMP manuals (Virginia Department of Forestry, 2002). Water bars are certainly helpful and do offer erosion control. However, in areas where soil erosion is not tolerable, such as stream approaches, water bars alone should not be the only BMP implemented. In combination with water bars, BMPs that provide soil stability should be applied. Establishing grass on skid trails can be very effective at stabilizing the soil, but ensuring there is adequate germination can be difficult. Multiple applications of seed along with application of fertilizer and lime may be needed. Erosion control is also not immediate and only occurs after seed has germinated. Applying a mulching agent is the best way to prevent erosion from occurring. Slash and Mulch treatments were the most effective at erosion control because they provide the most ground cover, which serves to stabilize the soil by providing protection from rainfall impact and reduction in overland flow velocity. The protection offered by the Slash and Mulch treatments is immediate and therefore these treatments should be implemented in areas that are highly susceptible to erosion, such as steep grades and fill slopes.

In forest applications, slash in the form of tree tops and limbs is a readily available mulching agent. The protection provided by slash is very near to that provided by straw mulch. Slash also has a lower decomposition rate than does straw mulch and therefore has a longer residual lifespan. This study has covered a time span of ten months, but if these treatments were to be followed for a longer time period it is likely that we would see the erosion rates of Slash treatments leveling out with the erosion rates of the Mulch treatments. Eventually as the mulch decomposes, the erosion control provided by Slash treatments may surpass that of the Mulch treatments.

LITERATURE CITED


West Virginia Division of Forestry, 2009. West Virginia silvicultural best management practices for controlling soil erosion and sedimentation from logging operations. WV Division of Forestry, Charleston. 38p.
