Skidding trail reinforcement with reduced amount of slash

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Abstract. Skidding trail sites are reinforced with slash to keep them from rutting by numerous skidding vehicles passes. As the number of passes is not uniform on the site, it is possible to reduce slash usage as the material for reinforcement. The amount of slash should be enough to keep safety characteristics of the slash covering for the definite number of passes. The investigation results of the skidding vehicle passes influence on rutting along the skidding trail (the length of skidding trail 150 m) are presented. Model of vehicle is a crawler skidding vehicle TDT-55A with a cable-winch. Six sites with various numbers of passes were studied. There were sites with 10; 12; 22; 24; 34; 36 passes. The amount of slash to be laid on the sites was determined: slash density should be – 18 kg/m² for 10 passes of the site; 22 kg/m² for 12 passes; 35 kg/m² for 22 passes; 37 kg/m² for 24 passes; 45 kg/m² for 34 passes; 46 kg/m² for 36 passes. For all sites with slash reinforcement the depth of the rut was not more than 220 mm after any number of passes compared with the sites without slash reinforcement with rut depth of 300 mm after just 6 passes. To reinforce a skidding trail, 27 % of the total slash amount are enough compared with 90 % commonly used in the similar conditions.

1. Introduction

Forest harvesting in Karelia (the region on the North-West of Russia) is usually carried out in moist soil conditions (on the soils with low bearing capacity) on cutting areas. To improve logging vehicle traffic and to reduce such soil disturbances as rutting and soil compaction, skidding trails are reinforced with slash. It has been observed that slash reinforcement is quite an effective method [1 - 10].

Slash as a covering material for the skidding trails improves vehicle traffickability i.e. makes it possible for a vehicle to pass easily along the trail as many times as it is necessary, on the site by two or three times in comparison with the skidding trails without slash reinforcement [11-13].

Taking into consideration the significance of slash as a valuable biomass resource, nowadays we have to deal with a twofold problem: efficient usage of slash both for skidding trails sites reinforcement and for recycling for industrial purposes.

So minimization of the slash amount for skidding trails sites reinforcement can be achieved in the following way. Slash covering should be formed only on the vehicle passes sites and its thickness and density should be in accordance with the number of the vehicle passes. A skidding trail consists of plots having various numbers of the passes. Thus, slash thickness and slash density should vary along a skidding trail.

The aim of this paper is to evaluate what part of the total amount of slash is enough to maintain machine traffic for the full cycle of vehicle passes during the logging process and how slash covering...
should be distributed by thickness and density along a skidding trail. An example of slash distribution according to vehicle passes distribution along the skidding trail is shown in the paper.

The article uses materials from the Russian-language article of the same author [14], in particular, the plan of the experiment and regression curves, but the current work presents an extended analysis of publications, a more detailed description of the experiment, regression functions and more accurate data of the experimental results.

2. Materials and methods

The study was done in conditions of tree-length logging in summer time (July). Trees were felled and then delimbed and topped at the stump with a chain-saw. Skidding was carried out by a cable crawler tractor TDT-55A, producer - Onezhsky Tractor Plant (OTZ), Russia (Figure1, Table 1). Growing stock on the cutting area was 160 cubic meters per hectare.

![Figure 1. Skidding vehicle TDT-55A (dimensions in mm).](image)

| Table 1. Brief specifications. |
|-------------------------------|
| **Technical parameters**      | **Value** |
| Machine dimensions (length, width, height), mm | 5800x2357x2560 |
| Operating Weight, kg          | 9600      |
| Travel Speed, km/h            | 2.9-12.8  |
| Ground Pressure, MPa          | 0.044     |
| Track width, mm               | 440       |
| Ground clearance, mm          | 555       |
| Load capacity, m³             | 8         |
| Engine Power, kW (h.p.)       | 70(95)    |

Limbs were carried to skidding trails for soil reinforcement. The skidding trail width was four meters. The cutting area was located on moist soils. Soil characteristics were controlled with a penetrometer DorNII (developer - Scientific Research Institute of Roads, USSR), Figure 2. Soil characteristics were determined by strikes number of a dropping load with weight 2.5 kg from the height of 452 mm. The load was dropped until the tip (tip diameter 11.3 mm) of the penetrometer penetrated into the soil to the depth of 100 mm The soil on the skidding trails was characterized on average by one or two dropping load strikes.

Experimental plots were selected on one skidding trail. There were four plots, one of them didn’t have slash reinforcement, three others were reinforced with slash.

The width of slash covering was 1.5 times as much as the vehicle caterpillar width. Each time when the skidding vehicle approached the experimental plots it moved along the same track. Besides passes made during the logging process some additional experimental passes were made on the reinforced plots. The total number of passes was 100.

At the beginning of the vehicle passes, the slash covering was not formed completely. Slash was added after the passes series in accordance with trail disturbance rates and rutting intensity. Thus, such
performance of the experiment helped to determine the minimal slash amount to support the skidding trails in required conditions throughout the complete cycle of passes.

Primary slash portions on the experimental plots are shown in Table 2.

Table 2. Primary slash portions on the experimental plots.

| Plots number | Slash amount on the plots, kg/m² |
|--------------|----------------------------------|
| 1            | 0                                |
| 2            | 16                               |
| 3            | 24                               |
| 4            | 30                               |

Each slash portion added after a cycle of passes was weighed. Experimental slash was in medium-dry condition because it had been kept on the cutting area for some time. Next portion was added when the risk of rut depth increase for more than 220 mm was observed.

After the primary six passes, plots #3 and #4 were used for further investigations (Table 2). The plan of the plots reinforcement with slash is shown in Table 3.

Table 3. Plan of the experiment for plots #3 and #4.

| Plot #3 | Plot #4 |
|---------|---------|
| Total amount of slash, V, kg/m² | Total number of vehicle passes, N |
| Total amount of slash, V, kg/m² | Total number of vehicle passes, N |
| 24 | 6 |
| 24 | 17 |
| Slash portion of 18 kg/m² was added |
| 42 | 31 |
| 42 | 40 |
| Slash portion of 6 kg/m² was added |
| 48 | 58 |
| 48 | 70 |
| Slash portion of 12 kg/m² was added |
| 60 | 84 |
| 60 | 100 |

Besides investigation of vehicle passes effect on the skidding trail plots with slash reinforcement, the vehicle passes distribution along the skidding trail was studied. The passes distribution was determined for the following logging conditions.

The distance between the skidding trails was 45 meters. Logging was carried out in series by lanes: the first lane was the skidding trail with 5 meters width; others – lanes with 10 meters width on the left and right sides from the skidding trail. First trees were felled and skidded from the skidding trail lane, then from the second lane next to the skidding trail on the right, the third lane on the left and etc. (figure 3). The skidding vehicle kept moving along the skidding trail when trees were skidded from the lanes on the left and right side from the skidding trail.

The length of the studied skidding trail was 150 meters.

Locations of the vehicle turns, the length of the plot for the vehicle loading with tree-lengths and the number of passes performed on the separate plots of the skidding trail were fixed.
3. Results and discussion

Soil disturbance values on the experimental plots without and with slash are presented in figure 4. Root depth values on the plots after the first six vehicle passes are presented in figure 5.

Figure 2. Penetrometer DorNII (dimensions in mm).  
Figure 3. Principal scheme of logging.

Figure 4. Soil disturbances after the first six vehicle passes: a) without slash (plot # 1); b) with slash.

The shape of the fitting curve, indicating the intensity rate of rutting with the increase of vehicle passes number, is shown in Figure 6. The shape of the curve was determined according to experimental data. So, the shape of the fitting curve, indicating the adequate slash density for reinforcement of the skidding trail site according to the number of passes, is shown in this figure. In Figure 6 the data are presented when the rut depth should be not more than 220 mm. The data were used from the experiments carried out on plots #3 and #4. Besides, the computed correlations are shown in this figure.
Figure 5. Root depth on the experimental plots after the first six passes.

Depth of ruts formed by vehicle passes and influence of total slash amount on rutting intensity for plots #3 and #4 are presented in Table 4. The amount of slash used in the experiments proved to be significantly less than the amount used during conventional logging with the same soil conditions. The experiments proved that the amount of slash to be used for reinforcement is connected with rutting intensity: the more amount of slash, the less gain of rut with every following vehicle pass.

Table 4. Rut depth formation on plots #3 and #4.

| Plot #3 | Plot #4 | Total number of vehicle passes, N |
|---------|---------|----------------------------------|
| Rut depth, H, mm | Rut depth, H, mm |                                      |
| 100     | 50      | 6                                 |
| 170     | 120     | 17                                |
| 200     | 130     | 31                                |
| 200     | 180     | 58                                |
| 200     | 200     | 70                                |
| 210     | 200     | 84                                |
| 220     | 220     | 100                               |

Slash amount increase on the skidding trail leads to decrease of rut depth. Just the first six vehicle passes showed that the more slash was used, the less was the rut depth (compared with the sites without slash reinforcement) (tables 2, figure 5). So, the values of slash density on plots 3 and 4 can be considered enough for soil protection from disturbances up to sixty passes. Up to the hundredth vehicle pass the rut depth for plots 3 and 4 was almost similar in spite of various slash density on these plots.

When numerous vehicle passes are performed the amount of slash which was primarily laid on the plots is not significant. Figure 6 shows, that soil disturbances are about equal for plots #3 and #4 after 100 passes, although the primary slash density was different.

Cross planking (figure 7) made from non-merchantable and small size stem wood is often used for skidding trails reinforcement. According to the experiments, slash covering can resist numerous vehicle passes required for the logging process. So cross planking should be substituted by slash...
covering made from branches and twigs. Non-merchantable and small size stem wood could be the additional resource for bioenergy.

![Graph a) Rut depth (H, mm) and number of passes (N) on the slash reinforcement plots; b) slash amount (V, kg/m²) and number of passes; ● Plot #3, ■ Plot #4.](image)

**Figure 6.** Correlation graphs: a) rut depth (H, mm) and number of passes (N) on the slash reinforcement plots; b) slash amount (V, kg/m²) and number of passes; ● Plot #3, ■ Plot #4.

![Image of cross planking on a skidding trail.](image)

**Figure 7.** Cross planking on a skidding trail.

So, a skidding trail is a traffic way with a different number of passes along the way. Thus, the skidding trail should be reinforced according to the vehicle passes distribution along the trail. The most loaded plots should have more slash amount; the slash amount should be less on the less loaded plots.

The vehicle passes distribution along the experimental skidding trail was determined. The forming of the passes distribution is presented in Figure 8. In Figure 8 it is shown, that there are plots with different numbers of passes.

On average a crawler vehicle moved 25 meters along the skidding trail for maximal loading when tree-lengths were collected from the skidding trail directly and 50 meters along the skidding trail for maximal loading when tree-lengths were collected from the lanes, on the left and right from the skidding trail.

The bounders of the skidding trail plots with various numbers of vehicle passes were determined by the length of plots necessary for the vehicle to be fully loaded by tree-lengths.
The example of slash distribution along the skidding trail according to the passes distribution is presented. Slash density required for the soil reinforcement is determined. Estimation is made for the data of plot #4. For this plot, rut depth in the passes range 10 – 36 is the least one compared with the other plots. In accordance with the passes distribution (Figure 8) the slash density is estimated with correlation presented in Figure 6,b. The required slash density is 18 kg/m² for the plot with 10 passes; 22 kg/m² – 12 passes; 35 kg/m² – 22 passes; 37 kg/m² – 24 passes; 45 kg/m² – 34 passes; 46 kg/m² – 36 passes. The slash distribution is presented in Figure 8 in relative size.

![Figure 8. Forming of the total passes distribution and distribution of slash for reinforcement along the skidding trail.](image)

4. Conclusions
According to the investigations of Russian forest scientific engineering institutes and centers, the standard slash amount is 14% of merchantable stem wood. For the present investigation, the slash amount is 22.4 cubic meters per hectare (the grown stock is 160 m³ per hectare). The slash amount on the plot with length 150 m (length of the skidding trail) and width 45 m is 15 cubic meters. The total amount of slash required for reinforcement of the complete skidding trail is 6.7 ton (about 4 cubic meters). This amount will be enough, provided the reinforcement will be only on the plots where tracked log skidder moves. The width of the reinforcement should be not less than 0.66 m for every vehicle track.

Consequently, for the present studied logging conditions, 27% of total slash amount is enough to support vehicle trafficability on one skidding trail and rut depth will not exceed 220 mm, compared with 90% of total slash amount commonly used in the similar conditions.

References
[1] Eliasson L and Wästerlund I 2007 Effects of slash reinforcement of strip roads on rutting and soil compaction on a moist fine-grained soil. Forest Ecol. Manag. 252 (1-3) 118
[2] Gerasimov Y and Katarov V 2010 Effect of bogie track and slash reinforcement on sinkage and soil compaction in soft terrains. Croat. J. For. Eng. 31 (1) 35
[3] Labelle E R, Jaeger D and Poltorak B J 2015 Assessing the ability of hardwood and softwood brush mats to distribute applied loads. *Croat. J. For. Eng.* 36(2) 227

[4] Han H-S, Page-Dumroese D, Han S-K and Tirocke J 2006 Effects of Slash, Machine Passes, and Soil Moisture on Penetration Resistance in a Cut-to-length Harvesting. *Int. J. For. Eng.* 17 (2) 11

[5] Han H-S, Han, S-K, Page-Dumroese D and Johnson L R 2009 Soil compaction associated with cut-to-length and whole-tree harvesting of a coniferous forest. *Can J. For. Res.* 39 976

[6] Jakobsen B F and Moore G A 1981 Effects of two types of skidder and of a slash cover on soil compaction by logging of mountain ash. *Aust. J. For. Res.* 11 24255

[7] McDonald T P and Seixas F 1997 Effect of slash on forwarder soil compaction. *International J. For. Eng.* 8 (2) 15

[8] McMahon S and Evanson T 1994 The effect of slash cover in reducing soil compaction resulting from vehicle passage. Logging industry research organization, *New Zealand Report* 19(1) 1

[9] Poltorak B J, Labelle E R and Jaeger D 2018 Soil displacement during ground-based mechanized forest operations using mixed-wood brush mats. *Soil Till. Res.* 179 96

[10] Wronski E B and Murphy G 1994 Responses of Forest Crops to Soil Compaction. In *Soil Compaction in Crop Production* eds Soane B D and Ouwerkerk C (Amsterdam: Elsevier), pp.317-342

[11] Byblyuk N, Styranivsky O, Korzov V and Kudra V 2010 Timber harvesting in the ukrainian carpathians: Ecological problems and methods to solve them. *J. For. Sci.* 56(7) 333

[12] Wood M J, Moffat A J and Carling P A 2003 Improving the design of slash roads used to reduce soil disturbance during mechanised harvesting of coniferous forest plantations in the UK. *Int. J. For. Eng.* 14 (1) 11

[13] Wood M J, Carling P A and Moffat A J 2003 Reduced ground disturbance during mechanized forest harvesting on sensitive forest soils in the UK. *Forestry* 76 (3) 345

[14] Piskunov M A 2009 To a question on research of slash cover properties with skidding vehicle passages. *Forestry Bulletin* [Lesnoj Vestnik – in Russian] 2 111