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THE EFFECT OF SLASH COVER IN REDUCING SOIL COMPACTION RESULTING FROM VEHICLE PASSAGE

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Figure 1 - Forwarder approaching a series of slash beds for the fourth and final pass

ABSTRACT

A study was performed within Kaingaroa Forest to assess the effects of two depths of slash cover in reducing soil compaction after four passes of a laden forwarder. The main findings of the study were:

- *slash cover appeared to reduce the impacts of vehicle passage on soil bulk density*
- *four passes of a laden forwarder were unlikely to cause detrimental soil compaction.*

INTRODUCTION

The passage of harvesting machinery across a soil has the potential to cause compaction, resulting in reduced tree growth and increased rainfall runoff (Greacen and Sands, 1980; Standish et al., 1988: Lousier, 1990). Considerable research, within both the forestry and agricultural sectors, has focused on methods or practices to reduce soil compaction due to heavy vehicles; this includes low ground pressure tyres and tracks, lighter machinery, and operational limitations based on site conditions.

A more recent development is the use of harvesting residue or slash as a ground cover on which harvesting machinery may move. With moves towards on-site slash retention to maintain site fertility, and increasingly more mechanised harvesting practices (McNeel and Ballard, 1992) the role of slash coverage in reducing detrimental compaction effects is likely to increase.

Several overseas studies of mechanised harvesting operations have found that slash coverage reduced soil compaction. Omberg (1969) studied the effects of three passes of a 45 tonne vehicle on a sandy to sandy loam textured soil, with 5cm to 10cm depth of humus. He found that rutting depths were reduced by approximately 66% where 5cm to 30 cm of slash covered the ground surface. Hallonborg (1982) found that on soils with a high bearing capacity, slash coverage had little effect on reducing compaction; it was the vehicle weight which had the greatest influence. However, for soils with low bearing capacities, it was found that a slash coverage of 3cm to 5cm reduced rut formation; greater thicknesses had no further effect. The effect of slash coverage in reducing soil compaction under a production thinning operation was also noted by King and Haines (1979). They found that there was no significant compaction of surface soils due to processor and forwarder traffic which they also attributed to low soil water contents.

Work by Burger (1983), Wronski (1984), Shetron et al. (1988), and Hoffman (1992) has shown that compaction by mechanised harvesting vehicles occurs in the initial (three to five) passes. Results from Jakobsen and Moore (1981) indicate that the protective effects of slash are reduced after three to seven passes due to destruction of the slash cover. From these studies, it is evident that there are advantages to be gained from the application of slash to extraction tracks. Those advantages depend on slash mat thickness, soil type, and soil moisture content.

In New Zealand, a study performed by Bryan et al. (1985) in Mangatu State Forest demonstrated that slash cover reduced the degree of soil disturbance resulting during tractor extraction. The degree of soil disturbance beneath a manually prepared slash bed, and beneath sections of track with light slash cover were assessed using a six-class classification system. This study also indicated that the presence of slash cover did not reduce travel speeds and provided benefits for traction on slopes exceeding 18°.

To investigate the influence which slash depth has on soil compaction further, a study was performed under controlled conditions. In this study, two depths of slash cover were manually laid on to replicated plots, and then traversed by a laden extraction vehicle. The study was performed in an area undergoing production thinning, allowing the use of slash produced by the mechanised feller-processor, and the fully laden forwarder to traverse the slash beds (Figure 1).

METHODOLOGY

Site

The study was performed within Compartment 311 of Kaingaroa Forest. The soils of the area have been classified as Kaingaroa loamy sands by Rijkse (1988). The topography of the site was flat and the site was well-drained.

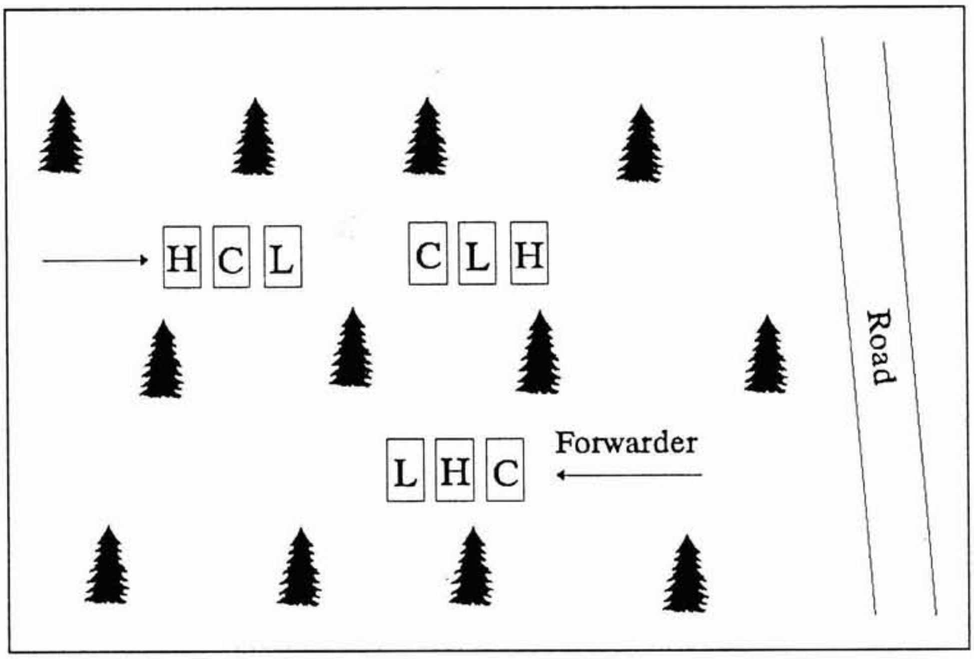

Figure 2 - Plot layout showing treatments (C= control, L = light slash, H = heavy slash)

The coarse textured nature of the soils meant that the soils were expected to have a low susceptibility to compaction (Carr et al., 1991).

Prior to planting, the site had been ripped and mounded, a practice common in central and southern Kaingaroa Forest. Prominent mounds located approximately 3m apart were still obvious surface features. The site was planted with radiata pine in 1979 at a stocking of 1250 stems/ha. At age six, the stocking was reduced to 575 stems/ha.

At the time of this study, during May, 1993, the compartment was being production thinned to a final stocking of 250 stems/ha. The mechanised thinning operation was carried out by a single grip harvester and forwarder.

Plot Establishment

Nine plots were established in three blocks on undisturbed areas between trails formed by the production thinning operation. Each plot measured 4m wide and 3m long, with a 1m gap separating plots in the same block (Figure 2). When considering the most appropriate position for the plots, it was necessary to ensure there was access for the forwarder on to and off the plots, and that the forwarder could travel in a straight line while on the plots.

The plots were established so that the direction of vehicle travel was parallel to that of the planting mounds. The mounds traversed the length of the plots through the plot centre, allowing the vehicle tyres to pass on the level ground between mounds.

Three treatments were imposed on each block. The treatments were as follows:

- no slash cover
- light slash cover
- heavy slash cover.

The light and heavy slash coverage corresponded to uncompacted depths of approximately 20cm and 40cm, respectively. Prior to laying the slash on the plots, it was weighed using a 100 kg suspended balance to ensure that the slash coverage was uniform across the two treatments. Mean $\pm$ standard deviation fresh slash weights for the light and heavy slash treatments were 9.2 ± 0.1 kg/m^2 and 18.6 ± 0.1 kg/m^2, respectively.

The placement of the treatments over each block of three plots ensured that each treatment occupied each position within the block (Figure 2).

The slash was laid evenly across the plot area, perpendicular to the direction of vehicle passage, with the stem ends of the slash orientated the same way. Average branch diameter, measured 10cm from the main stem, was 33mm (standard deviation = 8mm, sample size = 123). The 1m gaps separating the plots were also partially covered with slash to reduce edge effects at plot boundaries.

Soil Characterisation

Bulk Density

Prior to the slash being laid on the plots, the surface soils (0 to 65mm depth) were core sampled to determine pre-treatment bulk density (weight per unit volume of intact soil which include pore spaces and roots). Six cores of 490 cm^3 volume were taken from each plot - three from each side of the central mound.

Where cores had been excavated soil was replaced and the litter layer restored. The sample point was painted to allow identification following vehicle passage of previously cored areas.

Following vehicle passage, the slash cover was carefully removed and three core samples were taken from the centre of the tyre track on each side of the plot. Care was taken not to sample adjacent previously taken cores.

The core samples were analysed to determine field moisture content (%V/V) and oven dry bulk density. Soil samples were also taken prior to vehicle passage to determine volumetric water content using pre-compaction bulk densities and gravimetric water content.

Surface Relief

Prior to the slash being laid, one transect was located across each plot and the distance down to the litter surface from a fixed datum was measured at 10cm intervals. This exercise was repeated after vehicle passage following removal of the slash.

The average depth of the tyre depression was determined for each plot. In addition, the changes in relief profile area within the tyre ruts were determined.

Vehicle Passage

The treatment plots were traversed by a New Zealand-built Trackweld F20 forwarder (modified from a Moxy dump truck) carrying a full load of saw logs. This six wheel drive machine was fitted with 20.5 x 25 - 16 crossply tyres inflated to 70 p.s.i. These tyres were less flexible than radials. The tyre pressures were high because of the need to restrict excessive swaying of the forwarder as this can cause damage to residual trees. Also, radial tyres were more costly and believed to be more susceptible to puncture damage.

The vehicle was weighed empty by the Ministry of Police Transport Division using portable scales. The weight of the load was estimated by converting total measured log volume to a weight using a log density of 0.89 m^3/tonne. The total unladen weight of the forwarder was 18.28 tonnes, and loaded weight for this study was 33.7 tonnes.

The forwarder travelled in a straight line down the centre of each plot four times in the same direction at a constant speed of approximately 3.6 km/hr.

Operational Slash Cover

To gauge the extent of slash cover on operational processor/forwarder trails, the proportion of trail distance covered in slash was measured within Compartment 311 and Compartment 1053 previously thinned using the mechanised operation. The former had considerable regenerating Pinus contorta understorey which was crushed during the operation, adding to the slash cover. This regeneration was absent from Compartment 1053.

RESULTS AND DISCUSSION

Soil Bulk Density

Mean treatment bulk densities for before and after vehicle passage are shown in Table 1. Also shown is the percentage increase in bulk density for each treatment. The mean soil water content at the time of the study was 0.36 %V/V. The differences in treatment compaction were assessed using an analysis of variance and found not to be significant at the 90% confidence level.

Table 1 - Changes in soil bulk density due to vehicle passage

Treatment	Mean Bulk Density (tonnes/m^3)		% Increase in Bulk Density
	Pre-compaction	Post-compaction	
Control	0.56	0.70	25
Light slash	0.56	0.68	21
Heavy slash	0.57	0.66	16

Although not statistically significant ($P<0.1$), the results in Table 1 appear to indicate that slash cover reduced the extent of soil compaction due to vehicle passage and that the heavier slash cover was more effective than the light slash cover.

The initial bulk densities were very low reflecting the pumice content of the soil parent material. The 16% to 25% increase in mean plot bulk densities resulted in post treatment bulk densities of 0.6 - 0.7 t/m^3. This density is still low and unlikely to affect crop performance adversely. Even though the soil water content at the time of the study was approximately at field capacity (FRI unpublished data), the level of resultant soil compaction was low. This result was not unexpected given the loamy sand texture of the soil. It is likely that the degree of compaction would have increased had the soil water contents been higher (Lambe and Whitman, 1979). Wetter soil conditions are unlikely to prevail for more than short periods during and immediately following rainfall.

Surface Relief

Table 2 - Changes in surface relief due to vehicle passage

Treatment	Mean depth of tyre rut (cm)	Change in profile area within tyre rut (cm^2)
Control	4.5	47
Light slash	4.4	45
Heavy slash	4.9	49

The mean depth of tyre rut and the change in profile area within the rut for each treatment are shown in Table 2. A typical surface relief profile showing the planting mound and the area of compaction is shown in Figure 3.

The depths of tyre ruts were similar for the three treatments. At the two levels of slash cover used, it was expected that rut depths would have been less for the heavier slash cover as the vehicle weight should have been transferred over a larger surface area. In a similar study by Wronski (1990), it was found that for every 10 kg/m^3 of slash cover in excess of

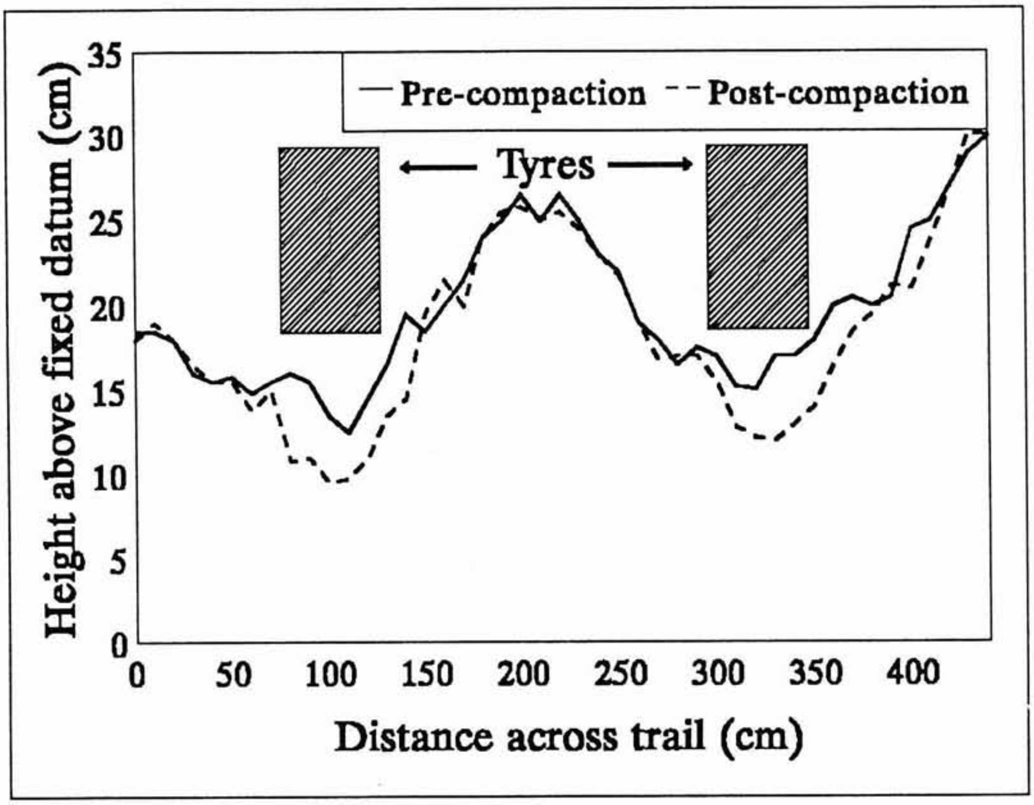

Figure 3 - A surface relief profile showing planting mounds and area of compaction

10 kg/m^3 there was a 25% increase in soil bearing capacity which significantly reduced rut depth. The lack of treatment effect in this study probably reflects the low compactibility of the soil and the fact that measurements were made to the litter surface rather than the soil surface.

Operational Slash Cover

The results of measurement of slash cover on vehicle trails within Compartments 311 and 1053 are summarised in Table 3.

Table 3 - Slash cover on trails resulting from mechanical production thinning operation

Compartment	Total trail length measured (m)	% slash cover
311	1435	65
1053	3306	61

The degree of slash cover on the trails will depend on the initial crop stocking prior to the mechanical thinning operation, the crop branching characteristics, and the final stocking. Typically, slash is deposited in front of the single grip harvester as the tree is delimbed. The harvester then travels forward over this slash until the next tree to be thinned is within reach. The forwarder follows the same trails as the harvester, travelling along each trail four to six times, depending on the width of the compartment, log production, and the number of log grades.

In the two compartments thinned using this mechanical operation, approximately 60% to 65% of the trail length was covered with slash. The effect of crushed understorey within Compartment 311 resulted in only a small increase in slash cover relative to Compartment 1053.

CONCLUSIONS

From this study a number of conclusions can be made:

(1) It appears that slash cover on trails reduced the degree of soil compaction by vehicle passage. The mean increase in soil bulk density below the heavy slash cover (40cm deep) was less than that under the light slash cover (20cm deep).

(2) The forwarder passage over both slash covered and control plots resulted in a 16% to 25% increase in mean bulk densities.

(3) In the two compartments measured, approximately 60% to 65% of the total trail lengths were covered with slash.

(4) Four passes of a laden forwarder is not expected to cause detrimental soil compaction due to:

   (i) the low initial bulk density of soil (mean = 0.56 t/m^3)

   (ii) the extent of slash cover.

   The likely exception to this may be vehicle passage during and immediately following a rainfall event.

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