Advantage

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Contents

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Soil compaction associated with summer harvesting in a mixedwood stand in central Alberta

Abstract

The Forest Engineering Research Institute of Canada (FERIC) studied a summer roadside harvesting operation in a hardwood-dominated mixedwood stand in central Alberta. This report describes the in-block soil compaction resulting from the felling and skidding phases.

Keywords

Soil compaction, Harvesting, Skidding, Soil bulk density, Soil strength, Alberta.

Introduction

Soil compaction can occur during forest harvesting activities and may reduce long-term forest productivity. Even minimal equipment traffic can have deleterious effects (Startsev 1999). Soil compaction can have detrimental effects at the planting microsite, cutblock, or watershed levels (Startsev and McNabb 2000), and compacted soils may take several years or even longer to recover (Corns 1988). Soil will not maintain gas exchange with the atmosphere when the volume of air-filled pores in the soil is reduced to 10% or less of the total soil volume; at this point, plant growth can be adversely affected (Xu et al. 1992). For this reason, moderately well drained and imperfectly drained soils, such as those in Alberta, are particularly susceptible to compaction because the normal air content of many of these soils is only slightly above 10% (Greenway and Startsev 2000). On these sites, reduced soil air space due to compaction can decrease the production of aspen root suckering and subsequent growth (Greenway 1999). In addition, direct mechanical damage to aspen root systems from equipment traffic can further reduce sucker density and size.

FERIC observed a summer roadside harvesting operation in a hardwood-dominated mixedwood stand in central Alberta. The site and stand conditions, the harvesting system, and productivities and costs for the harvesting phases are described in Kosicki (2002). This report presents soil compaction results associated with in-block felling and skidding equipment.

Site and stand descriptions

The study block was located 60 km north of Athabasca, Alberta, in Alberta-Pacific Forest Industries Inc.'s operating area. The site was considered suitable for summer harvesting with the stipulation that rain and/or evidence of rutting would cause skidding activities to stop immediately (Kosicki 2002). Soil compaction and rutting hazards ranged from medium to high[1] (Beckingham and Archibald 1996). Other site and stand characteristics for the block are summarized in Table 1.

[1] The rating system is based on moisture regime and related soil drainage. High means summer operations would unlikely take place. A medium rating indicates that operations may be possible in dry periods.

Table 1. Site and stand characteristics (modified from Kosicki 2002).

Total area (ha)	200
Ecological area [a]	Boreal Mixedwood (BM)
Natural subregion [a]	Central Mixedwood
Ecosites [a]	Low-bush cranberry Aw, and dogwood Pb-Aw
Stand composition (% by volume)	
Hardwood (trembling aspen and balsam poplar	92
Softwood (white spruce)	8

[a] Beckingham and Archibald 1996.

Harvesting operations

Two Timberjack 618 feller-bunchers, equipped with 0.9-m-wide tracks, worked back and forth parallel to the closest haul road, starting from the back boundary of the cutblock. Two Timberjack 560 grapple skidders, a John Deere 748 G–II, and a 748 E skidder were equipped with 77.5-cm-wide tires. Tire condition varied from new or partially worn with 5.6-cm lug height on three of the skidders, to very worn on one machine. The two skidders with the most-worn tires were equipped with ring chains. Bunches of stems were skidded to roadside using a dispersed skidding pattern. Skidders moved along relatively straight routes to the closest haul road, decking stems in a fairly continuous row along, and on both sides of, the haul road. The stems were processed at roadside and hauled to the mill.

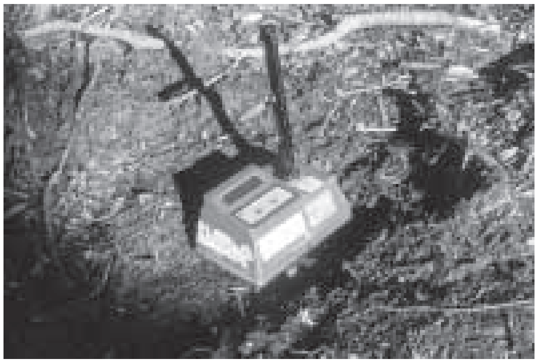

Figure 1. Recording soil bulk density with a single-probe, nuclear, moisture/density gauge.

Study methods

During felling and skidding operations, FERIC located stations throughout the cutblock to monitor equipment traffic according to track or tire imprints. Stations for monitoring skidder traffic were selected where the number of machine passes (loaded and empty) over the same track was known. In contrast to skidder traffic, feller-buncher traffic was dispersed across the block. As a result, each feller-buncher station represented one pass of the machine.

Approximately one month following harvesting, whole-soil bulk density was measured at each station using a single-probe nuclear moisture/density gauge (Figure 1). Bulk density was measured at 10-cm and 20-cm depths at two sample locations at each station, one centered on the disturbed track and the other at an undisturbed location nearby to serve as a control. On the disturbed track, the number of roots >2.5 cm in

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diameter encountered in the organic layer was recorded and classified into three categories (0–1, 2–3 and >3). The thickness of the organic layer was recorded at each undisturbed sample location.

Soil bulk density was also sampled at 30 roadside stations, with each station consisting of three sample locations. The first location was on the truck wheel path and represented the road; the second was at 10 m at a right angle to the road centerline and represented skidder traffic at the log deck; and the third was at 35 m at a right angle to the road centerline and represented the area adjacent to the log deck. No undisturbed controls were available at these locations.

For the skidder stations, the soil bulk density data were analyzed using analysis of variance (ANOVA) and covariance to determine if a relationship existed between change in bulk density and number of passes.

Results and discussion

Table 2 summarizes the average whole-soil bulk densities, in Mg/m^3, recorded for the feller-buncher, skidder, and roadside stations. In total, 121 stations, representing between one and 44 skidder passes, were sampled across the block. Sample size was small for higher traffic levels; therefore these samples were grouped into 5–10, 11–20, and >20 passes.

The skidding pattern in this harvesting system was dispersed, however traffic was often funneled into corridors so that skidders could avoid large stumps, single trees, clumps of trees, and understory patches (Figure 2). For long skidding distances, machine operators had a tendency to use the same trail repeatedly once an initial path had been established. Naturally occurring or undisturbed soil bulk densities ranged from 1.16 to 1.26 Mg/m^3 at the 10-cm depth, and from 1.30 to 1.36 Mg/m^3 at the 20-cm depth. These values are similar to the undisturbed bulk densities recorded on silty loam soils in a study of the effects

Figure 2. Skidder by passing a clump of residual trees.

of skidder traffic on soil properties in west central Alberta (McNabb et al. 2001).

A single pass of the feller-buncher did not increase average soil compaction at either the 10-cm or 20-cm depth.

For skidder traffic, the average soil bulk density was higher on the track compared to the undisturbed locations, with the increase being greater at the 10-cm than the 20-cm depth. However, an analysis of variance using a completely randomized block design, found no clear trend between change in bulk density and numbers of passes. Therefore an analysis of covariance was applied to determine if the covariates of the initial undisturbed bulk density, or of root density, paired with each increase in numbers of passes, influenced variability. Again, no significant increase in soil bulk density with increased number of passes was found, even when skidder traffic exceeded ten passes (Table 2).

Felling and skidding occurred during an extended period of below-normal rainfall. While soil moisture was not measured at that time, samples of soil excavated within 30 cm of the surface were dry to the touch and crumbled without forming a cast when squeezed.

Medium-textured and fine-textured soils that have a low moisture content tend to have high soil strength and be resistant to compaction, in part due to increased contact between soil particles (McNabb et al. 2001). McNabb and Boersma (1996) state that the compressibility of forest soils decreases substantially if the soil water content is drier than field capacity. In a study of the effects

Table 2. Change in average soil bulk density at 10-cm and 20-cm depths

Equipment/traffic	Samples (no.)	Bulk density @ 10 cm Track (Mg/m³)	Bulk density @ 10 cm Undisturbed (Mg/m³)	Bulk density @ 10 cm Change (%)	Bulk density @ 20 cm Track (Mg/m³)	Bulk density @ 20 cm Undisturbed (Mg/m³)	Bulk density @ 20 cm Change (%)
Feller-buncher							
1 pass	26	1.23	1.23	0	1.33	1.36	-2
Skidder							
1 pass	14	1.23	1.16	6	1.32	1.31	1
2 passes	37	1.22	1.17	4	1.33	1.32	1
3 passes	10	1.31	1.22	7	1.43	1.35	6
4 passes	8	1.24	1.16	7	1.37	1.30	5
5–10 passes	25	1.26	1.17	8	1.36	1.31	4
11–20 passes	21	1.31	1.24	6	1.40	1.36	3
>20 passes	6	1.36	1.26	8	1.42	1.36	4
Decking area	30	1.29	1.20 [a]	8	1.38	1.33 [a]	4
Deck	30	1.28	1.20 [a]	7	1.39	1.33 [a]	5
Road	30	1.66	1.20 [a]	38	1.65	1.33 [a]	24

[a] Mean bulk density from all undisturbed locations combined.

of skidding on forest soil infiltration in west central Alberta, Startsev and McNabb (2000) reported that skidding with 0.8 to 1.1-m-wide tires on soils dryer than field capacity did not cause an increase in soil bulk density, and had minimal negative effects on pore space and infiltration of surface water. From the same study, McNabb et al. (2001) concluded that soil wetness at the time of skidding, and the level of traffic, dominate the compaction process in medium-textured and fine-textured boreal forest soils. Such relationships are supported by the results of this study; had soil moisture been higher during this study, higher levels of soil compaction would be expected on these soils. McNabb et al. (2001) found significant increases in soil bulk density on wet soils after three skidder cycles (i.e., three passes loaded and three passes empty).

The increases in bulk density encountered at the 10 and 20-cm depths were variable and not proportional to the number of skidder passes (see the skidder track bulk density values in Table 2). This lack of a clear trend of increasing soil bulk density with higher numbers of passes, can be explained in part by the considerable variation in naturally-occurring soil bulk density in the undisturbed soil. Additionally, once large pore space has collapsed, contact between soil particles increases so the soil tends to become stronger and resist further compaction from subsequent passes.

An increase in soil bulk density was also evident at the roadside locations. The increases in bulk density at the log deck and adjacent to the deck were similar to the increases recorded in the block for three or more passes of the skidder (Table 2). Soil bulk densities were predictably highest on the wheel path of the road, increasing by 38 and 24% above block averages for undisturbed locations at 10 and 20-cm depths, respectively.

The depth of the organic layer at undisturbed locations varied from 4 to 15 cm, while the average depth, when grouped by number of machine passes, varied from 8 to 10 cm. Few ruts were evident anywhere on the study block, and the organic layer on skidder tracks remained largely intact even after high numbers of passes (Figure 3). The high bearing capacity of the soil, resulting from dry operating conditions, helped minimize rutting and displacement of the organic layer due to tire slip. Greenway (1999) states that soils with high strength will resist deformation and act to buffer the roots from direct injury from equipment. Tree roots in the organic layer can also increase the strength of this layer and therefore its ability to resist displacement from tire slippage and rutting. However, injury to shallow aspen roots may occur as the number of passes increases. On skidder tracks with high numbers of passes (>20), a degree of tilling of the organic layer and of the upper few centimetres of mineral soil was evident due to the scuffing action of the skidded aspen tops (Figure 4).

Observations of the skidder revealed numerous instances where the load size was large enough to lift, or nearly lift, the front wheels of the skidder clear of the ground. The resulting load imbalance increases pressure on the soil as the combined weight of the skidder and load was concentrated on the rear axle only. Decreasing the load size would distribute a greater proportion of the load to the front axle.

A full skidder load most often consisted of one bunch of stems that had been accumulated by the feller-buncher. For 36% of the skidder cycles monitored, however, a full load consisted of two or three smaller bunches grappled during the skid to roadside (Kosicki 2002). Building the payload in this way increased the amount of maneuvering required and therefore the cycle time, reducing skidder productivity. If the feller-buncher could optimize bunch size such that the skidder could achieve a full but not excessive payload, then this would serve to minimize skidder cycle time and reduce the area of ground incurring skidder traffic.

Figure 3. One year after skidding, minimal disturbance of organic layer on a skidder track subjected to 15 passes.

Figure 4. One year after skidding, tilled organic layer on a skidder track subjected to 44 passes.

Conclusions and implementation

Felling and skidding were conducted in summer during a prolonged dry period in central Alberta. Under these conditions, soil strength was high, a factor that likely contributed to the relatively low increases in soil bulk density associated with forest-harvesting machine traffic. FERIC observed no statistically significant trend of increases in bulk density correlating with increasing numbers of skidder passes.

While the risk of soil compaction was low, direct injury to shallow aspen roots from increasing numbers of passes, and the resulting negative effects on aspen regeneration, may be of some concern. Injury could be reduced by avoiding overloading of skidders and high numbers of passes. Results from other studies indicate that these medium-textured soils would have considerably lower strength when wet and would be prone to significant compaction after as few as three machine passes.

Felling and skidding during a rainless period—i.e., when soil is dry and soil strength is high—is one of the best strategies for minimizing damage to soils with a medium or high rating for compaction and rutting hazards. Other strategies include:

- Minimize the period between felling and skidding. Because trees transpire soil water, soil moisture is likely to be lower immediately after harvesting than after some time has passed. A short interval between felling and skidding also reduces the likelihood that rain will increase the moisture content of the soil.
- Reduce ground pressure by using wider tires or tracks on machines.
- Limit load size on skidders to keep the weight distributed between the front and rear axles.
- If soils become wet, postpone equipment operation until soils are sufficiently dry or are frozen.
- Optimize bunch size during felling. The skidder will then transport a full load and be most productive. Extra traffic to maneuvre and grapple several small bunches will be avoided.

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