Disturbance of Soil by Skidding Operation and Its Impact on Residual Vegetation

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Abstract

Mechanized harvesting systems provide higher quality and more consistent end products than conventional logging methods; however, they may result in a considerable amount of soil disturbance. Besides, impact of mechanized logging on physical properties of forest soil leads to damages on residual vegetation. In order to maintain the advantages of mechanized operations while overcoming the problems associated with soil disturbance, mechanized logging systems should be efficiently designed considering the importance of the physical properties of the soil for residual vegetation. Optimal soil density and soil porosity must be ensured during the operation. In this study, the effects of rubber-tired skidder on soil and their biological consequences on residual vegetation are investigated. The results indicated that defining the skidding operation in terms of physical properties of soil in the logging site and potential soil disturbance during the operation may provide environmentally friendly operations and reduce the impact on residual vegetation.

Key Words: *Skidding operation, soil disturbance, logging impact on residuals*

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Introduction

There is an increasing interest in mechanized ground-based harvesting systems in North America since labor productivity using conventional methods decreases as tree size decreases (Bettinger et al., 1993). Ground-based systems generally provide a safer work environment, higher quality end products, and greater labor productivity (Kellog and Bettinger, 1994). In these systems, transporting logs from the stump to a landing are usually done either by skidding or forwarding, or a combination of the two. The skidding operations are usually done with skidders and crawler tractors that transport logs by dragging them with a grapple or chokers (Figure 1). Rubber-tired skidders are lighter and less expensive than crawler tractors with similar horse-power. They have twice as much speed as tracked vehicles. Besides, skidders operate on slopes up to 45 % (Bromley, 1968).

Mechanized ground-based harvesting systems consisting of heavy-duty machines with large-size rubber-tires may cause serious impact on physical properties of forest soil which then leads to damages on residual vegetation (Erdas, 1993). Crawlers have a larger ground contact area, which leads lighter ground pressure, nearly the same as the pressure of a man's foot, and provides better traction in mud and on slippery soils (Simmons, 1979). Therefore, skidding operations should be efficiently designed to minimize the cost and to reduce the impact of the physical properties of the soil for residual vegetation. Performing ground-based operations over a slash layer can also reduce the impact (Wronski and Humpherys, 1994). In this study, the effects of rubber-tired skidder on soil and their biological consequences on residual vegetation will be investigated. The results from a previously conducted study will be also presented (Erdas, 1993).

The performance of a rubber-tired skidder is highly dependent on its drawbar horsepower, weight, and traction obtainable under the ground conditions during operation. Skid distance is generally the most important variable since it affects cycle time more than any other variables. If the skid distance increases, travel time will increase as well. In some cases where skid trail is quite straight, the longer the distance, the faster the travel speed without load.

Figure1— An example of a rubber-tired grapple skidder.

In the case where ground slope on the skid trail is steep, vehicle travels in a lower speed, which means that cycle time will be longer. Greater load weight also reduces the travel speed slightly. The load size variables such as weight, number of bunches grappled, or number of trees hooked are also important in skidding. As number of bunches grappled per turn increases, the time spent on grappling increases, which will increase the cycle time.

Methods

Interaction between soil and rubber tires

The wheel load of a skidder is transmitted to the soil surface through ground contact area of a rubber tire. The ground contact area can be computed as follows (Becker, 1960):

$$A = L \times 98.07 / IP \qquad (1)$$

where

A = ground contact area (cm^2)

L = load (kg)

IP = inflation pressure (kPa)

When soil strength is high, the ground contact area increases as deformation of a rubber tire increases under wheel load (Abeels, 1983). If soil strength is low, rubber tire modifies the form of soil and generates wheel sinkage (rut depth). To predict the performance of a vehicle in relation to the various soil strengths, following equation has been suggested (Knight et al. 1962 and Turnage et al. 1972):

$$Z / d = 0\ 4.61 \times n^{0.5}(CI / NGP)^{-2.6} \tag{2}$$

where

Z = rut depth (mm)

n = number of passes of a single loaded wheel

CI = cone index of the soil, representing soil strength (kPa)

NGP = nominal ground pressure (kPa) of the tire

d = tire diameter (mm)

According to Wronski and Humpherys (1994), using a slash layer over skidding trails can increase the soil strength which leads to reduction in the rut depth (Figure 2). In this study, reduced nominal ground pressure of the tire (NGP') due to slash layer is computed using slash adjustment factor (F_S):

$$NGP' = F_S \times NGP \tag{3}$$

where Fs is estimated based on slash density, S_D (m^3/ha):

$$F_S = 1 / (0.0033 \times S_D + 0.93) \tag{4}$$

$$S_D = (p \times T \times L)/w \tag{5}$$

where

p = slash as percent of extracted timber

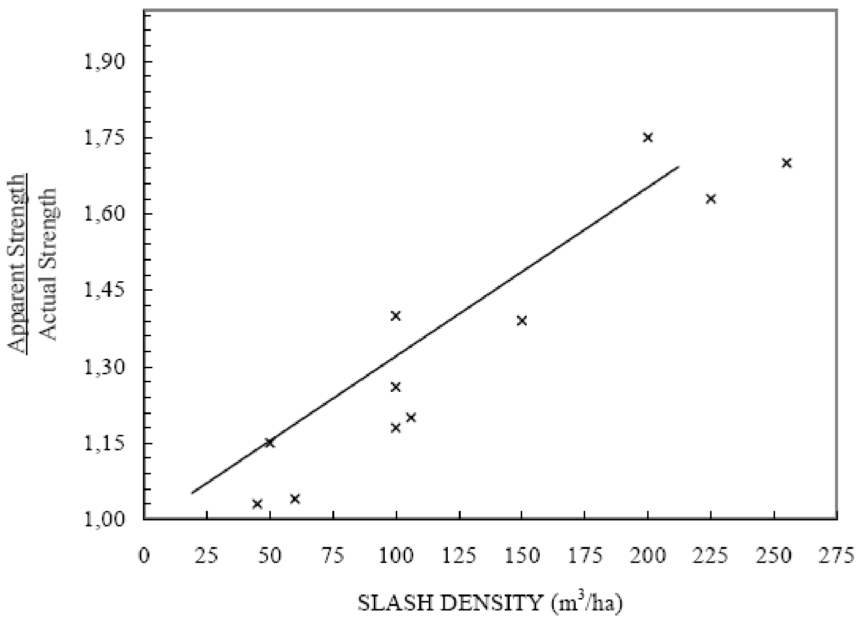

Figure 2— The apparent increase in soil strength with increasing slash density on the trail (Wronski et al. 1990).

T = timber extracted from the unit area (m^3/ha)

S = forwarder trail spacing (m)

W = width of the forwarder trail (m)

Sample Application

The sample application is from a previously conducted study (Erdas, 1993) where the effects of various types of rubber-tired skidder on soil are investigated. Table 1 indicates the specifications of the skidders used in this study. The mechanic properties of the soil in the research area are illustrated in Table 2.

Table 1— The specifications of the skidders.

Specification	Skidder I	Skidder II	Skidder III	Skidder IV	Skidder V
Engine Hp	80	75	65	65	60
Ground clearance (m)	0.47	0.47	0.50	0.50	0.43
Tire size	16.9-30	18.4-26	7.5-16 16.9-30	7.5-16 16.9-30	12.4-24
Tire inflation pressure	1.0	1.2	1.0-1.2	1.0-1.2	0.8-1.0
Total weight (kg)	6100	6000	3500	3500	2800
Load distribution Front Axel Rear Axel	 % 65 % 35	 % 65 % 35	 % 65 % 35	 % 65 % 35	 % 65 % 35
Load capacity (m^3)	4.0	4.0	2.0	2.0	2.0

Table 2— Soil properties in the research area.

Soil Types	Water content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Liquid Index
Wet clay	30.9	45.5	19.0	26.5	0.45
	247	40.6	18.3	22.3	0.29
	28.8	36.9	19.8	17.1	0.53
Sandy silt	39.6	-	-	-	-
	40.0	-	-	-	-
Wet clay-silt	28.7	24.9	19.1	5.8	1.65

In each trip, the skidders are loaded with full capacity. The rut depths are measured to investigate the correlation between soil deformation and the number of trips. Deformed soil samples are collected after the trips to indicate changes on the mechanical properties of the soil.

Results and Discussion

The results indicated that the number of trip increases as the amount of timber production increases which leads to various sizes of rut depths formations. The factors that produce various rut depths include type of the tires, structure of the tires, weight load on axels, soil capacity, number of trips, and terrain topography (Sitkei and Sohne, 1969). Figure 3 indicates the relationship between rut depths and the number of trips for sandy silt soils (Erdas, 1993). The relationship between rut depths and the number of trips are also investigated with respect to various tire inflation pressures (0.8, 1.0, and 1.2) and results are indicated in Figure 4 (Erdas, 1993).

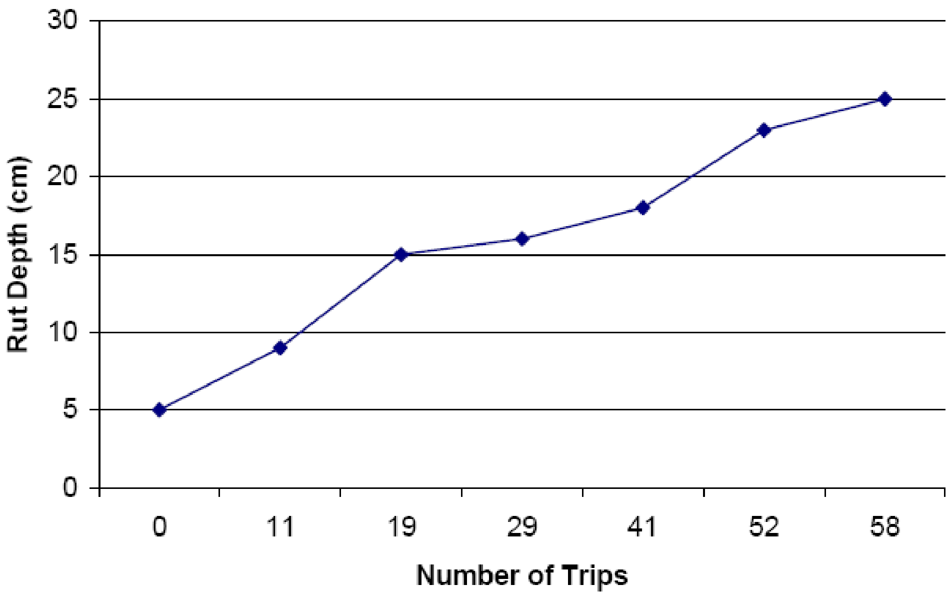

Figure 3— Rut depths produced after number of trips along the skid trail.

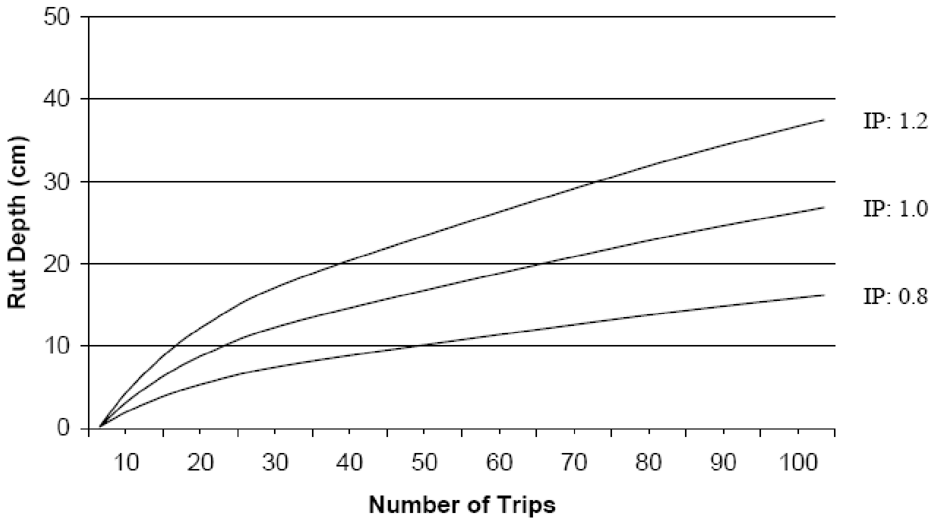

Figure 4— Rut depths produced after number of trips with respect to inflation pressures (IP).

Soil compaction generated by the skidders, especially on soils with very low water saturation levels, reduces large-size pore in soils, decreases the soil density, prevents water transmission, disorders the soil ventilation, obstacles root development, produces erosion, reduces biological activities, and decreases growth rate (Loffler, 1985). In order to determine the changes on mechanical properties of the soil due to skidding operations, various soil samples are collected following specified number of trips and the relationship between water content, dry soil density, and water saturation are investigated with respect to the number of trips.

The results indicated that dry soil density and water saturation increases as the number of trips increase. The optimal compaction occurs when water content is also optimal. However, compaction increases as the number of trip increase till the point of optimal compaction. If the water content is greater than the optimal level, soil compaction does not increase as the number of trip increase. The results also indicated that the lower the initial water saturation level of the soil, the higher the compaction rate and with respect to the number of trips.

If the water saturation level of the soil is optimal, skidding operations does not produce any soil compaction, therefore, roots are restricted by a mechanical resistance in the soil. However, deep rut depth formations can damage the roots or break them into pieces. This may result in reduction in volume and growth rate (Bredberg and Wasterlund, 1983).

If the water saturation level is very low, soil compaction occurs after number of trips which then leads to reduction soil porosity. In general, for optimal living conditions of the plants, soil porosity should be 47%, 45%, and 40% in clay, silt, and sand, respectfully (Hildebrand, 1983). The minimum acceptable porosity level to allow normal root development in sand and clay and silt are 40% and 37-38%, respectfully (Erdas, 1993).

On the other hand, minimum dry soil density levels should be 1.55 ton/$m^3$and 1.65 ton/m^3 for clay and sand, respectfully (Hildebrand, 1983). The previous studies indicated that increasing soil density from 0.3 ton/m^3 to 1.5 ton/m^3 decreases the amount of root by 35% (Erdas, 1993). In order to analyze the effect of skidding operations, soil samples are collected from fine and rough soil classes to determine dry soil density and porosity. The results indicated that the porosity in fine soils is in the biological tolerance level (40%), while it is higher than the tolerance level. The dry soil density is found to be normal in both soil classes. In a previous study conducted in Canada (Raghavan, 1977) indicated that dry soil density increased from 1.25 ton/m^3 to 1.7 ton/m^3 after the number of trips on silt.

Conclusions

To ensure environmentally sound operations and reduce the damages on residual vegetation, the skidding operations should be well defined in terms of physical properties of soil in the logging site and potential soil disturbance during the operation. First of all, low tire inflation pressure and wide ground contact area should be retained during the skidding operation. In the logging areas with low soil strength, the skidders should not be operated with full load capacity. During the skidding operations, rut depth should be kept smaller by maintaining high soil strength and tire inflation pressure and less number of trips. Acceptable limits for soil porosity and dry soil density levels should not be exceeded on fine soils during the operation to protect root system and to ensure normal growth rate.

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