IJNES International Journal of Natural and Engineering Sciences 3 (1): 79-82, 2009
ISSN: 1307-1149, www.nobel.gen.tr

Investigation of Forest Soil Disturbance Caused by Rubber-tired Skidder Traffic

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Received: August 15, 2008
Accepted: October 17, 2008

Abstract

Soil compaction and rutting from ground skidding is a common consequence of soil disturbance on skid trails. In this research the superficial transformation and degree of soil compaction caused by rubber-tired skidders Taf E655 was investigated in Patom district, hyrcanan forests, IR-Iran. To measuring superficial transformation of soil, skid trail cross profiles were taken in every 10 meter and changes were recorded after skidder passes. Rut depths were measured with the leveling instruments and ruler. The field method and sand bottle cylinder were used to estimation of soil bulk density. Results showed that the rut depth developed with increasing of skidder traffic. Also, at the center of skid trail (140-260cm) little change of depth with traffic was observed. While at the edge of the skid trails the rut was deeper than the center. Skidder traffic significantly increased the soil bulk density. The maximum increase in soil bulk density was occurred in 18th pass (1.62 gr cm^{-3}). Beyond 18th pass, there was no significant increase in bulk density. The forest soil compaction and rutting problems can be reduced by restricting the amount of ground area covered by skid trails, using of tire pressure-control systems and choice of best machine with respect to environmental impact and productivity.

Keywords: Soil rutting, Soil compaction, Skid trail, Skidder Taf E655, Hyrcanian forests.

INTRODUCTION

Forest soil is the foundation of skid trail, though different types of soils exhibit a range of performance characteristics as a skid trail foundation material. Some soils have strength under wheel loads and drain well, while others provide little strength and do not drain [12]. The skidder's travel on skid trail causes damage to forest soil. The soil bearing strength is a mechanical feature which represents the capacity of the soil to resist external forces and it is determined by settling of soil under external load [16].

Soil disturbance can be defined as an alteration in the properties of a soil. Examples of detrimental soil disturbance include compaction and rutting on skid trail. Soil compaction is the reduction in unit volume caused by bringing soil particles closer together [14]. The response of trees to compaction, whether established trees retained in a partial harvesting system, or subsequent regeneration, is difficult to predict because of the interactions between soil strength, soil aeration, water availability, and nutrient supply [5]. Residual trees may show short-term decreases in growth due to root or other damage. Growth after compaction of soil also varies with tree species [13].

Rutting occurs when soil strength is not sufficient to support the applied load from vehicle traffic. Rutting affects aesthetics, biology, hydrology, site productivity and vehicle safety [19]. Where canalized flow to an open water body occurs, rutting can result in contributing sediment into an open water body [3]. While not always a water quality issue, excessive rutting is certainly a sign that ongoing forest operations need to be modified to prevent further damage to soil and forest resources [2].

In general, increasing levels of skidder traffic led to increasing depth of rutting. Rutting depths tended to be deeper for moist than for dry soil conditions, the effect often becoming more noticeable with increasing traffic. For both dry and moist soil conditions increasing levels of skidder traffic led to increasing amounts of exposed mineral soil [15].

Ground based systems cause greater soil disturbance, including detrimental disturbance, than cable systems. Sites ground skidded during the 1970s, in the southern interior of British Columbia, were estimated to have up to 32% of the area in skid trails. In this region of British Columbia, the main difference in area of total soil disturbance between cable and ground based systems (22–30% versus 40–45%) is the presence of the skid trail network for the latter system [10].

The extent and degree of soil compaction and rutting is dependent on several factors including soil texture, soil moisture content at the time of trafficking, soil organic matter, slash and twigs content, soil structure, parent materials and pore size distribution, vehicle mass, machine size, machine type, number of skidding cycles and duration of loading, grade of skid trail, direction of skidding and extraction pattern, stand structure, density, species composition and life traits, harvesting system training, experience and expertise of equipment operators [4, 9 and 11].

The degree and depth of soil compaction are closely related to the number of skidder's passes [8]. Most researches show that soil compaction is the highest during the first several passes, after which soil density acquires a certain value, which increase slowly in terms of quantity and depth with the following passes [17 and 18]. Soil compaction has been found to reduce infiltration, saturated hydraulic conductivity, pore-size distribution and volume, N mineralization, and microbial number, biomass, and activity. Each of these effects can potentially reduce tree growth [1].

The objectives of the present study were (i) to evaluate the superficial transformation of soil in skid trails caused by rubber-tired skidders Taf E655 traffic and (ii) to determine the relationship between skidder traffic and degree of soil compaction.

MATERIALS AND METHODS

Site descriptions

The study was carried out in Patom District. The compartment 116 with an area of 42 hectare was selected for this research (Figure 1). The chosen site is located on a south-facing slope, 750 meter above sea level and is dominated by *Fagus orientalis* Lipsky (Beech). The results of conducted inventory in this forest showed that the trees density and stock growth were 371 tree/ha and 349 Silve/ha respectively. The litter cover depth was 1 cm. Soil type was forest brown and its texture was loam clay in surface and clay in depth. The mean liquid limit, plastic limit and moisture content were 51%, 21% and 23% respectively. Compartment 116 has a skid trail with the length of 366 meter which its maximum and minimum longitudinal gradient is +14% and -18% respectively. The average of skid trail width was 4 meter.

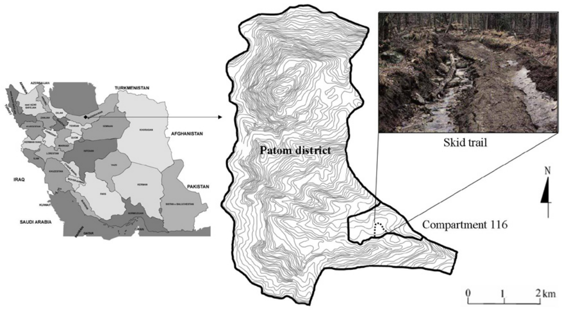

Figure 1. Geographical position of the study area

Timber harvesting

The rubber-tired Taf E655 is an articulated skidder which has designed for timber skidding operations. Articulated skidders have a better maneuvering efficiency and can operate on steeper slopes [20]. The pulling force on slopes 20% is 3200-4100 kgf. The other main technical characteristics of the Taf E655 are shown in Table 1.

Table 1. Technical characteristics of the skidder Taf E655.

Machine	Weight (Kg)	length (m)	Width (m)
Taf E_{655}	6345-6800	5.75	2.40

Data collection

The total length of skid trail (366 m) was divided into three sections. Once the test sections were built, a trafficking test was conducted in which the skid trail was traveled by a loaded four-axle skidder Taf E655 equipped with a winch. Taf E655 was loaded at 4000 kg (Beech timbers with dimensions of 9.8 m in length and 70 cm in diameter). Tire inflation was 26 Atmospheres. The touch area of skidder tires to ground in loaded and unloaded conditions were 2339 cm^2 and 2191 cm^2 respectively. The study was limited to 21 passes of skidder due to time and budget constraints. Then to measuring superficial transformation of soil in each section, 12 cross profiles were taken in every 10 meter and changes were recorded after skidder pass. Rut depths were measured with the leveling instruments and ruler. The schematic of this method is shown in Figure 2.

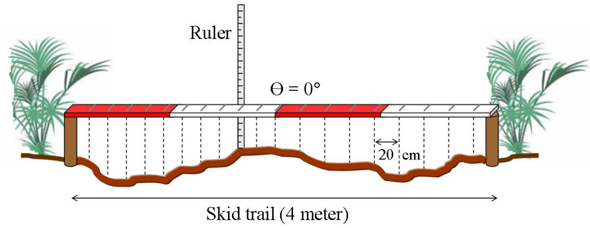

Figure 2. The measurement method of rut depths and cross profiles

Soil bulk density was systematically measured within units on skid trail after skidder passes. The field method and following equation were used to estimate soil bulk density. Sampler removed a hole with dimensions of 12 cm in depth and 10 cm in width. Then the sand bottle cylinder was put on the hole. This hole was filled by the standard sand (0.25-0.52 mm) with the weight of 3 kg.

$$BD_{moist} = \frac{W_{soil} \times B_{sand}}{W_{sand}} \quad [1]$$

Where BD_{moist} is the moist bulk density, W_{soil} is the soil weight which was in the hole, W_{sand} is the sand weight which filled the hole and B_{sand} is the sand bulk density.

Statistical analysis

Data were analyzed using the ANOVA procedure provided by the SAS software. When the analysis was statistically significant, the LSD test for separation of means was performed. Statistical significance was judged at P<0.05.

RESULTS AND DISSCUTION

The results of analysis of variance revealed high significant differences between the amount of soil disturbance at the center and edge of the skid trails (P<0.0001). Also the skidder traffic and interplay of passes and position were significant on the amount of soil disturbance at probability level of 5% (Table 2).

Table 2. Summary of the effects of different treatments on soil disturbance

Treatment	DF	SS	MS	F
Number of Passes	20	15.86	5.28	3·46*
Position on the skid trail	1	87.75	87.75	57.44***
Passes and position	20	13.80	4.60	3.01*

The center of the skid trail cross profiles (140-260 cm) showed little change of depth with traffic, i.e. the ruts did not deepen. While at the edge of the skid trails the rut was deeper than the center (Figure 3, 4 and 5).

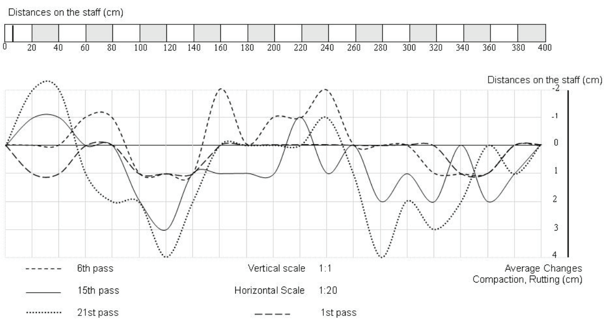

Figure 3. Cross profile of the skid trail after skidder Taf E655

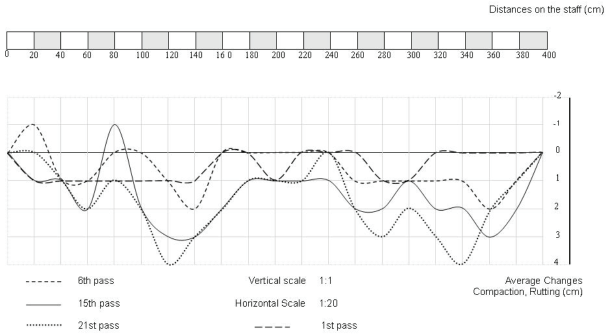

Figure 4. Cross profile of the skid trail after skidder Taf E655 passes on section II

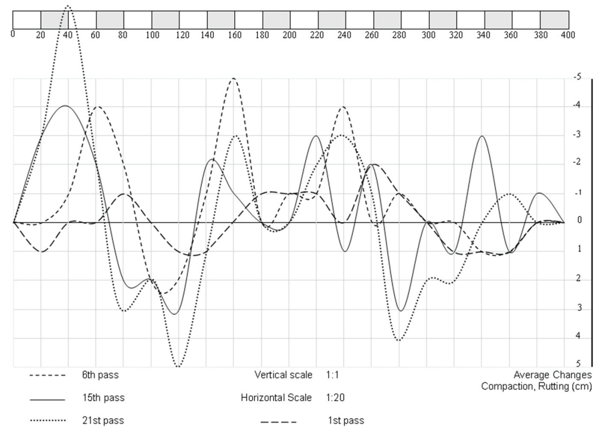

Figure 5. Cross profile of the skid trail after skidder Taf E655 passes on section III

As shown by Figure 6, rut depth became significant after 1st, 6th, 15th and 21st passes, reaching an average of 1.07, 1.47, 2.46 and 3.29 cm respectively. Therefore rut depth developed with increasing of skidder traffic.

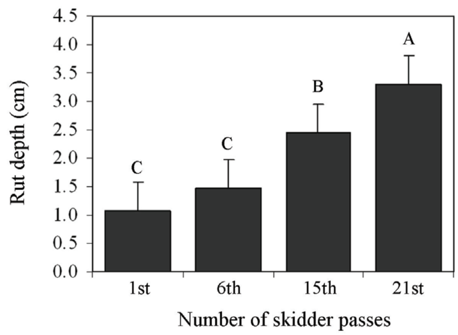

Figure 6. Rut depth development with skidder Taf E655 traffic

In this study, skidder Taf E655 traffic significantly increased the soil bulk density. The maximum increase in soil bulk density was occurred in 18th pass (1.62 gr cm-3). Beyond 18th pass, there was no significant increase in bulk density (Figure 7). The reason for this was probably an increase in the soil's bearing capacity inside the tracks through higher shear strength after compaction by the first 18 skidder passes. This result is consistent with Jamshidi et al. [9] findings.

A unique aspect of forest soils is their low bulk density, high macro porosity, and high rate of infiltration [7]. Soil compaction from ground skidding is a common consequence of soil disturbance. Forest soils easily compact from the use of logging machinery, such as skidding machines, which carry heavy loads in off-road conditions. The unprotected forest soil acts as a weak receptor against static and dynamic forces created by skidding and forwarding machines especially on skid trails and landings where high frequencies of machine movement exists [6].

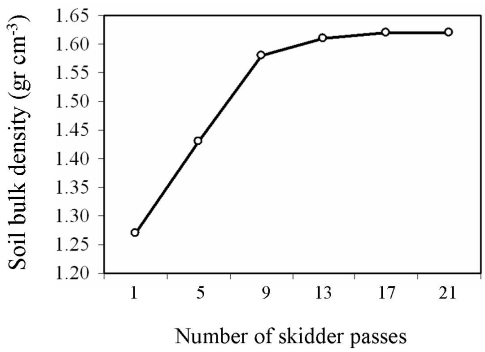

Figure 7. The relationship between soil bulk density and skidder Taf E655 traffic

CONCLUSSION

The wheel rutting could cause serious erosion during a rainstorm, damaging both the skid trail and the environment as surface runoff is channeled down the wheel ruts, which increases the erosive power of the water and can channel sediment into nearby streams.

Tire pressure-control systems (TPCS) that optimize tire pressures to match the tire's working conditions are used extensively by many forestry companies in Canada. Forestry companies are implementing TPCS technology in their operations to help improve traction and mobility and to extend the haul season during the spring thaw and the fall rainy season. This system can be used in skidding operations to avoiding of forest soil rutting and compaction. Reducing tire pressures has been found to improve ride, traction, and mobility; delay the development of deep ruts; reduce aggregate losses and sediment production.

Also, the forest soil compaction and rutting problems can be reduced by restricting the amount of ground area covered by skid trails during harvesting operations. Restricting the area in skid trails requires advance planning and clearly flagging trail before logging. The incorrect choice of machine or perseverance with unsuitable existing machines may lead to severe ground damage. Harvesting and extraction machines should also be compatible with respect to environmental impact and productivity.

ACKNOWLEDJMENTS

The author would like to thank the administration of forestry in Nowshahr city and educational & research forest of faculty of natural resources of Tehran University especially to Dr. Houshang Sobhani.

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