

Rutting and soil displacement caused by 450C Timber Jack wheeled skidder (Asalem forest northern Iran)

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ABSTRACT: The use of skidding machinery in logging operations causes destructive effects especially on soil but has many advantages such as extracting long and heavy logs, optimum use of useful logging time and absence of defect in wood production quality and thus an increase in the added value of wood. In this research compartment 40 of the second district of Nav-Asalem in northern Iran at an altitude of 1,050–1,450 m above sea level was chosen in order to assess the amount of displaced soil volume and depth of ruts due to the traffic of Timber Jack 450C rubber wheeled skidder along the skid trail. Therefore, the correlations between two independent variables, longitudinal slope and soil texture, with two dependent variables, displaced soil volume and average depth of rut, along the skid trail were examined after 20 passes of skidder machinery. The results of this research showed a significant difference between the longitudinal slope increase of skid trail and the amount of soil volume displaced ($P < 0.001$). However, there was no significant correlation between the mean rut depth and different classification of longitudinal slope along the skid trail. The highest measured rut depth was 22 cm and occurred in the slope class of more than 25%. There was no significant correlation between the amount of displaced soil volume and rut depth with changes in soil texture along the skid trail.

Keywords: soil displacement; rutting; skid trail; Timber Jack 450C wheeled skidder; Iran

Logging always leads to a wide range of disturbing effects on the forest ecosystem. Soil surface disturbance, changes in chemical and physical properties of soil and damage to natural regeneration and tree stand are the main effects of logging operations and wood extraction on soil and forest stand. Using skidding machinery in logging operations causes destructive effects on soil.

Soil compaction is the first consequence arising from skidder traffic because due to the weight of the machine with load, engine vibrations and wheel slip the soil in skid trails will be compacted. Therefore water and air infiltration decreases and runoff increases (PINARD et al. 2000; GRIGAL 2000; DEFOSSEZ, RICHARD 2002; BUCKLEY et al. 2003; HAMZA, ANDERSON 2005).

Skidder traffic on the forest soil bed along skid trails leads to rutting and soil displacement because skid trails lack the superstructure (MAC DONALD et al. 2001; TRAUTNER, ARVIDSSON 2003; ELIASSON 2005). Since the soil in skid trails is displaced and disturbed due to traffic, soil erosion along skid trails is noticeably higher than in control areas.

ARVIDSSON et al. (2001) showed that the amount of soil vertical displacement caused by the heavy traffic of machinery in sandy loam and clay soils was between 50 and 70 cm in different soil moisture content conditions.

Effective indices in designing skid trails such as longitudinal slope, soil moisture content, depth and texture, as well as effective factors of wood extraction such as load volume, weight and shape and number

of skidder passes are the most important effective factors of soil disturbance in skid trails. Soil displacement consists in the physical movement of soil materials resulting from skidder traffic (MOORE, BURCH 1994). In this regard the type of skidding method (in ground skidding system), slope, aspect and soil physical properties are the main factors affecting soil displacement (RAPP et al. 2001; WILLIAMSON, NEILSON 2003). Rutting is defined as a created groove of at least 5 cm depth caused by skidding machinery wheels and logs. In other words the rut is the trace of machinery wheels or logs that usually occurs under high soil moisture content conditions (QUESNAL, CURRAN 2000; MAC DONALD et al. 2001). Rutting is the beginning of soil compaction or in other words it occurs concurrently with compaction, which causes the drainage to fail and after rainfall water flows along the rut, the runoff rate will increase and finally it causes soil erosion. Rutting will also damage the soil structure and the root development of residual trees will be affected (RAPP et al. 2001).

ELIASSON (2005) studied compaction effects on rut depth and dry bulk density of soil and showed that after five passes of a skidder the rut depth had reached 9.2 cm (with tire pressure of 600 kPa). NUGENT et al. (2003) studied soil disturbance due to the traffic of skidding machinery in sensitive forest areas of Ireland. They showed that there was a significant difference between the rut depth and machine traffic rate and that the rut depth ranged between 7.8 and 15.3 cm. The phenomenon of rutting and its expansion rate were more severe mainly in fine grained soils, in a way that by continuous rainfall and increasing machinery traffic the rut depth increased and changed into gully (QUESNAL, CURRAN 2000).

LOTFALIAN (1996) carried out a study of skidding effect by TAF E655 rubber wheeled skidder on two types of soil in Kheiroud Kenar forest of Noshahr, northern Iran. This is one of the few studies that have been conducted to assess damage arising from skidding machinery traffic to the soils of northern forests of Iran. He measured the rate of lateral profile changes during wood extraction along the skid trail and showed that most changes occurred along the curves and steep slopes of skid trail. By measuring the amount of soil compaction in sample locations of skid trails he also showed that maximum soil compaction occurred after 21 passes.

NAGHDI (2004) studied damage caused by tree length and cut to length logging methods to skid trails in Neka forests in Mazandaran. The maximum soil compaction caused by Timber Jack 450C wheeled skidder occurred after 18 to 20 passes.

During research carried out by SOLGI (2007) in the Amreh forest of Mazandaran, soil disturbances in the skid trail caused by HSM 904 skidder were measured. In this research by comparing the mean rut depth of soil in different slopes, it was concluded that the rut depth was significantly higher on a skid trail with the longitudinal slope of more than 20%. By measuring the amount of soil dry bulk density in sample locations of skid trail, it was also concluded that by increasing the traffic of a skidder from 14 to 20 passes, soil bulk density changes were insignificant.

NAGHDI et al. (2007) showed that the soil bulk density increase compared to the control caused by different rates of traffic of Timber Jack 450C skidder along skid trails was between 15.8% and 62.6%. The study that was carried out along the skid trail with clay soil showed that there was no significant difference in the soil bulk density increase between two types of soil (clay soil with high liquid limit and clay soil with low liquid limit). At present the ground skidding system and winched skidding machinery are the only mechanized method of wood extraction equipments in northern forests of Iran. An increase in the efficiency of ground skidding system depends upon the prevention of soil damage and therefore soil erosion will be controlled. The soil is one of the main components of forest ecosystem and without it other sources of forest will be lost in time.

In this research the destructive effect of wheeled skidder in skidding trails on different slope classes and soil textures are studied. With respect to this, the amount of soil displacement and rut depth at sample locations are measured.

MATERIALS AND METHODS

This research was carried out in compartment 40 of the second district of Nav-Asalem forest in northern Iran, at the altitude ranging from 1,050 to 1,450 m a.s.l. and with average annual precipitation of 1,100 mm. The area is located between 48°44'36" and 48°49'58" of longitude, and 37°37'23" and 37°42'31" of latitude.

Asalem forest is one of the best forest stands in northern Iran, which plays an important role in national wood production. At present a ground skidding system is the only mechanized method of harvesting used in these forests. The use of ground skidding system and construction of skid trails for wood extraction have made these regions one of the most vulnerable areas for forest soil damage and erosion.

The forest was uneven-aged and its type was *Fagus-carpinetum* and the area of the compartment

was 41 hectares, the dominant slope of the compartment was 20–60% and the dominant aspect of the compartment was north. The silvicultural method carried out in the study region was a single selection method. The total volume of production was 650 m³ and wood extraction was carried out from stump area to roadside landing by the ground-based skidding system in the shape of tree length and short and long logs. The skidding direction along the skid trail was downward. The parent material is calcareous and the type of soil is leached brown forest soil. The skidder type used in this study was 450C Timber Jack cable skidder, model 6BTA5.9 with 177 hp and 10,257 kg weight.

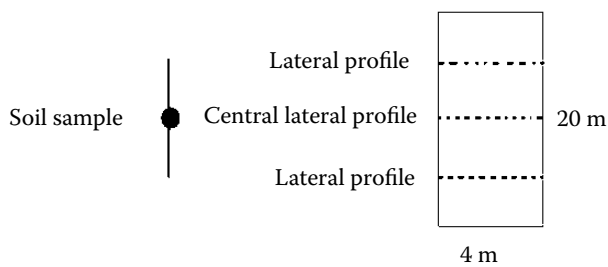


Fig. 1. A sample plot of the study area

Precise field work assessment was carried out in the studied compartment. A skid trail of 750 m length was chosen with downward skidding. An effort was made to choose a skid trail with different range of longitudinal slope classes and without any lateral slope. After the skid trail levelling and drawing the longitudinal profile of the trail and with regard to a maximum slope of 36%, three slope classes were considered (0–15, 15–25 and more than 25%).

In each slope class, 6 repetitions along the skid trail were selected and studied. In order to assess the state of soil damage with regard to sample plot size and width of the skid trail (LAFLEN et al. 1991), sample plots of 4 × 20 m dimensions were considered. Consecutively to determine the volume of the soil disturbed by skidder traffic, in each sample plot

at 3 locations (with 5m interval from each other) and along the perpendicular to the skid trail, sampling was carried out (Fig. 1). Then a nylon string was attached on two sides of the skid trail and vertical height (distance) of the string to the surface of the trail was measured in a 50cm interval along the string (Fig. 2). In this study soil disturbance (rutting and displaced soil volume) measurement was carried out after 20 passes of the skidder in different slope classes along the skid trail. In studies carried out by researchers on soil damage caused by Timber Jack 450C skidder in northern forests of Iran, it was reported that maximum compaction occurred after 20 passes (LOTFALIAN 1996; NAGHDI 2004).

In each predetermined sample plot, the amount of displaced soil and ruts were measured using the lateral profile of the skid trail. With regard to this, ruts of more than 5 cm depth and minimally 2 m length are regarded as soil damage (QUESNAL, CURRAN 2000; NUGENT et al. 2003).

In each rut the depth of the rut was measured at 25 mm intervals and an average figure was obtained (Fig. 2).

In order to determine the soil texture in each sample plot, a soil sample was taken adjacent to the central lateral profile (Fig. 1). First litter was removed from the soil surface and then by digging a pit, approximately 1 kg soil was sampled. After coding, the soil samples were sent to a laboratory and the soil texture was determined by a hydrometric method.

Analysis of variance and Touché test (ZAR 1999) were used to estimate different amounts of displaced soil volume in each slope class. Pearson test was used to investigate the relationship between the longitudinal slopes, volume of displaced soil and mean rut depth. In the above method with the use of SPSS software correlations between the volume of displaced soil and mean rut depth were analyzed in different slope classes. Pearson test was also used to calculate correlations between these two variables (volume of displaced soil and mean rut depth) and soil texture. For this purpose all soil samples were

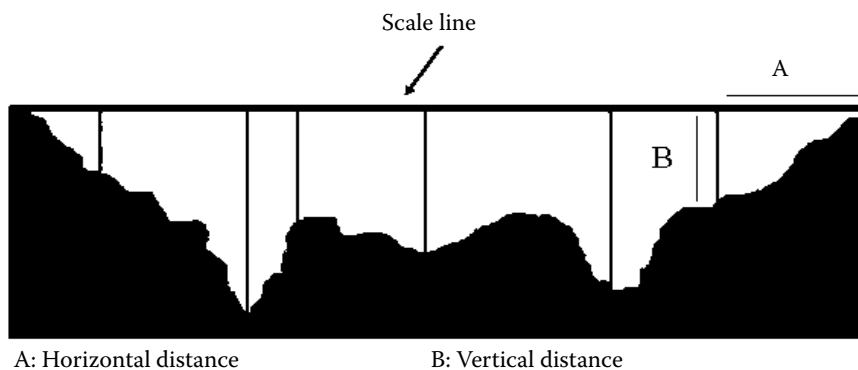


Fig. 2. Lateral profile in each plot

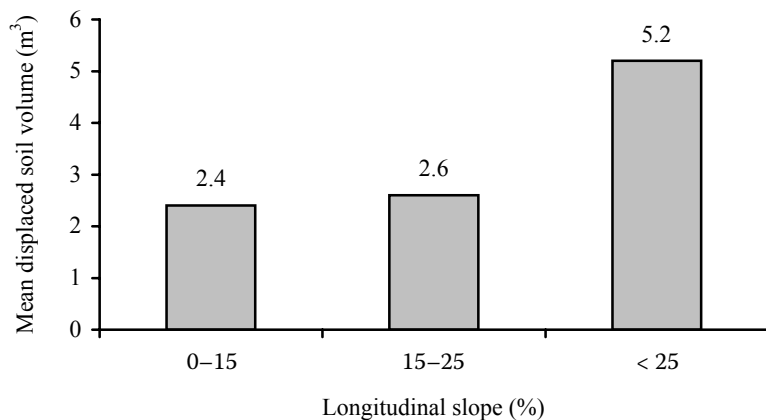


Fig. 3. Mean displaced soil volume in different longitudinal slopes of skid trail

coded with regard to the soil texture, then the volume of displaced soil in each code was tested with each other.

RESULTS AND DISCUSSION

The results of this research showed that by increasing the longitudinal slope of the skid trail, the displaced soil volume increases. The sample plots with more than 25% longitudinal slope and average volume of 5.2 m³ of displaced soil show maximum disturbance (Fig. 3).

The results of ANOVA between three longitudinal slope classes and displaced soil volume showed a significant difference ($F = 66.4$, df_{217} , $P < 0.001$). The correlation between the longitudinal slope with displaced soil volume and rut depth was estimated and the results showed a significant correlation between longitudinal slopes with displaced soil volume ($r = 0.947$, $n = 18$, $P < 0.05$), while there was no correlation between longitudinal slope and rut depth ($r = -0.102$, $n = 18$, $P > 0.05$) (Fig. 4).

Soil texture testing of samples in the laboratory determined four types of soil: loam, clay loam, sandy

loam and sandy clay loam. The soil moisture content was from 18 to 22%. The results of this study showed the maximum volume of displaced soil in slope class 2 (15–25%) in sandy loam soil (Fig. 5). There was no significant correlation between the mean rut depth and soil texture ($r = -0.194$, $n = 18$, $P > 0.05$). No correlation was observed between the volume of displaced soil and the type of soil texture ($r = 0.19$, $n = 18$, $P > 0.05$).

In this study, the relationship between two independent variables, longitudinal slope and soil texture, was investigated on two dependent variables, the volume of displaced soil and mean rut depth, after 20 passes of Timber Jack 450C skidder along the skid trail.

The analysis of variance of the above-mentioned components showed that with an increase in the longitudinal slope of skid trail, the volume of displaced soil will increase, which is consistent with the results from SOLGI's research (2007) on an increase in the amount of soil vertical displacement with an increase in the slope of skid trail. However, LARSON et al. (1983) and ARVIDSSON et al. (2001) analyzed the amount of soil displacement in relation to a change in soil moisture content, soil texture and traffic rate

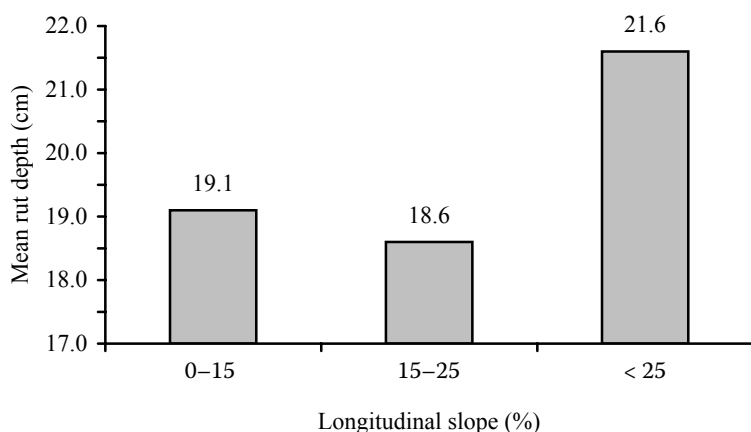


Fig. 4. Mean rut depth in different longitudinal slopes

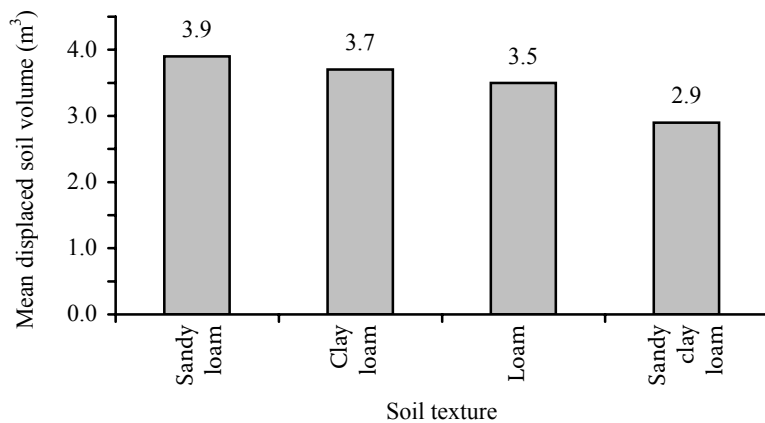


Fig. 5. Mean displaced soil volume concerned with soil texture in longitudinal slope 15–25%

along skid trails, but this present study showed that the longitudinal slope of skid trail can play an important role in the amount of soil displaced.

Based on the results from this research, there was no significant difference between the mean rut depth and different slope classes along the skid trail and the deepest rut depth of 22 cm occurred in slope class 3 (more than 25%) with 21% average soil moisture content. In this regard the maximum measured rut depth was 37 cm during skidding by HSM 904 skidder with the soil moisture content of 40% (SOLGI 2007). In their study McCURDY et al. (2004) concluded that logging caused soil rutting and this was due to the high soil moisture content at the time of logging. SOANE (1990) and RAPER (2005) also concluded that fine grained soils with high moisture content are more susceptible to rutting and soil rutting occurs when the soil is vulnerable to compaction. With regard to this high moisture content the soil strength of fine grained soils decreases and therefore the soil is more vulnerable to compaction.

This research showed that there was no significant difference between the soil texture and volume of displaced soil and rut depth along the skid trail. The results also showed that the volume of displaced soil in sandy loam soil was higher than in loam and clay loam soils, but the difference was not significant. In this regard ARVIDSSON et al. (2001) illustrated in a research that the amount of soil displacement caused by the traffic of skidding machinery in sandy soils was higher than in clay loam soils.

CONCLUSIONS

In the mechanized logging system in northern forests of Iran, logs are extracted by cable wheeled skidders. The different types of used skidders cause damage to forest soil and stand. So it is necessary to use machines that are compatible with conditions of northern forests

of Iran and cause less damage. Results from this study showed that the slope is an effective factor on the amount of soil disturbance along skid trails. The highest soil disturbance and displacement occur in slope class 3 (more than 25%). So precise planning of skid trails before skidding operations is one of the effective solutions in order to decrease damage resulting from skidding machinery operations. In this regard, limiting skid trails to a longitudinal slope of less than 25% and planning skid trails in areas with low slope should be considered. Another way of decreasing damage is that skidding operations be postponed to the time when the soil has a low moisture content.

Appropriate and precise scheduling of skidding operations in order to minimize damage to soil requires the knowledge of soil and terrain conditions and machine characteristics. So it is necessary to know the relationship between forest soils and their susceptibility to damage arising from skidding machinery operations.

Determining and decreasing soil damage is a necessary part of sustainable management strategies. Thus by assessing the skid trail network in forest management plans of northern Iran problems and deficiencies can be removed by providing appropriate solutions to prevent more soil disturbance.

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Vyrytí kolejí a přemístění půdy způsobené lesnickým kolovým traktorem s navijákem Timberjack 450C v lese Asalem v severním Íránu

ABSTRAKT: Použití kolových mechanizačních prostředků k soustředování dříví při těžebních operacích má za následek destruktivní účinky zejména na lesní půdu. Má však také své výhody, jakými jsou vyklizování dlouhých a těžkých klád, optimální využití pracovního času, nepřítomnost vad kvality dřevní produkce a následně zvýšení její přidané hodnoty. V severním Íránu v nadmořské výšce 1 050–1 450 m bylo pro účely výzkumu vybráno oddělení

č. 40 lesa Nav-Asalem, aby se určila velikost objemu přemístěné půdy a hloubka kolejí vyrytých provozem lesnického kolového traktoru (LKT) s navijákem Timberjack 450C po přibližovací lince. Při dvaceti průjezdech LKT byla vyšetřována korelace dvou nezávislých proměnných – podélného sklonu a zrnitosti půdy – se dvěma závislými proměnnými – objemem přemístěné půdy a průměrnou hloubkou vyryté koleje. Výsledky výzkumu ukázaly významnou vazbu mezi zvětšujícím se podélným sklonem přibližovací linky a velikostí objemu přemístěné půdy (hodnota $P < 0,001$). Významná korelace nebyla zjištěna mezi průměrnou hloubkou koleje a různou třídou podélného sklonu přibližovací linky (do 15 %, 15–25 %, nad 25 %). Největší naměřená hloubka koleje činila 22 cm a vyskytla se při podélném sklonu třídy nad 25 %. Žádná významná závislost nebyla zjištěna mezi velikostí objemu přemístěné půdy či hloubkou koleje a měnící se zrnitostí půdy na lince.

Klíčová slova: přemístění půdy; koleje; přibližovací linka; lesnický kolový traktor; Írán

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