International Journal of Biosciences (IJB)
ISSN: 2220-6655 (Print) 2222-5234 (Online)
Vol. 2, No. 11, p. 50-57, 2012
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Assessing soil disturbance from ground based logging operation in the northern forests of Iran

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Received: 11 October 2012
Revised: 26 October 2012
Accepted: 27 October 2012

Key words: soil compaction, rutting, logging, skidding, forest road.

Abstract

In this research the extent and severity of soil disturbance caused by Timber jack 450C wheeled skidder was assessed on a selectively logged parcel in Nav Asalem forest area in the North of Iran. The line intersect method was used to determine the extent of soil disturbance in the logged parcel and severity of soil disturbance were classified by visual assessment of soil disturbance method. The results indicated that 55.6% of surface soils were undisturbed, 16.3% slight disturbed, 14.8% moderate disturbed and 13.3% strongly disturbed by logging operation. About 399 m^2 of surface soils were disturbed by chain saw and skidding operation for each harvested tree. Soil bulk densities in the top 10 cm on slight, moderate and strongly disturbed area on average 7.9, 10.7 and 20.3 percent are higher than densities in undisturbed soils. The soil bulk densities and rut depths on tire tracks were significantly increased with increasing of slope of skid trails, especially on higher than 25% slopes. Pre harvest planning and identifying winching area before logging operation can reduce damages to soil in these forests. In the northern forests of Iran, consistent attention to operation standards is required to minimize the soil disturbance during ground based logging operation.

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Introduction

Soil is a relatively nonrenewable natural resource and soil condition is critical for sustainable management of forests (Miller et al., 2010).Timber harvest activities cause some degree of soil disturbance (Grigal, 2000). Mechanized ground-based logging systems are widely used since they generally provide a safer work environment, higher quality end products, and greater labor productivity (Akay and Sessions, 2001). Soil physical, chemical, and biological properties altered by soil disturbance resulting from timber harvest may have implications for sustained site productivity (Binkley, 1991). In recent decades, concerns were raised about the protection of soils during forest operation. Logging operation can lead to soil disturbance that include compaction, rutting and soil displacement (Arnup, 1999). Soil disturbance from harvesting can also increase erosion potential. Compaction is the most commonly cited form of soil disturbance resulting from harvest activities because of its potential to negatively impact vegetation growth (Parker et al., 2007; Wang et al., 2007). Soil compaction is the increase in soil density that results from the bringing together of soil particles in response to applied external forces. Harvest activities that compact soils limit the effective rooting depth of plants by restricting access to water and nutrients and reducing gaseous exchange (Gomez et al., 2002). Soils recover from compaction at varying rates. Meek et al. (1992) reported a reduction in infiltration rates of 54% when soil was compacted from 1.6 g/cm^3 to 1.8 g/cm^3. Rutting is defined as impressions in the soil caused by heavy equipment (Page-Dumroese et al., 2009). Rutting can have detrimental impacts on site productivity by creating preferential flow patterns for overland water flow, decreasing infiltration and gaseous exchange (Page-Dumroese et al., 2009). The risk of soil rutting increases with increased soil moisture content (Grigal, 2000). Soil displacement is the mechanical movement of soil or forest floor materials by equipment and movement of logs. Soil disturbance influences stand growth and yield by affecting seed germination, seedling survival and establishment and root growth. Laffan et al. (2001) found phosphorous, nitrogen, and soil organic carbon reduced by 30-40% where the soil surface layer had been displaced during harvest operations relative to undisturbed areas in the harvest area. Soil compaction and rutting can increase bulk density, decrease air-filled porosity and decrease hydraulic conductivity. When forest soils are compacted, the environment in which the roots of vegetation exist becomes alerted. Soil compaction can increase surface runoff because of reduced infiltration rate. Seed germination and seedling emergence may be adversely affected by soil compaction (Greacen and Sands, 1980). Soil displacement can exposure of unfavorable sub soils, creating unfavorable conditions for the germination and establishment of desirable species, exposure of mineral soils sensitive to erosion and redistribution of soil materials resulting in loss of nutrients. The extent and degree of soil disturbance associated with skidder extraction are variable and appear to be related to slope (Stuart and Carr, 1991), soil texture (Clayton, 1990; Jusoff, 1991) and soil moisture content at the time of logging (Jusoff, 1991). Mechanized logging, if uncontrolled, can have the high damaging effect on forest structure, composition and regenerating capacity (Sist et al., 1998). The objective of this study was to assess the extent and severity of soil disturbance following ground based logging operation in a selectively logged parcel in the northern forests of Iran.

Material and methods

Study area

The study area (37^o 31' N - 37^o 45' N, 48^o 33' E - 49^o 1' E, 800-1150 m above sea level) on two parcels (237 and 238) of Nav District is located in the Northern Forests of Iran. In the study area (75 hectare), average ground slope were 30 to 65 percent and the dominant aspect was north. The mean annual precipitation was approximately 950 mm and the mean annual temperature was 9.1^o C. The original vegetation of this area is uneven-aged mixed forest dominated by *Fagus orientalis* and *Carpinus betulus*. Average growing stock in these parcels was 300 cubic meters per hectare and average number of trees was about 231 per hectare above 7.5 cm DBH (Diameter at Breast Height). The soil type is forest brown and soil texture varies between sandy clay loams to clay loam.

Logging operation

During December and January of 2009, marked trees (801 trees) were felled using manual chain saw, topped at merchantable height or 20 cm DIB (Diameter inside Bark) and skidded in the shape of full length or long logs from stump area to roadside landings using Timber jack 450C wheeled skidder. The weight of skidder was 9.8 ton and the width and length of machine was 3.8 and 6.4 meter. The length of winch cable was 50 meter and its diameter was 20 mm. The skid trails and decks planned by foresters were constructed during the first cutting period in 1980. The decks were located on the top of the hill at roadside, and the timbers were extracted uphill to decks. Nine skid trails branched from forest road in these parcels and sum of length of skid trails was 1251 m. The skid trails were spaced on average 140 meter apart in this area. The total volume of extracted woods in these parcels was 1180 cubic meters.

Sampling design

The line intersect method was used to determine the extent of soil disturbance in the logged parcel (Hazard and Geist, 1984; Geist et al. 1989; Page-Dumroese et al. 2000; Miller et al., 2010). Starting points for transects were systematically located by placing a square grid over a map of the harvested area. Sampling covered the operable area, which included the winching area and skid trails. Grid intersections were the starting points of transects. Dimension of grid was set as 100×100 m and length of each transect was 30 m. From each grid points a random azimuth used to lie out transect whit a compass and a 30 m tape in the field. Soil disturbance along transect were identified using visual assessment of soil disturbance method (McIver, 2004; Scott, 2007; Page-Dumroese et al., 2009) and were recorded into four classes: 1) Undisturbed, no evidence of past equipment operation. No evidence of physical disturbance to forest floor, mineral soil not exposed. No soil displacement evident. Soils are non disturbed or considered to be in natural state. 2) Slight disturbed, some visible indications of equipment operation. Litter and duff layers intact. 3) Moderate disturbed, Equipment tire tracks or cleat tracks are evident. Litter and duff layer partially missing. Small area amounts of surface soil removed or displaced. 4) Strongly disturbed, strong evidence of past equipment operation. Litter and duff layer removed. Surface soils partially or totally removed or mixed with subsoil material. Subsoils exposed and compacted. The four classes were recognized visually and their extent measured by determining of length of each transects line contained in each class. Lengths were converted to line percentages that equate directly to area percentages.

Bulk densities (BD) were measured in the line intersects as soil compaction. From each soil disturbance classes 10 soil samples were taken. The cylindrical sampling method was used to determine dry soil bulk density. The cylinder soil sampler used was a 5 cm diameter and 10 cm height. Surface litter and duff were removed before sampling. The soil samples were oven dried at 105°C for 24 hours to obtain dry bulk density (Lee et al., 1983). Sample volumes and weights were corrected for large roots, wood, or gravel. The dry bulk density was calculated from the following formula:

$$\rho_d = \frac{(W_d - W_c)}{V_c} \qquad (1)$$

Where, ρ_d is the soil dry bulk density (g/cm^3), W_d is dry weight of the sampler (g), W_c is weight of the cylinder sampler (g) and V_c is volume of the cylinder sampler (cm^3).

Also, soil compaction and rut depth on skid trails were measured immediately after logging operation. So, a skid trail of 700 m length was selected and amount of soil compaction and rutting were measured on different longitudinal slope classes (0-15, 15-25 and more than 25%). From each longitudinal slop class 10 soil samples were taken.

The rut depths were measured at 2 m interval along skid trails on tire truck.

Statistical analysis

Analysis of variance (ANOVA) and Duncan (if equal variances assumed) or Dunnett (if equal variances not assumed) tests were used for comparing means of soil bulk density and rut depth between soil disturbance classes and skid trail slope classes. In all cases, the significance level were used to reject the null hypothesis was 0.05. Normality of data distribution was tested by Smirnov-Kolmogorov (S-K) test. Since the value S_K did not prove significant in any characteristics ($P > 0.05$), so the data were normally distributed. All analyses were performed using SPSS 19.

Results and discussion

The results showed 44.4% (31.97 ha) of surface soils in logged parcel were disturbed and 55.6% (40.03 ha) undisturbed following ground based logging operation (Fig.1). The soils distribution were occurred in different intensity, so 16.3% (11.73 ha) slight, 14.8% (10.66 ha) moderate and 13.3% (9.58 ha) strongly disturbed (Fig. 1). These results indicated that 399 m^2 (31.97/801=0.0399) of surface soils were disturbed by chain saw and skidding operation for each harvested tree. The extent of disturbed soils by ground based logging system was reported 218 m^2 in Brazil forests (Verissimo et al., 1992) and 94 m^2 in Malaysia forests (Pinard et al., 2000) for each harvested tree.

The soil dry bulk densities in the top 10 cm on slight, moderate and strongly disturbed areas were measured 0.845, 0.867 and 0.942 g/cm^3 (Fig. 2). The soil dry bulk densities on slight, moderate and strongly disturbed areas were increased 7.9%, 10.7% and 20.3% than undisturbed densities (0.783 g/cm^3). Murphy et al. (2004) reported height growth of *Pinus radiate* decreased due to soil compaction following logging operation.

Table 1. Analysis of variance for the effects of soil disturbance class on soil bulk density

	SS	df	Ms	F	Sig.
Between groups	0.129	3	0.043	3.696	0.020
Within groups	0.420	36	0.012		
Total	0.550	39			

Harvest activities that compact soils limit the effective rooting depth of plants by restricting access to water and nutrients and reducing gaseous exchange (Gomez et al., 2002). Krause (1998) reported that compaction from harvesting equipment can reduce water infiltration and permeability to air which is detrimental to the establishment and growth of regenerating species. Tavankar et al. (2009) found that soil bulk density of top 10 cm on the winching area and skid trails increased 17.5% and 35.6% than untouched area following wheeled skidder wood extraction operation in the selection cutting forest in the north of Iran.

Table 2. Analysis of variance for the effects of slope of skid trail on soil bulk density.

	SS	df	Ms	F	Sig.
Between groups	0.423	2	0.211	4.626	0.019
Within groups	1.233	27	0.046		
Total	1.656	29			

Williamson and Neilsen (2000) found that a single pass by a rubber-tired skidder increased bulk density by 22% in the upper 10 cm.

Table 3. Analysis of variance for the effects of slope of skid trail on soil rutting depth.

	SS	df	Ms	F	Sig.
Between groups	1634.596	2	817.298	33.529	0.000
Within groups	654.147	27	24.376		
Total	2292.742	29			

Rutting can have detrimental impacts on site productivity by creating preferential flow patterns for overland water flow, decreasing infiltration and gaseous exchange (Page-Dumroese et al., 2009).

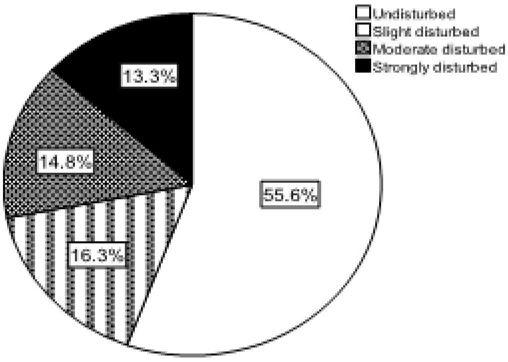

Fig. 1. Percentage of soil disturbance from ground based logging operation.

One-way ANOVA showed that this means of soil bulk densities (undisturbed, slight, moderate and strongly disturbed area) have statistical different at α=0.05 (Table 1). Duncan test showed that mean of soil bulk density on strongly disturbed area was statistical higher than undisturbed area, but no statistical difference between slight disturbed, moderate disturbed and undisturbed areas (Fig. 2).

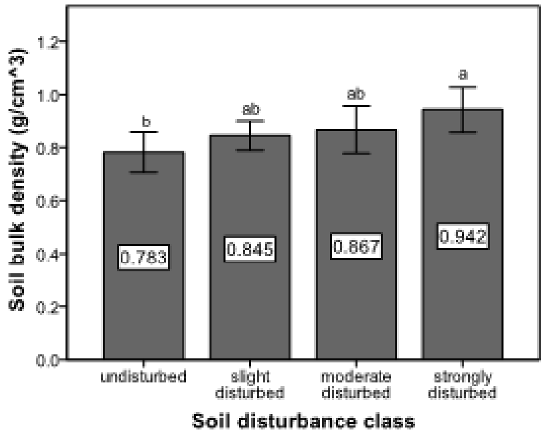

Fig. 2. Soil bulk density on soil disturbance classes (Different letters among disturbance classes indicates statistically significant differences (p < 0.05)).

Soil bulk density increased with the increasing of slope of skid trail (Fig 3). One-way ANOVA showed that means of soil bulk densities on the skid trails in lower 15% (mean=1.277, SD=0.212), 15-25% (mean=1.416, SD=0.186) and upper 25% (mean=1.567, SD=0.239) slope of skid trail have statistical different at α=0.05 (P-Value=0.019, Table 2). Dunnett test showed that mean of soil bulk density on skid trails in upper 25% slopes was statistical higher than 15-25% and lower 15% slopes, also was statistical different between soli bulk density means on the skid trails in lower 15% and 15-25% slopes (Fig. 3).

Fig. 3. Soil bulk density on different slopes of skid trail (Different letters among slope of skid trails indicates statistically significant differences (p < 0.05)).

The results indicated that rut depth was increased with increasing of slope of skid trail (Fig. 4). Means of rut depth on tire track were measured 25.00 (SD= 4.62), 30.73 (SD= 5.18) and 42.72 (SD= 4.99) cm in lower 15%, 15-25 and higher 25% slope of skid trail (Fig. 4). One-way ANOVA showed that this averages of rut dept have statistical different at α=0.01 (Table 3). Duncan test showed that mean of rut depth on tire track in upper 25% slopes was statistical higher than 15-25% and lower 15% slopes, also was statistical different between rut depth means on the tire tracks in lower 15% and 15-25% slopes (Fig. 4).

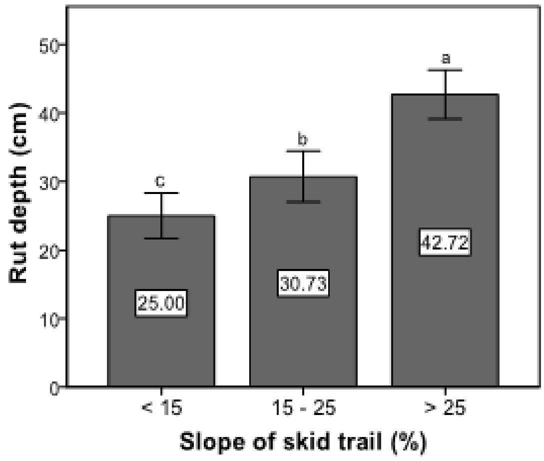

Fig. 4. Soil rut depths on different slopes of skid trail (Different letters among slope of skid trails indicates statistically significant differences ($p < 0.05$).

Conclusion

In this research logging damages to soils were studied in the northern forests of Iran. These forests are natural, uneven aged and mixed stands. The management method in these forests is selection cutting. The ground based logging system is the most common harvesting method in the northern forests of Iran. The results of this study showed that 44.4% of surface soils in the logged parcel were disturbed to varying levels following logging operation. Also the results indicated that soils were compacted significantly in the disturbed areas. Visual assessments of soil disturbance provide a rapid assessment of soil condition that can be useful for monitoring soil disturbance during timber harvesting (McIver, 2004). It is now recognized that reducing logging damage to both forest and soil can shorten the felling cycle length because it ensures better natural regeneration and growth of the desired commercial species (Putz, 1994). Mechanized logging, if uncontrolled, can have the high damaging effect on forest structure, composition and regenerating capacity (Sist et al., 1998). Forest soil maintenance is a key factor for sustaining productive forests (Curran et al., 2005). The Forest Service must be able to manage soil disturbance in order to maintain sustainable production of natural resources (Craigg and Howes, 2007). The selective logging can be accomplished with entries into the stand every 10 years, which increases the potential for soil compaction and damage to residual trees. To achieving sustainable forest management the main requirements is minimizing the logging damages. In order to minimizing soil disturbance during ground based logging operation, pre harvest planning of roads, landings and skid trails, identifying unstable and sensitive areas prior to the start of any forestry operations and avoid skid trail construction and winching operation in these areas are necessary and layout skid trails prior to harvesting are essential operation. Also limit skidding during wet periods, Utilize directional felling techniques, begin skidding operations after ground is frozen or snow cover is adequate to prevent damage and avoid skidding directly up and down steep slopes for long distances are important applications to minimize soil disturbance in these forests.

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