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Technical Note

Skidders traffic assessment on forest soil properties

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Abstract

Harvesting of timber using ground based machinery is still a common practice around the world. Track and road building, and movement of machinery during harvesting operations cause soil disturbance. Therefore the aim of this study was to investigate the change in soil properties after logging operation on skid trails (2 years and 7 years after logging) and compare disturbed soil properties with control sampling (undisturbed soil). For this purpose, soil samples were collected from the skid trail and undisturbed area. Electrical conductivity, pH, organic carbon, moisture equivalent, moisture, total porosity and bulk density were determined on the skid trail and undisturbed area. Soil characteristics were examined in two ages (2 years and 7 years skid trail). There were crucial differences in the values of electrical conductivity, organic carbon, moisture, total porosity and bulk density from skid trail and undisturbed area in 2 years skid trail (p<0.05). But on 7 years skid trail, there were no significant differences in values of mentioned factors from skid trail and undisturbed area (p>0.05) except bulk density (p=0). It has been concluded that 7 years after logging, all soil properties except bulk density were completely recovered on skid trail. These findings have important implications for assessing the impact of skidders traffic and recovery time in skid trails.

Keywords: *Skidders traffic; Skid trail; Soil recovery; Soil properties.*

1. Introduction

Each case of human interference in forest environment, especially harvesting timber crops, is associated with disturbances in forest ecosystems [1]. The harvest phase of forest management brings along major disturbances of forest soil. Maintaining the long term site productivity is an essential requirement for sustainable forest management [2]. Harvesting of timber using ground based machinery is still a common practice around the world. Track and road building, and movement of machinery during harvesting operations cause soil profile disturbance [3]. Also, there is ongoing trend to increase almost constantly the size, power and load of logging machines, with weights that generally amount up to 12-16 tones in unloaded state. Machines induce soil compaction owning to the exerted normal pressure, vibration and shear stress [4]. This may cause soil degradation in forest ecosystems as the passes of harvesting machines modify important soil structural characteristics [5-7].

Ground based skidding may result in soil compaction and other soil structural changes, influencing soil water retention, and reducing soil aeration, drainage and root penetration [8-14]. Soil damage on forest roads, skid roads and landings includes the removal of the organic layer and top soil, soil compaction and erosion of the exposed soil. The soil damage affects hill slope infiltration and surface and subsurface flows [15].

Persistence of soil compaction and recovery of soil properties is likely to vary degree of soil compaction, depth of compacting soil layer, soil type, vegetation and climate [16]. The restoration of properties of compacted soil may require between 5-40 years recovering [17]. The rates of recovery so far reported were different and depending on method of skidding, soil texture and site [13,16,18].

Given the importance of soil in forest ecosystems, investigating the changes in soil properties can be a guide to improve the degraded soils caused by skidder traffic. Therefore, the aim of this study was to investigate the change in soil properties including bulk density, total porosity, moisture, moisture equivalent, organic carbon, electrical conductivity and pH according to skid trails ages (2 and 7 years after logging operation on skid trails) and compare disturbed soil properties with control sampling (undisturbed soil).

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2. Materials and Methods

Pashakola forest is located on south of the city of Savadkooh in Mazandaran province, Iran (Fig. 1). Large areas of this forest are located on steep to very steep slopes with an average altitude greater than 1000 m above sea level. The main system for wood extraction in the Pashakola forest is based on ground skidding by skidder 450 C and HSM.

Fig. 1 Map and Geographical location of the study area

Sampling for soil measurements was carried out in October 2012, about 2 and 7 years after harvesting (Fig. 2). To examine the impact of skidding on the skid trail, the upper soil layer (down to 10 cm depth) in comparison with the undisturbed area, the skid trail were sampled at different points (at 50 m intervals) and from the undisturbed area protected from skidding at least 40 cm away from the skid trails. In order to take samples, standard steel cylinders (10 cm height and 8 cm diameter) were used. Using mentioned cylinders some samples were taken from inside and outside of the skid trail. All samples were put in bags and labeled. Samples brought to the laboratory from the research area, were promptly weighted. Soil samples were dried in an oven less than 105°c for 24 h. percentage of moisture was calculated from the different between the values of wet and oven dried samples. Organic carbon (Walkley and Black wet digestion method), bulk density (ASTM C29), total porosity (ASTM D7263), moisture equivalent (ASTM D425), pH (measured by pH meter) and electrical conductivity (measured by EC meter) values were measured in the laboratory [6, 15]. In order to increase accuracy, each of mentioned tests were conducted with 6 replication and the results were analyzed using statistical analysis. The values for the undisturbed area and skid trails were compared statistically at $p<0.05$ significance level by using independent sample t-test statistical analysis.

Fig. 2 Sampling for soil measurements; a: Disturbed; b: Undisturbed

3. Results and Discussion

This study provides further evidence that forest harvesting practices such as skidding and skid trail construction can have significant effect upon surface soil properties. Some soil properties such as, pH and moisture equivalent do not show significant differences in the undisturbed area and on 2 years skid trail (Table 1). However, soils on skid trail had a lower pH and moisture equivalent than on the undisturbed soils (Fig. 3, 4). Soil compaction, disturbance, surface runoff and soil erosion caused by skidder traffic are the main reasons for these changes. According to the results, it could be found that indicators condition had been slightly improved after 7 years.

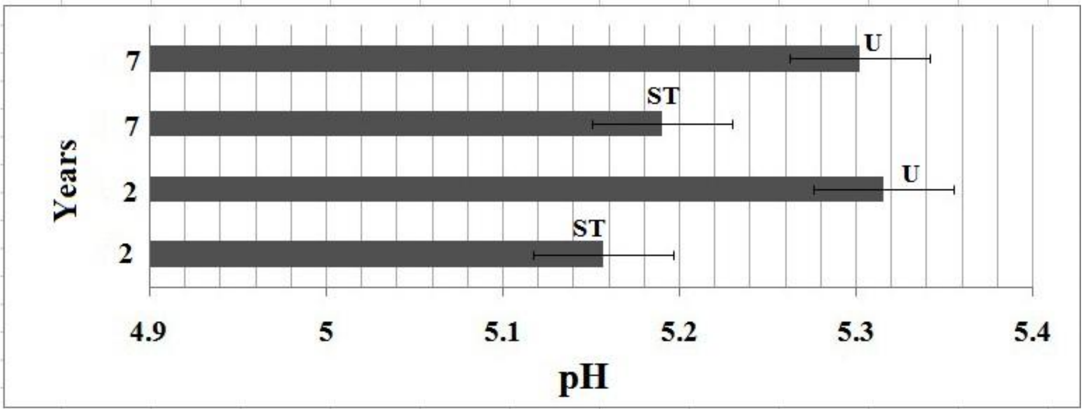

Fig. 3 The recovery process in pH value on skid trails and undisturbed areas

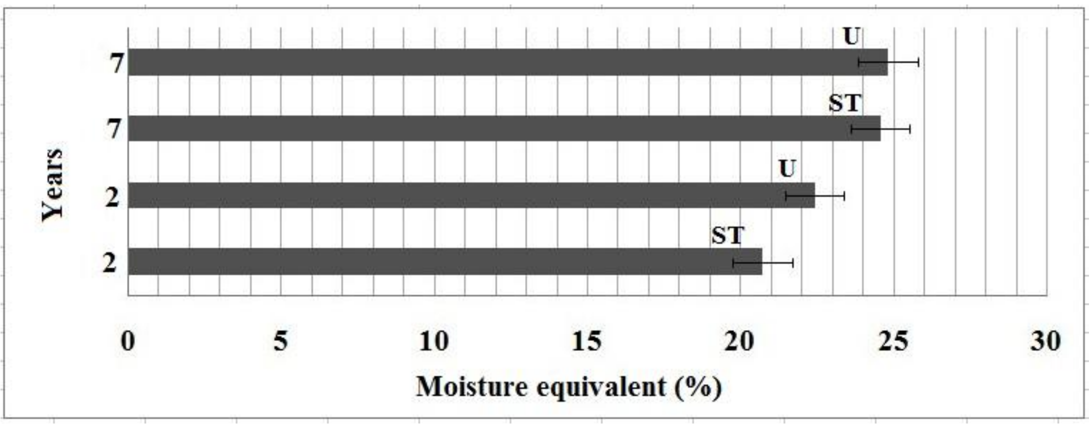

Fig. 4 The recovery process in moisture equivalent value on skid trails and undisturbed areas

Table 1 Investigated soil properties on 2 years skid trail

Characteristics	Unit	Disturbed	Undisturbed	sig.2-tailed
pH		5.16	5.31	$0.121^{n.s}$
Electrical conductivity	(µmhoS cm^{1})	78.23	86.6	0.046^{*}
Organic Carbon	(%)	0.57	0.8	0.018*
Moisture equivalent	(%)	20.7	22.4	$0.142^{n.s}$
Moisture	(%)	23.6	19.66	0.046*
Total porosity	(%)	44.61	53.88	0.001*
Bulk density	(g dm^{3})	982.05	730.96	0.00*

Values are mean. Significance levels are: ns represents non significant, * p<0.05.

Other investigated soil properties such as electrical conductivity, organic carbon, moisture percentage, total porosity and bulk density show significant differences between undisturbed area and 2 years skid trail (Table 1). Considerably higher bulk density values because of the movement of vehicle were found on skid trails compared to the undisturbed area [2,4,10,11,15]. Similarly, the moisture rate increased and the total porosity decreased considerably due to compaction on the 2 years skid trail. Reasons such as compaction of soil via traffic on skid trail, decreasing porosity, moisture equivalent, electrical conductivity and increasing moisture (Fig. 4, 5, 6, 7, 8). Also, due to higher bulk density, soils on skid trail had significantly lower space than the soil of control area [16].

Results for the soil samples taken from 7 years skid trail are different from the results found for 2 years skid trail except bulk density, pH and moisture equivalent. The results show that there is no significant difference between soil samples from 7 years skid trail and undisturbed area except bulk density (Table 2).

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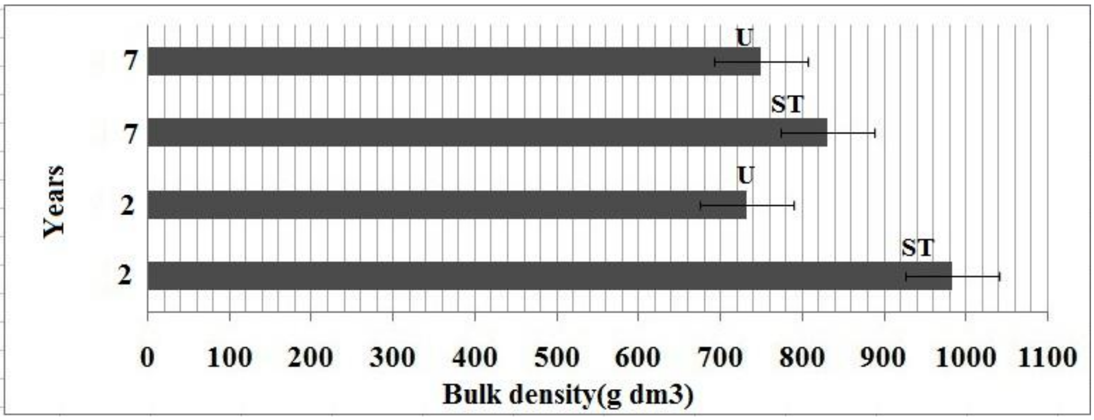

Fig. 5 The recovery process in bulk density value on skid trails and undisturbed areas

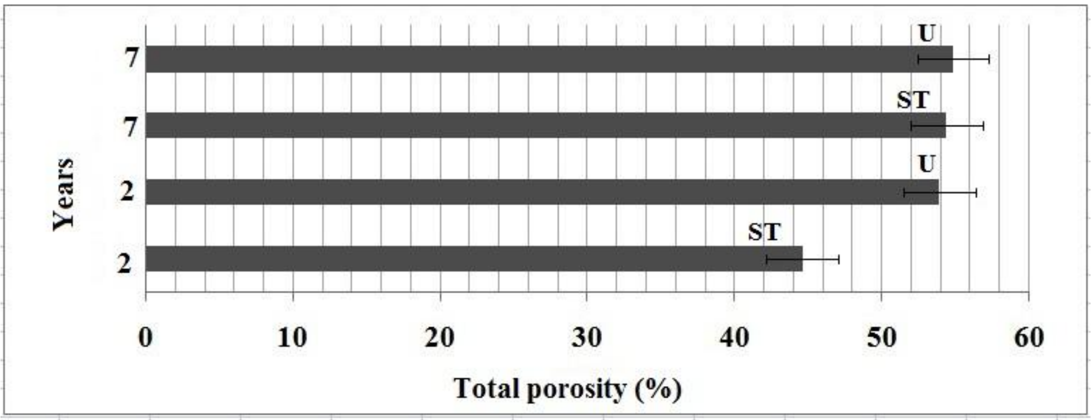

Fig. 6 The recovery process in total porosity value on skid trails and undisturbed areas

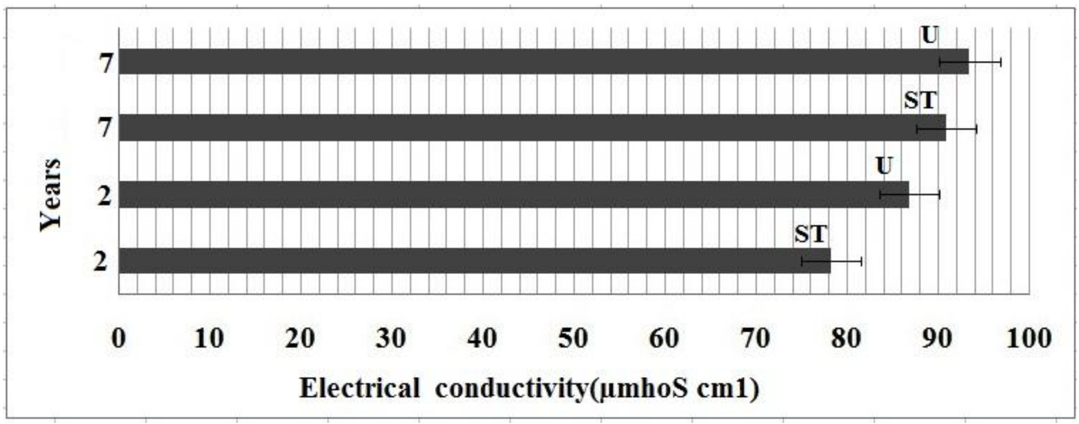

Fig. 7 The recovery process in Electrical conductivity value on skid trails and undisturbed areas

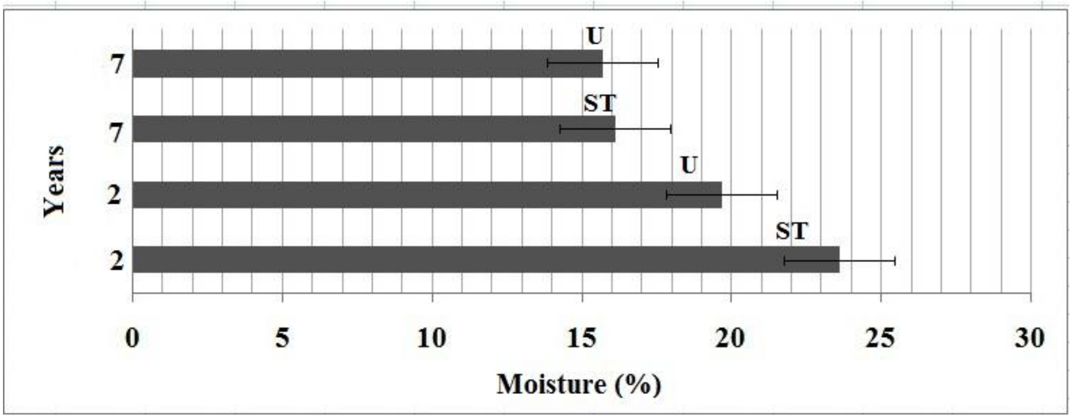

Fig. 8 The recovery process in moisture value on skid trails and undisturbed areas

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Table 2 Investigated soil properties on 7 years skid trail

Characteristics	Unit	Disturbed	Undisturbed	sig.2-tailed
pH		5.19	5.30	0.415$^{n.s}$
Electrical conductivity	(μmhoS cm^{1})	90.88	93.41	0.343$^{n.s}$
Organic Carbon	(%)	0.73	0.74	0.82$^{n.s}$
Moisture equivalent	(%)	24.55	24.8	0.8$^{n.s}$
Moisture	(%)	16.1	15.7	0.55$^{n.s}$
Total porosity	(%)	54.38	54.83	0.61$^{n.s}$
Bulk density	(g dm^{3})	830.53	749.13	0.00*

Values are mean. Significance levels are: ns represents non significant, * p<0.05.

As 2 years skid trail, the higher soil bulk density in 7 years skid trail may be due to the exposure of the denser subsoil during the initial process of ground skidding [20]. High values of bulk density in the 7 years skid trail confirm the persistence of the effects of machinery compaction over this time period. Also, the recovery of bulk density is depending on level of initial compaction, vegetation, soil type and climate condition [16]. However, soil recovery lingers from a few years up to half century [17-18]; this study demonstrated those 7 years after logging, all soil properties except bulk density were relatively recovered on skid trail (Fig. 5).

Soil moisture content has an important role on the degree of soil compaction. Maximum soil compaction occurs when the soil moisture content is optimum [21]. Therefore, if forest engineers choose an appropriate time according to soil moisture status, soil compaction could be reduced. This can help the soil recovery process.

The importance of soil organic carbon as a structural and functional component of soil productive capacity and in providing the critical linkage between management and productivity is widely recognized for forest soils [19]. Organic carbon rate on the 2 years skid trail has been found quiet lower than the undisturbed area (Fig. 9). It is generally claimed that the skidding work cause decreasing organic carbon amount in the soil [9,15,16]. Skidder traffic and it's heavy weight (about 10.3 tons for the Skidder 450C) cause disturbance in soil profile. Disturbance of top soil causes movement of organic matter to different part of soil profile. Therefore, organic carbon distribution does not change much with respect to soil depth [22]. Time passing can return the organic matter to surface of disturbed soils. Therefore, given the result of this study, it can be understood that soil organic carbon status is better after 7 years.

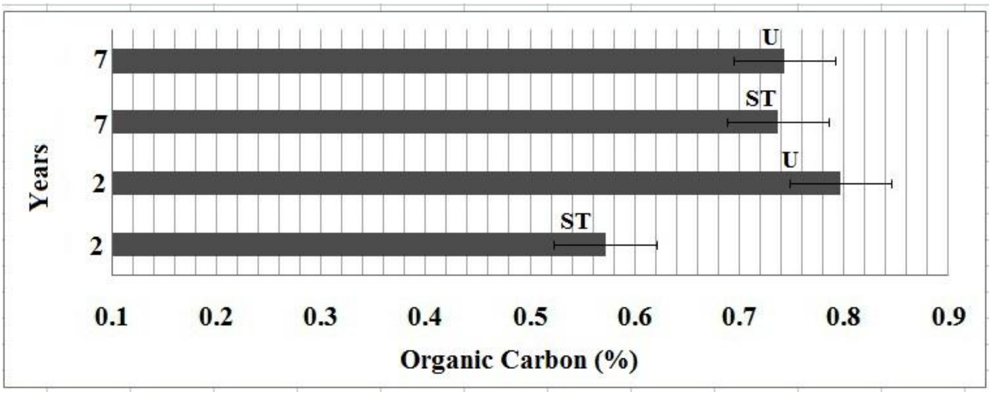

Fig. 9 The recovery process in organic carbon value on skid trails and undisturbed areas

3. Conclusion

This study was conducted with the overall objective of describing the effects of skidding on soil properties of skid trail. Although the results were different among treatments. Recovery was assessed using arrange of indices including bulk density, pH, electrical conductivity, porosity, etc. Soil bulk density is the only index that shows no significant recovery over the 7 year time period, highlighting the more persistent nature of machinery compaction on the surface soil of disturbed forest skid trails. It is obvious that changes because of soil compaction will cause negative impacts on the soil of skid trail. Hence, to reduce the detrimental effects of skidding and skid trail construction on soil properties, forest manager should minimize compaction during logging activities. Also, to minimize the impacts of logging on soil properties, the areas occupied by general harvested areas and skid trail need to be reduced. Furthermore, by restricting machine traffic to designated skid trail, the soil between the trails is left undisturbed and can recover from the disturbed status.

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