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IMPACTS OF FOREST HARVESTING OPERATIONS ON SOIL COMPACTION IN SCOTCH PINE-FIR MIXED STANDS (ÇANKIRI SAMPLE)

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ABSTRACT

This study investigated soil compaction, caused by tree felling and ground based forest harvesting operations, in sandy loamy brown forest soil, located in mixed forest stand harvesting units. In the study area, conventional forest harvesting is still practiced and this resulted in considerable soil compaction. As the forests are on the mountainous landscape, ground skidding is carried out by human, animal or tractor power. The impacts of harvesting operations in felling and skidding areas on soil compaction were assessed in this study. Thirty nine sample areas were taken for two soil depths (0-5 cm and 5-10 cm) before and after tree felling and ground skidding activities measuring 7 samples for each, in four different stands. Soil compactions at logged areas were nearly two times greater than the unlogged areas, except tree felling values at 5-10 cm depth.

Keywords: Soil compaction, brown forest soil, tree felling, ground skidding, penetrometer

INTRODUCTION

Forest harvesting operations (FHO) can cause considerable soil disturbances as removal and mixing of topsoil, compaction of soil layers (Jurgensen et al., 1997; Kozlowski, 1999; Agherkakli et. al., 2010). Disturbance can negatively affect soil physical properties via increased soil compaction (Tan et. al., 2005; Naghdi, et. al., 2007; Gebauer et al 2012). Soil compaction increases bulk density (Van Rees et al 2001; Ares et al. 2005; Demir et al. 2007; Makineci et al. 2007; Lotfalian and Bahmani, 2011), decreases porosity, infiltration capacity (Kozlowski, 1999; Grigal 2000; Startsev and McNabb 2000; Özgöz and Okursoy 2001; Rohand et al. 2004; Ares et al. 2005; Ampoorter et al. 2007; Demir et al. 2007), saturated hydraulic conductivity (Wood et al. 2003; Grace et al. 2006; Ampoorter et al. 2007) and microbial activities (Jordan et al 2003; Ares et al. 2005; Tan et al. 2008). The soil compaction can reduce tree root volume by increasing soil resistance to root growth or decreasing oxygen and water supply to plant roots (Murphy et al., 2004). These characteristics have potential to mitigate plant and tree growth (Corns 1998; Murphy et al 2004; Lotfalian and Bahmani, 2011; Gebauer et al 2012). Besides soil compaction, soil mixing, puddling, and rutting are important types of soil disturbances that can cause a disruption of matter flow of disturbance (Agherkakli et. al., 2010). In addition, degree of hazard caused by FHO depends on several factors such as soil moisture content (Ampoorter 2011; Ares et al 2005; Eliasson 2005; Korb 2011; Naghdi et al 2007), topography, operation method (clear-cut, single-tree selection, group selection), harvesting method (ground based logging, skyline or even helicopter systems) (Lister 1999; Donagh et al 2010; Ampoorter 2011), type of machinery used and the number of machinery passes (Donagh et al 2010; Eliasson 2005; Gebauer 2012; Hutchings 2002; Junior et al 2007). When all adverse effects on forest soil and environment were considered, the timber harvesting may be considered as an disturbance activity all over the world (Najafi et. al., 2009).

The objective of this study was to assess the soil disturbance and compaction caused by FHO in Ilgaz Forests, located in north central of Turkey. For this purpose, we measured soil compaction before and after tree felling and ground skidding with rubber-tyred tractors in highly productive Scotch Pine-Fir Stands.

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MATERIALS AND METHODS

Study area

This study was carried out in Scotch Pine-Fir Stands located in Yenice Forest District, Ilgaz Forest Management Directorate, approximately 100 km northeast of Çankırı Province (41° 02' 20"-41° 02' 10"N latitudes and 33° 46' 24"-33° 47' 45"E longitudes) in north central Turkey (Figure 1).

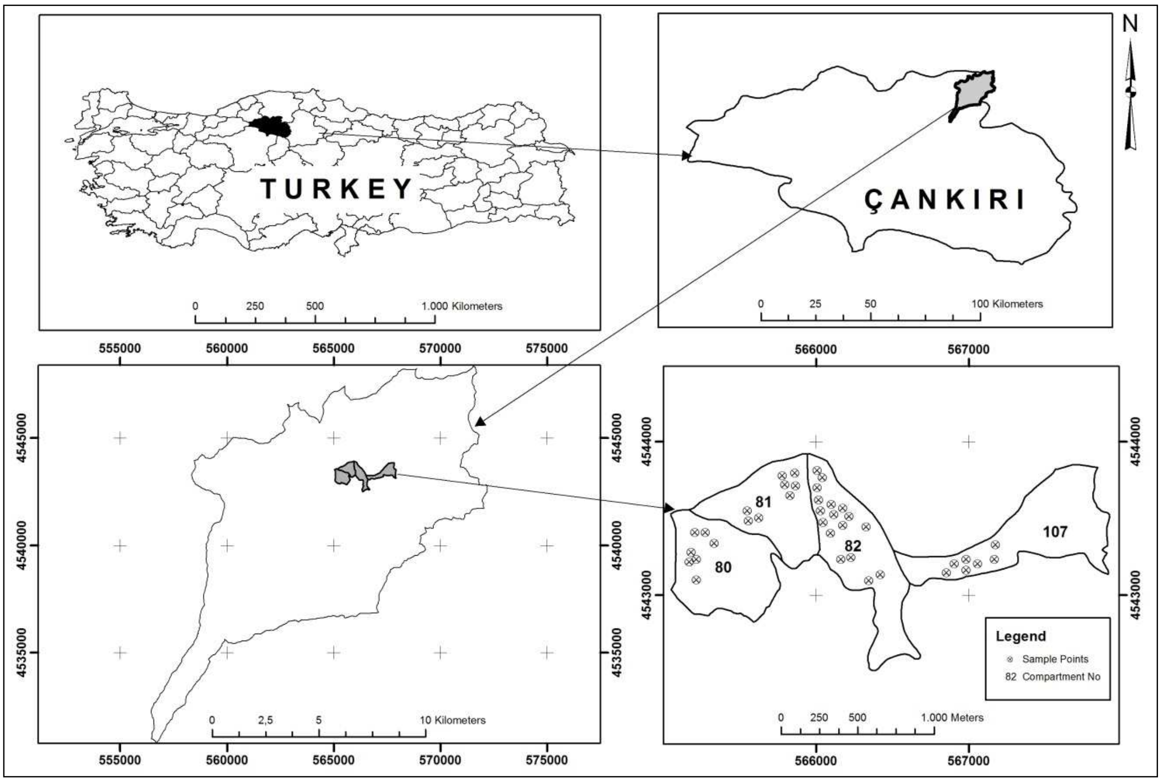

Figure 1. Location of the samples in the study area in Çankırı-Turkey

The elevation in the study area ranges from 1380 m to 1620 m with average of 1460 m (Figure 2) and average slope is 30-35% according to the IUFRO slope classification (Figure 3).

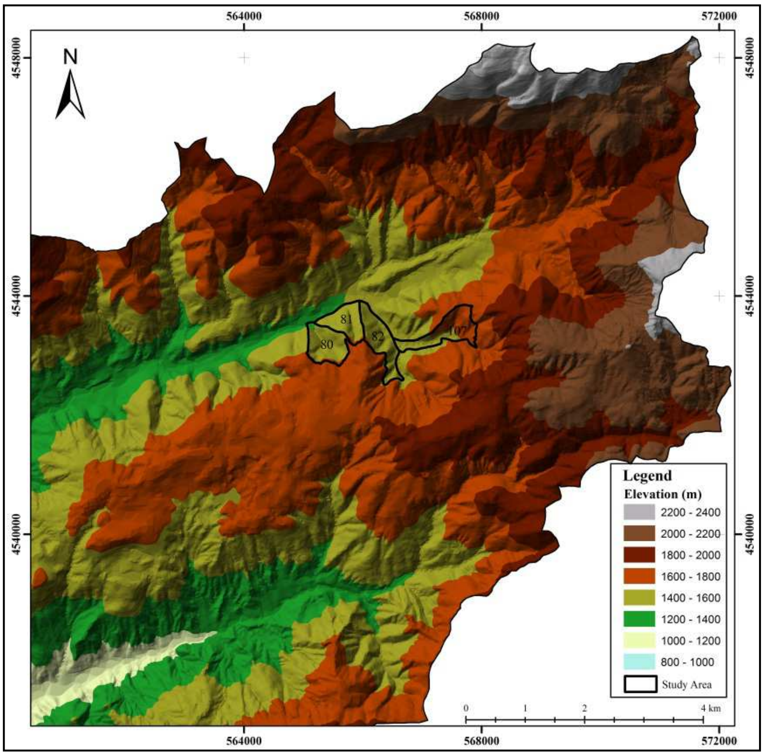

Figure 2. Elevation map of the study area

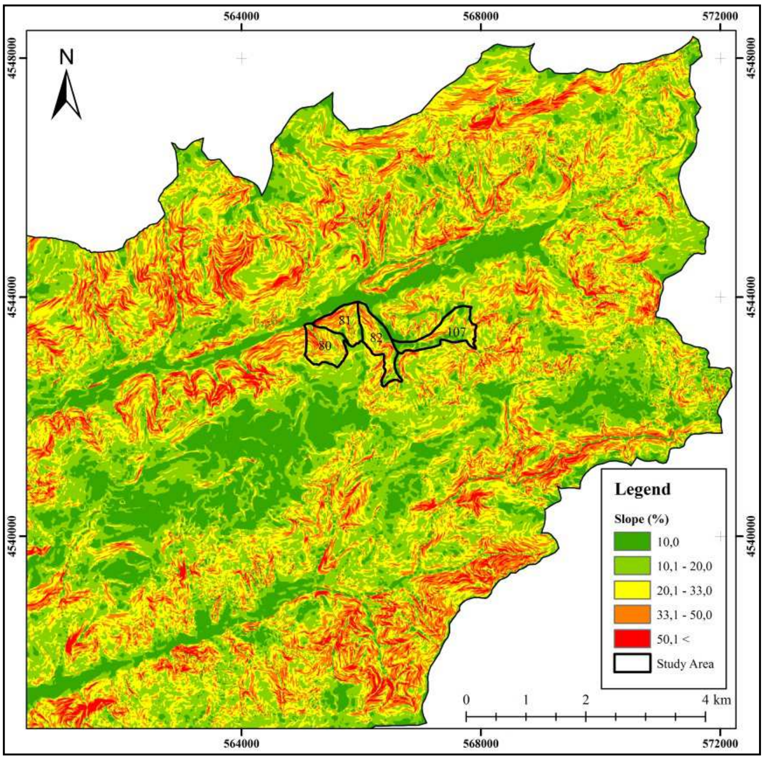

Figure 3. Slope map of the study area

The climate in the study area is continental-coastal type, with the mean annual temperature of 8.2 °C. Mean annual precipitation is 410 mm, approximately half of which occurs as snow, and the rest as of rainfall occurs in the growing season between May and October (Anonymous, 2008). Prior to harvest, the forest stand was dominated by Scotch Pine (*Pinus sylvestris* L.) and Fir trees (*ağabeyes nordmanniana* subsp. *Bornmulleriana* Mattf.), and some Austrian-pine (*Pinus nigra* Arnold). Brown forest soil is the main soil type (sandy loam and and sand) in the study area (Göl et al. 2010). Single-tree selection harvesting system is implemented, individual trees that are ready for harvest are removed in the study area. The total volume of production at the studied compartments (80, 81, 82 and 107) was 3320 m^3 and extraction of logs from the stump area to roadside landing was achieved by a ground-based skidding system. The use of the farm tractor is widespread throughout Turkey with the advantages of assembling appropriate technical equipment for the terrain conditions and several items of forestry equipment (loading, skidding and road surface smoothing equipment) (Melemez et al 2013). Rubber-tyred farm tractor was used in the study area to skid logs to a landing point for loading onto trucks is conventionally carried out in the areas where slope was less than 30% and this method is known as the worst method causing soil disturbance.

Data preparation

We studied the impact of FHO on soil compaction in four different compartments (Figure 1). Soil compaction was measured before and after tree felling and ground skidding activities at different sample points. Trees were felled and branches were cut by using power saw. Hand-held cone (30˚) penetrometer was used to examine the impact of tree felling and ground skidding activities on soil compaction. Herbaceous, litters and debris at measurement points were cleaned and measurements were taken by placing the cone on the soil surface with the shaft upright. The cone was pressed into the soil until the soil is level with the base of the cone to minimize variability in starting depth (Figure 2). Soil compaction was measured at 39 sample areas, measuring 7 different points for each on felling direction for two soil depths (down to 0-5 cm and 5-10 cm depth). To examine the impact of skidding on the skid road, soil compaction was also measured on skid roads, before and after ground skidding at the same sample areas, measuring 7 different points for each for the same soil depths.

Figure 2. Hand-held cone (30˚) penetrometer

Data Analysis

Soil compaction values measured in two different depths and areas were compared to determine the effect of tree felling and ground skidding activities in soil compaction by using analysis of student's t test. The student's t test was performed by using SPSS version 15.0 (SPSS Institute Inc., 2008) to evaluate whether there is enough evidence that the means of soil compaction measurements differ at 95% significance levels for before and after tree felling and ground skidding activities.

RESULTS AND DISCUSSION

In Table 1, some descriptive statistics were presented for soil compactions measured for different logging activities and soil depths. The logged and unlogged areas have statistically significant different soil compaction values at 95% significant levels (Table 2). The mean soil compactions measured, before and after tree felling are; 2.1464 kgf/cm^2 and 3.9040 kgf/cm^2 for 0-5 cm depth (t-value=-33.913, df=544, $p<0.05$), 7.3833 kgf/cm^2 and 8.6583 kgf/cm^2 for 5-10 cm depth (t-value=-26.095, df=544, $p<0.05$) respectively. The mean soil compactions measured, before and after ground skidding are; 6.9813 kgf/cm^2 and 10.2884 kgf/cm^2 for 0-5 cm depth (t-value= -36.444, df=544, $p<0.05$), 13.4926 kgf/cm^2 and 24.5825 kgf/cm^2 for 5-10 cm depth (t-value=-72.604, df=544, $p<0.05$) respectively. Soil compactions at logged areas were nearly two times greater than the unlogged areas, except tree felling values at 5-10 cm depth (Table 1). The results of FHO effects on soil compaction obtained in this study are similar to some studies; e.g. Ares et al. (2005); Donagh et al. (2010); Ampoorter et al. (2007); Horn et al. (2004); Makineci et al. (2007) and Demir (2007).

Table 1. The soil compaction content at the unlogged and logged areas

	Felling				Skidding			
Depths (cm)	**0-5**		**5-10**		**0-5**		**5-10**	
Statistics	**Pre-Felling**	**Post-Felling**	**Pre-Felling**	**Post-Felling**	**Pre-Logging**	**Post-Logging**	**Pre-Logging**	**Post-Logging**
Minimum	1.09	2.17	6.36	6.67	5.58	11.28	11.78	12.09
Maximum	2.95	5.43	8.22	10.08	8.61	12.71	15.19	29.30
Mean	2.1464	3.9040	7.3833	8.6583	6.9813	10.2884	13.4926	24.5825
Std. Error	0.02972	0.04246	0.02594	0.04140	0.04430	0.07919	0.05982	0.14054
Std. Deviation	0.49098	0.70160	0.42857	0.68411	0.73199	1.30851	0.98847	2.32213
Variance	0.241	0.492	0.184	0.468	0.536	1.712	0.977	5.392

Table 2. Student's t test results at 95% significant levels for soil compaction comparisons in different logged activities and soil depth

Logging activities and soil depth	df	t-value	p
Soil compactions measured in 5 cm soil depth for felling activities	544	-33.913	<0.05
Soil compactions measured in 10 cm soil depth for felling activities	544	-26.095	<0.05
Soil compactions measured in 5 cm soil depth for skidding activities	544	-36.444	<0.05
Soil compactions measured in 10 cm soil depth for skidding activities	544	-72.604	<0.05

CONCLUSIONS

Forest harvesting activities, carried out in Yenice Forest District, increased compaction of soil layers; 82% for 0-5 cm depth and 17% for 5-10 cm depth at tree felling, 47% for 0-5 cm depth and 82% for 5-10 cm depth at ground skidding. Tree felling activities caused higher soil compaction effect at topsoil layer (0-5 cm) than lower ones. However, ground skidding activities engendered lower soil compaction effect at topsoil layer (0-5 cm) than lower ones. These relationships can be explained by tree felling direct impact on topsoil, and by splitting of the upper soil layer at ground skidding. Placement of harvesting waste in places of forwarders' and harvesters' passages might be a good solution to minimise soil compaction (Gebauer et al. 2012).

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