DOI: 10.3195/ejejfs.982791

Research Paper – Araştırma Makalesi

Eurasian Journal of Forest Science

2021 9(3): 107-121

http://dergipark.org.tr/tr/pub/ejejfs

Short-term monitoring of the winching and skidding effects on soil microbial biomass in Turkish red pine in the Mediterranean Region

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Abstract
Harvesting activities in forests can seriously damage soils and cause short and long-term changes in some of their properties. The aim of this study is to determine the effects on the microbial properties of the failure of the soil by the whole tree method using a farm tractor in the short term in the Turkish red-pine forests of Kahramanmaraş Forestry Operations Directorate in Başkonuş Forest Enterprise Chief. In total, 72 soil samples were collected on two soil layers (0-10 and 10-20 cm) and three seasons (spring, summer, and autumn) for identifying some physicochemical and microbial properties of soil. Mean values of the soil organic carbon and nitrogen were statistically different in the skidding (2.15% - 0.13%) and control (2.90% - 0.16%) areas, respectively. Also, It was determined that the skidding activities had a statistically significant effect on the microbial biomass carbon, nitrogen, and microbial soil respiration. A significant reduction in organic carbon and microbial biomass was observed in the soils in the skidding line. According to the seasonal patterns, the microbial biomass of the samples was found the lowest in summer (657.17 µg g^{-1}) and the highest (763.76 µg g–1) in autumn. In the control areas, the lowest was 773.99 µg g^{-1} in the spring season and the highest was 886 µg g– 1 in the autumn season. It is predicted that the decomposition rate may have increased in parallel with the soil temperature, which increases as a result of the removal of the litter layer from the soil surface to any other places in the harvesting application. Consequently, it is important for forest and soil health to monitor the changes in the microbiological characteristics of soils for long periods and to produce in a way that causes minimum damage to the soil in harvesting activities of forests. Therefore, harvesting activities should be carried out in periods when the soil is hard. In seasons, when soils are soft and sensitive, there is a need to develop alternative harvesting methods such as aerial yarding systems from stump to landing instead of skidding.
Keywords: harvesting activities, carbon, soil properties, microbial biomass, seasonal pattern

Akdeniz Bölgesinde Kızılçam meşcerelerinde taşıma ve sürütme ile bölmeden çıkartma faaliyeti sonucu toprakların mikrobiyal özelliklerinin değişiminin mevsimsel olarak izlenmesi

Özet
Ormanlarda yapılan hasat (üretim) faaliyetleri topraklara ciddi şekilde zarar verebilmekte ve bazı özelliklerinde kısa ve uzun vadeli değişikliklere neden olabilmektedir. Bu çalışmanın amacı, tarım traktörü kullanılarak bütün ağaç yöntemi ile hasat yapıldıktan sonra yırtılan (bozulan) toprakların kısa vadede bazı fizikokimyasal ve mikrobiyal özellikleri üzerindeki etkilerini belirlemektir. Toprağın bazı fizikokimyasal ve mikrobiyal özelliklerini belirlemek için iki toprak katmanında (0-10 ve 10-20 cm) ve üç mevsimde (ilkbahar, yaz ve sonbahar) toplam 72 toprak örneği toplanmıştır. Toprak organik karbon ve azot ortalama değerleri sırasıyla örneklerde (%2.15 ve %0.13) ve kontrol (%2.90 ve %0.16) alanlarında istatistiksel olarak farklı bulunmuştur. Ayrıca, üretim uygulamasının mikrobiyal biyokütle karbon, azot ve mikrobiyal toprak solunumu üzerinde istatistiksel olarak önemli etkilere sahip olduğu belirlenmiştir. Özellikle sürütme hattındaki topraklarda organik karbon ve mikrobiyal biyokütlede önemli miktarda azalma gözlenmiştir. Mevsimsel desene göre, toprak örneklerinin mikrobiyal

biyokütlesi en düşük (657.17 μg g^{-1}) yaz ve en yüksek (763.76 μg g^{-1}) sonbahar mevsiminde bulunmuştur. Kontrol alanlarında en düşük 773.99 μg g-1 ilkbahar mevsiminde, en yüksek 886 μg g-1 sonbahar mevsiminde olmuştur. Üretim faaliyetleri sonucunda ölü örtü tabakasının toprak yüzeyinden uzaklaştırılması sonucu artan toprak sıcaklığı ve azalan toprak nemine paralel olarak toprakların mikrobiyal özelliklerinde azalmalar olduğu gözlemlenmiştir. Sonuç olarak, ormanlarda üretimden sonra toprakların mikrobiyolojik özelliklerindeki değişimlerin uzun vadede izlenmesi, toprağa en az zarar verecek şekilde üretim yapılması orman ve toprak sağlığı için önemlidir. Bu nedenle üretim faaliyetleri toprağın sert olduğu dönemlerde yapılmalıdır. Toprakların yumuşak ve hassas olduğu mevsimlerde bütün ağaç veya sürütme yöntemi yerine alternatif hasat yöntemlerinin geliştirilmesine ihtiyaç vardır.

Anahtar Kelimeler: hasat faaliyetleri, karbon, toprak özellikleri, mikrobiyal biyokütle, mevsimsel farklar

1. Introduction

Some physicochemical properties and especially microbiological properties of soils show considerable sensitivity to changes in environmental factors and forestry practices such as harvesting, afforestation, restoration (Foote et al. 2015; Kara et al. 2016; Babur 2019). A significant amount of carbon is stored in the litter and topsoil of forest ecosystems. The amount of stored carbon under the influence of climate change and human affects these pools negatively (Chen et al. 2013; Dangal et al. 2014). Timber harvesting, which is one of the main forestry activities, causes loss a huge amount of organic matter in the forest ecosystem by soil compaction, soil rupture, and erosion. So, this decreases the productivity of forest ecosystems. Unless an appropriate and sustainable harvest planning is made, the fertility of the soils is endangered due to the decrease in the C and N resources of the ecosystem (Henderson 1995; Carter et al. 2002; Turner and Lambert 2011). However, the forest ecosystems can only be able to renew itself in about 100 years (Chen et al. 2013; Kellman et al. 2014). In addition, soil compaction and degradation with rupture caused by harvesting activities increase soil temperature and bulk density, changing the soil structure and porosity, which directly affects the soil aeration and water capacity which extremely related with infiltration capacity (Labelle and Jaeger 2011; Cambi et al. 2015).

Considering that the microbiological population and indices are affected the most against all these changes in forest ecosystems, and microbiological soil properties can be used as indicators about changes in an ecosystem (Wardle 1992; Jordan et al. 2003; Frey et al. 2009).

Harvesting processes made according to different methods cause different effects on forest soils and litter (Jones et al. 2011; Grand and Lavkulich 2012; Kellman et al. 2014; Scott et al. 2014). However, it has not been clearly demonstrated how this method affects carbon and nitrogen amounts in soils and litter, microbial decomposition rates and soil aggregation. Six et al. (2004) stated in their study that there is degradation in the microaggregates of the top soils compaction as a result of harvesting activities. In addition, it has been determined that soil compaction decreases root biomass in the upper soils and N uptake from the soil, N washing and denitrification in the ecosystem (Torbert and Wood 1992; Jordan et al. 2003).

Soil microbial organisms play an important role in C and N storage and nutrient cycle (Haubensak et al. 2002; Allen and Schlesinger 2004). There are positive relationships between soil microbial biomass and C and N stocks of soils (Li et al. 2004; Kara et al. 2016; Babur 2019). LeDuc and Rothstein (2007) reported that the post-production reductions in C and N may result in a reduction in microbial biomass. In addition, it has been stated that microbial activity in the top soils significantly decreased due to the effect of soil compaction on the air and water economy of the soils (Li et al. 2004; Mariani et al. 2006).
In this study, the effects of the deteriorated soil structure on some physicochemical and microbial properties in the short term were investigated after the whole tree method was removed from the partition using a farm tractor.

2. Materials and Methods

2.1. Material

This study was located at 50 km far from northwest of Kahramanmaraş province in the Northeast Taurus Mountain region of Turkey (37º 35’ 19’’ N; 36º 36’ 13’’E) in the Turkish red pine forests of Kahramanmaraş Forestry Operations Directorate in Başkonuş Forest Enterprise Chief and was carried out in the spring, summer and autumn seasons throughout 2018 (Figure 1). Pure Turkish red pine stand in section 33 to be sampled has been put into production and the trees cut with the whole tree method in this area were transported by sliding uphill using a single drum crane mounted in front of an agricultural tractor in April 2018. During transportation, especially the parts of the log that were separated from the bottom log, destroyed the soil by tearing and removed the litter on it, revealing the mineral soil. In particular, samples were taken along this destroyed line and control samples were taken from undisturbed areas on both sides of this line (Figure 2). According to Köppen-Geiger climate classification (*www.koeppen-geiger.vu-wien.ac.at/*), the study site is characterized as a "hot and dry summer" environment (Csa). Weather data, including the long-term (1990-2017) normal averages for monthly air temperature (°C) and monthly precipitation (in mm) at Başkonuş in Kahramanmaraş province, Turkey, were obtained from the Turkish State Meteorological Service (*www.mgm.gov.tr/*). The mean annual temperature is 13.3 °C and annual accumulated average precipitation is 700 mm, with peaks slightly exceeding the 110 mm in December and the minimum is below 10 mm in July and August. Sandstone bedrock is dominant in the area and topography of the study site is highly variable, with an average slope of 30% and elevation 1000 m. Soil particle fractions such as average sand, silt, and clay ratios were found the higher coarse fractions in soil samples. Study site soils were found in sandy clay loam texture class.

Some characteristics for the sites under study, including sand, silt and clay content (%), slope, stand canopy, and others, are presented in Table 1.

Figure 1. Geographical location of the study site in Turkey.

Figure 2. Turkish red pine timber extraction by using farm tractor: uphill winching (a), crumbs of soil left on the log (b) and damage to the soil by skidding whole tree (c)

Table 1. Location and selected topographic features, soil texture, and pH classes of the study site in the Kahramanmaraş province, Turkey.

Properties	Sample Area	Control Area
Longitude	36º36’35’’	36º36’50’’
Latitude	37º35’25’’	37º35’50’’
Altitude **(m)**	1000	1000
Slope **(%)**	30	30
Vegetation Types	Çzcd3	Çzcd3
Canopy (%)	70-100	70-100
Soil texture	Sandy Clay loam	Sandy clay loam
pH classes	Slightly alkaline	Moderately alkaline

2.2. Method

2.2.1. Experimental design and soil sampling

Disturbed, undisturbed and microbial soil samples were taken from two levels (0-10 cm and 10-20 cm) from the middle of the scuffing pit and the closest undisturbed control areas every 20 m along two different skidding lines (60 m). In order to monitor the seasonal changes in the skidding line, soil samples were taken in three different seasons (spring, summer and autumn), with regarding to the average temperature and precipitation values of the seasons. Thus, a total of 72 soil samples, 2 lines x 6 points x 2 depth levels x 3 seasons, were collected from the study areas. Disturebed soil samples were taken for some physical and chemical analyses, and undisturbed soil samples (using 8 cm x 10 cm steel cylinders) were taken to determine the bulk density. In addition, microbial soil samples, which were passed through a 2 mm sieve and moistened 50-60% with distilled water, were kept in a +4 ºC refrigerator in the laboratory until their analysis.

2.2.2 Physical and Chemical Properties of Soils

Following field study, soil samples were oven-dried until constant mass weight in the laboratory (Karaöz 1992). Prior to analysis of soil parameters, air-dried soils were sieved to pass a 2 mm screen. The bulk denisity of the soil samples was calculated as the dry weight (105 °C at 24h) of soil divided by its volume. Soil moisture content was determened by gravimetically. Soil pH and electrical conductivity (EC) were measured in distilled water by using a glass electrode (1:2.5 w/v and 1:5 w/v soil/ water suspension for soil pH and EC, respectively) (Rowell, 1994). Soil particle size for texture determination was performed by mechanical analysis of the samples following the Bouyoucos Hydrometer Method (Ashworth et al., 2001; Bouyoucos, 1962). Organic matter values were determined by using the wet-oxidation method of Walkley-Black (Walkley and Black 1934) and total nitrogen was analyzed by usin midified-kjeldahl digestion method (Karaöz, 1992; Rowell, 1994). After saturating soil samples with taps water for 24 hours, soil water content at the field capacity (FC) was measured equilibrating soil moisture for 24 hours at 33 kPa and the permanent wilting point (PWP) was measured equilibrating soil moisture for 96 hours at 1500 kPa by using a pressure plate apparatus (Gülser and Candemir, 2014).

2.2.3. Soil microbial biomass and microbial respiration

Soil samples were removed from the refrigerator and equilibrated at room temperature for the soil microbial biomass analysis. Then, soil C_{mic} was analyzed in the incubation beakers by following the chloroform-fumigation-extraction method (Ladd and Amato, 1989). The C_{mic} of soils were determined by using the modified Walkley-Black method (Brookes et al., 1985; Vance et al., 1987). Briefly, 30 g (oven-dry basis) moist soil was fumigated for 24 h at 25 °C with ethanol-free chloroform ($CHCl_3$). Following fumigant removal, the sample was extracted with 40 mL 0.5 M K_2SO_4 by 30 min horizontal shaking at 90 rpm min^{-1} and filtered through a folded filter paper. Another 30 g portion of the same soil sample was also weighed for the nonfumigation analysis. The nonfumigated samples was similarly extracted with 40 mL 0.5 M K_2SO_4 by 30 min horizontal shaking at 90 rpm min^{-1} and filtered through a folded filter paper without utilizing the chloroform-fumigation process. Finally, the C_{mic} was calculated as follows in Eq. (1) (Vance et al., 1987):

Microbial Biomass C (C_{mic}) = $K_{EC} \times 2.64$ (1)

where K_{EC} refers to the difference in extractable organic C between the fumigated and unfumigated samples and 2.64 is the proportionality factor that accounts for the biomass C released by the fumigation extraction process.

The N_{mic} was analyzed according to the Modified Kjeldahl digestion method by using the following Eq. (2) (Brookes et al., 1985; Anderson and Ingram, 1996):

Microbial Biomass N (N_{mic}) = $F_N/0.54$ (2)

where F_N is the difference between N extracted from fumigated and unfumigated samples and 0.54 is the fraction of microbial biomass N released by the fumigation extraction process.

Microbial respiration (MR) was estimated with the sodium hydroxide (NaOH) trap method (Alef, 1995). Briefly, 30 g oven-dry equivalent weight was transferred separately into 250 mL capacity glass beakers.

Small beakers filled with 10 mL of 1 M NaOH were placed at the bottom of the jar to trap the evolved CO_2. The jars were fastened airtight and incubated for 7 d at 25 °C. After a week of incubation, the small beaker with the CO_2 absorbed in NaOH solution was removed and titrated with 0.1 M HCl after the addition of $BaCl_2$. The NaOH solution without soil, incubated as above, was also titrated. Then, MR was calculated as the amount of CO_2 evolution over the incubation period divided by the dry mass of soil. The $q CO_2$ was calculated as the ratio between MR rates (mg CO_2-C h^{-1} g^{-1}) to C_{mic} (Anderson and Domsch, 1990; Anderson and Domsch, 1993).

2.3. Statistical analysis

All of the soil samples taken from the field in different periods were analyzed in paralel. The SPSS 16.0 software package program was used for all statistical analyses. The normality of data was assessed with the UNIVARIATE procedure. Prior to analysis, assumptions of equal variances for each group were visually checked by plotting the studentized residuals against predicted values at $P > 0.05$. Across response variables and tree species, assumptions of homoscedasticity and approximation to normal distribution were met for all comparisons. By using the independent samples t test, the differences between some physical, chemical and microbiological properties of the soils in the control areas and the skidding areas were determined at the sgnificant level ($P<0.05$).

3. Results and Discussion

3.1. Physical and chemical properties of soil

The average values of some physical, chemical and moisture properties of soil samples taken from the rubbing and control points are shown in Table 2. According to these average values, sandy clay loam soil texture was noticed in both areas. The amount of sand, silt and clay of the top soils in the skidding area was found 62.8%, 12.9% and 24.3%, and in control areas 64.86%, 11.64% and 23.50%, respectively. There was no statistical difference in the mean values of the sand, silt and clay percentages of the top soils in the skidding and control areas ($P>0.05$). In the subsoils, it was determined that there was a decrease in the percentage of sand and an increase in the percentage of clay in the friction areas. The reason for this is thought to be due to the fact that 3-5 cm of the topsoil was torn away from the area and the topsoil of the skidding area was taken more deeply than the control area. The topsoils of both areas are lime-free and slightly alkaline and subsoils are less calcareous and medium alkaline soils. It was determined that soils were statistically significantly affected by harvesting in terms of lime and pH values ($P<0.05$). In terms of electrical conductivity average values, the EC values of the upper soils were higher than the lower soils. The mean values of soil organic carbon (SOC) and toral nitrogen (TN) were found to be statistically different from each other in the skidding (2.15%-0.13%) and control (2.90%-0.16%) areas ($P<0.05$). Also, It was determined that there was a significant decrease in the amount of carbon and nitrogen stock (26.17 C kg/ha-1.88 N kg/ha) in the topsoil of the skidding areas compared to the control areas (34.27 C kg/ha-2.01 N kg/ha) (Table 2). So, the carbon loss or displacements in the area as a result of harvesting activities are an effective factor in this.

Statistically significant differences were found in the C_{org}/N_{total} ratio ($P<0.05$). It is predicted that the rate of decomposition may have increased in parallel with the increasing soil temperature as a result of the removal of the litter layers from the soil surface in the skidding areas. Therefore, the C_{org}/N_{total} ratio was found to be lower (25%) in the skidding areas than in the control areas. As it is known, the increase in the amount of nitrogen in the soil is an indicator of increased mineralization and accelerated decomposition (Babur and Dindaroglu, 2020). Zeller et al. (2000) noticed that the high C_{org}/N_{total} (>20) ratio in forest ecosystems causes low carbon and nitrogen mineralization, while low C_{org}/N_{total} ratio (<20) ratio is an indicator of intense carbon and nitrogen mineralization.

As a result of the examination of the water potential of the soils, it was determined that the average values of the FC, PWP and plant available water capacity (PAWC) were higher in the control areas and that the skidding negatively affected the water holding capacity of the soils. The mean particle density and bulk density values of the sample and control area soils were found to be statistically insignificant (P>0.05). In addition, the porosity of the soils was found to be almost close to each other.

Table 2. Comparison of some general characteristics of the soils belonging to the control and destroyed areas by harvesting activities in the production area (n=36).

Soil properties	Soil samples		Control	
	Topsoil	Subsoil	Topsoil	Subsoil
Sand %	62, 78±4,62a	60, 77±4,71a	64,86±4,60a	62, 53±5,13a
Silt %	12,93±1,53a	12,03±2,48a	11,60±0,58a	12,97±3,79a
Clay %	24,20±6,06a	27,20±4,05a	23,50±5,19a	24,50±3,98a
pH (H_2O)	7,68±0,10a	7,55±0,08a	7,92±0,27a	7,66±0,26a
EC ds m^{-1}	0,11±0,01a	0,04±0,01a	0,19±0,01b	0,05±0,00c
C_{org} %	2,15±0,15a	1,63±0,27a	2,90±0,32b	1,85±0,10a
N_{total} %	0,13±0,03a	0,08±0,01a	0,16±0,03a	0,08±0,00a
C_{org}/N_{total}	13,94±0,22a	15,83±1,41a	17,18±1,17b	20,60±0,51a
C_{stock} kg/ha	26,17±1,45a	20,48±3,01a	34,27±2,92b	23,41±1,24a
N_{stok} kg/ha	1,88±0,12a	1,30±0,23a	2,01±0,30b	1,14±0,04a
FC	27,97±1,52a	30,27±0,59a	29,96±2,04a	33,05±1,30a
PWP	16,41±1,53a	15,92±1,11a	16,51±1,71a	18,49±0,94a
AWHC	11,55±2,53a	14,36±1,24a	13,45±0,95a	14,53±0,72a
Bulk density	1,22±0,03a	1,26±0,03a	1,19±0,29a	1,27±0,02a
Particle density	2,67±0,04a	2,77±0,05a	2,58±0,25a	2,78±0,04a
Porosity	54,37±1,22a	54,64±1,73a	54,04±1,48a	54,43±1,41a

Abbreviations: EC: Electrical conductivity, C_{org}: Organic carbon, N_{total}: Total nitrogen, FC: field capacity, PWP; parmenent wilting point, AWHC: Available water holding capacity

3.2. Seasonal changes of microbial soil properties

As a result of seasonal variations of the temperature and moisture values of the soils belonging to the sampling and control areas, it was determined that the soil surface was significantly affected by the climatic conditions as a result of the destruction of the litter covering the surface of the soil in the skidding areas and the breaking of the stand cover as a result of production ($P<0.05$; Table 3). The increase in temperature and the low rainfall in summer caused a significant increase in soil temperature. Although the temperature of the sample area soils is higher than that of the control areas in summer season, this is the opposite in terms of soil moisture (Table 3). The destruction of the litter layers, which protects the soil against external influences and acts as a buffer, along the skidding line has caused a significant decrease in soil moisture. As a result of the seasonal changes of the pH and EC average values of the topsoil, the highest pH average value of 7.92 was found in the control areas in the spring, and the lowest pH value of 7.45 in the summer season in the plowing areas. Also, in the subsoils, the highest average pH values were observed in the spring and autumn seasons. The highest mean EC values of the topsoils were found in the summer and autumn seasons of the control areas soils, as well. There was no statistical difference in the mean EC values in the subsoils.

When the changes in the OC and TN amounts of the topsoils according to the seasons were examined, it was determined that the highest carbon content (3.01%) was in the control areas in autumn, and the lowest OC amount was in the summer months. In order to meet the nutrient requirements of plants and microbial organisms in the summer season, the organic material in the soil must be synthesized and organic matter consumption is higher than the amount of organic matter entering the soil, causing a decrease in the amount of organic carbon (Kara et al., 2016; Babur et al., 2021). The highest total nitrogen content of the soil (0.18%) was found in the autumn season in the control area, and the lowest total nitrogen average value (0.13%) was found in the spring season in the skidding areas. The total nitrogen average values of the soils in the subsoil level were found to be close to each other and had no significant difference (Table 4).

It was determined that the harvesting activities had a statistically significant effect on the C_{mic}, N_{mic} and

MR average values of the soils. The C_{mic} values of the topsoil in the sampling areas were lowest in the summer with 657.17 μg•g^{-1} and the highest in the autumn with 763.76 μg•g^{-1}. In the control areas, the lowest C_{mic} value was 773.99 μg•g^{-1} in spring and the highest 886.15 μg•g^{-1} in autumn (Figure 3 and 4). Significant reductions in microbial biomass were observed with loss of organic carbon in the soils in the skidding areas. This is thought to be due to the loss of organic matter and moisture in the soil which are the most important parameters for the life of soil microorganisms (Patel et al., 2010; Babur and Dindaroğlu, 2020). In addition, statistically significant differences were found in microbial properties in parallel with seasonal variations in changing the temperature and humidity values in the soil (P<0.05; Table 3 and 4). It was also determined that the amount of N_{mic} in the both soil layers of the control areas of the research areas was higher than the amount of N_{mic} in the sample areas (Table 3 and 4; Figure 4).

From the results obtained, it was determined that the chemical and microbial properties of the topsoil in the skidding areas decreased significantly compared to the control areas. Soil macro and micro organisms are very sensitive to even the smallest changes in the soil (Babur ve Dindaroglu, 2020). Microbial biomass and microbial activities of soils significantly affect the amount of soil organic matter (Jenkinson, 1988). In addition, some other characteristics such as temperature, humidity, pH, lime content, soil structure and texture, parent material, plant species and stand type ...etc. affect the populations and contents of soil microbial organisms (Patel et al., 2010; Babur, 2019). The results found in this study ara similar to soil C_{mic} (61–2,000 lg g-1) found in temperate forests by Vance et al., (1987b); (102–2,073 lg g-1) in tropical forests by Hernot and Robertson (1994) and (386–1,050 lg g-1) in larch forests by Kara and Bolat (2007).

From the data obtained in the study, it was determined that the microbial biomass carbon (r=0.709*) and nitrogen (r=0.915**) values of the topsoil were positively and strongly related to soil moisture and therefore negatively related to temperature (r=-0.317* ve r=-0.676*, respectively). In addition, soil C_{mi} and N_{mi} values were found to have positive relationships with soil carbon (r=0.719* and r=0.725*) and nitrogen values (r=0.885** and r=0.629*, respectively).

Microbial quotient (C_{mic}/C_{org}) and metabolic quotient (MR/C_{mic}) ratios of microbial indexes of topsoils in the study areas have changed significantly (P<0.05). It was also found that the C_{mic}/N_{mic} ratio in the skidding areas were higher than the control areas. The C_{mic}/N_{mic} ratio is used as an indicator of the microorganism type. A ratio of 3-5 indicates that the bacterial population is dominant, while a ratio of 10-12 indicates that the fungal population is dominant (Devi and Yadava, 2006). According to our results, it was determined that both bacterial and fungal populations are present in the topsoils of the research area, but the bacterial population is more dominant into the deeper of soil (Table 3 and 4). N_{mic}/N_{total} percentages of the topsoil of the skidding areas were higher than the control area in all seasons except summer. Statistically significant differences were found in the N_{mic}/N_{total} percentages in different seasons (P<0.05). It was determined that the N_{mic}/N_{total} amount of control areas was higher in subsoils. A high rate indicates that the amount of available nitrogen in the organic matter composition is good (Khan and Joergensen 2006). If this value is low, it is an indication of poor soil substrate quality (Bauhus et al., 1998).

Microbial soil respiration is the amount of CO_2 released into the atmosphere as a result of the oxidation of organic matter by aerobic microorganisms. Soil microbial respiration is used to predict the microbial activity of soils (Winding et al., 2005). According to Sparling (1997) and Alvarez et al., (2009), soil microbial respiration is a very important parameter in monitoring the rate of decomposition. However, soil respiration is affected by ecological and edaphic factors such as moisture content, temperature, substrate quality…etc. (Tufekcioglu et al., 2006; Güner et al., 2010; Babur, 2019). Nilsen and Strand (2008) determined that thinning affects soil respiration by directly affecting soil moisture, temperature, litter biomass and stand cover.

The mean values of soil microbial respiration in the skidding areas were found to be higher than the soils of the control areas, in contrast to the C_{mic} and N_{mic} values. The reason for this is that microbial organisms tend to continue their lives by breathing more due to moisture loss in the soil that is directly exposed to external factors such as sunlight after skidding. In this study, microbial respiration have average values varying between 1.24 and 2.08 lg CO_2–C g^{-1} h^{-1} in the topsoils and 0.68–0.99 lg CO_2–C g^{-1} h^{-1} in the subsoils (Figure 5). Microbial respiration directly affects the carbon storage capacity in terrestrial ecosystems as it affects all of the soil organic matter and other microbial parameters (Alef, 1995; Winding et al., 2005).

It was determined that the metabolic quotient (qCO_2) average values of the topsoils were highest in the skidding area soils in summer months and the lowest values in the control areas in the spring. According to the seasons, the qCO_2 average values of the skidding soils were found to be statistically higher than the control ($P<0.05$). Similarly, Anderson (2003) emphasized that neutral microbial respiration ranged between 0.5 and 2.0 mg CO_2–C g^{-1} C_{mic} h^{-1}. Bolat (20014) found a negative relationship between qCO_2 and SOC, pH and lime. High qCO_2 amount is one of the stress indicators of terrestrial ecosystem. Odum (1985), and Anderson and Domsch (1993) also stated that the amount of qCO_2 is higher in unhealthy soils. However, it was stated that low qCO_2 amount was associated with plant succession (Insam and Haselwandter, 1989). In addition, qCO_2 provides information about the ecophysiological (Anderson and Domsch 1985; Insam et al., 1996), substrate quality and availability of soil microbial communities (Dilly et al., 1997; Dilly and Munch, 1998).

The percentage of C_{mic}/C_{org} (microbial quotient) also correlates with substrate quality. This rate is also sensitive to changes in the ecosystem and is highly affected (Bauhus et al. 1998; Anderson, 2003). In addition, this ratio can help us to predict changes in soil carbon (Anderson and Domsch 1989). Jenkinson and Ladd (1981) stated that the equilibrium threshold of C_{mic}/C_{org} percentage in soil is 2.2. Also, the C_{mic}/C_{org} percentage has been reported to have a wide range of values between 0.27 and 7.0% (Anderson and Domsch, 1989). In this study, it was determined that the C_{mic}/C_{org} average values of the skidding soils were higher than those of the control soils. According to data, the highest C_{mic}/C_{org} ratio was found in the topsoils of the skidding areas in autumn (3.64%) and the lowest (2.17%) in the subsoils of control in the spring (Tables 3 and 4). Smilarly, Kara et al., (2008) found the ratio of C_{mic}/C_{org} in the soils of temperate forests to be between 2.26–3.17%.

These results show us that changes in some factors such as soil, plant biodiversity, forestry practices and sampling time have a significant effect on the change in the C_{mic}/C_{org} ratio (Anderson and Domsch, 1989; Vesterdal et al., 1995).

Table 3. Seasonal changes in some physicochemical and microbial properties of topsoils (0-10 cm) (n=12).

Soil	**Soil sample**			**Control**		
properties	Spring	Summer	Autumn	Spring	Summer	Autumn
Temp. C°	15,30±0,27a	25,93±0,60c	18,13±0,15e	13,97±0,15b	22,33±0,21d	19,57±0,12f
SM %	30,53±1,02a	11,88±0,84c	42,98±1,23e	38,88±2,73b	27,99±1,25d	53,27±0,32f
pH(H_2O)	7,68±0,10a	7,45±0,11	7,63±0,12e	7,92±0,27a	7,80±0,22	7,91±0,24e
EC ds m^{-1}	0,11±0,01a	0,13±0,02c	0,13±0,01e	0,19±0,01b	0,20±0,00d	0,20±0,02f
OC %	2,15±0,15a	2,02±0,11c	2,10±0,15e	2,90±0,32b	2,85±0,30d	3,01±0,36f
TN%	0,13±0,03a	0,16±0,01	0,14±0,02e	0,16±0,03a	0,17±0,02	0,18±0,04e
C_{mic}	700,9±71,6a	657,17±65,4c	763,57±76,3e	773,99±70,1b	855,17±77,6d	886,15±75,5e
N_{mic}	97,65±1,95a	93,62±2,18c	105,19±4,07e	112,20±9,43a	118,49±5,05d	124,29±6,03f
MR	1,24±0,11a	2,08±0,30c	1,55±0,32e	1,30±0,17a	1,69±0,10d	1,67±0,11e
C_{mic}/N_{mic}	7,17±0,63a	7,01±0,55	7,27±0,79e	6,90±0,10a	7,21±0,38	7,13±0,41e
C_{mic}/C_{org}	3,26±0,20a	3,25±0,27	3,64±0,23e	2,68±0,24b	3,01±0,29	3,00±0,35f
N_{mic}/N_{total}	7,72±1,60a	6,09±0,32	7,87±1,62e	7,18±1,03a	7,08±0,96	7,66±0,94e
MR/C_{mic}	1,77±0,22a	3,17±0,10c	2,03±0,11e	1,68±0,19a	1,98±0,19d	1,88±0,15f

Abbreviations: SM; soil moisture, EC; electrical conductivity, OC; organic carbon, TN; total nitrogen, MBC; microbial biomass carbon, MBN; microbial biyomass nitrogen, MR; microbial respiration,

Table 4. Seasonal changes in some physicochemical and microbial properties of subsoils (10-20 cm) (n=12).

Soil properties	**Soil sample**			**Control**		
	Spring	Summer	Autumn	Spring	Summer	Autumn
Temp. C°	14,50±0,17a	23,57±0,40c	19,03±0,25e	13,33±0,2b	21,17±0,21d	20,40±0,44f
SM%	26,15±1,59a	17,70±1,14c	39,04±0,80e	42,39±1,5b	30,04±1,29d	50,23±2,75f
pH(H_2O)	7,55±0,08a	7,40±0,04c	7,57±0,06e	7,66±0,26a	7,59±0,21c	7,66±0,27e
EC ds m^{-1}	0,04±0,01a	0,04±0,06c	0,05±0,01e	0,04±0,00a	0,05±0,00c	0,04±0,00e
OC %	1,63±0,27a	1,58±0,28c	1,67±0,26e	1,85±0,10a	1,82±0,10c	1,93±0,07e
TN%	0,08±0,01a	0,10±0,01c	0,09±0,01e	0,08±0,00a	0,09±0,00c	0,09±0,00e
MBC	382,37±12,2a	401,2±12,3c	432,6±21,1e	400,9±9,8a	438,5±25,8c	457,3±25,7e
MBN	65,11±4,1a	68,60±3,1c	72,41±2,2e	93,74±2,5b	97,91±1,0d	103,01±1,8f
MR	0,68±0,03a	0,99±0,05c	0,87±0,06e	0,75±0,07a	0,88±0,09c	0,85±0,10e
C_{mic}/N_{mic}	5,89±0,42a	5,86±0,37c	5,99±0,66e	4,28±0,21b	4,48±0,25d	4,44±0,25f
C_{mic}/C_{org}	2,38±0,36a	2,59±0,44c	2,62±0,30e	2,17±0,10a	2,41±0,03c	2,37±0,06e
N_{mic}/N_{toplam}	8,82±1,55a	6,77±1,25c	8,64±1,77e	11,92±1,54a	10,93±0,36d	11,28±0,62e
MR/C_{mic}	1,77±0,26a	2,46±0,25c	2,01±0,22e	1,87±0,23a	2,01±0,14c	1,86±0,23e

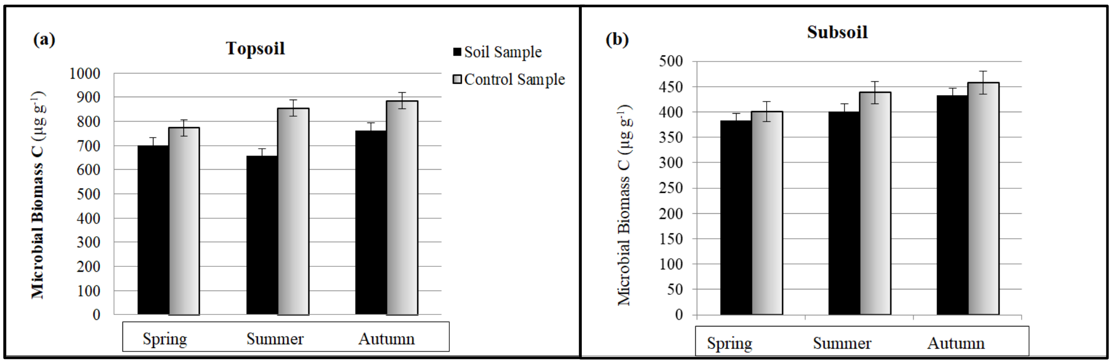

Figure 3. Seasonal changes in microbial biomass C content of topsoil (a) and subsoil (b) samples. Values showed by different numbers and lowercase letters differ significantly between seasons ($p < 0.05$).

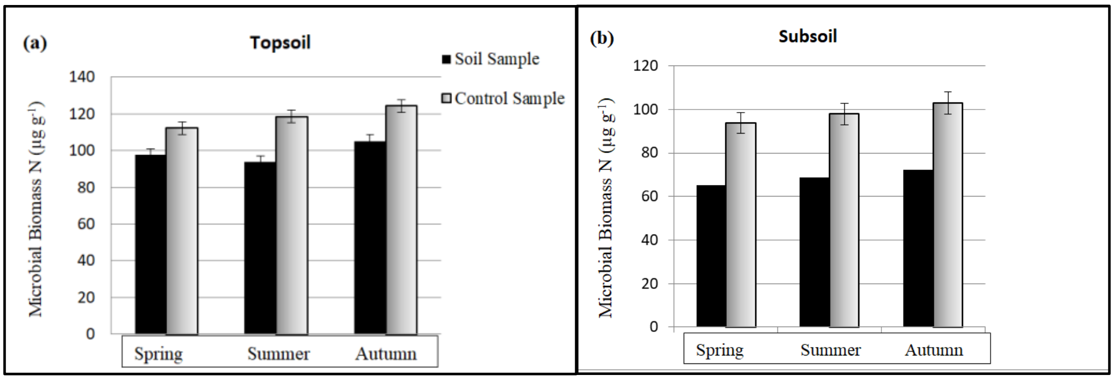

Figure 4. Seasonal changes in microbial biomass N content of topsoil (a) and subsoil (b) samples. Values showed by different numbers and lowercase letters differ significantly between seasons ($p < 0.05$).

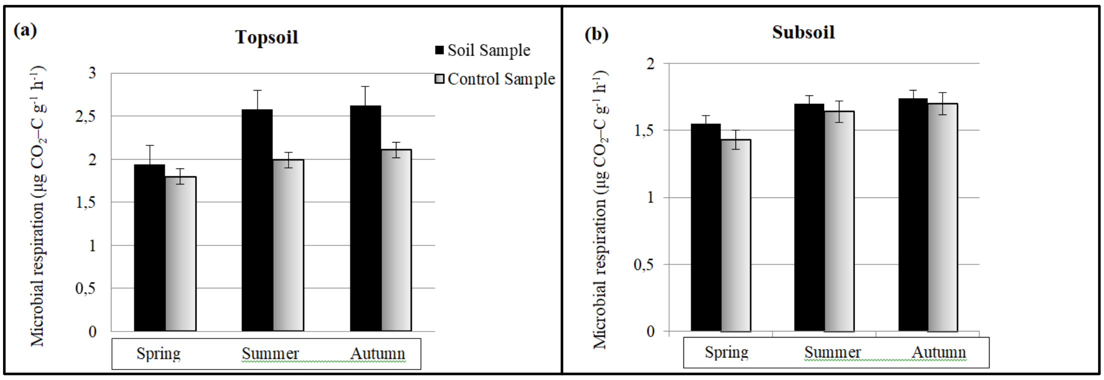

Figure 5. Seasonal changes in microbial respiration of topsoil (a) and subsoil (b) samples. Values showed by different numbers and lowercase letters differ significantly between seasons ($p < 0.05$).

4. Conclusion

In this study, the effects of the harvesting application on some physicochemical and microbial properties in the short term were investigated after the whole tree method was removed from the partition using a farm tractor. As a result of short-term monitoring in the research area, it has been observed that the skidding and production processes of wood raw materials cause significant changes in the soil properties such as the organic carbon, total nitrogen, temperature, moisture, microbial biomass C, N, and microbial respiration. Significant decreases were observed in the carbon and nitrogen stoks and microbiological properties of the soils compared to the control areas, especially in the summer months when drought is observed in the soil destroyed as a result of harvesting. The most negative effect of skidding can be seen as degradation and destroying the topsoil (5-10 cm deep-Ah horizon) with the dead cover on it. The microbial respiration and metabolic quotient values in the control areas are less than the sample areas. This is an indication that the microbial population in the sampling areas consumes more energy in parallel with the increase in temperature and that stress conditions begin to occur in the soil. In forestry activities, it is important for forest and soil health to monitor the changes in the microbiological properties of soils over long periods and to produce in a way that will cause minimum damage to the soil. For this reason, skidding is required during the periods of production activities when the soils are harder. In addition, there is a need to develop alternative extraction methods without skidding and destruction of the soil surface.

Acknowldgemend

I am grateful to Dr. Sercan GÜLCİ at the Kahramanmaraş Sütçü Imam University and unit chief Nihat NURDOĞAN at the Kahramanmaraş Forestry General Dirortorate for their valuable Assisting in the supply of the research area and the equipment used.

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Dergiye başvuru tarihi: 09.10.2021 Yayınlanmaya kabul edilme tarihi: 29.09.2021