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Dependency of Soil Organic Carbon Mineralization to Moisture and Temperature under Different Land Uses

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Abstract: Temperature and humidity are the important environmental factors that control the decomposition of organic carbon in the soil. The sensitivity of the soils to temperature and moisture may vary. The aim of this study is to determine the change in mineralized C content of different soils (agriculture, pasture and forest) at different temperature (20 ºC and 35 ºC) and humidity conditions (30% and 60% of field capacity). This study was carried out in agriculture, forest and pasture lands in Almus district of Tokat province. In the study, soil samples were taken from 0-5, 5-15 and 15-30 cm depths by hand probe. Particle distribution, pH, lime, organic matter, total C, organic C, microbial biomass C and mineralize C were determined in the samples. Mineralize C content was determined by incubation of 30% and 60% of field capacity at 20 ºC and 30 ºC. Soils were generally classified as clay texture. The highest organic C was found in forest soil. Microbial biomass C showed significant change depending on land use. The difference between the land uses at 20 °C incubation was only observed at 60% of field capacity. The similar trend was also seen at 35 °C temperature. Significant differences have been observed between uses at high humidity conditions. While the increase in the amount of moisture significantly increased the amount of mineralize C in agricultural soil, the increase in temperature in forest soil was significant. This result indicates that the amount of mineralize C in the forest soil is more sensitive to temperature, while agricultural soil is more sensitive to the increase in moisture content.

Keywords: Land use, soil temperature, soil moisture, mineralize C

Farklı Arazi Kullanımlarında Organik Karbon Mineralizasyonun Sıcaklık ve Neme Duyarlılığının Belirlenmesi

Öz: Çevresel faktörlerden sıcaklık ve nem toprakta organik karbonu ayrışmasını kontrol eden faktörlerdir. Farklı kullanımlar altındaki toprakların sıcaklık ve neme karşı duyarlılıkları farklılık gösterebilir. Bu çalışmanın amacı farklı kullanımlar altındaki (tarım, mera ve orman) toprakların farklı sıcaklık (20 ºC and 35 ºC) ve nem koşullarında (tarla kapasitesi (TK) % 30 ve % 60) mineralize C içeriklerindeki değişimin belirlenmesi. Bu çalışma Tokat ili Almus ilçesindeki tarım, orman ve mera arazilerinde yürütülmüştür. Çalışmada toprak örnekleri 0-5, 5-15 ve 15-30 cm derinliklerden el burgusu yardımıyla alınmıştır. Alınan örnekler analize hazırlandıktan sonra toprakların tekstür, pH, kireç, organik madde, toplam C, organik C, mikrobiyal biyokütle C ve mineralize C değerleri belirlenmiştir. Mineralize C miktarı tarla kapasitesin % 30 ve % 60 nem düzeyinde, 20 ve 30 ºC sıcaklıklarda inkübasyonla belirlenmiştir. Topraklar genel olarak killi tekstür sınıfında bulunmuştur. Organik karbon arazi kullanımına göre en yüksek orman toprağında belirlenmiştir. Mikrobiyal biyokütle C arazi kullanımına bağlı olarak önemli değişiklik göstermiştir. Farklı kullanımlar altındaki toprakların 20 °C sıcaklık ve iki farklı nem koşulunda, kullanımlar arasında fark yalnızca TK % 60 nem düzeyinde görülmüştür. Benzer durum 35 ºC sıcaklıkta da görülmüştür. Yüksek nem koşullarında kullanımlar arasında önemli farklılık oluşmuştur. Nem miktarındaki artış tarım toprağında mineralize C miktarını önemli düzeyde artırırken, orman toprağında sıcaklıktaki artış önemli olmuştur. Bu durum orman toprağında mineralize C miktarının sıcaklığa daha duyarlı olduğunu ortaya koyarken, tarım toprağının nem miktarındaki artışa daha duyarlı olduğunu görülmüştür.

Anahtar kelimeler: Arazi kullanımı, toprak sıcaklığı, toprak nemi, mineralize C.

1.Introduction

The wrong use of lands lead to the increase of the greenhouse gases (CO_2) that affect the climate change, which is the greatest problem in this century by returning organic carbon to the atmosphere (Lal, 2003; Zinn et al., 2005). Thus, it is great importance to keep CO_2 in the form of organic carbon through vegetation in the soil (IPCC, 2000). The soil of our country has been cultivated since 7000 years and it is very poor in organic matter (Dinç et al., 2001). This is mainly due to the burning of harvest waste and low organic matter inputs in the soil. The reduction of soil organic matter reduces the water holding capacity of the soil, the amount of nutrients, microorganism activities, and soil aggregation.

The studies conducted in the Midwest of the United States, perennial meadow plants gain 1.1 t ha^{-1} of carbon per year to the soil. This amount accounts for 23% of the same area lost by agriculture (McLaughlin and Walsh, 1998). In terrestrial ecosystems, carbon is squestred in soil and vegetation. This means is in forests, pastures and in agricultural areas. Over time, it is possible to store these organic compounds in the soil for many years. Changes in climate, vegetation type, soil characteristics, erosion, bedrock, land use are important factors affecting the amount and duration of carbon deposition in terrestrial ecosystems. Organic carbon can be protected in the soil for a very long time under suitable conditions. On the other hand, changes in land use and intensive soil cultivation techniques for agricultural use, erosion, different silvicultural applications in forests significantly reduced carbon stocks in terrestrial ecosystem. The amount of organic carbon in the soil falls to the lowest level in the first 20 years of land use change, while a period of about one hundred years is needed to maximize the amount of organic carbon in the same soil. There was a significant relationship between plant type and microbial activity and organic matter quality). A study conducted in Mediterranean indicated that carbon mineralization rates of soils were only significant in Pinus (1.39% for marl and 3.30% for conglomerate), whereas this difference was not significant for *Olea europaea L.* and *Pistacia terebinthus L.* (Sağlıker ve Darıcı 2005). The increase in soil temperatures as a result of global warming will significantly affect the rate of decomposition of organic carbon. Research findings showed that CO_2 output is higher in forest soil than mineral soil samples. They determined that the CO_2 output in the forest cover increased with temperature, but the lowest rate in both dry and humid environments (Bowden et al., 1998). Carbon mineralization and temperature dependence in the upper layers of the paddy field soil were investigated and carbon mineralization increased with the increases of temperature from 20 to 25 ^oC as 9.22 to 11.35 mg CO_2-C g^{-1}, respectively (Pan et al., 2010). The increase in soil temperature as a result of global warming will affect the amount of carbon mineralized in different ecosystems. The effect of temperature and humidity on carbon mineralization may vary under different land uses. The objective of this study was to determine the sensitivity of the mineralized carbon to moisture and temperature in soils under forest, pasture, and cultivated lands.

2. Materials and Methods

This study was carried out in natural pasture, forest and agricultural areas in the district of Almus in Tokat, Turkey. In each area, three different sampling locations were selected which could represent the land well. The study has ustic moisture and mesic soil temperature regime. Three different samples were collected from each sampling site and all analyzes were performed in these compose samples. In this study, soil samples were taken from 0-5, 5-15 and 15-30 cm depths using a hand probe. These samples were stored at 4 ° C until the analysis and the changes during the waiting period were reduced to minimum. Soil particle distribution, soil reaction (pH), organic matter (%), lime content (%), field capacity, total C, organic C, mineralized C, and microbial biomass carbon were determined in the soil samples. Soil particle distribution was determined by Bouyocous hydrometer method (Bouyoucous, 1951). Soil reaction (pH) was determined in the mixture of soil and water (1:2.5 w/v) (Richards, 1954). Soil carbonates were determined by the calcimeter method (Nelson, 1982). The field capacity was determined after saturating the soil samples and exposing to 1 bar pressure (Klute, 1986). Soil organic matter content was measured using the modified Walkley-Black wet oxidation procedure (Nelson and Sommers, 1982). Microbial biomass was determined by fumigation-incubation method (Horwarth and Paul, 1994). In order to determine the effect of different temperature and humidity on mineralized C, two different temperatures (20 ºC and 35 °C) and humidity value (60% and 30% of field capacity) were used in the study. Soil samples were determined by laboratory incubation for 28 days at specified temperature and humidity values (Paul et al., 2001). The data obtained were analyzed by ANOVA and the smallest mean difference test was made by using SPSS 15 according to α = 0.05 significance level.

3. Results and Discussions

Soil particle distribution through the soil depth is given in Table 1. The sand content was highest in the forest soil while the lowest was in the agricultural field. The change in the amount of sand and clay was found to be significant ($p < 0.05$). The silt content was similar in three different land uses. In terms of depth, no significant change was observed in sand, clay and silt contents ($p > 0.05$). Clay content was higher in agricultural soil compared to other uses. It is seen that clay content is very similar in pasture and forest. It is observed that soil texture is a clay texture with the exception of 0-5 cm depth of the forest which is clay loam. In addition, a decrease in clay content was observed in the forest by washing clay on the surface.

Table 1. Soil particle distribution under different land uses
Çizelge 1. *Farklı kullanımlar altındaki topraklarda tanecik dağılımı*

Land use	Depth (cm)	Sand (%)		Silt (%)		Clay (%)		Soil Class
Agricultural field	0-5	13.07 (1.77)[1]		22.61 (2.91)		64.32 (2.00)		Clay
	5-15	1.07 (1.77)		23.61 (5.37)		65.32 (5.14)		Clay
	15-30	6.40 (1.16)		26.28 (1.00)		62.32 (4.17)		Clay
Forest	0-5	30.40 (6.02)		28.61 (6.77)		43.32 (5.01)		Clay loam
	5-15	23.07 (4.81)		23.28 (8.01)		53.65 (5.82)		Clay
	15-30	27.07 (4.06)		24.61 (2.91)		48.32 (1.16)		Clay
Pasture	0-5	16.40 (1.16)		31.28 (8.02)		46.99 (8.20)		Clay
	5-15	17.73 (1.33)		28.61 (4.81)		53.65 (5.34)		Clay
	15-30	15.73 (3.53)		26.61 (1.33)		57.65 (1.33)		Clay
		Mean	P[2]	Mean	P	Mean	P	
Land use	Ag-field	10.17		24.16		63.98		
	Forest	26.84	0.005	25.50	ns	48.43	0.017	
	Pasture	16.62		28.83		52.76		
Depth	0-5	19.95		27.50		51.54		
	5-15	17.28	ns	25.17	ns	57.54	ns	
	15-30	16.40		25.83		56.10		
Land use*Depth			ns		ns		ns	

[1] indicates standard error.
[2] represent probability.

There was no significant different in soil pH due to land use and depth (Table 2). Land use and depth interaction were also not significant in this study ($p > 0.05$). In general, the pH values of soils showed a slightly alkaline condition. A slight decrease in the surface soil pH was observed in the forest. This is an effect of the acidic character of forest waste. The land use did not have a significant impact on the lime content ($p > 0.05$). According to depths, the highest value was observed on surface soil. Interaction between land use and depth was found insignificant (p> 0.05). Oğuz and Acar (2011) found the highest lime content in the surface soil of the orchard and the lowest lime content in the surface soil of the agricultural land in different land uses. Soil organic matter content varies between 2.08% and 5.34%. The amount of organic matter in the soil is closely related to the climate, soil texture, topography, drainage, the quality of the organic matter added to the soil and the processes applied to the soil. The high organic matter in the forest is a result of the high amount of organic matter added to the soil and the slowness of decomposition. The reason for the lower organic matter in the agricultural land is that the intensive soil cultivation causes the organic matter to decompose rapidly by increasing the aeration and a large part of the organic matter produced is removed from the soil as the product. The amount of organic matter in the soil is the result of the balance between the organic matter falling into the soil and decomposing in the soil. The climate affects the microorganism activities in the soil. There is an inverse relationship between soil cultivation and the amount of organic matter. Riezebos and Loerts (1998) and Jaiyeoba (2003) showed that organic matter content decreased in forest that were converted to agriculture use. The field capacities of the soils are similar in different land uses. The effect of land use and depth on field capacity was not significant (p> 0.05). This is the result of the similar of soil texture classes. The amount of clay and organic matter contents in the soil is highly effective on the field capacity.

Table 2. Soil pH, lime, organic matter content, and field capacity of soils under different land uses
Çizelge 2. *Farklı kullanımlar altındaki toprakların pH, kireç, organik madde ve tarla kapasiteleri*

Land use	Depth (cm)	pH	Lime (%)	Soil organic matter (%)	Field capacity (%)
Agricultural Field	0-5	7.81 (0.11)[1]	10.88 (1.65)	2.29 (0.20)	61.25 (2.30)
	5-15	7.82 (0.13)	7.84 (1.71)	2.08 (0.32)	51.18 (10.77)
	15-30	7.64 (0.01)	10.68 (2.44)	2.34 (0.11)	61.5 (11.16)
Forest	0-5	7.60 (0.11)	12.00 (0.38)	5.34 (0.21)	56.95 (1.20)
	5-15	7.80 (0.06)	6.60 (0.57)	3.20 (0.33)	60.00 (4.63)
	15-30	7.94 (0.07)	11.71 (1.91)	2.23 (0.31)	70.85 (4.39)
Pasture	0-5	7.76 (0.08)	17.06 (1.36)	3.42 (0.61)	69.10 (0.60)
	5-15	7.81 (0.05)	8.20 (2.33)	2.49 (0.26)	61.97 (2.22)
	15-30	7.82 (0.08)	17.21 (4.31)	2.56 (0.16)	61.93 (5.78)

		Mean	P[2]	Mean	p	Mean	p	Mean	p
Land use	Ag-field	7.75		9.79		2.34		57.97	
	Forest	7.80	ns	10.10	ns	3.58	0.001	62.60	ns
	Pasture	7.79		14.15		2.82		64.33	
Depth	0-5	7.27		13.31		3.68		62.43	
	5-15	7.81	ns	7.54	0.021	2.59	0.001	57.71	ns
	15-30	7.82		13.19		2.37		64.76	
Land use* depth			ns		ns		0.004		0.001

[1] indicates standard error.
[2] represent probability.

The change in organic carbon content was found to be significant according to land use (Table 3). The highest organic carbon content was found in forest soil and the lowest one was determined in agricultural field. When we look at the change in depth, the amount of organic carbon has decreased significantly through soil depth from the surface. Land use and depth interaction was statistically significant. Zhao et al. (2005) indicated that conversion of a natural pasture to cultivated land was reduced organic carbon and deteriorated soil. The total amount of organic C stored in the forest is about twice than the agricultural land. A large part of the C stored in the forest is stored in the surface soil. This is the result of the accumulation of forest waste on the surface soil. Pasture had the second largest organic C content after the forest and the organic C decreased from the surface to the lower layers and remained fairly constant at 5-15 and 15-30 cm depths. There was no significant difference between the depths in agricultural soil. Since the top layer is constantly mixed with cultivation in the agricultural soil. However, the organic C content will decrease when further go to deeper depths in the agricultural soil. With the opening of the forest area to agricultural use caused 50% loss of organic C. Microbial biomass C has changed significantly according to land use. The effect of land use on microbial biomass was found to be statistically significant ($p < 0.05$). The highest microbial biomass was measured as 46.66 mg C kg^{-1} in forest soil and the lowest value was determined as 27.57 mg C kg^{-1} pasture soil. The effect of depth on microbial biomass C was not significant in the three land uses ($p > 0.05$). Land use and depth interaction are significant. Kara and Bolat (2008) found the highest microbial biomass C in forest soil compared to other land uses.

Table 3. Soil organic C, microbial biomass C, and total C under different land uses
Çizelge 3. *Farklı kullanımlar altında organik C, mikrobiyal biyokütle C ve toplam C*

Land use	Depth (cm)	Organic C (g C kg^{-1})		Microbial biomass C (mg C kg^{-1})		Total C (g C kg^{-1})	
Agricultural Field	0-5	13.27 (1.14)[1]		35.71 (10.42)		26.33 (2.61)	
	5-15	12.07 (1.82)		30.27 (9.52)		21.48 (3.45)	
	15-30	13.55 (0.63)		24.71 (3.10)		26.36 (2.81)	
Forest	0-5	30.97 (1.21)		55.6 (15.86)		55.21 (9.90)	
	5-15	18.57 (1.89)		41.85 (10.41)		26.50 (2.57)	
	15-30	12.9 (1.82)		42.52 (8.64)		26.95 (3.78)	
Pasture	0-5	19.82 (3.54)		25.81 (5.14)		41.29 (3.23)	
	5-15	14.43 (1.50)		35.95 (10.65)		28.69 (5.01)	
	15-30	14.83 (0.94)		20.96 (0.23)		37.48 (3.07)	
		Mean	P[2]	Mean	p	Mean	p
Land use	Ag-field	12.96		30.23		24.72	
	Forest	20.81	0.001	46.66	0.033	36.22	0.01
	Pasture	16.35		27.57		35.82	
Depth	0-5	21.35		39.04		40.94	
	5-15	15.02	0.001	36.03	ns	25.55	0.002
	15-30	13.76		29.4		30.26	
Land use* depth			0.004		ns		0.039

[1] indicates standard error.
[2] represent probability.

The mineralize C contents of the soils under different temperature (20 and 35 °C) and field capacity (30 and 60% field capacity) are given in Table 4. The effect of depth on mineralized C was not significant. The increase in the amount of moisture caused a slight increase in the mineralized C at the surface soil of forest. The highest carbon mineralization at 20 °C was observed in pasture at 60% of field capacity. The difference between the land use types was significant at 60% of field capacity. Carbon mineralization decreased dependent on the depth. The interaction between land use and depth was significant. A study has indicated that the amount of mineralized C in the lake mud is directly related to temperature and the amount of organic C in the lakes will decrease by 4% to 27% in the future due to global warming (Gudasz et al., 2010). The increase in moisture content caused an increase in mineralized C content, especially in agricultural soil at 35 °C. However, the similar trend was not observed in pasture and forest soils.

Table 4. Mineralize C content under different temperature and moisture content in agricultural, pasture, and forest lands

Çizelge 4. *Tarım, mera ve orman topraklarında farklı sıcaklık ve nem değerlerinde mineralize C durumu*

		20 °C Incubation				35 °C Incubation			
Land use	Depth (cm)	30% Field cap.		60% Field cap.		30% Field cap.		60% Field cap.	
		$g\ C\ kg^{-1}$				$g\ C\ kg^{-1}$			
Agricultural Field	0-5	0.36 (0.02)[1]		0.36 (0.00)		0.37 (0.00)		0.40 (0.01)	
	5-15	0.39 (0.01)		0.38 (0.01)		0.38 (0.02)		0.41 (0.01)	
	15-30	0.37 (0.01)		0.39 (0.01)		0.39 (0.01)		0.40 (0.00)	
Forest	0-5	0.40 (0.03)		0.44 (0.02)		0.41 (0.00)		0.41 (0.00)	
	5-15	0.35 (0.01)		0.38 (0.02)		0.37 (0.01)		0.38 (0.01)	
	15-30	0.37 (0.01)		0.36 (0.01)		0.37 (0.01)		0.37 (0.00)	
Pasture	0-5	0.38 (0.01)		0.35 (0.01)		0.38 (0.01)		0.39 (0.01)	
	5-15	0.36 (0.01)		0.37 (0.01)		0.37 (0.01)		0.37 (0.01)	
	15-30	0.35 (0.01)		0.34 (0.01)		0.37 (0.01)		0.37 (0.01)	
		Mean	P[2]	Mean	p	Mean	p	Mean	p
	Ag-field	0.37		0.37		0.38		0.40	
Land use	Forest	0.37	ns	0.39	0.006	0.38	ns	0.38	0.001
	Pasture	0.36		0.35		0.37		0.37	
	0-5	0.37		0.38		0.38		0.40	
Depth	5-15	0.36	ns	0.37	ns	0.37	ns	0.38	ns
	15-30	0.36		0.36		0.37		0.38	
Land use* depth			ns		0.005		0,033		0.043

[1] indicates standard error.

[2] represent probability.

This result indicates that the mineralization at the surface of agricultural soil was controlled by moisture content. The effect of depth on mineralized C was not significant (p> 0.05). Interaction between land use and depth was found to be significant (p <0.05). A study found that the amount of mineralize C is significantly affected by land use and depth and the interaction between land use and depth is significant (Demirci, 2008). In this study, the highest mineralize carbon were found in agriculture and forest soils. There was no significant difference in mineralize C in the incubation of 35 ° C and 30% of field capasity. This result revealed that it was not important in the change of mineralize C contents related to depth. It was observed that the interaction between land use and depth was significant (p<0.05) at 35 ° C and 30% field capacity. There is no significant difference occurred in different land uses at 30% of field capacity due to greater limitation of moisture on microbial activity. Schwendenmann et al. (2007) emphasized that the amount of active organic C in forest is more than pasture and it is important to examine the changes in land use. The mineralization ratios of different organic materials can vary depending on composition of material and environmental factors (Arslan et al., 2009). Kutlay et al. (2010) examined the mineralize C in the Mediterranean climate and found that the mineralize C was higher at 80% of the field capacity than 60% of the field capacity. Similarly, the highest values were determined at high humidity level. The decomposition of the organic materials added to the soil is highly related to the soil moisture content. It was determined that the highest decomposition of the different organic materials added to the soil in laboratory conditions was 50% of field capacity (Mohammed et al., 2014).

4. Conclusions

Soil, which is one of the most important sources of carbon, can serve as a good storage if appropriate management systems are used. Carbon storage in the soil is directly related to soil cultivation and land use. Carbon in the soil is not only important in terms of global warming and climate change, but also in terms of soil fertility and sustainable agriculture. Organic carbon is the highest in forest soil and the lowest in agricultural land. Microbial biomass has changed significantly depending on land use. The mineralize C in the agricultural soil was proportionally high compared to the forest and pasture. The effect of increases in soil temperature at 30% of field capacity was limited on C mineralization. The effect of land use on mineralized C was found to be significant at high humidity levels. The increase in moisture level increased the mineralized C content in the most depth of agricultural land. This shows that agricultural soils have a high dependence on moisture content. In general, the highest values were determined at high humidity and temperature. In this study, the effect of moisture on mineralized C was higher than the temperature. This is also the result of a low 30% humidity level. The sensitivity of the forest and pasture soils to temperature is higher. The increase in temperature in the future may lead to a further increase in the amount of mineralized C in the forest and pasture. Although total C content is low in agricultural soils, mineralized C value is high. Intensive cultivation systems in agricultural lands cause organic C to remain unprotected.

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