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Relationships between Root - and Soil Organic - Carbon: A Case Study from Olur, Turkey

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Abstract

This study analyzes the relationship between the vertical distribution of root carbon and soil organic carbon (SOC) content in the semi-arid grasslands of Olur sub-basin, Turkey. Three elevation levels and two different aspects were selected. Root carbon (0-30 cm) and SOC (0-15 and 15-30 cm) were calculated in 44 sampling points and are analyzed on per ha basis. Simple regression equations were used to calculate the relationship between SOC and root carbon at each site. A one-way ANOVA was conducted to try to answer the research question. The results showed that the root carbon content generally increased with elevation and the SOC content decreased as soil depth and elevation increased. There was asignificant relationship between SOC and root carbon at all elevation levels. When all data pooled, SOC and root carbon strongly correlated due to strong relationship between them (R^2= 0.608). Moreover, sunny aspects stored more root carbon and SOC than shaded aspects.

Keywords: *root carbon, soil organic carbon, coruh river, grassland*

Introduction

Grassland ecosystems are one of the most important biomass sources on earth (40 %) and are estimated to contain more than one-third of the world's carbon (C) reserves (Shantz, 1954; Menke and Bradford, 1992; Scurlock et al., 2002; Haferkamp and Macneil, 2004; Reynolds et al.,2005; Mara, 2012). 30 % of world soil carbon from a comparison of soil organic matter (Batjes and Sombroek, 1997; Scurlock et al., 1998), which play an important role in regulating the global carbon cycle. The area of Turkey's grasslands is approximately 14,6 million hectares, covering 27 percent of the country's total land (Tuik, 2016b).

Soil organic carbon (SOC) can be both a carbon sink and carbon source and has an important role in the global C cycle within terrestrial ecosystems(Wiesmeier et al., 2012; Jandl et al., 2014; Li et al., 2013; Gray et al., 2015; Song et al., 2016; Stockmann et al., 2013; Weissert et al., 2016). Soil organic carbon (SOC) is portion of soil organic matter (SOM) (Brady and Weil, 2002), which in practical terms is any material from biota in soils excluding living plant roots. It has a strong influence on soil quality, soil structure, water holding capacity, erosion rates, the ecosystem and the climate (Torn et al., 1997; Brady and Weil, 2002; Riston and Sochacki, 2003; Sanderman et al., 2010; Hoyle et al., 2013). Stock of SOC are controlled by the balance of carbon inputs from plant production and outputs from decomposition (Jenny, 1941; Schlesinger, 1997; Grego and Lagomarsino, 2008). The SOC content in soil promotes soil health, plant growth, and production (Li et al., 2013; Liu et al., 2015). Therefore, SOC is fundamental to ecosystem services and plays an important part in provisioning services (e.g. food, fuel, fiber), regulating services (e.g. climate and greenhouse regulation), cultural services (e.g. recreation, ecotourism), and supporting services (e.g. weathering, soil formation, nutrient cycling) (Stockmann et al., 2013; Gray et al., 2015; Adhikari and Hartemink, 2016).

Soil organic carbon storage in the topsoil layer is 1.5 times higher that of the total carbon storage in the present natural vegetation and crops (Sombroek et al., 1993; Grace, 2004; Lal, 2004). Many studies state that the majority of SOC is found primarily between 0-30 cm because it is the most biologically active zone (Zdruli et al., 2004; Jones et al., 2005; Wells et al., 2011), andorganic carbon content decreases with increasing depth from the surface (Gaudinski et al., 2000; Wynn et al., 2004). The amount of organic carbon stored in soil is controlled by natural factors, such as parent material, climate, topography and land cover, as well as human-induced factors associated with land use (Schils et al., 2008; Piñeiro et al., 2010).

Studies on soil carbon have mainly focused on SOC distribution (Tao et al., 2006), human influences on SOC, such as livestock grazing activities (Dong et al., 2005) andthe effect of plant species (Li et al., 2003). Research on root biomass has been poorly studied among the reseachers, because of the lack of a simple and effective method to accurately estimate root biomass (McNoughton et al., 1998; Vogt et al., 1998; Tüfekçioğlu et al., 2002). A few studies addressed how the patterns of root biomass were shaped (Hu et al., 2005), the effect of the environment on root biomass (Tao et al., 2006) and the relationships between above-ground biomass and root biomass (Wang et al., 1995; Dinc, 2017) in the grasslands. Contrarily, root biomass was accounted for a substantially higher portion of total biomass in grasslands (Jackson et al., 1996; McNoughton et al., 1998), especially in the semi-arid grasslands (Azarnivand, 2003) and was an important component of ecosystem carbon stock (DeDeyn et al., 2008).Generally, the relative proportion of C storage by root biomass in arid ecosystems is less than those of soil; however, it has an extra importance because of its role in producing the organic C that is stored in the soil (Northup and Brown, 1999; Scurlock, 2002).To better understand the effects of root biomass on soil organic carbon storage, we examined 44 sampling plots along the Olur sub-basin within Coruh River Basin, NE Turkey. We analyzed the SOC and root carbon in the top 30 cm and explored the relationships between the SOC and root biomass.

MATERIAL AND METHODS

Study Area

The study area is located in Erzurum province, Turkey. It stretches from 40^0 44' 32" N to 42^0 19' 50" E in Northeastern of Turkey (Figure 1) with a total area coverage of 42105 ha. The area covered with grassland (51%), degraded forest (21%), productive forest (12%), crop field (11%) and other land uses (5% for residential, bare rock and water) (Dinc, 2017). The topographic features in the Olur was quite mountainous, steep slopes and changing very quickly with average elevation of 1930 m. The average slope is 32 % and the site generally has a southern aspect.

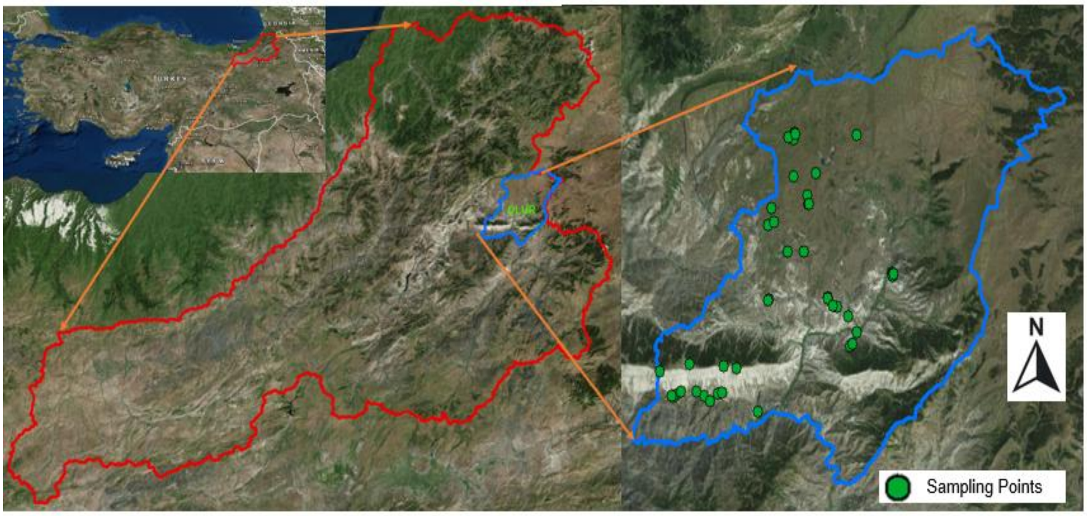

Figure1. *Location of the study area with sampling sites.*

The mean annual temperaturefor the last 17 years is 10,2°C and the mean annual precipitation is 439,2 mm. The coldest month is January, with a minimum temperature of –2,1 °C, and the hottest month is August, with a maximum temperature of 22,7 °C. More than 65% of precipitation is concentrated in the spring and summer months and the climate is categorized as semi-arid. The weather data for the study was obtained from the weather station located in Olur. The most common soil types in the sub-basin was brown forest soil, brown soil, chesnut soil and high mountain grassland soil (URL-1). The soil has sandy loam texture with sand content of 68 %, silt content of 12 % and clay content of 20 %. Electric conductivity (uS/cm) is 185 and the pH is 7,3 (Duman, 2017).

Three different elevation levels (1000-1500, 1500-2000 and 2000-2500 m) and two aspects (shaded and sunny) were selected within the study area. The dominant species were *Agrostis sp.*, *Festuca sp.*, *Veronica sp.*, *Ajuga sp.*, *Muscari sp.*, *Cardamine sp.*, and *Thyymus sp.* (Kocamanoğlu, 2015).

Sampling and Measurement

Samples were collected in 2015 (from July to September), we randomly distrubeted 44 sampling across the study area using data management tool of ArcGIS 10.1™ (ESRI, 2010). They were stratified based on their elevation and aspect classes.

To estimate root biomass, 196 root samples were collected from soil depths of 0-30 cm in 44 sites, where most of the root biomass stored at this level (Eissenstat and Yanai, 1997; Tufekcioglu et al., 2002; Li et al., 2011). The soil was dug by steel cylinder with a diameter of 6,4 cm and a lenght of 30 cm (Figure 2a). Each root samples were taken to soil laboratory of Artvin Coruh University and then transferred to plastic bottles and water added. They were waited for one night to separate the soil from the roots. Then, they were washed in order to remove from the soil using a 0,2 mm-sieve. Later on, the root were put into White cups and dead pieces and the other matters were removed with the help of a tweezer (Figure 2b). Finally, these samples were oven-dried at 80 ^{0}C(24 hours) and weighed. After measuring biomass, the carbon content within it, was calculated using related conversion coefficients in the literature. Lales et al., (2001)' s carbon formula was used for conversion.

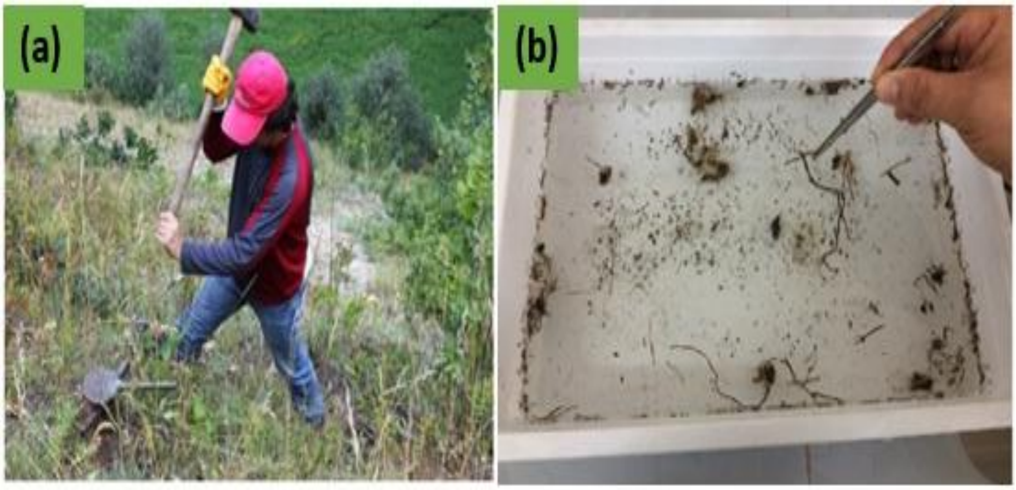

Figure 2. *Root sampling with a steel cylinder (a), washing and removing roots from soil (b).*

In each sampling plot, 30-cm-depth soil profiles were excavated, each seperated into two layers with a depth of 15 cm to collect soil samples. After being air-dried and sieved (using of 2 mm mesh), the soil samples were carefully handipicked to extract the surface organic debris and fine roots for SOC analysis. The Walkley–Black wet oxidation method was used to determine SOC(Karla and Maynard, 1991). Simple regression equations were used to calculate the relationship between SOC and root biomass for each site.

The dry weight of root and SOC were calcuated in ton ha^{-1}. Linear regression was used to transform the equations and the significance of the coefficient (H0:a=0) was tested. Statistical analyses were conducted by one-way ANOVA and significant differences between means were tested using the Tukey t-test. The significance value (p) was chosen as to be between 0.05 and 0.01. SPSS 19.0 (SPSS, 2006) were used to analyze the data.

Results

Root Carbon

There was not a significant difference in root carbon by elevation levels at the three sites ($p < 0.01$). Generally, root carbon increased with the elevation (Table 1). On average, root carbon amount of Olur sub-basin grassland were 1.83 ton ha^{-1} (1000-1500 m), 1.95 ton ha^{-1} (1500-2000 m) and 2.09 ton ha^{-1} (2000-2500 m). More carbon stored in the sunny aspects than shaded aspects (Table 1).

Soil Organic Carbon

There was a significant difference in the amount of SOC between elevation levels and soil depths ($p < 0.01$). For all elevation levels, the SOC content decreased asthe soil depth increased (Table 1) and SOC decreased as the elevation levels increased. Sunny aspects had more soil organic carbon than shaded aspects (Table 1). The SOC was greatest in the 0-15 cm depth, at about 56% (1000-1500m), 58 % (1500-2000 m) and 60 % (2000-2500 m) of the total SOC, and it was lowest at 15-30 cm depth (Table 1).

Table1. *Distribution of root carbon and soil organic carbon in the study area*

Depth (cm)	Aspect	Study Sites (m)		
		1000-1500	1500-2000	2000-2500
Root Carbon (ton ha^{-1})				
0-30 cm	Sunny	1.85±0.26^{a}	1.97±0.49^{a}	2.1±0.38^{a}
	Shaded	1.81±0.28^{a}	1.93±0.21^{a}	2.09±0.43^{a}
Total		1.83±0.26^{a}	1.95±0.36^{a}	2.09±0.38^{a}
Soil Carbon (ton ha^{-1})				
0-15 cm	Sunny	32.4±1.5^{a}	31.5±1^{a}	30.1±2.7^{a}
	Shaded	32.1±2.1^{a}	31±0.2^{a}	29.03±4^{a}
Total (0-15 cm)		32.3±1.7^{a}	31.2±0.7^{a}	29.6±3.2^{a}
15-30 cm	Sunny	25±2^{b}	22.8±0.2^{b}	21.1±3.5^{a}
	Shaded	24.7±2.1^{b}	21.9±0.8^{b}	18.1±2.3^{a}
Total (15-30 cm)		24.9±2^{b}	22.3±o.7^{ab}	19.9±3.3^{a}
Total (0-30 cm)	Sunny	57.4±3.2^{b}	53.7±0.4^{ab}	51.3±5.6^{a}
	Shaded	56.8±4^{b}	53.4±1.^{ab}	47.2±5.6^{a}
Total		57.2±3.4^{b}	53.5±1.3^{ab}	49.5±5.8^{a}

Within columns, means±S.D. Different letters represent statistically significant at $P<0.05$ and $P<0.01$, n=44.

Relationship between Root Carbon and SOC

The results showed an significant relationship between root carbon and SOC at all elevation levels (Figure 3). According to the results, the higher proportion of SOC stored in the surface layer and lower proportion in the deeper layers of soil. With all data pooled, SOC and root carbon strongly correlated, due to strong relationship between them (R^2= 0.608, Figure 3).

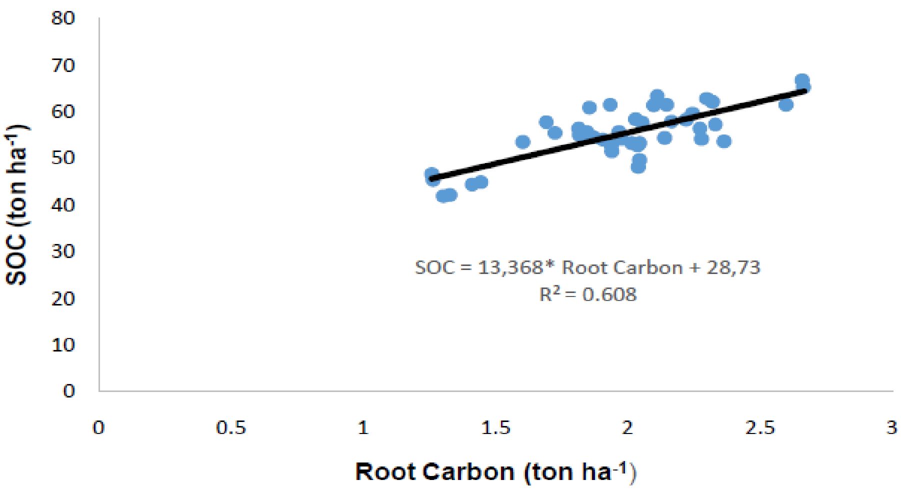

Figure3. *Relation between content of SOC and Root carbon at all elevation levels, n=44. The fitted regression was SOC=13,368*Root Carbon+28,73 (R2=0.608).*

Discussion

Soil is the largest pool of terrestrial organic carbon in the biosphere. It stores more carbon than those of all plants and the atmosphere (Schlesinger, 1997). SOC decreases with increasing depth from the surface (Wang et al., 1998; Gaudinski et al., 2000; Wynn et al., 2004) according to the distribution of animal and plant residue, agrees with the findings of other studies (Wang et al., 1998).

SOC is mainly stored by roots and leached from organic matter; since the percentage of organic matter was low below 20 cm in depth (Zhang and Gao, 2008), the SOC decreased as depth increased. The main source of SOC is decomposing stalks, leaves, animal, and plant residue (Zhang and Gao, 2008). In arid regions, vegetation cover is low and thus falling leaves are few. The main source of SOC was decomposition of animal and plant residue (in forest, grassland and crop fields), especially root biomass. In semi-arid regions such as the study area, root carbon is the largest percentage of total carbon and the proportion of above-ground carbon to total plant carbon is small(Dinc, 2018). Root and humus from the root residues is the main source of SOC. In the present study, a significant positive correlation found between SOC and root carbon at all 3 elevation levels. As soil depth increased, SOC content decreased at all 3 elevation levels(Zhang and Gao, 2008) and also SOC content decreased with increase in the elevation. An accurate assessment of plant roots is essential for understanding the role of roots on C storage in the soil and the functioning of the ecosystem. This knowledge gap increases uncertainty in assessing the potential for C sequestration in ecosystems (Chirinda et al., 2011).

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