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Relationship between Root Biomass and Soil Organic Carbon: Case Study of Arid Shrub Lands of Semnan Province

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Abstract

This study analyzed the relationship between the vertical distribution of root biomass and soil organic carbon (SOC) content in the arid shrub lands of Semnan province in Iran. Three sites were selected based on differences in canopy cover of *Artemisia sieberi* (5%, 10% and 15%). Average density of shrubs, root biomass and SOC were determined at different depths (0-20, 20-40, 40-60, 60-80 cm) in 20 quadrats at each site and are expressed on a per ha basis. Simple equations were used to calculate the relationship between SOC and root biomass for each site. Statistical analyses were conducted using ANOVA. The results showed that the root biomass and the SOC content generally decreased as soil depth increased. There was an acceptable relationship between root biomass and SOC at all sites. The proportion of SOC in the soil was found to be positively related to the vertical distribution of root biomass; 75% of total root biomass was found at 0-25 cm, while this same soil layer contained 48% of SOC.

Keywords: Belowground biomass; Soil carbon; Artemisia sieberi; Carbon percentage

1. Introduction

Soil organic carbon (SOC) can be both a carbon sink and carbon source and is one of the most important carbon pools in the terrestrial ecosystem. It has a strong influence on soil quality, the ecosystem and the climate (Riston and Sochacki, 2003; Torn et al., 1997). SOC storage is controlled by the balance of C inputs from plant production and outputs from decomposition (Jenny, 1941; Schlesinger, 1997).

The abundance of organic C in the soil is affected by plant production, and it plays a key role in soil fertility and agricultural production (Dokuchaev, 1883; Tiessen et al., 1994). An understanding of the patterns and control of SOC storage are critical for understanding the biosphere, given the importance of SOC in the ecosystem and the feedback of this pool to the atmospheric composition and the rate of climate change (Trumbore, 2000; Woodwell et al., 1998).

Rangelands comprise about half of the global land area, and contain a third of C stores (Allen-Dias, 1996). Dry land covers 45% of the global land mass and, despite the low organic carbon concentration in soil; it comprises 16% of the global soil carbon pool (Jobbagy and Jackson, 2000); understanding the t factors that influence soil carbon in rangeland ecosystems is vital.

Studies on soil carbon have mainly focused on SOC distribution (Tao et al., 2006), the effect of plant species (Li et al., 2003) and human influences on SOC, such as livestock grazing (Dong et al., 2005). Research on root biomass has been directed toward the influencing factors of soil and nitrogen and on the formation of root biomass (Wang et al., 1998), 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).

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It has been shown that roots, as the major input sources of C and N to soil are important to C and N sequestration (Rees et al.,2005; Hieroo et al.,2000), especially in arid rangelands where root biomass is a large proportion of total biomass (Azarnivand, 2003). Generally, the relative proportion of C storage by root biomass in arid ecosystems is less than that for soil; however, it has an extra importance because of its role in producing the organic C and N that is stored in the soil (Northup and brown,1999; Scurlock, 2002).

Artemisia sieberi covers most arid rangeland in Iran and is representative of the type of vegetation on the major grazing lands of the region (Azarnivand, 2003). In some areas, this species is the sole vegetative cover.

2. Material and methods

2.1. Study area

The study area is approximately 1000 ha of arid shrub land covered by *Artemisia sieberi* located in the province of Semnan in Iran (35°53' N, 54°05' E). The mean (20 yr) annual temperature is 16.3°C and the mean annual precipitation is 104.9 mm. More than 64% of precipitation is concentrated in the autumn and winter months and the climate is categorized as cold-arid. Easterly winds prevail in 70% of daily observations and the mean annual wind speed is 4.73 m s^{-1}. The weather data for the study was obtained from the main weather station in Semnan.

The soil is fluvial with a large proportion of grit and gravel covers about 50% of the soil surface. The soil is a sandy loam texture with sand content of 69.8 ± 0.6%, silt content of 15.3 ± 0.3% and clay content of 14.9 ± 0.3%. Electric conductivity (ds/m) is 0.45 and the pH is 7.7. The topography is glacis with an average elevation of 1400 m. Slope ranges from 2% to 5% and the sites generally have a southerly aspect.

Three sites were selected within the study area based on differences in the canopy cover of *A.sieberi* (5%, 10% and 15%). The dominant species was *A.sieberi*; other shrubs comprised less than 1% of cover.

2.2. Sampling and measurement

Sampling was done in November 2008. At each site, appropriate sampling points were determined based on surface indicators. Plant community characteristics were determined for 20 1m×1m quadrats in 2 systematically located transects 200 m in length. The quadrat size was determined by the minimum area method. The percentage of canopy cover and density of *A.sieberi* were recorded and their averages calculated per ha for each quadrat.

To estimate root biomass, 20 shrubs of different volumes and ages were removed completely from each site and the root biomass of each shrub was collected and weighed. All roots found at each depth (0–20, 20–40, 40–60, 60-80 cm) were retained in a 2 mm sieve.

Samples were dried in an oven for 48 h at 65°C and weighed and dry matter coefficients were used to convert fresh biomass data into dry matter. The average density of *A.sieberi* shrubs and average dry weight of root biomass were determined for each site and then average of root biomass was determined for each layer of soil in the sites (kg/ha).

Six core samples (40 cm in diameter) were collected to depths of 80 cm and each core was divided into segments of the prescribed size. Soil samples were also collected from the quadrats in which roots were collected. Soil samples were air-dried, gravel and roots were separated out, and samples were passed through the 2 mm sieve. The gravel and roots (after drying) for each sample were weighed.

The Walkley–Black method was used to determine SOC. Soil bulk density [Blake and Hartge, 1986] was determined by converting soil C concentration (gr/kg) to C aggregate (T/ha). Simple equations were used to calculate the relationship between SOC and root biomass for each site.

The dry weight of the root was calcuated in kg. Linear regression was used to transform the equations and the significance of the coefficient (H_0:a=0) was tested. Then functions were constructed ($y = ax$ + b) for dry weight of the root to SOC in each layer. Statistical analyses were conducted by one-way ANOVA and significant differences between means were tested using the Duncan t-test. EXCEL and SPSS were used to analyze the data.

3. Results

3.1. Vertical distribution of root biomass

There was a significant difference in root biomass by soil layer at the three sites ($p < 0.01$).

Generally, root biomass decreased as the soil depth increased (Table 1). At all sites, the percentage of root biomass was greatest for the 0-25 cm layer, at about 75% of total biomass and lowest at 75-100 cm, at about 2% of total biomass. About 89% of total root biomass occurred in the top 50 cm of the soil (Table 1).

3.2. Vertical distribution of SOC

There was a significant difference in the amount of SOC between layers at the 3 sites ($p < 0.01$). For all 3 sites, the SOC content decreased as soil depth increased (Table 1). The SOC was greatest for the 0-25 cm layer, at about 48% of total SOC, and it was lowest at 75-100 cm, at about 7% of total SOC (Table 1). About 75 % of SOC occurred in the top 50 cm.

3.3. Relationship between root biomass and SOC

The results showed an acceptable relationship between root biomass and SOC at all sites (Fig. 1). According to the results, the higher proportion of SOC in the surface layer and lower proportion in the deeper layers of soil is related to the vertical distribution of the root biomass. For example, the layer at 0-25 cm in depth contained 75% of the total root biomass and 48% of the total SOC.

Table 1. Distribution of root biomass and soil organic carbon in study sites

Soil layers	Study Sites		
	Site1	Site2	Site3
	Root Biomass(kg ha^{-1})		
o-25 cm	1161±101 a	1800±144 a	2011±210 a
25-50 cm	239± 27 b	405±31 c	549±48 b
50-75 cm	64±14 c	115±33 c	131±28 c
75-100 cm	20±10 c	36±18 d	52±12 d
Total root C	1484± 111	2356±315	2743± 344
	Soil (ton ha^{-1})		
o-25 cm	13.73± 1.28 a	15.44 ± 1.30 a	16.25± 1.62 a
25-50 cm	7.81± 0.51 b	9.80 ± 1.00 b	10.34± 1.10 a
50-75 cm	4.62± 0.83 c	5.44± 1.10 c	5.41± 1.09c
75-100 cm	2.02± 0.83 d	2.43± 0.83 d	2.52± 0.83 d
Total (0-100cm)	28.18± 2.1	33.11± 2.85	34.52± 3.1

Within columns, means±S.D. Different letters represent statistically significant at P<0.05, n=20

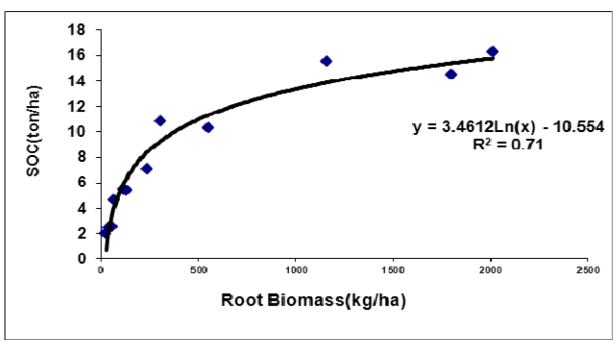

Fig. 1. Relation between content of SOC and Root biomass in all sites, n=12

4. Discussion

Soil is the largest pool of terrestrial organic carbon in the biosphere. It stores more carbon than is contained in all plants and the atmosphere combined (Schlesinger, 1997). The change in the level of SOC, which decreases as the depth increases in accordance with the distribution of animal and plant residue, agrees with the findings of other studies (Wang et al, 1998).

SOC is mainly secreted 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 areas, plant cover is low and fallen leaves are scarce. Here, the main source of SOC was decomposition of animal and plant residue, especially root biomass. This study found that there was a significant correlation between root biomass and SOC.

In arid regions such as the study area, root biomass is the largest percentage of total biomass and the proportion of above-ground biomass to total plant biomass is small. Root secretion and humus from root residues is the main source of SOC. The present study found a significant positive correlation between SOC and root biomass at all 3 sites.

The higher proportion of total root biomass at the surface correlates with the higher proportion of total soil organic matter. As soil depth increased, SOC content decreased at all 3 sites (Zhang and Gao, 2008).

Several factors related to root measurement limited understanding of root C input. An accurate assessment of plant roots is essential for understanding the role of roots in the soil on C storage and the functioning of the ecosystem. This gap in knowledge increases uncertainty in assessing the potential for C sequestration in ecosystems (Chirinda et al., 2011).

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