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Relationships between particle size distribution and organic carbon of soil horizons in the Southeast area of Turkey

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The interdependent relationships between soil organic carbon and texture within the soil profile are little known. In order to determine this relationship, carbon and texture analyses were carried out on soil samples from Harran Plain. Soil samples were taken from 16 profiles (3 replications) in 1 m soil depth; all samples were taken from the same climate, vegetation and topography. Soil organic carbon (SOC) concentration was found to be directly related to soil texture at all depths. In statistical analysis ($p<0.001$), the strongest relationship was found between clay (R^2=96.0) and silt (R^2=95.0). The relationship between sand and SOC was determined as (R^2=65.46). A very strong relationship was found between the organic carbon (OC) present in the soil and the texture in Harran Plain soils. The findings indicated that, in practice, areas containing low carbon should be preferred for use in carbon storage rather than areas containing high carbon stocks.

Keywords: carbon cycle, soil texture, soil organic carbon

INTRODUCTION

Soil texture (silt+clay+sand) protect soil organic matter (SOM) from being decomposed by physical, chemical and biological mechanisms (Six et al., 2002; Krull et al., 2003). It was suggested that chemical stabilization of organic molecules takes place *via* mineral-organic matter bonds from the start (Gonzalez and Laird, 2003). It was found that soil organic matter comprises approximately 60% of continental carbon pools and is generally very sensitive to agricultural land management (West and Post, 2002). It is suggested that agricultural practices resulted in the release of 55 Pg C from soil to the atmosphere in the 19th and 20th centuries (Paustian et al., 2000). When perennial vegetation constitutes agricultural areas, SOM accumulates, and thus a potential is created for atmospheric C sequestration (Post and Kwon, 2000; Follett, 2001). However, the factors affecting the importance, ratio and type of this accumulation are still not known (McLauchlan, 2006). The factors affecting soil formation for long periods, such as time – climate periods, organisms, relief and parent materials, can affect soil organic carbon accumulation (Jenny, 1941). Studies of the different pasture vegetation of North American Great Plains showed that organisms had minimum effect on SOC pools and accumulation rates (Vinton and Burke, 1997). Other studies indicated that parent material variations, different soil texture classes or clay concentrations are important variables in SOC accumulation ratio and C sequestration (McLauchlan, 2006).

According to some evidence, clay concentration affects SOC accumulation in different ratios. It was found that maximum and medium SOC increased with increasing clay content in soil (Nichols, 1984; Burke et al., 1989). However, this relationship could not be generalized as SOC was sometimes much more strongly related to other factors in comparison to clay (Percival et al., 2000; Krull et al., 2003). The relationship between clay concentration and SOC content was expressed to be strong (at a sufficient level) according to SOM models such as Century (Parton et al., 1987) and RothC (Jenkinson, 1990). As clay concentration increases, SOM weathering decreases. It was found that, if other factors were fixed, as clay concentration increased, SOC accumulated faster (Jenkinson, 1990). Many studies showed that soil texture affected soil aggregation (Kemper and Koch, 1966; Chaney and Swift, 1984; Schlecht-Pietsch et al., 1994). As the clay constituents increase, they combine with SOC to form stable aggregates. For this reason, soil texture also plays direct and indirect role in chemical and physical protection mechanisms (Plante et al., 2006).

Clay content has a different effect on weathering of different SOC pools (Franzluebbers et al., 1996). For example, *in vitro* studies failed to find any relationship between clay and SOC (Wang et al., 2003; Muller and Hoper, 2004). It was determined that C mineralization rates in the natural environment generally decreased with increasing

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clay content (Hassink, 1997), but this trend could not always be demonstrated in the laboratory incubations (Scott et al., 1996). These observations suggest that clay particles protect some kinds of SOC from weathering (McLauchlan, 2006; Sakin, 2012).

The present study examined the effect of climate, temperature and rainfall, which are among the abiotic factors affecting SOC stocks and accumulation and texture. In order to determine the relationship between texture and SOC stocks, analyses were carried out on samples taken from 16 soil profiles in Harran Plain horizons.

EXPERIMENTAL

Material and Methods

Database

Soil Information

The study was carried out in the Harran Plain located in Southeastern Turkey; between 38º 48' to 39º12' E longitude and 37º 09' to 36º 42' N latitude. The total area of the plain is 225 000 ha. Rainfall is limited during most of the year, and the climate is arid. According to 33 years of data collection (1975–2008) by the Turkish State of Meteorology Service (TSMS, 2008), the average annual precipitation was 277.8 mm at Akcakale station and 448.1 mm at Sanliurfa station. The soil moisture regime of important parts of the plain is Xeric, and the temperature regime is Mesic. An Aridic soil humidity regime is established in parts of the areas near the south of the plain (Soil Survey Staff, 1996). Soil samples were taken from 16 series of genetic horizons on the Harran Plain and were taken as 3 replications from each horizon with profile depth of 1 m in the area of study. Analyses were carried out on 131 samples taken for the study.

Soil analysis was performed by the organic carbon-potassium dichromate acid method. Samples were titrated with dichromate iron sulphide. Before carrying out texture analysis, organic matter was burnt with hot hydrogen peroxide (H_2O_2). Sodium hexametaphosphate was used to determine the dispersion of particles. The hydrometer method was used to analyze particle-size distribution. Carbon stocks and bulk density were determined according to methods for bulk density (Black, 1965).

RESULTS AND DISCUSSION

Soil texture analysis showed that the Harran Plain samples contained 65-28% clay, 41-22% silt and 3-31% sand. A summary of statistically analyses showing the distribution of carbon content and texture particle amounts of soil samples is presented in Table 1. Table 2 shows the statistical relationship between soil texture and organic carbon ($p<0.001$). As shown in Table 3, a strong relationship was found between SOC and soil texture (R^2=92.01). Regression analysis of the relationship between soil texture particles and SOC is given in Eq. 1.

$$SOC(kgCm^{-2})=0.0305Clay\%+0.0015\ Silt\%+0.0162Sand\% \quad (1)$$

Table 1. Statistical distribution of texture class and organic carbon.

	N	Mean	Standard deviation
SOC (kg C m^{-2})	131	1.870	1.019
Clay %	131	51.504	7.054
Silt %	131	33.298	4.989
Sand %	131	15.290	6.844

Statistical analyses of soil particles (clay-silt-sand) and SOC are given in Table 3. There is a very significant relationship between SOC and clay, silt and sand, with the strongest relationship in the order clay›silt›sand. Thus, it was observed that as the amount of clay in soil increased, the amount of SOC increased and a close relationship was detected between SOC and clay (R^2=96.0). Although it is a physical disadvantage that soils of Harran Plain are very clayish, it is an advantage for accumulation and protection of SOC. Clay constitutes organo-mineral complexes by combining with SOC in soil and helps to retain carbon within the soil for long periods. Since the soils contain 2:1 type clay minerals, the carbon entering into the layers flips and is thus protected against oxidation and weathering of organisms. Some metals in soil clay minerals, Ca and Fe constitute complexes with carbon in soil and protect carbon.

Table 2. General relationship between soil texture and organic carbon

Source	DF	SS	MS	F	P	RMSE
Factor	3	183349.5	61116.5	1995.25	0.000	2.11
Error	520	15928.1	30.6			
Total	523	199277.6				
R^2 = 92.01						

Table 3. Correlation relationship between texture particles (clay-silt-sand) and SOC

Source	DF	SS	MS	F	P<(0.001)
Factor	1	161359.3	161359.3	6352.97	0.000
Error	260	6603.7	25.4		
Total	261	167963.0			
Clay R^2 = 96.07					
Factor	1	64693.8	64693.8	4990.64	0.000
Error	260	3370.4	13.0		
Total	261	68064.2			
Silt R^2 = 95.05					
Factor	1	11796.2	11796.2	492.77	0.000
Error	260	6224.0			
Total	261	18020.2			
Sand R^2 = 65.46					
Factor	2	165175.9	82588.0	3273.59	0.000
Error	390	9839.1	25.2		
Total	392	175015.0			
Clay+Silt	R^2 = 94.38				

Plante et al. (2006) examined soils in Ohio and Saskatchewan, and found a statistically strong relationship (r^2=0.48; P=0.012) and (r^2=0.46; P=0.0028), between clay and SOC. According to their study, as the amount of clay increased, the amount of carbon retained in soil also increased. Nichols (1984) and Burke (1989) determined a strong relationship between clay and organic carbon concentration (r=0.86) in Southern Great Plains soils. Arrouays et al. (2006) detected a very strong correlation between SOC and clay content. Burke et al. (1989) and Schjonning (1999) found that SOC content and clay concentration were related. Many researchers reported a strong relationship between soil particles and SOC (Kern, 1994; Burke et al., 1995; Homann et al., 1998; Percival et al., 2000; Arrouays et al., 2006). In numerous studies it is suggested that SOC storage depends on soil texture (Scott and Cole, 1996; Bosatta and Agren, 1997; Hassink et al., 1997). In a study of New Zealand soils, Percival *et al*. (2000) found a weak relationship between clay and carbon concentration (R=0.05) Although there was no relationship between soil texture and soil carbon in many studies, Kölbl and Kögel-Knabner (2004) established that the amount of organic carbon in soil increased with the increase in the amount of clay. They also suggested that this relationship was not global, and sometimes depended on factors such as extractable aluminium, allophone content or physical surface area, that can extract more SOC than clay (Percival et al., 2000; Krull et al., 2003). The role of clay content is important within nitrogen cycle in the soil, and plays a key role in the mineralization of nitrogen (Cote et al., 2000). According to some studies, nitrogen mineralization decreased with an increase in clay content (Giardina et al., 2001; McLauchlan et al., 2006).

A strong relationship was detected between soil silt particles and soil organic matter. A close relationship was found between soil organic carbon and silt (R^2=95.0). Therefore, it was concluded that the most important fraction in storing SOC was clay, followed by silt. A strong relationship was found between soil sand particles and SOC. However, this relationship was not as strong (R^2=65.46) as that found for clay and silt.

Hassink and Whitmore (1997) determined that, on the condition that soil organic carbon combined with clay and silt fractions of soil, SOC retention was maximized, which was suggested to cause excessive accumulation of organic carbon in soil. Hassink (1997), Kiem et al. (2002), Kiem et al. (2002), and Six et al. (2002) found that mineral soil particles (clay-silt) protected organic carbon against chemical weathering. Many studies indicated that soil texture affects aggregation (Kemper and Koch, 1996); Chaney and Swift, 1984; Schlecht-Pietsch et al., 1994), and thus increasing clay content combines with increasing aggregation or aggregate stability. It was found that, on the condition that soil aggregation increased, soil clay content indirectly affected carbon storage and thus protected soil carbon against oxidation and organisms. According to Plante et al. (2006), there was a statistically significant relationship between SOC and clay + silt (P=0.99, r^2=0.76) in Ohio and Saskatchewan soils. Many researchers found a strong relationship between SOC and clay + silt. This correlation was observed as: R^2= 0.91, R^2= 0.97, R^2= 0.98, R^2= 0.86 and R^2= 0.93, respectively

(Roscoe et al., 2001; Neufeldt et al., 2002; Ruggiero et al., 2002; Zinn et al., 2005).

Contrary to the findings of the present study and previous studies in the literature, some researchers have reported a very weak relationship between SOC and texture. McLauchlan (2006) reported a very weak relationship between SOC and texture, and thus texture had a lower effect on SOC storage in comparison to other parameters. According to Six et al. (2000), clay concentrations have a very weak effect on SOC accumulation rate and soil aggregate dynamics are relatively affected by low clay concentration. Plante et al. (2006) reported a direct proportional link between organic carbon concentration and silt + clay in the soil (R^2=0.48 and 0.46).

CONCLUSION

In worldwide studies, the effect of texture on SOC stocks was found to be very positive. In particular, the interaction of clay and silt fractions with SOC is extremely important. The present results from Harran Plain are similar to those of studies carried out in other parts of the world. A very strong relationship was found between these studies, since the quantity of clay and silt is high in Harran Plain soils. Another important finding of the present study is the statistically strong relationship between sand and SOC. The results suggest that retaining SOC in arid and semi-arid regions may depend on texture fractions.

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ВЗАИМОВРЪЗКИ МЕЖДУ РАЗПРЕДЕЛЕНИЕТО НА ЧАСТИЦИ ПО РАЗМЕРИ И ОРГАНИЧНИЯ ВЪГЛЕРОД В ПОЧВЕНИ ХОРИЗОНИ В ЮГОИЗТОЧНА ТУРЦИЯ

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(Резюме)

Малко известни са взаимовръзките между текстурата на почвата и съдържанието на органичен въглерод в тях. За установяването на тези взаимовръзки са извършени анализи на въглерода и текстурата на проби от почвата в равнината Харан. Пробите (трикратно) за взимани от 16 профила на дълбочина до 1 м. Пробите за взимани от места с еднакъв климат, растителност и топография. Концентрацията на почвения органичен въглерод (SOC) се оказва пряко свързана с текстурата на почвата на всички дълбочини. Според статистическия анализ ($p<0.001$) най-силна зависимост е намерена за глината (R^2=96.0) и тинята (R^2=95.0). При пясъка тази корелация спрямо SOC е R^2=65.46. Силна зависимост е намерена между органичния въглерод (OC) почвената текстура в равнината Харан. Получените резултати показват, че площите съдържащи органичен въглерод трябва да се предпочитат за съхранение на въглерод пред площите с високо въглеродно съдържание.