

The Relationship between Specific Surface Area and Soil Organic Carbon in Loess-Derived Soils of Northern Iran

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ABSTRACT

Soil organic carbon (SOC) can act as a sink or source of atmospheric carbon dioxide, therefore, it is important to understand the amount and composition of SOC in terrestrial ecosystems, the spatial variation in SOC, and the underlying mechanisms that stabilize SOC. Relationships between minerals specific surface area and organic carbon (OC) concentration were examined for sediments and soil A-horizons from throughout the world. The organic compositions can be absorbed by minerals surface, and also exist a positive relation between specific surface area (SSA) and OC. Much of our current understanding is based on laboratory experiments, the results of which often do not support observations made in the field. The present study attempted to demonstrate the relationship between specific surface area, SOC rate and clay content in the pasture soils, in Golestan province. 7 soil profiles formed under different moisture regimes (udic, xeric and aridic regimes) were sampled from their surface horizons (0-30 cm depth). Correlation and linear regressions were performed between SOC, SSA and particle clay size. Results indicate that the content of clay showed significant linear correlations with SSA ($R^2 = 0.63$, $P < 0.05$) but SOC did not show significant linear correlations with SSA ($R^2 = 0.50$, $P < 0.07$). The results demonstrated that mean residence time of organic carbon in soil increase with higher specific surface area. Soils with high clay levels show greater SOC than soils with high sand contents.

Keywords: correlation and linear regression, losses soils, moisture regimes, organic carbon absorption, surface horizons

Abbreviations: OC, organic carbon; OM, organic matter; SOC, soil organic carbon; SSA, specific surface area

INTRODUCTION

As the negative environmental effects of greenhouse gases become more evident over time, governments, academics and the public have recognized the need to reduce global CO₂ emissions (Wiseman and Puttmann 2005). However, one problem in incorporating soils as part of efforts to reduce atmospheric CO₂ levels is the knowledge gaps with respect to the mechanisms involved in the sequestration of carbon. Much of our current understanding is based on laboratory experiments, the results of which often do not support observations made in the field (Kalbitz *et al.* 2000). The content of fine particles/clay is therefore probably crucial for the preservation of organic carbon (OC) in soils. On the other hand, interaction of organic substances with mineral surfaces is recognized as one of the mechanisms, which protects organic matter (OM) in soil against decomposition (Sollins *et al.* 1996). The evidence suggests that organic compounds can be stabilized by adsorption on mineral surfaces. A number of studies have established a significant positive relationship between specific surface area (SSA) and the OC concentration of sediments (Mayer 1994; Kahle *et al.* 2002; Kennedy *et al.* 2002) and soils (Mayer and Xing 2001). Shahriari *et al.* (2009) have found that specific surface area have a positive and significant relation with OC/(silt+clay) ratio and OC/clay ratio, but did not find any relation between OC and specific surface area. The mean residence time of soil OC has also been shown to increase with increases in SSA (Saggar *et al.* 1996). In analysing the relationship between SSA and OC concentrations, it is thus important to consider the sorptive potential of different minerals in a given soil, in addition to the available mineral surface for adsorption (Wiseman and Puttmann 2005). Clay minerals or the phyllosilicates can also help preserve organic matter, as indicated by strong relationships observed between the OC and clay content of soils (Ladd *et al.* 1985;

Schimel *et al.* 1985). Nonetheless, not all mineral surfaces are equally important, however, in the sorptive preservation of OC. In addition, the relationship between clay concentration and SOC content is sufficiently strong that SOM models such as century (Parton *et al.* 1987). On the other hand, clay content may have distinct effects on the decomposition of different SOC pools (Franzluebbers *et al.* 1996). The main objective was to determine the relationship among SSA, SOC content and soil texture.

MATERIALS AND METHODS

Seven soil profiles formed in different moisture regimes (udic, xeric and aridic regimes) were sampled (depth of 0-30 cm) in Golestan, Iran. Sampling locations are shown in Fig. 1. Particle size distribution was determined using disturbed soil samples sieved through a 2 mm by the Bouyoucos hydrometer method (Bouyoucos 1962). Organic carbon was measured by wet oxidation with chromic acid and back titrated with ferrous ammonium sulphate (Merck Fluka, Germany) according to Nelson and Sommers (1982). The soil pH was measured in saturation paste. Electrical conductivity was determined in the saturation paste extract (Page *et al.* 1982). Specific surface area was measured according to Carter *et al.* (1986). As organic material can affect estimates of SSA, it was first eliminated using peroxidation. For this, a 10% (by volume) solution of H₂O₂ was added continuously and the samples heated (70°C) until conspicuous effervescence had stopped and the solution had become clear. The method used to measure SSA was an adapted version of that developed by Carter *et al.* (1986), which employs ethylene glycol monoethyl ether (EGME). This method allows for the determination of the internal SSA of smectites. Specific surface area was calculated from:

$$A = \frac{W_{EGME}}{W_s \times 0.000286}$$

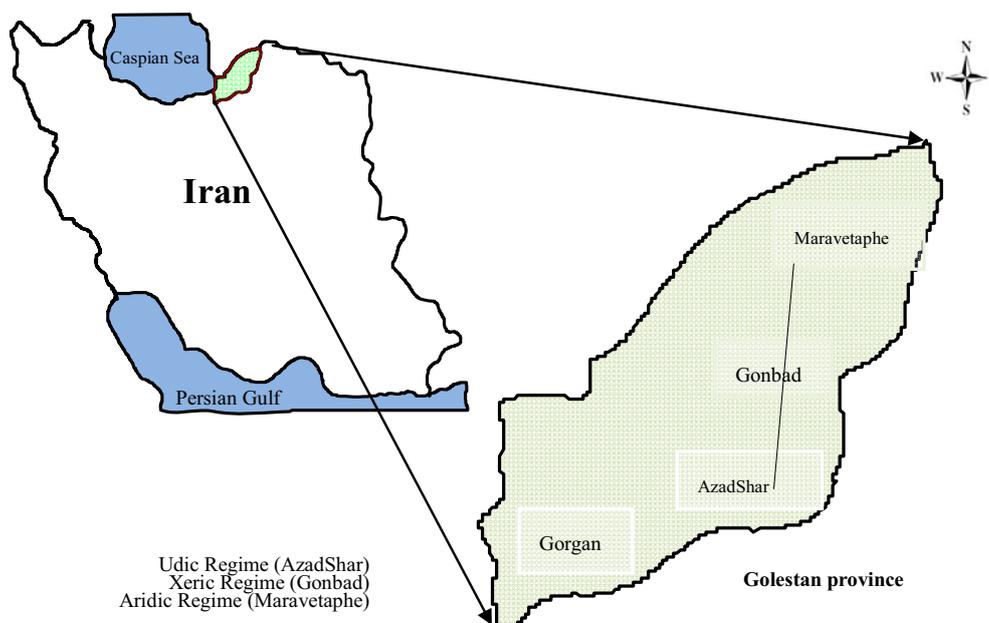


Fig. 1 Geographical location of the study area.

Table 1 Physico-chemical characteristics of the soils samples and their classification.

Profile	SOC ^a	SSA ^b	Particle-size fractions ^c			pH	EC ^d	Classification
			Clay	Silt	Sand			
P1	27.40	129.09	358.3	550	91.7	6.9	0.80	Typic Argiudolls
P2	16.25	132.84	391.7	500	108.3	7.49	0.89	Typic Halpoxerolls
P3	16.58	51.50	225	450	325	7.54	1.40	Typic Halpoxerepts
P4	16.37	84.73	325	500	175	7.54	1.42	Typic Calcixerepts
P5	8.45	78.69	258.3	633.3	108.4	7.48	1.60	Typic Haplocalcids
P6	7.25	55.63	208.4	658.3	133.3	7.62	3.28	Typic Haplocambids
P7	3.37	51.70	325	633.3	41.7	7.6	3.13	Typic Torriorthents

^a: by gram per kilogram (g Kg⁻¹), ^b: by square metre per gram (m² g⁻¹), ^c: by gram per kilogram (g Kg⁻¹), ^d: by deci siemens per metre (dsm⁻¹)

where A = SSA (m² g⁻¹), W_{EGME} is the weight of EGME retained by the sample (g), W_s is the weight of the sample (g) and 0.000286 is the weight of a monolayer of EGME (g) on 1 m² of surface.

Statistical analyses of results were conducted using by SAS software version 8 (SAS 1999). Correlation and linear regressions were performed between SOC, specific surface area (SSA) and clay size particle.

RESULTS AND DISCUSSION

The total number of 7 soil profiles were described and classified, according to the Keys to Soil Taxonomy (Soil Survey Staff 2010). Table 1 presents the results of specific surface area, pH, EC, particle size distribution and organic carbon contents of the soils studied. The soils are all derived from loess parent material with large silt contents. The profiles 7 and 6 had the least OC, with 3.4 and 7.3 g C Kg⁻¹ soil, respectively. Soil 1 contained the greatest OC concentrations 27.4 g Kg⁻¹. The second largest OC concentrations at equivalent depth were measured for profiles 3 with 16.6 g Kg⁻¹ and 4 with 16.4 g Kg⁻¹. The concentrations of OC declined rapidly from udic regime (profile 1) to xeric moisture regime (2, 3, 4 and 5) and to aridic regime (6 and 7) (Table 1). Specific surface area varied from 51.7 to 129.09 m² g⁻¹ increased from 51.70 m² g⁻¹ to 129.09 m² g⁻¹ with increasing the OC concentration from 3.4 g Kg⁻¹ to 28 g Kg⁻¹ (Table 1). The greatest and the lowest clay content were related to profiles 2 and 3, respectively. Correlation and linear regressions were performed between SOC, specific surface area (SSA) (Fig. 2) and particle clay size (Fig. 3). Results indicated that the content of clay showed significant liner correlation with SSA (R² = 0.63, P < 0.05) but SOC and SSA did not show significant liner correlations (R² = 0.50, P <

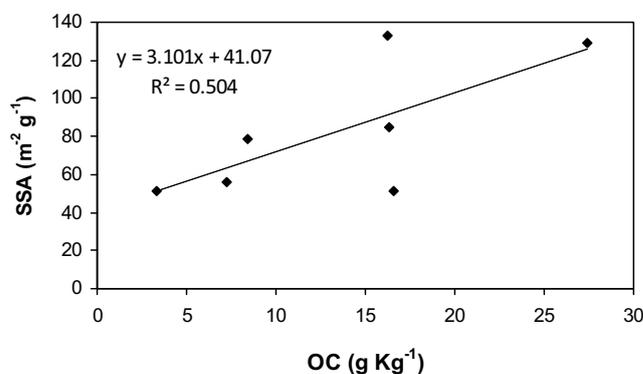


Fig. 2 Relationships between organic carbon (OC) and specific surface area (SSA). Correlation is not significant at P < 0.05.

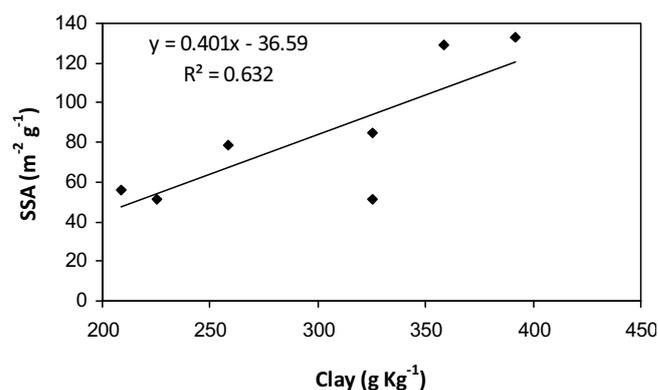


Fig. 3 Relationships between particle clay size and specific surface area (SSA). Correlation is significant at P < 0.05.

0.07). Shahriyari *et al.* (2009) found that specific surface area did not have any relation between OC and SSA. The results showed that SSA alone is not sufficient to account for the variability observed for OC concentrations in the soils (Wiseman and puttmann 2005). Mayer and Xing (2001) found that SSA did not correlate well with OC in their investigation of acid soils in Massachusetts. The relationship between SSA and OC is probably a reflection of the importance of other mineral surfaces in the stabilization of organic matter in this study. Wiseman and puttmann (2005) showed that specific surface area correlated significantly with the OC content of the B and C horizons of one Umbrisol and the entire profile of the Anthrosol/Vertisol/Gleysol-Chernozem. Saggari *et al.* (1996) demonstrated that mean residence time of organic carbon in soil increase with higher specific surface area. Soils with high clay levels show greater SOC than soils with high sand contents (Bredja *et al.* 2001).

CONCLUSION

From the results obtained in our work, organic compositions can be absorbed by mineral factors. Clay contents have significant relation with specific surface area also organic carbon did not show significant linear correlations with specific surface area. The reason of non significant linear correlations between organic carbons may due to the less number of samples.

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