

Estimation of Organic Carbon Loss Potential in a Climosequence in Golestan Province, Northern Iran

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ABSTRACT

Soil carbon oxidized by neutral KMnO_4 has been used as index of labile C by several workers. Study area a climosequence (udic-xeric-aridic regimes) with loess parent material in Golestan province, Iran. Samples from 7 different soil orders with pasture land use (Mollisols, Inceptisols, Aridisols and Entisols) were collected at (0-20 cm) depth. Permanganate-oxidizable carbon (POC), an index of soil labile carbon, was used to show soil potential loss of organic carbon (OC). This index shows the maximum loss of OC in a given soil. Maximum loss of OC for each soil was estimated through POC and bulk density. The potential losses of OC were estimated between 1930.6 and 69180.9 $\text{Kg ha}^{-1} \text{C}$. The lowest organic C loss was related to Entisols because of containing the lowest OC, and maximum potential loss of OC has been detected in Mollisols mainly due to having a lot of fresh organic tissue in mollic epipedon. In addition, the total amount of OC which were oxidised by KMnO_4 ranged from 15.6 to 60.73% of the total C. The effect of soil texture on POC was examined, clay + silt/OC, silt/OC and clay/OC accounts for 63, 68 and 51%, respectively, of the variability in soil POC ($P < 0.05$). And also soil POC of 7 soil sample were regressed with their total C contents and were found to be highly correlated ($R^2 = 0.94$, $P < 0.01$). Stable organic constituents in the soil include humic substances and other organic macromolecules that are intrinsically resistant against microbial attack, or that are physically protected by adsorption on mineral surfaces or entrapment within clay and mineral aggregates.

Keywords: x labile carbon, loess parent material, pasture soils, permanganate-oxidizable carbon

Abbreviations: BD, bulk density; C, carbon; KMnO_4 , potassium permanganate; OC, organic carbon; OM, organic matter; Pg, Peta gram; POC, permanganate-oxidizable carbon; SOC, soil organic carbon; SOM, soil organic matter

INTRODUCTION

Increasing attention has been paid to soils in recent years in terms of their potential to act as carbon sinks to help meet CO_2 emission reductions as agreed to under the Kyoto Protocol (Freibauer *et al.* 2004). Current knowledge regarding the mechanisms which are responsible for the preservation of soil organic carbon (SOC) is not sufficient enough, however, to adequately justify their incorporation in strategies to reduce emissions (Wiseman and Puttmann 2006). Soil organic matter (SOM) is the repository for approximately 60% of the global terrestrial carbon (C) pool and is especially sensitive to agricultural land management (West and Post 2002). The global carbon cycle is strongly dependent on the turnover of SOM (Schlesinger 1991; Lal 2001). As Paustian *et al.* (2000) estimated that 55 Pg C were released from the soil to the atmosphere during the 19th and 20th centuries because of agriculture. OM is a key component of soil, which affects its physical, chemical and biological properties.

OM improves soil structure, increases the water holding capacity and promotes biological transformations such as N-mineralization (Velayutham 2000). Factors that influence the formation of soils over long periods of time climate, organisms, relief, and parent material may also affect the accumulation of soil SOC on decadal time scales in former agricultural fields (Jenny 1941).

SOM can be divided into labile or rapidly decomposed, and stable or slowly decomposed fractions. The most labile components of SOM include cellular contents such as carbohydrates, amino acids, peptides, amino sugars and lipids. Soil carbon oxidized by neutral KMnO_4 , or permanganate-oxidizable carbon (POC), has been used as index of labile carbon by several workers, although the nature of OC oxi-

dized has not been well elucidated (Tirol-Padre and Ladha 2004; Shahriari *et al.* 2011).

Shahriari *et al.* (2011) showed the potential loss of OC was estimated between 38.07 and 72.32 $\text{Mg C ha}^{-1}/30 \text{ cm}$. These researchers have found that the (Clay + Silt)/OC ratio had a negative significant ($P < 0.05$) correlation with POC content, confirming the effect of fine particles in conserving of SOM.

The labile fractions of soil carbon are important to study in their own right as these fractions fuel the soil food web and therefore greatly influence nutrient cycles and many biologically related soil properties. The labile fractions of soil carbon are often termed the active C pool, to distinguish it from the bulk of the soil C, which belongs to a highly recalcitrant or passive C pool that is only very slowly altered by microbial activities (Weil *et al.* 2003). Three key processes are proposed to explain the formation of this passive or long-residence-time SOM fraction: (i) chemical recalcitrance, i.e. stabilization due to the structural properties of the OM, (ii) inclusion of OM into aggregates or micropores, leading to physical protection of OM from microbial attack and (iii) interaction of carbon compounds with soil minerals (Anderson and Paul 1984; Sollins *et al.* 1996; Baldock and Skjemstad 2000).

Using the amount of OC oxidizable by potassium permanganate as a measure of SOC lability, Blair *et al.* (1995) demonstrated the decline of a more labile form of OC under cropping but its accumulation under a legume pasture of lucerne.

In contrast, KMnO_4 has many characteristics that are propitious for a routine field method. The intense purple color of the KMnO_4 solution enables it to serve as its own indicator. If properly prepared and stored, permanganate solutions can be stable over several months (Swift 1939). It

Table 1 some properties of the soil studied.

Samples	OC (g kg ⁻¹)	POC (g kg ⁻¹)	BD (kg m ⁻³)	Particle-size fractions (g kg ⁻¹)			POC(g ha ⁻¹ 20 cm ⁻¹)	Classification	Epipedons
				Clay	Silt	Sand			
1	27.4	16.64	1386	388.3	550	91.7	69180986	Typic Argiudolls	Mollic
2	16.3	11.38	1760	391.7	500	108.3	60099937	Typic Halpoxerolls	Mollic
3	16.6	7.75	1390	225	450	325	32330376	Typic Halpoxerepts	Ochric
4	16.4	8.49	1555	325	500	175	39601672	Typic Calcixerepts	Ochric
5	8.4	5.46	1510	258.3	633.3	108.4	24743051	Typic Haplocalcids	Ochric
6	7.3	3.82	1470	208.4	658.3	133.3	16828980	Typic Haplocambids	Ochric
7	3.4	0.49	1310	325	633.3	41.7	1930634	Typic Torriorthent	Ochric

OC= Organic carbon, POC= Permanganate oxidizable carbon, BD= Bulk density

is so safe to handle that solutions ranging from 0.006 to 0.3 M are recommended in human and veterinary medicine as an antiseptic treatment for skin infections and wounds (Brander *et al.* 1982). In a neutral to slightly alkaline solution, KMnO₄ is a powerful oxidizing agent because of the large negative value (-1.45 V) of the potential between the Mn²⁺ and MnO₄⁻ ions (Cotton and Wilkinson 1988). At pH 7.2, portions of SOC react with KMnO₄ to partially bleach the deep purple permanganate color to light pink or clear (Loginow *et al.* 1987).

Specifically, slightly alkaline KMnO₄ is known to hydrolyze and oxidize simple carbohydrates, amino acids, amine/amide sugars, and C-compounds containing hydroxyl, ketone, carboxyl, double bond linkages and aliphatic compounds, to give a light pink color (Skoog and West 1969; Stanford 1978; Loginow *et al.* 1987). Blair *et al.* (1995) concluded that only one KMnO₄ concentration (0.333 M) was needed to distinguish labile soil C (oxidized by KMnO₄) from recalcitrant soil C (not oxidized by KMnO₄).

Our objective was to determine the amount of labile carbon and evaluation ingredients that effective on values of labile carbon establishment with 7 different pasture leys.

MATERIALS AND METHODS

The study area was a climosequence (udic-xeric-aridic regimes) with loess parent material in Golestan province, Iran. Seven different soil samples from different soil orders (Mollisols, Inceptisols, Aridisols and Entisols) (Soil Survey Staff 2010) were collected (depth of 0-20 cm). The land uses of whole samples were pasture. Air-dried soil samples were crushed and passed through a 2 mm sieve. The bulk density (BD) was measured by using method of Brasher *et al.* (1966) (Saran Resin, Applichem, Germany). Particle size distribution was determined using disturbed soil samples sieved through a 2 mm by the Bouyoucos hydrometer method (Bouyoucos 1962) (Sodium Hexameta Phosphate, Merck, Germany). Total OC in the soil samples was measured with using the method of Walkley and Black (1934) (potassium dichromate, Merck, Germany; sulfuric acid, Applichem, Germany).

Separate soil samples (<500 μm) containing 15 mg C were shake for 24 hrs in 25 mL of 33 mM KMnO₄ (potassium permanganate, Merck, Germany) with repetition 12 (rpm). The oxidation of OM was measured by the change in KMnO₄ concentration, measured at 565 nm, the concentration KMnO₄ from the samples and blanks was determined using the standard calibration curve, and the results expressed as mg C g soil⁻¹. The amount of POC in the sample was computed as follows:

$$\text{POC (mg g}^{-1}\text{)} = \frac{(\text{mM Blank} - \text{mM Sample}) \times (50/2) \times 25 \times 9}{1000 (\text{ml l}^{-1}) \times \text{weight of sample (g)}}$$

where mM blank and mM sample are the concentrations (mmol L⁻¹) of KMnO₄ the blank and sample, respectively, determined from the standard regression curve: 50/2 = the dilution factor (mL mL⁻¹); 25 = the volume (mL) of KMnO₄ added to the soil sample; 9 = the amount of C oxidized for every mole of KMnO₄ (g mol⁻¹ or mg mmol⁻¹) (when Mn⁷⁺O₄⁻ is reduced to Mn²⁺O₂ and C is oxidized from the natural state (0) to C⁺⁴ three moles of C are oxidized for every four moles of Mn⁷⁺ reduced) (Tirol-Padre and Ladha 2004). Maximum loss of OC for each soil was estimated through POC and BD.

Statistical analyses of results were conducted using by SAS software (SAS 1999, Ver. 8). There were 3 repetitions per soil sample. Correlation and simple linear regression analyses were used to establish relationships between POC, total OC and particle size fractions variables.

RESULTS AND DISCUSSION

Table 1 presents the values of OC (g kg⁻¹), POC (g kg⁻¹), BD (kg/m³), POC (g C ha⁻¹ 20 cm⁻¹), particle size distribution, classification and epipedons of the soils studied. The total number of 7 soil profiles were described and classified, according to the Keys to Soil Taxonomy (Soil Survey Staff 2010). The sample 1, 2, 3 and 4 contain large amounts of OC, ranging from 16.3 (sample 2) to 27.4 g kg⁻¹ (sample 1). OC concentrations then decrease suddenly with reduction of rainfall, and the sample 7 contains the lowest amounts of OC 3.4 g kg⁻¹. The greatest and the lowest clay content were related to profiles 2 and 6, respectively. Silt size particles are also present in large amounts in whole samples (up to 658.3 g kg⁻¹), because of loess parent materials (**Table 1**).

As regards **Table 1**, soil labile OC rate is absolutely related to SOC that reduction with move from moist moisture regimes (udic) to dry moisture regimes (aridic). Soil labile OC amount was varied between 0.49 to 16.64 g kg⁻¹ soils that, this value of soil labile OC in this soils type is logical. The result of Lal *et al.* (1995) in Mollisols and Inceptisols soil orders is the most of predominant with soil labile OC or active C. The most labile components of SOM include cellular contents such as carbohydrates, amino acids, peptides, amino sugars and lipids.

The potential losses of OC were estimated between 1930.6 to 69180.9 Kg ha⁻¹ C. Shahriari *et al.* (2009) were estimated the potential loss of OC between 1253.3 and 2410.8 Kg ha⁻¹ C. The lowest organic C loss was related to Entisols because of containing the lowest OC, fresh organic tissue and also was situated into aridic regime, and maximum potential loss of OC has been detected in Mollisols mainly due to having a lot of fresh organic tissue in mollic epipedon. The total amount of OC which were oxidised by KMnO₄ ranged from 15.6 to 60.73% of the total carbon. Lefroy *et al.* (1993) resulting that the total amount in the three fractions which were oxidised by KMnO₄ ranged from 14 to 25% of the total carbon.

The KMnO₄ oxidation provides useful information on the nature and turnover rate of different OM pools. These changes in OM are being correlated with changes in chemical and physical characteristics of soils under different cropping regimes in northern NSW, southern Queensland, north-east Thailand and the central Philippines (Lefroy *et al.* 1993).

The effect of soil texture on soil POC was examined by analyzing the relationships of clay + Silt/OC, Silt/OC and Clay/OC ratios (**Fig. 1**). With regard to (**Fig. 1**) Clay + Silt/OC ratio and Silt/OC had a significant (*P* < 0.05) inverse relationship with soil POC. Shahriari *et al.* (2009) have found a negative significant (*P* < 0.001) correlation between (Clay + Silt)/OC ratio and POC content, confirming the preserving effect of fine particle. Clay/OC ratio had not significant relationship with POC; because of their soil parent material was loess and has less amount of clay.

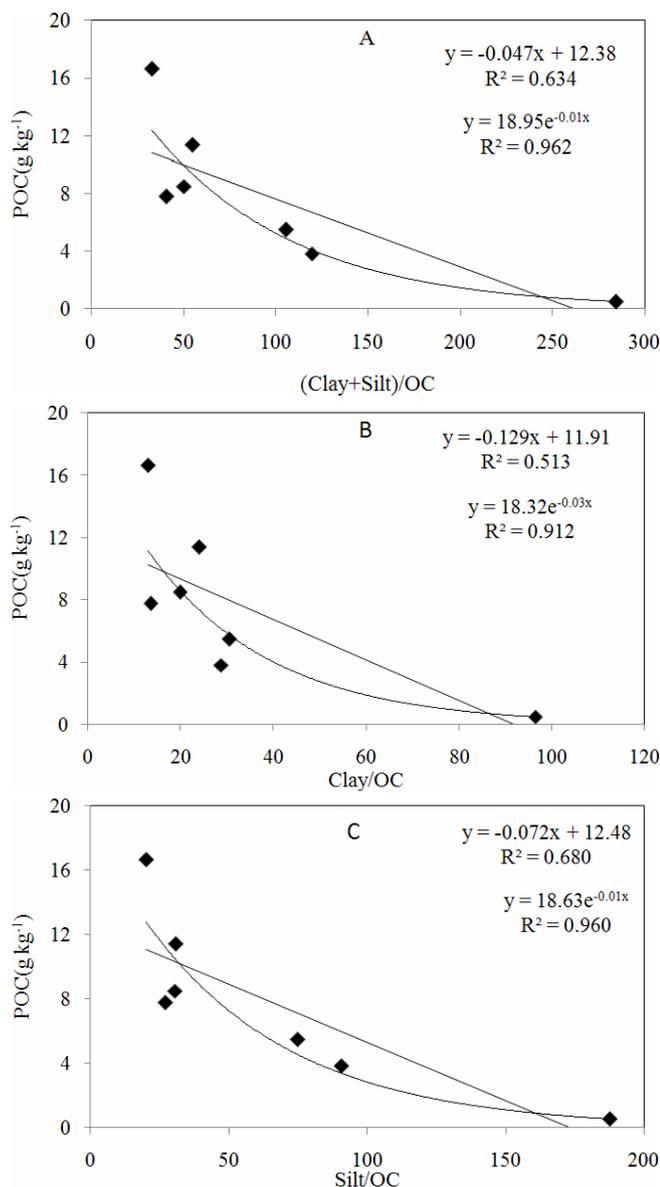


Fig. 1 Scatter plots and linear regression of soil permanganate oxidizable carbon with (A) clay+silt/OC, (B) clay/OC, (C) silt/OC.

Clay + silt/OC, silt/OC and clay/OC accounts for 63, 68 and 51%, respectively, of the variability in soil POC. The nonlinear models were preformed for parameters above, and an exponential model showed the best correlation with POC ($P < 0.01$).

The above results show that although soil POC predominately influenced by total soil C, it is also affected by soil texture. Clay and silt particles may render some degree of physical protection for oxidizable C groups in lignin (Tirol-Padre and Ladha 2004). Soil POC of 7 soil sample were regressed with their total C contents and were found to be highly correlated ($R^2 = 0.94$, $P < 0.01$) (Fig. 2).

CONCLUSIONS

The studied estimation of organic carbon loss potential in Golestan province had shown that the potential losses of OC were estimated between 1930.6 and 69180.9 Kg ha⁻¹ C. The lowest organic C loss was related to Entisols because of containing the lowest OC, and maximum potential loss of OC has been detected in Mollisols mainly due to having a lot of fresh organic tissue in mollic epipedon. The effect of soil texture on soil permanganate oxidizable carbon (POC) was examined, clay + silt/OC, silt/OC and clay/OC accounts for 63, 68 and 51%, respectively, of the variability in soil POC ($P < 0.05$).

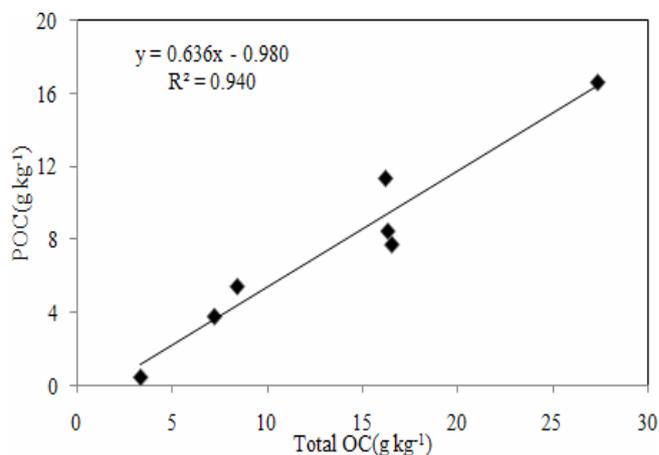


Fig. 2 Relationship of soil permanganate oxidizable carbon (POC) and total OC.

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