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Effect of a long-term cultivation and crop rotations on organic carbon in loess derived soils of Golestan Province, Northern Iran

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Abstract

The effects of 34 years cultivation on organic carbon content of the loess derived soils were studied in Golestan province, northern Iran. Soil organic carbon (SOC) showed significant decrease in most of cases. The minimum and maximum SOC decreases were 4 and 51.14 Mg C ha^{-1}/30 cm for 34 years. In a few cases there was an increase in SOC up to 16.93 Mg C ha^{-1}/30 cm over the period of 34 years indicating a favorable management, application of manure, and incorporation of the crop residues. Permanganate-oxidizable carbon (POC) was used to establish the potential loss of SOC, which was estimated between 38.07 and 72.32 Mg C ha^{-1}/30 cm. 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 soil organic matter.

Keywords: Mollisols; Soil organic carbon; Management; Long term cultivation.

Introduction

Increasing population demands for more production from limited land resources in many parts of the world and this often leads to a considerable degradation of these resources (Blair et al., 1995). Loess derived soils rich in organic carbon (OC) are among the most fertile soils in the world. High silt content of these soils together with enough clay, increase the available water potential for plants. Aeration, cultivation, and seed bed preparation in these soils are rather less time consuming and economic (Catt, 2001). Wakene (2001) reported 40 years cultivation activities in Bako Area, western Ethiopia, that caused a decrease in organic carbon by 43%. Working on a pasture soil Celik (2005) reported that when the pasture was converted into cultivation, the soil organic matter pool for the surface 0-20 cm layer was significantly reduced by about 49%, during 12 years of cultivation activities in the area.

Soil organic matter can be divided into the labile or rapidly decomposing, and the stable or slowly decomposing fraction. It is accepted that labile constituents decompose within a few weeks or months, whereas stable counterpart can persist in the soil for many years (Theng et al., 1989). The labile fractions of soil carbon influence nutrient cycles and many biologically related soil properties (Weil et al., 2003). According to Woomer et al. (1994), the most labile components of soil organic matter are carbohydrates, amino acids, peptides, amino sugars, and lipids, followed by less readily metabolized structural materials such as waxes, fats, resins, lignin, cellulose, hemi-cellulose, and also some recalcitrant plant residues. Lefroy et al. (1993) and Bell et al. (1998) reported on the relationships between fractions of SOC oxidized by 0.033 M, 0.167 M, and 0.333 M $KMnO_4$ solutions and certain critical soil physical and chemical properties. The SOC fraction most closely correlated with the properties deemed critical to the quality. These researchers suggested that sustainable cropping on these soils would require management practices that maintain adequate concentrations of 0.033 M $KMnO_4$-oxidizable soil carbon.

Our aims in this study were: (1) to examine long term cultivation effects on SOC content, and (2) to estimate the potential loss of organic carbon following cultivation.

Materials and Methods

The study area includes the southern alluvial and piedmont plains of Gorgan River extended from east to west direction in Golestan province, Iran. The pedons studied were classified as Mollisols according to Soil Taxonomy (Soil Survey Staff, 2010). The soils include eight series and were sampled from the plough layer (0-30 cm). According to a soil survey carried out by the Ministry of Agriculture and Natural Resources of Iran in 1973 more than 70 thousand hectares of Mollisols were reported in Golestan province. Mollisols in the area have been cultivated for more than 34 years. The previous soil data and sampling locations were also used.

Samples were taken in June 2007. The samples were air dried and passed through a 2 mm sieve. Particle size analysis was performed using Boyoucous (1962) hydrometric method. Total carbon was determined using the method of Walkley and Black (1934) and bulk density using the cold method (paraffin method) (Brasher et al., 1966).

The method of Tirol-Padre and Ladha (2004) method was used for the determination of Permanganate Oxidizable Carbon (labile carbon). This method was modified from Blair et al. (1995) method. The labile carbon was determined at INRES-Soil Science of Bonn University, in Germany using a 0.033 M solution of potassium permanganate was used. In this research, the oxidation process was extended to 24 hours, as Tirol-Padre and Ladha (2004) showed the permanganate oxidizable carbon (POC) in different organic compositions with 0.033 M $KMnO_4$ during the first 6 hours increases and will reach to a constant level afterwards.

Statistical analysis was performed using SAS Software (1999). Analysis of variance was performed to examine significant changes in 34 years period for SOC content of whole series and also for each series, separately. Regression and correlation analysis was also applied to examine relationships between POC and soil textural parameters.

Results and Discussion

Soil organic carbon

The results revealed that there was a significant correlation at P<0.05 for the SOC content for the whole series. The soils studied have been cultivated for more than 50 years and the minimum and maximum SOC decrease were 4 and 51.14 Mg C ha^{-1}/30 cm per 34 years. The gradual changes of SOC content sometimes show favorable management practices and it can also monitor time distance between converting native forest or range to farm and first sampling (34 years ago).

Statistical analyses showed a significant correlation at P<0.05 for SOC content for Sarli, Shahpasand and Gorgan series. Sarli series had maximum decrease in SOC. This could be related to climatic conditions since it has minimum mean annual precipitation and also maximum mean of annual temperature. The accumulation rate of SOC as well as its fractions, depends on soil texture, precipitation, and temperature (Amelung et al., 1998). Burke et al. (1989) found that organic carbon increases with precipitation and decreased with increasing temperature. The decrease in SOC could threaten sustainable agriculture and is an indication of unsuitable management practices in most of the soils studied.

In few cases, there was an increase in SOC content, which was not significant. The minimum and maximum SOC increase were 1.71 and 16.93 Mg C ha^{-1}/30 cm per 34 years, respectively (Table 1). This increase could mainly be related to a favorable management, alternatate cultivation of wheat and rice and addition of manure (Wu et al., 2004).

Table 1. SOC (soil organic carbon) in 1973 and in 2007 contents and Difference between old and new SOC contents of samples.

Soil Series	SOC in 1973 (g/kg)	SOC in 2007 (g/kg)	Difference between Old and New SOC (Mg C ha^{-1}/30 cm)
Dahaneh-1	14.00	22.43	
Dahaneh-2	20.00	15.60	$8.81^{n.s}$
Dahaneh-3	17.00	19.01	
Minoudasht-1	19.00	17.82	
Minoudasht-2	16.00	18.20	$1.71^{n.s}$
Minoudasht-3	17.90	18.01	
Galikesh-1	11.80	17.25	
Galikesh-2	18.40	18.40	$16.93^{n.s}$
Galikesh-3	13.60	17.83	
Sarli-1	17.00	7.80	
Sarli-2	21.60	12.40	-51.14^{*}
Sarli-3	19.80	10.10	
Shahpasand-1	21.00	13.72	
Shahpasand-2	19.00	13.70	-39.86^{*}
Shahpasand-3	22.00	13.71	
Ramian-1	11.00	19.50	
Ramian-2	19.00	13.50	$-4.18^{n.s}$
Ramian-3	22.00	16.50	
Amirabad-1	13.00	17.55	
Amirabad-2	25.00	19.00	$-4.00^{n.s}$
Amirabad-3	19.00	18.28	
Gorgan _1	16.00	14.04	
Gorgan _2	19.00	9.30	-35.89^{*}
Gorgan _3	19.00	11.67	

* Significant correlation at P≤0.05, $^{n.s}$ no significant.

The main factor affecting the SOC content in this study was management practices. To compare other researches, SOC content changing in our study, didn't change much. Not clear it seems that physiographic affected the SOC content, as the study area includes the alluvial and piedmont plains without slope. The stable physiographic location of the study area including mainly the piedmont plains could be the reason for gradual and sometimes insignificant decrease in SOC.

Soil labile carbon

The POC is an index of soil labile carbon, which was used to show potential loss of SOC and consequently maximum organic matter decrease in a given soil.

Maximum potential loss of OC was estimated through bulk density of the soil and POC for each soil series (Table 2). The relationship between POC and OC was significant at $P<0.05$. Almost more than 50 percent of SOC was labile carbon (Table 2), which is a dominant type of carbon in Mollisols (Lal et al., 1995). There was a close positive relationship between the proportion of particles <20 µm in a soil and the amount of C associated with this fraction. This can be used as a first estimation for the capacity of a soil to preserve C. The amount of C in macro organisms is controlled by soil management, while the amount of C protected by clay and silt particles is controlled mainly by soil texture (Hassink et al., 1997). As Tirol-Padre and Ladha (2004) showed, the clay + silt/organic carbon ratio negatively affected the POC. Our study supports Tirol-Padre and Ladha (2004) findings.

The above statements indicate the need for more research on the interaction between SOC and it's protection by soil mineral fractions. Fitzsimmons et al. (2004) also believed land use change is an important resource for carbon emission to atmosphere by human, after fossil fuels.

Table 2. Estimated OC loss potential in different soil series.

Soil series	OC (g/kg)	POC (g/kg)	POC %	Clay %	Silt %	(C+S) /OC	C/OC	S/OC	Bd (kg/m^3)	C (Mg/ha/ 30 cm)
Dahaneh	19.01	10.06	52.90	32	66	51.55	16.83	34.72	1460	44.05
Minoudasht	18.01	9.97	55.34	38	49	48.31	21.10	27.21	1510	45.15
Galikesh	17.83	13.78	77.29	45	45	50.48	25.24	25.24	1750	72.32
Sarli	10.10	6.97	69.04	40	49	88.12	39.60	48.51	1820	38.07
Shahpasand	13.71	9.68	70.59	41	53	68.56	29.91	38.66	1910	55.46
Ramian	16.50	11.56	70.08	28	49	46.67	16.97	29.70	1670	57.94
Amirabad	18.28	10.28	56.25	30	55	46.50	16.41	30.09	1840	56.75
Gorgan	11.67	7.37	63.17	31	43	63.41	26.56	36.85	1890	41.80

Clay and silt percent, OC=organic carbon of soil, POC=permanganate-oxidizable carbon, (C+S)/OC=(clay+silt)/OC ratio, C/OC=clay /OC ratio, S/OC=silt/OC ratio, Bd=soil bulk density and C=amount of carbon that a given soil can lose.

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