Influence of Soil Type and Fertilization on Accumulation and Stabilization of Organic Carbon in Different SOM Fractions

Elke Schulz[1]**, *Lidya S. Travnikova*** [2]**, *Natalya A. Titova*** [2]**, *Boris M. Kogut*** [2]
and ***Martin Köschens***[3]

[1]Centre for Environmental Research Leipzig-Halle Ltd., Department of Soil Science Halle
E-mail: eschulz@bdf.ufz.de
[2] Dokuchaev Soil Science Institute Moscow
[3]Martin-Luther-University Halle-Wittenberg, Institute of Plant Nutrition and Soil Science

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1 Introduction

At steady state of SOM the mean residence time of carbon (C) varies depending on the stability of the organic substances and environmental factors. Accordingly the total SOM contains pools of different quality and stabilization degree. Total SOM consits of a more or less inert C pool (C_{inert}) and a decomposable C pool (C_{decomp}). C_{inert} depends on soil type and climate and correlates well with the clay and fine silt fraction (Köschens 1980). Management strategies only change the C_{decomp} pool (Köschens *et al.*1998).

The parameter of hot water extractable carbon (C_{hwe}) can be used to quantify a pool of labile SOM (Schulz 1997). Interactions of SOM with clay minerals are of importance for SOM stabilization by forming stabile mineral-organic complexes or associates determining quality and fate of organic substances in soil.

2 Materials and methods

Basing on extreme treatments of two German long-term field experiments – Static Fertilization Experiment Bad Lauchstädt (Haplic Chernozem) and Nutrient Depletion Experiment at Thyrow (Albic Luvisol) – the influence of soil type and fertilization on accumulation and stabilization of soil organic matter (SOM) in different soil fractions was investigated. Selected soil characteristics are given in Table 1.

Table 1 Selected chemical parameters of the experimental soils

	Nutrient Depletion Experiment Thyrow (started in 1937)		Static Fertilization Experiment Bad Lauchstädt (started in 1902)	
	without fertilization	FYM + NPK	without fertilization	FYM + NPK
C_{org} (%)	0.37	0.70	1.57	2.03
clay (%) (< 2 μ m)	5		21	

A hot water fractionation of SOM was performed to isolate a characteristic C pool of high turnover rates for estimating a pool of decomposable carbon (C_{decomp}). Air dried soil samples were extracted under reflux for one hour with water (1：5, w：v). The clear extracts were used for C and N determination (wet oxidation of organic C using potassium dichromate; N determination according KJELDAHL) .

Performing a method of physical fractionation according both particle sizes and differences in the specific densities SOM pools of (a) associations with mineral soil constituents like clay sized particles and (b) in case of the specifically light density fractions a pool of SOM that is only loose connected with the mineral part of soil (modified method according Travnikova *et al.*, 1993) were discriminated. SOM associated with clay sized minerals (< 1μm) was isolated by treating a soil – water suspension (1∶3.5, w∶v) with ultrasonic energy. The remaining was used to isolate SOM of specifically light density by partitioning the soil in liquids of different densities. By this procedure two "Light fractions" (LF) of SOM were isolated: LF1: < 1.8 g • cm^{-1} and LF2:1.8— 2 g • cm^{-1}.

Carbon and nitrogen contents of the fractions were determined using a VARIO EL elemental analyzer (dry combustion).

3 Results and discussion

Hot water extractable SOM fraction contains soil microbial biomass and other simple organic substances (sugars, amino acids *etc*., Leinweber 1995) hydrolyzing or depolymeryzing under the given extraction conditions. This fraction can be assumed to be the most readily degradable part of decomposable C pool (Franko 1997). Significant correlations were found between the C content of the hot water extractable fraction (C_{hwe}) and activities of soil microbial biomass e.g. exhalation of CO_2 (r^2 =0.97, n=15) and production of mineral nitrogen (r^2 =0.91, n=22) (Schulz & Köschens 1998).

In both soil types the influence of fertilization on the amount of decomposable C pool is reflected in the hot water extractable SOM fraction (Table 2). Compared to the treatment without fertilization this fraction was more than doubled in the treatment FYM application with additional applied mineral fertilizers.

Table 2 Influence of fertilization on hot water extractable SOM pool

	Nutrient Depletion Experiment Thyrow (started in 1937)		Static Fertilization Experiment Bad Lauchstädt (started in 1902)	
	Without fertilization	FYM + NPK	without fertilization	FYM + NPK
C_{hwe} (mg kg^{-1})	115	267	170	550

From the results of a wide range of European long-term experiments it is evident that C_{hwe} values less 200 mg • kg^{-1} express a depletion of decomposable SOM as in the unfertilized treatments of the two long-term experiments (Köschens *et al.,* 1998; Schulz 1997).

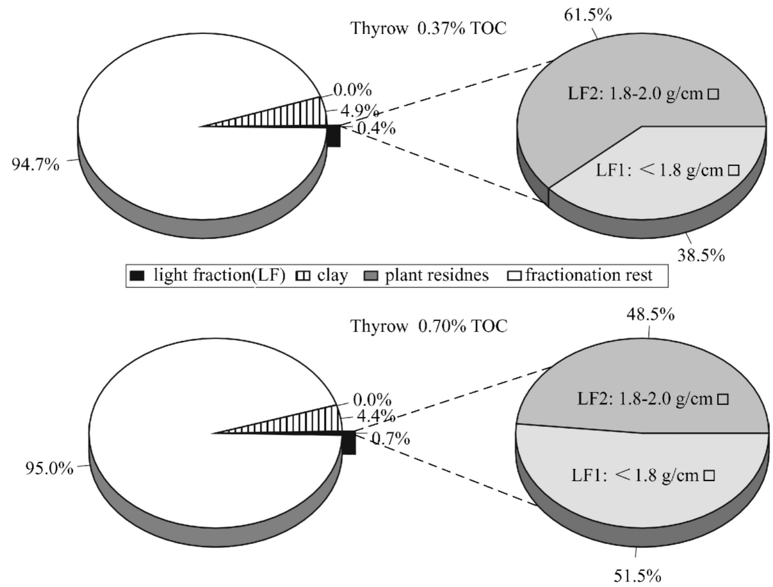

Fig.1 Distribution of masses of SOM fractions differing in particle sizes as well as in specific densities of a very light sandy soil (Albic Luvisol) at Thyrow Nutrient Depletion Experiment

A stabilization of SOM can be reached by interacting with the mineral part of soil like clay minerals resulting in true chemical linkages or sorption complexes. Such interactions of humic substances with clay minerals are typical processes in soil and they are of essential importance because large parts of SOM are associated with clay minerals (Ziechmann 1996). The resulting mineral - organic associates decicive determine nature and behaviour of SOM (Greenland 1965 a,b; Huang & Schnitzer 1986).

A mass distribution of SOM fractions differing in particle size as well as in specific densities reflects soil type as well as fertilization influence. Clay contents (< 1μm) of the light sand at Thyrow of 5 % and of the Chernozem at Bad Lauchstädt of 16 % were measured. In both soil types the share of the whole light fraction (LF) of the organic and mineral fertilized treatments is doubled compared to the unfertilized soils, demonstrated in Figure 1 for Albic Luvisol at the site Thyrow as example. In detail organic and mineral fertilization is reflected especially in the light fraction of less density (LF1 < 1.8 g • cm^{-3}).

From investigations of Kogut *et al.* (1998) is concluded that fertilization strategies are reflected in C content of the light fractions. In contrast the C content of the clay fraction can be assumed to be a relatively constant site specific parameter. However, from Figure 2 it is visible that fertilization also increases more or less clay associated SOM pool as well as SOM in LF2 (increase in TOC of these fractions). In contrast, looking at the enrichment factors of organic carbon (E-SOC) we find a decrease with increasing TOC of the soils (Figure 3).

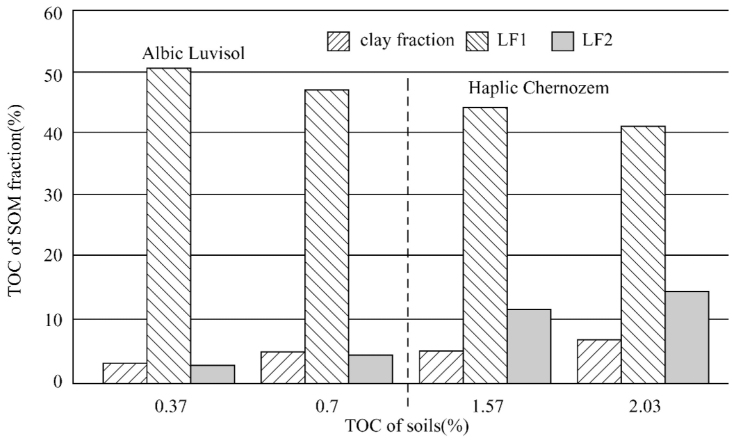

Fig. 2 Influence of soil type and fertilization on carbon contents of different SOM fractions

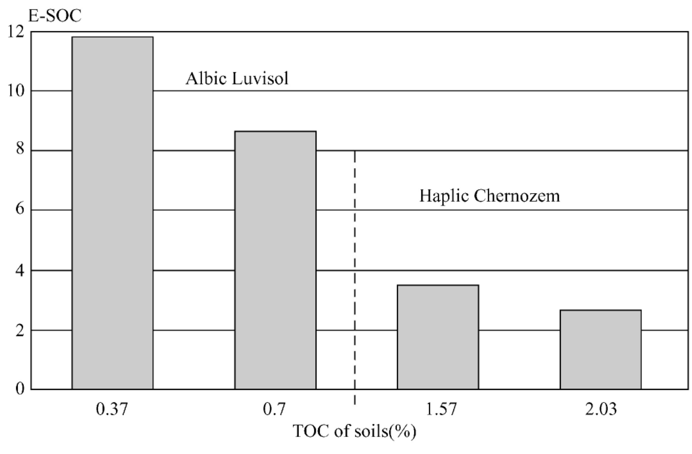

Fig. 3 Carbon enrichment factors (E-SOC) of SOM in clay fraction of fertilized an unfertilized plots of two German long-term field experiments

Carbon enrichment factor (Christensen 1992) in clay fraction is increased in soils of higher turnover rates due to management and wether conditions of the site (Amelung *et al.,* 1998). The E-SOC values (Figure 3) correspond with the observed higher SOM turnover in the Albic Luvisol at Thyrow compared to the Haplic Chernozem at Bad Lauchstädt (Franko 1997).

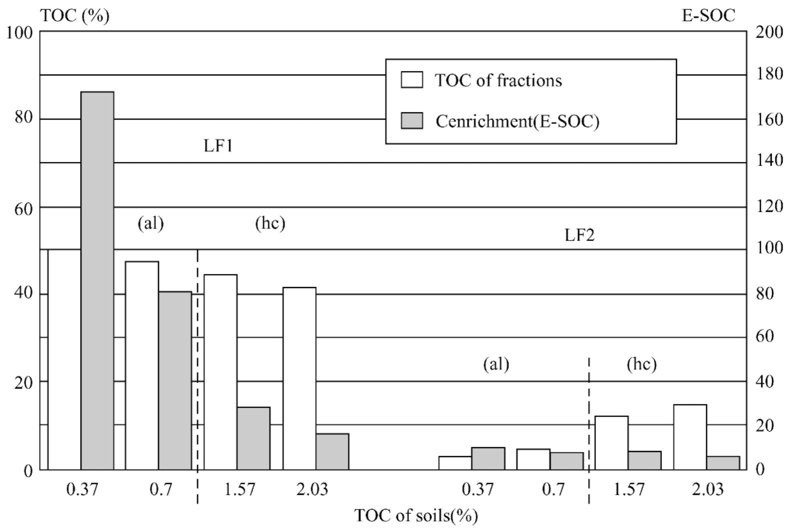

Fig. 4 Carbon content and carbon enrichment factors (E-SOC) of two specific light SOM fractions of extreme fertilized plots of an Albic Luvisol (al) and a Haplic Chernozem (hc)

Influence of fertilization on carbon content as well as E-SOC values of the two specifically light SOM fractions has to be differentiated (Figure 4). In LF1 carbon content as well as E-SOC decrease with increasing TOC of the soils (soil type and fertilization). Compared to that in LF2 carbon content increases in the same order but E-SOC decreases. The hypothesis is a chemical stabilization of SOM in LF2 so that higher microbial activities in plots treated with mineral and organic fertilization did not lead to a consumption of that fraction. SOM in LF1 will be consumed due to increased microbial activities what is expressed by decreasing TOC and E-SOC values of that fraction.

4 Conclusions

From our investigations on the influence of soil type and fertilization on accumulation of carbon in different stabilized SOM fractions we can conclude:

- Fertilization increases easily decomposable SOM pools reflected (1) in C content of a hot water extractable SOM fraction and (2) in mass of a specifically light SOM fraction (LF1: < 1.8 g • cm^{-3})
- fertilization also influences the C pool associated with clay minerals
- compared to Haplic Chernozem high C enrichment factors of the clay fraction of an Albic Luvisol demonstrate the more intensive SOM transormation processes (turnover rates) according to site specific climatic conditions and the quality of SOM
- C contents as well as C enrichment factors in the two light fractions point on different chemical stabilization degree and degradeability of the SOM in these fractions
- Comparing all results of the two soils it is visible that SOM transformation depends on both the transformation conditions (site) and the quality of SOM

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