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Carbon Stocks and Isotopic Composition of the Organic Matter in Soils Covered by Native Vegetation and Pasture in Sorocaba, SP, Brazil

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ABSTRACT: Land cover change constitutes one of main way of alteration of soil organic matter in both quantitative and qualitative terms. The goal of this study was to compare the carbon stock and the isotopic signature of the organic matter in the soil of areas with different land use, covered with forest and grass (pasture). The study area is located at Sorocaba, SP, Brazil. Using un-deformed soil samples, we measured the carbon content and bulk density. The isotopic signature of soil carbon was determined through the analysis of isotopic ratio $^{12}C/^{13}C$. The pasture soil stocks 48% less carbon than the soil covered by natural forest. The isotopic signature indicated that 42.2% of organic matter of the soil covered by pasture is originated from grasses. This characterizes a highly degradation of organic matter in the environment, both quantitatively and qualitatively. Hence, some guidelines of recuperation are described in order to restore the soil organic matter, structure and porosity.

Key words: Soil organic matter, Soil carbon stock, Carbon isotope, Soil management, Recuperation of degraded soil

INTRODUCTION

Soil is a crucial component of biosphere. Its ecological role in the biosphere is not just act as a part of an agricultural system, but, moreover, acting in maintenance of the environmental quality, with effects in a local, regional and planetary scale.On its turn, the organic matter realizes multiple functions in the soil, especially under conditions of tropical and subtropical climates.

One of the most import role that the organic matter plays is regarding the maintenance of stability of soil aggregates and structure, improvement of the water infiltration and retention, resistance against the erosion, increasing the soil cation exchange capacity, soil aeration and enhancement of the microbial biomass (Primavesi, 1987).In natural ecosystems the soil organic carbon has a principal source the litter and roots generated by vegetation. In agroecosystems, the major part of the soil carbon presents at least two sources: the remaining of the native vegetation that had occupied the local in preterit periods and the produced by decomposition of the vegetal wastes of the one or more introduced cultures (Bernoux, 1999).

The amount and quality of organic matter in a soil covered by native vegetation is approximately constant, but is highly sensible to kind and level of management in a determined soil. Due to such sensibility, management practices that dig the soil cause expressive reduction in the amount of organic matter. In consequence it diminishes the aggregation of the particles and also of the cation exchange capacity, promoting a loss on the soil quality (Lopes, 1994).The stocks of total carbon in the soil are considered indicator of environmental quality, because they are related

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with the performance of many functions and process on the soil. They are correlated with physic, chemical and biological proprieties (Bernoux *et al.,* 1999).

The sources of carbon in these ecosystems have been analyzed through the variation of the isotopic relation $^{12}C/^{13}C$, named relation $\delta^{13}C$. This method is based on the existence of changing on the isotopic composition of the soil carbon, when the native vegetation constituted predominantly by plants of C3 metabolism is substituted by C4-plants (Fernandes *et al.,* 2007).The ratio of the isotopic composition is due the isotopic fractioning that occurs according to some physiological characteristics of the plants, limitations on the diffusion of the gases located inside of vegetal tissue and the ratio between the internal stomatal pressure and the atmospheric pressure (Farquhar *et al.,* 1989).

Sorocaba, located in the São Paulo State, is a municipality where the land has been used for many purposes since some centuries ago. The natural vegetation has been gradually changed by new kinds of soil cover. One of the "artificial" cover is the pasture, aiming the livestock production. Besides the vocation of the city is currently largely industrial, significant rural areas covered by grasses still remains. Nowadays 36% of the municipality is covered by pasture (Silva, 2005). The rural propriety that was the local of this investigation is an example of such situation. On the other hand, studies that investigate the change in the carbon amount and quality of the organic matter do not exist in Sorocaba, characterizing expressive demand for studies on this issue. The aim of this study was comparing the carbon stock, as well as, comparing the isotopic signature of the organic matter of soil covered with natural vegetation, and soil covered by pasture. Both areas are located in a farm, located in Sorocaba, SP.

MATERIALS & METHODS

The study area is a rural propriety located in Sorocaba Municipality (Fig. 1). It has 278 ha and there are currently 300 animals (livestock) managed without advanced technology. The soil is covered mainly by pasture (74% of study area). Regions presenting exposed soil also occur along 20% of study area. Soil covered with natural vegetation is 5% and covered by cultures 1% (Ikematsu & Nogueira, 2008).

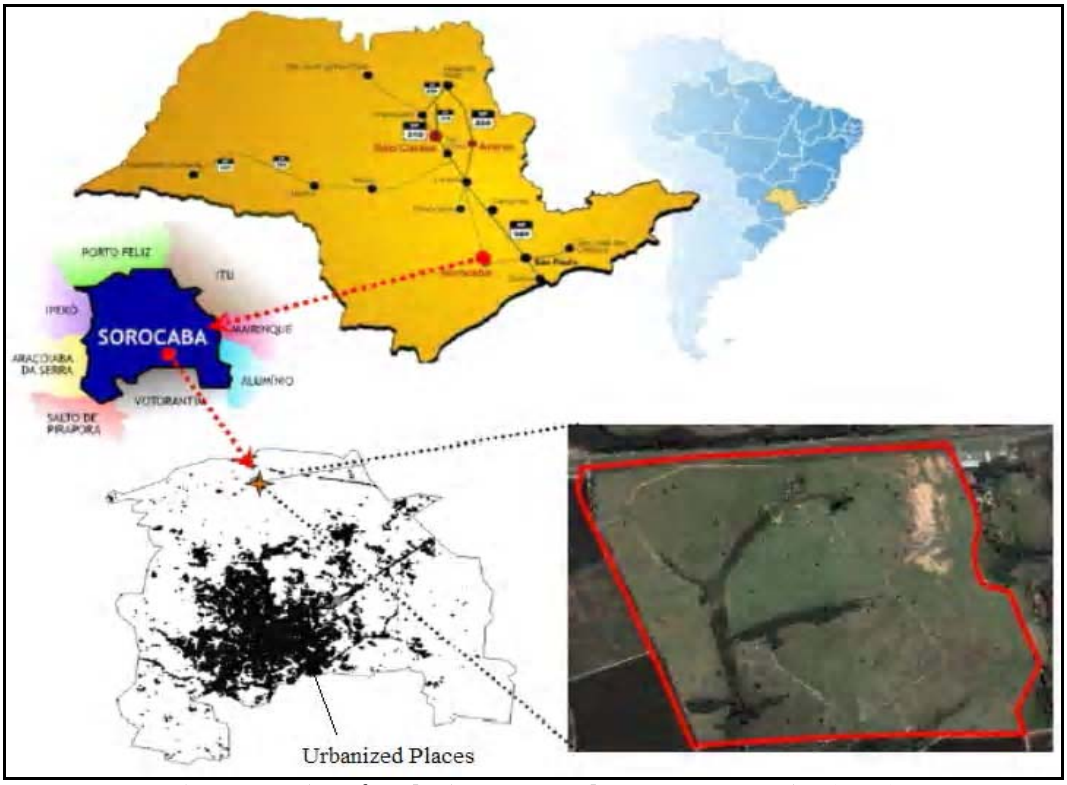

Fig. 1. Location of study site. Source: Ikematsu & Nogueira (2008)

Un-deformed soil samples were collected in a 0 – 30 cm thickness. Samples were collected in pasture and others collected in area covered with native vegetation. The samples were divided into three parts. The first part was sent to Department of Soil Science of Esalq – USP (Piracicaba, SP, Brazil – http://www.solos.esalq.usp.br) for analyzes of the following parameters: organic matter, pH (water and $CaCl_2$), P, N, Ca, Mg, K, Cation Exchange Capacity and Sum of Basis.

The second part was sent to Laboratory of Isotopic Ecology of CENA/USP (www.cena.usp.br) for quantification of the amount of organic carbon and stable isotopic. This quantification was done through gas chromatography after burn of the sample in an oxidant medium. Part of this processed sample was analyzed by an elementary analyzer Carlo Erba 1110 conjugated with a mass spectrometer of isotopic ratio Finningan Delta Plus (Mello, 2006).

A third part of these samples was transported for Campus de Sorocaba – UNESP and oven-dried (90°C – 48 hours) for analysis of bulk density (wax method with individual aggregate), particles density (volumetric flask method) (Sengik, 2005) and porosity (by mathematical formula) (Vieira, 1988).Conversion of organic carbon from % to kg.ha^{-1} in soil was made using the following equation, according to Melo (2003), Ponce-Hernandez (2004), and Robert (2002):

$$CS_h = C * DA * h \qquad (1)$$

Where: CS_h – Carbon stock in horizon "x" (t.ha^{-1}); C – Carbon concentration (g.kg^{-1}); Bulk density - DA (g.cm^{-3}); h – is the thickness of the surface soil.Through field incursions was observed that the locals presenting exposed soil were evenly associated with area covered by pasture. Due this fact, for carbon stock computation, areas presenting exposed soil were computed jointly with areas covered with pasture.Additionally, the percentages of carbon derived from forest and from pasture were estimated. The estimative was done through the isotopic dilution (Bernoux *et al.,* 1999, Fernandes *et al.,* 2007), using the following equations:

$$C_p = \frac{\delta - \delta_{C3}}{\delta_{C4} - \delta_{C3}} * 100 \qquad (2)$$

$$C_f = 100 - C_p \qquad (3)$$

Where:

- C_p = % of carbon derived from pasture.
- C_f = % of carbon derived from forest.
- ä = ä^{13}C (ratio $^{13}C/^{12}C$) of the sample of soil covered by pasture.
- $ä_{C4}$ = value of ä^{13}C of plant C4.
- $ä_{C3}$ = value of ä^{13}C of the soil covered by forest – C3.

$^{13}C/^{12}C$ ratios are expressed relative to a standard as ä^{13}C values, where:

$$\delta^{13}C = \frac{R_{sa} - R_{st}}{Rst} * 1000 \qquad (4)$$

Where:

R_{SA} - is the $^{13}C/^{12}C$ ratio in the sample.
R_{ST} - is the $^{13}C/^{12}C$ ratio in the standard.

The standard is carbonate from Pee Dee Belemnite limestone and units are per mille (‰). Atmospheric CO_2, plant material, and soil organic matter are depleted in ^{13}C relative to the standard and therefore have negative ä^{13}C values. The more depleted in ^{13}C a material is, the more negative the ä^{13}C value will be (Powers, 2005).

RESULTS & DISCUSSION

Table 1 presents database regarding the chemical parameters and pH. All chemical parameters of the soil covered by pasture presented lower values than the soil covered by forest. The pH values were very similar. However, equal values of pH does not indicate same amount of changeable cations. Changeable cations are more dependent of the Cation Exchange Capacity - CEC (Primavesi, 1987). In fact, this was verified on this study, once the CEC of the soil covered by forest was approximately four times higher than the CEC of soil covered by pasture.

Organic matter amount was almost three times higher in soil covered by forest than in the soil covered by pasture. Two factors that are occurring simultaneously in the pasture site seem have influence on it: 1) high rates of soil loss, and 2) high rates of decomposition of the organic

Table 1. Values of the physic and chemical parameters of the soils covered by forest and by pasture

Site	pH (H_2O)	pH ($CaCl_2$)	OM g . kg^{-1}	P µg . kg^{-1}	N %	CEC	SB	Ca	Mg	K
						mmol$_c$. kg^{-1}				
Pasture	5.1	4.4	16.0	2.67	0.05	33.27	9.93	5	5	0.6
Forest	5.0	4.5	42.0	15.00	0.18	144.20	49.90	55	40	4.2

OM – Organic Matter; CEC – Cation Exchange Capacity; SB – Sum of Basis

matter. These factors clearly point out the soil mismanagement of the farm.

Regarding to erosion process, there was in study area a high number of locals presenting channels and ravines (square-shaped channels with sides up to 0.5m). Assuming that the pastured soil of study area is in general poorly covered by grasses, sheet erosion also seems occur, due small quantity of mulch. Hence, it seems that the erosion's vicious cycle was definitively installed there: the erosion weakens the soil and difficult the soil cover's establishments. Consequently, the soil becomes more susceptible to erosion and more poorly uncovered, favoring the erosive process (Sparoveck, 1991 *in* Silva *et al.,* 2007).

Bulk density was higher and soil porosity was lower in pasture soil than in forest soil (Table 2). The differentiated percentage of organic matter among the two sites suggests having some influence over these two parameters. Such relation was also observed by Siqueira Neto (2006) and mentioned by Lopes (1994). The traffic of animals and the exposition of the soil to the weather also have some influence on bulk density of the soil covered by pasture, independently of the amount of organic matter of the soil (Siqueira Neto, 2006).

Table 2 . Bulk and particle densities and porosity of the soil of the studied sites

Site	Bulk density (g/cm^3)	Particle density(g/cm^3)	Porosity (%)
Pasture	1.4	2.5	42.4
Forest	1.2	2.5	53.0

Table 3 shows the values of carbon concentration, bulk density, the considered thickness of the surface soil for the computation of the carbon stock. If we assume that the quantities of stored carbon were equals or very similar in the two sites in the time before to deforestation of the area that currently is covered by pasture, we observe 52% of reduction of carbon stock.

Table 3 . Carbon amount, bulk density, thickness and carbon stock in the two studied sites

Site	C amount (g.kg^{-1})	Bulk density (g.cm^{-3})	Thickness (meters)	C Stock (t.ha^{-1})
Pasture	6.7	1.44	0.30	28.9
Forest	16.0	1.16	0.30	55.6

The database regarding the carbon stock for the soil covered by pasture here observed are, in parts, divergent from the database verified in literature and, in parts, concordant. While some authors observed major accumulation of carbon in soils used for pasture in relation to reference, forest areas (Bernoux *et al.,* 1999: Fernandes *et al.,* (2007; Mello, 2003) – this last one for some classes of soil), other authors observed the opposite (Mello (2003) – for some classes of soil, Siqueira Neto (2006)).The diminution of carbon stock is possibly related to decomposition rates of the carbon, which might be differentiated according to soil class (Bernoux *et al.,* 1999; Mello, 2003). However, good management practices are the main responsible for increasing of carbon stock in cultivated areas (Bernoux *et al.,* 1999; Siqueira, 2006, Silva *et al.,* 2004) but this is not the case of this study site.

Considering the values of carbon stock according to values presented in Table 3 and also the areas occupied by each one of the classes of land cover in the rural propriety, the amount of stored carbon estimated for the study area (considering areas occupied by pasture, forest and uncovered soil) is 8,360.8 tons for the 30 cm thickness of soil surface.The isotopic analyses revealed a value of -24.02‰ for forest soil. Comparatively, Mello (2003) found values changing from -28.6‰ to -25.2‰ for soils located at Amazon biome. Fernandes et al. (2007) found for soils located at Pantanal biome, values changing from –24.3‰ and -23.7‰. Siqueira Neto (2006) found the value -25.0‰ for soils located at Cerrado biome.

For the pasture soil the observed value for this study was -19.37‰. Such value indicated that for the pastured area, 42.2% of the organic matter there existing is derived from grasses (pasture), showing that important alterations already occurred in the quality of the organic matter of the soil due to change of the land cover and land use.

Comparatively, Fernandes *et al.,* (2007) observed the evolution of the quality of the organic matter in two pasture soils located in Pantanal, being one area with pasture formed 10 years ago and other formed 20 years ago. For the pasture of 10 years, observed 52.4% of the carbon was derived from pasture and for pasture of 20 years, 76.1% of the soil carbon was derived from pasture. There are many forms to modify such unfavorable situation and promote the environmental adequacy in the study area. One of the options is the installation of beds, in order to break the erosive force of the runoff and avoiding the accelerated degradation of the soil. However, the dimensioning should be carried out with carefulness in order to avoid the disruption of the beds and increasing the problem of erosion already existing there (Silva *et al.,* 2007).

On the other hand, Primavesi (1987) mentions that the actual soil conservation is not promoted only with practices that break the erosive force of the runoff, but mainly that ones that arise and keep the soil structure and increase the infiltration of the water through the soil. Possibly the best way to get this goal is starting the activities of recuperation through the surface application of lime and gypsum (Ikematsu and Nogueira, 2008). In order to complement the activities for soil recuperation, the application of phosphate fertilize can also be considered (Lopes, 1994). The increasing the of production of straw and of root system in phosphorus-fertilized soils pasture provides a more efficient nitrogen cycling and provides an increasing in carrying capacity, in consequence of the increasing of the pasture yield (Ikematsu & Nogueira, 2008).

Exemplifying: Schunke et al. (1992), in a pasture formed by *Brachiaria decumbens* (the same grass specie cultivated in the area here studied), cultivated in a sandy and phosphorus-fertilized soil, found increasing of 100% in production of dry matter of the aerial part of the plants, with an expressive increasing of the straw deposited over the ground and also observed the improvement in availability of the nutrient for the roots of the plants.

However, the most important factor is the cattle management. In the new-conservation system here proposed, the farmer should looks for the maximization of the animal yield without affect the permanency of pasture. The division of the area in paddocks, limited by fences and the adoption of the system of rotation of pasture seem be the most promissory ways. Hence, the soil of the study area would change the ecological role: from carbon source (carbon emitter from soil to atmosphere) to carbon think (sequestrating carbon from atmosphere to the soil).

CONCLUSION

The management system of the soil and the livestock currently applied on the study area has caused a diminution on the soil carbon stock. The organic matter of the pasture soil presented significant alteration, both quantitatively and qualitatively. Finally, the study area needs urgent actions in order to recuperate the essential soil proprieties and, among other ends, promote the carbon sequestration and the improvement of the local environmental quality.

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