SOIL ORGANIC MATTER DYNAMICS IN DENSITY AND PARTICLE-SIZE FRACTIONS AS REVEALED BY THE $^{13}C/^{12}C$ ISOTOPIC RATIO IN A CERRADO OXISOL

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1. INTRODUCTION

The Cerrados region occupies an area of 207 million hectares (24.42% of the Brazilian territory), localized mostly in the Mid-West region, and small areas fringing other regions such as Northeast and North regions. It is localized between the parallel 5°50' to 21°26'. The Cerrados region contributes significantly to the Brazilian agricultural and forestry product. Due to the inadequate management systems adopted, these soils are easily degraded leading to decrease in crop yields, losses of organic matte and nutrients, structure degradation, erosion, high runoff, sedimentation and contamination of the water.

Soil organic matter dynamics under Cerrado ecosystems are still unclear. Losses of up to 80% of the total soil organic matter (SOM) in 5 years of soybeans were already reported, showing the risks of degradation of the Cerrado soils under cultivation (Silva et al., 1994). However, the losses of carbon in cultivated pastures can be minimal and, in some cases, the content of SOM can be even higher than in the natural ecosystem (Corazza et al., 1999).

The isotopic composition of the carbon can be successfully used for SOM dynamic studies (Balesdent and Mariotti, 1996). The $^{13}C/^{12}C$ ratio widely differs between plants that follow the C_3- and C_4-photosynthetic pathways, providing a natural tracer when a C_3 vegetation is substituted by a C_4 one (Balesdent and Mariotti, 1996).

In order to better understand the impact of converting native Cerrado into pasture, we studied the dynamics of different physically separated SOM pools in different depths of a Cerrado's Oxisol (Typic Haplustox), under natural conditions and after 23 years of cultivated pasture (*Brachiaria spp.*) via the replacement of the native C (C_3-derived) by pasture C (C_4-derived).

2. MATERIAL AND METHODS

The study was carried out at the Maize and Sorghum National Research Centre – Brazilian Institute of Agricultural Research (EMBRAPA-CPMS), Sete Lagoas-MG, Brazil. The area is located at latitude 19°26'S and longitude 44°10' W, and has a mean altitude of 730 m. The mean annual temperature is 22.1°C, and annual precipitation is 1340 mm, with a dry season from April to September. Two representative sites were selected in a homogeneous Dark Red Latosol (Typic Haplustox) soil unit. Site 1 was a reserve of native "cerrado sensu-stricto" vegetation, dominated by C_3-plants (Roscoe et al, 2000). Site 2 was an adjacent cultivated pasture, where the native Cerrado was replaced by *Brachiaria spp.* 23 year before sampling. In the last year, however, the pasture was plowed (10 cm) and cultivated with millet. The possible influence of the millet cropping could be higher in the upper soil layer (Ap horizon). At the sampling time (two months after harvest), Brachiaria spp. was covering about 60% of the area. Though the millet material is also C_4-derived, we neglected that influence and considered the last year as equivalent to the previous ones. Duplicated profiles were described per site and sampled until 1m depth.

SOM was separated after density and particle-size fractionation of soil. Air-dried soil samples (20 g of soil < 2 mm) of the Ah, AB_1, AB_2 and Bw_2 horizons (Site 1), and Ap, AB, and Bw_2 horizons (Site 2) were fractionated in triplicate. Low-density organic matter (LDOM) was separated by flotation using a NaI solution (1.7 g cm^{-3}) after end-over-end shaking, getting the free-LDOM fraction, and after sonication dispersion (260 - 270 J ml^{-1}), getting the occluded-LDOM fraction. The heavy fraction was then separated into sand (2000 - 50 μm) silt (50 - 2 μm) and clay (< 2 μm).

Organic Carbon (OC) was analyzed for all the samples and fractions in an Interscience Elemental Analyser EA1180. ^{13}C abundance was determined after the conversion of total C to CO_2, purified by CuO and Ag, in a VG/SIRA 9 Mass Spectrometer at the Centre for Isotope Research at the University of Groningen, the Netherlands. Results were expressed as $\delta^{13}C$ (‰). For the calculations, we used a mass balance equation (1), according to Balesdent and Mariotti (1996):

$$TOC \times \delta^{13}C_T = SOC_{C3} \times \delta^{13}C_{C3} + SOC_{C4} \times \delta^{13}C_{C4} \quad (1)$$

Where: TOC = total soil organic carbon; SOC_{C3} = soil organic carbon derived from C_3 vegetation; SOC_{C4} = soil organic carbon derived from C_4 vegetation; $\delta^{13}C_T = \delta^{13}C$ of total soil organic carbon; $\delta^{13}C_{C3} = \delta^{13}C$ of soil organic carbon derived from C_3 vegetation; $\delta^{13}C_{C4} = \delta^{13}C$ of soil organic carbon derived from C_4 vegetation.

The reference values for C_3-derived carbon were the value observed for the Cerrado plot. The reference $\delta^{13}C$ value for the C_4-derived carbon (C from pasture) was calculated for each depth and OC fraction using the $\delta^{13}C$ of the pasture litter (-13,52 ± 0.07‰) and the same ^{13}C proportional discrimination ($D_{(\%)}$) during the decomposition observed in the C_3 reference profile. The $D_{(\%)}$ was obtained by: $D_{(\%)} = (\delta^{13}C_{litter} - \delta^{13}C_{fraction})*100/\delta^{13}C_{litter}$. Where $\delta^{13}C_{litter}$ is the $\delta^{13}C$ of the cerrado litter (-27.84 ± 0.50‰) and $\delta^{13}C_{fraction}$ is the $\delta^{13}C$ of each fraction at a given depth.

Linear and non-linear models were fitted to the data of $\delta^{13}C$ and OC contents as a function of depth. The least square criterion was used to select the best-fitted model for each of these two parameters in total soil and in different fractions. Fitted curves for Cerrado and pasture were compared by the F test at 5% of probability according to Snedecor & Cochran (1967).

3. RESULTS

No significant differences in OC contents were observed between the fitted models for Cerrado and pasture in the fractions: occluded-LDOM (Figure 1C), sand (Figure 1D), and silt (Figure 1E). Then the average model for the two sites could describe the behavior of OC contents with depth. On the other hand, for total soil (Figure 1A), free-LDOM (Figure 1B), and clay (Figure 1F), significant differences were observed between the models using the F test at the level of 5% of probability (Snedecor & Cochran, 1967). However, considering the 95% confidence interval of the differences of the predicted values, only in the first 2 cm of the Cerrado topsoil significantly higher values of OC for total soil and free-LDOM were observed. In the clay fraction, the difference was not significant through out the profile. In general, the differences between the sites were close to zero, suggesting no significant losses of carbon after 23 years of cultivated pasture.

No significant trend in $\delta^{13}C$ values with depth was observed in the Cerrado plot for total soil, free-LDOM, sand, silt, and clay. The average and standard deviation were respectively -24.87 ± 0.72‰, -27.19 ± 0.41‰, -25.52 ± 0.62‰, -25.55 ± 0.57‰, and -24,25 ± 0.68‰. For the occluded-LDOM, $\delta^{13}C$ increased logarithmically with depth till 50 cm depth, according to the equation $\delta^{13}C = 0.28 \, Ln(depth) - 27.81$ ($R^2 = 0.76^{***}$). In the pasture, plot the values of $\delta^{13}C$ were, in general, significantly higher than the Cerrado plot through out the profile for all fractions. A decreasing trend in the values was also observed for all the fractions (Table 1).

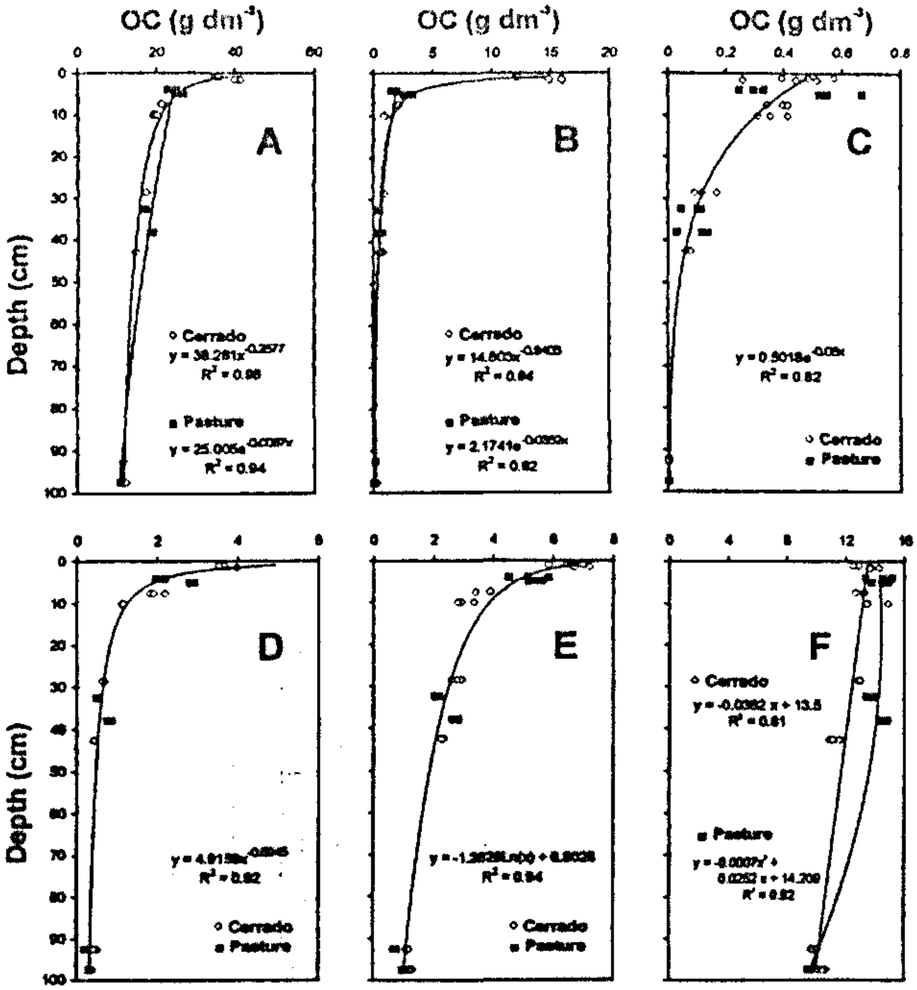

Figure 1. Total organic carbon (OC) contents in the Cerrado and pasture, as a function of depth: (A) for total soil; (B) for free-LDOM (low density organic matter); (C) for occluded-LDOM; (D) in sand (2000-0.05 μm); (E) in silt (0,05-2 μm); and (F) in the clay fraction (<2 μm). In A, B, and F, the two lines represent the equation fitted for data from Cerrado and pasture separately. In C, D, and E the line represents the equation fitted for data from Cerrado and pasture together.

The percentage of carbon from the pasture present in the total soil and in each of the fractions was calculated by equation (1), using the integrated predicted values of OC and $\delta^{13}C$. In each horizon, the OC from pasture substituted about the same quantity of Cerrado's OC in the total soil and in all the fractions, but occluded-LDOM (Table 2). In Ap, the free-LDOM substitution also tended to be slightly higher than in the other fractions. The occluded-LDOM showed the lowest replacement among all the fractions and horizons. For all the fractions the replacement of Cerrado's OC tended to decrease with depth.

Table 1. Models describing the changes in $\delta^{13}C$ with depth in the pasture plot.

Fraction	Model	R^2
Free-LDOM	Y = - 1.405 Ln(depth) – 18.6	0.73^{***}
Occluded-LDOM	Y = - 0.834 Ln(depth) – 23.7	0.97^{***}
Sand (2000-50μm)	Y = - 0.027 (depth) – 21.1	0.83^{***}
Silt (50-2μm)	Y = - 0.032 (depth) – 20.3	0.70^{***}
Clay (< 2μm)	Y = -0.025 (depth) – 19.8	0.41^{*}
Total soil	Y = -0.022 (depth) – 20.1	0.40^{*}

4. DISCUSSION AND CONCLUSIONS

After 23 years of pasture, the levels of organic carbon in the studied soil did not change significantly in the first 100 cm. The high biomass production (especially roots) of the tropical C_4-grass *Brachiaria spp.* (Corazza et al. 1999) was probably able to maintain more or less the same supply of OC to the soil. Similar studies in Cerrado have shown that cultivated pastures not only can maintain the OC contents of the soil, but may also increase it (Carazza et al., 1999).

Table 2. Percentage of the total organic carbon in the whole soil and in the different fractions originated from the pasture after 23 years. The values were integrated for each horizon from the combination of the models describing OC and $\delta^{13}C$ distribution with depth.

Horizon[a]	Free-LDOM	Occluded-LDOM	Sand (2000-50μm)	Silt (50-2μm)	Clay (< 2μm)	Whole Soil
	%					
Ap (0-9cm)	47	17	33	39	35	36
AB_1(10-25cm)	32	6	30	36	34	33
AB_2 (26-46cm)	25	1	26	31	31	29
Bw_1 (47-75cm)	20	-	21	25	24	26
Bw_2 (76-100cm)	16	-	16	19	19	22

[a] depth of the horizon in Site 2 (pasture).

In general, the high replacement of OC from Cerrado by pasture material showed that the carbon dynamics in this soil was relatively fast, regardless to its high clay content (>700 g kg^{-1}). The OC half-life in the total soil and fractions (except occluded-LDOM) was in average 34 year in the Ap horizon, increasing to 85 years in Bw_2. These findings were in accordance with previous studies suggesting a fast turnover time of SOM in tropical Oxisols (Shang and Tiessen, 1997).

In contrast with our results, higher turnover times for free-LDOM than for heavy fractions (sand, silt, and clay) were usually reported in literature (Golchin et al., 1995). However, we observed abundant fragments of charcoal in the free-LDOM throughout the pasture profile, with a $\delta^{13}C$ of $-27.94 \pm 0.50‰$. The charcoal probably was responsible for a substantial part of the remaining carbon from Cerrado in this fraction.

The occluded-LDOM showed the lowest replacement of Cerrado derived carbon among the soil fractions. This fraction was removed after aggregate disruption, suggesting that the aggregation was somehow protecting OC from decomposition (Golchin et al., 1995). Although the contents of carbon in this fraction in relation to total soil was very small (Figure 1), it might give a rough estimation of the aggregate turnover and processes of OC protection. A better understanding of the occluded-LDOM would provide useful information about aggregation processes and management impact in Oxisols.

5. REFERENCES

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