Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9275
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v34i4.15061

Carbon, nitrogen and natural abundance of $\delta^{13}C$ e $\delta^{15}N$ of light-fraction organic matter under no-tillage and crop-livestock integration systems

Arcângelo Loss[1*], Marcos Gervasio Pereira[2], Adriano Perin[3], Sidinei Julio Beutler[1] and Lúcia Helena Cunha dos Anjos[2]

*[1]Programa de Pós-graduação em Agronomia, Ciência do Solo, Departamento de Solos, Instituto de Agronomia, Universidade Federal Rural do Rio de Janeiro, BR-465, km 7, 2389000, Seropédica, Rio de Janeiro, Brazil. [2]Departamento de Solos, Instituto de Agronomia, Universidade Federal Rural do Rio de Janeiro, Seropédica, Rio de Janeiro, Brazil. [3]Instituto Federal de Educação Ciência e Tecnologia Goiano, Campus Rio Verde, Rio Verde, Goiás, Brazil. *Author for correspondence. E-mail: arcangeloloss@yahoo.com.br*

ABSTRACT. This study aimed to quantify the light organic matter mass (LOM) in water, free light fraction (FLF) of soil organic matter (SOM) and carbon (C), nitrogen (N) contents and natural abundance of $\delta^{13}C$ e $\delta^{15}N$ contained in the mass of LOM, C and N in the FLF in land use systems in the Cerrado region of Goiás State, Brazil. Were evaluated a crop-livestock integration system - CLIS (corn+brachiaria/bean/cotton/soybean) and no-tillage system - NTS (sunflower/millet/soybean/corn). The vegetal coverage of natural Cerrado, adjacent to NTS and CLIS, was considered as the original soil condition. Soil samples were collected at depths of 0.0-5.0 and 5.0-10.0 cm in full random experimental design. The CLIS showed the greatest mass and levels of C-LOM (5-10 cm), and too greatest mass and levels of C and N of FLF (0-10 cm) when compared with the NTS. Regarding the Cerrado, the CLIS showed higher values for N-LOM and 1δ15N-LOM (0-5 cm), C and N of FLF (0-5 cm). Through physical indicators LOM and FLF, it was possible to infer that the CLIS increased the SOM fractions when compared to the NTS.

Keywords: Cerrado, brachiaria, plant residues, isotopic composition, physical indicators.

Carbono, nitrogênio e abundância natural de $\delta^{15}N$ e $\delta^{13}C$ da matéria orgânica leve sob sistemas plantio direto e integração lavoura-pecuária

RESUMO. Este trabalho teve como objetivo quantificar a massa da matéria orgânica leve (MOL) em água e da fração leve livre (FLL) da matéria orgânica do solo (MOS) e os respectivos teores de carbono (C), nitrogênio (N) e abundância natural de $\delta^{15}N$ e $\delta^{13}C$ contidos na massa da MOL, C e N na FLL em sistemas de uso do solo no Cerrado goiano (Cerradão). Foram avaliados um sistema de integração lavoura-pecuária - SILP (milho+braquiária/feijão/algodão/soja) e sistema plantio direto - SPD (girassol/milheto/soja/milho). A cobertura vegetal de Cerrado natural, adjacente ao SPD e SILP, foi considerada como condição original do solo. Coletaram-se amostras de solo nas profundidades de 0-5 e 5-10 cm, em delineamento inteiramente casualizado. O SILP apresentou maior massa e teores de C na MOL (5-10 cm) e, também maior massa e teores de C e N na FLL (0-10 cm) quando comparada com o SPD. Em relação ao Cerrado, o SILP apresentou maiores valores para N-MOL e $\delta^{15}N$-MOL (0-5 cm), C e N da FLL (0-5 cm). Por meio dos indicadores físicos, MOL e FLL, foi possível inferir que o SILP aumentou essas frações da MOS quando comparado ao SPD.

Palavras-chave: Cerrado, braquiária, resíduos vegetais, composição isotópica, indicadores físicos.

Introduction

The impact of soil management systems on the dynamics of the soil organic matter (SOM), or on the carbon (C) cycle in agroecosystems deserves special attention. Regarding the Cerrado biome, this attention must be double, as this is a region of the agricultural frontier, which stands out as producer of food and energy to meet the domestic needs and also other countries. The soils of this biome are characterized by being highly weathered, with low natural fertility. In addition, the seasonal climate is also a factor, with hot and rainy summer and cold and dry winter, resulting in high rates of plant residues decomposition (RESCK et al., 2008).

Therefore, management systems able to maintain and/or even increase the organic C contents may contribute to maintaining the productive capacity of soils, reducing CO_2 emissions to the atmosphere (CERRI et al., 2010; SIQUEIRA NETO et al., 2011). Thus, efficient and practical methods to assess C dynamics are required in order to create soil management strategies that reduce the impact of agriculture on the environment (FRAZÃO et al., 2010; LOSS et al., 2009a and b; SOUZA et al., 2006).

Studies such as those of Pinheiro et al. (2004), Conceição et al. (2005), Xavier et al. (2006), Maia et al. (2007), Rangel et al. (2008), Loss et al. (2009a and b, 2010, 2011), Pereira et al. (2010), Pillon et al. (2011) and Fontana et al. (2011) have shown that some SOM compartments can more rapidly detect changes in soil C content associated with management. Reductions in these compartments are generally higher than those observed when considering only the total soil organic C content (JANZEN et al., 1992; LOSS et al., 2009b).

Light organic matter (LOM) is an active fraction in soil that consists of partially humified organic residues at various decomposition stages, which has a residence time in soil ranging from 1 to 5 years (JANZEN et al., 1992). LOM is a fraction with size between 0.25 and 2.0 mm and can be quantified by means of flotation of the light material in liquid of density ranging from 1.6 to 2.0 kg L^{-1} (SOHI et al., 2001) or in water (ANDERSON; INGRAM, 1989). The LOM in soils is mainly composed of parts of plants and can also contain residues of animals and microorganisms in various decomposition stages. One of the most important activities of soil microorganisms is the organic matter decomposition, releasing nutrients to the soil solution and its absorption by plants (RUIVO et al., 2005). The maintenance of this compartment (LOM), is essential for the sustainability of farming systems, since it represents, in short and medium term, potential for nutrient cycling (COMPTON; BOONE, 2002).

The crop rotation in no-tillage system (NTS) associated with pasture create an integrated production system, which is commonly referred to as crop-livestock integration system (CLIS). These transfer large amounts of plant biomass to the soil, especially when cover plants, such as brachiaria, are used to increase the fodder production, also serving as food source for cattle. Thus, the CLIS is associated to the NTS, creating a more diverse environment compared to the NTS alone, without the use of brachiaria (LOSS et al., 2011).

The CLIS can lead to greater levels of labile fractions (LOM in water and free light fraction - FLF of SOM), when compared to NTS, without the use of brachiaria and pasture. The aim of this study was to quantify the mass of LOM and FLF of SOM and C, N content and natural abundance of δ^{13}C e ^{1} δ^{15}N in the LOM and C e N of FLF in land use systems in the Cerrado region of Montividiu, Goiás State, Brazil.

Material and methods

The study was conducted at "Vargem Grande" Farm, belonging to the Peeters Agriculture and Livestock, located at Montividiu, Goiás State, Brazil (17º21'S and 51º28'W). The climate is characterized by two well-defined seasons: a dry season (from May to September) and a rainy season (from October to April). For the 2008 crop year (period of soil sample collection), and the mean annual rainfall and temperature are shown in Figure 1.

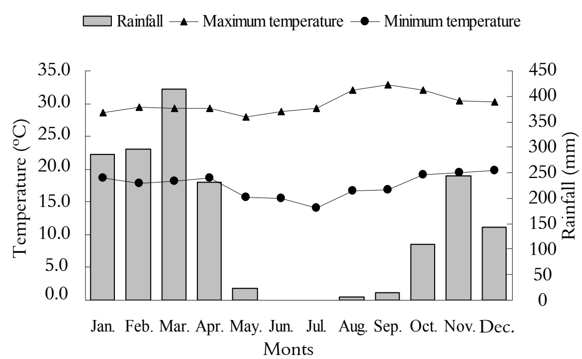

Figure 1. Mean rainfall and temperatures in the year of 2008. Source: meteorological Station of Fesurv - University of Rio Verde (17°48'S, 50°55'W), Rio Verde, Goiás State, Brazil.

The soil in the systems evaluated was classified as LatossoloVermelho Distrófico (Oxisol) with clayey texture (EMBRAPA, 2006). In the mineralogical composition of the clay fraction, gibbsite, kaolinite and hematite stand out.

The original vegetal coverage of the soil is the Cerrado field (Cerradão), taken in 1975 to establish pastures (*Urochloa decumbens*), with continuous use for 10 years, until 1985 (Figure 2).

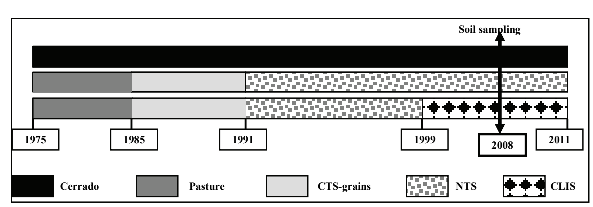

Figure 2. History of uses and land use change processes, with respective dates of implementation in the "Vargem Grande" Farm, Peeters Agriculture and Livestock, Montividiu, Goiás State, Brazil (CTS = conventional tillage system, NTS = no-till system, CLIS = crop-livestock integration system.

Then, the systems were managed by means of plowing and harrowing (CTS) until 1991 (7 years) for the cultivation of grains (corn, bean, soybean and sunflower). Later, the NTS was implemented with crop rotation - corn, soybean, cotton, bean - (1991-2008) and, from 1999, part of the NTS was transformed into CLIS (1999-2008). Therefore, the systems evaluated had been conducted in NTS with the same crop rotation, with only NTS (1991-2008) and CLIS (1999-2008) (Figure 2).

The systems evaluated are cultivated in NTS for 17 years: one with crop rotation only (sunflower-millet-soybean-corn), at coordinates 17°21,120'S, 51°29,461'W and altitude of 958 m, and another with brachiaria (*U. ruziziensis*) intercropped with corn to increase the fodder production in the dry season (corn-brachiaria-bean-cotton-soybean), at coordinates 17°21,854'S, 51°28,599'W; and altitude of 859 m. The vegetal coverage of natural Cerrado, adjacent to cultivated systems (17°26,642'S, 51°22,522' W and altitude of 951 m) was considered as the original soil condition.

In the CLIS (corn-brachiaria-bean-cotton-soybean) was used corn and brachiaria being planted simultaneously (brachiaria between corn rows). After the corn harvest, the introduction of cattle in the system was made (2.0 ha per AU; AU - animal unit) for 90 days (July-September). After removal of the cattle, only brachiaria clumps remained. Then, after the first rains, brachiaria was fertilized with 200 kg ha^{-1} of N P K formulation (20-00-20) in the first half of September. After regrowth, when the soil was completely covered by the grass, desiccation was made and beans were grown.

Liming was made in the CLIS in July 2005 using a dose of 3.60 Mg ha^{-1} of dolomitic limestone, with PRNT = 70%, to raise the base saturation to 70%. The same procedure was performed for the NTS, also in July 2005, using a dose of 2.90 Mg ha^{-1} of dolomitic limestone, with PRNT = 70%, to raise the base saturation to 60%. The sequence of crops and fertilizers used in both systems from 2002 to 2008 is described in Table 1.

Table 1. Sequence of crops and fertilizers used in the evaluated systems of the "Vargem Grande" Farm, Peeters Agriculture and Livestock, Montividiu, Goiás State, Brazil.

Year	Month	Culture	Fertilizer	
			Crop	Coverage
			CLIS (corn-brachiaria-bean-cotton-soybean)	
2002	October	Soybean	580 kg ha^{-1} of 02-20-18	--------
2003	February	Corn + brachiaria	500 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2003	October	Soybean	580 kg ha^{-1} of 02-20-18	---------
2004	February	Corn + brachiaria	450 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2004	October	Soybean	500 kg ha^{-1} of 02-20-18	---------
2005	February	Corn + brachiaria	490 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2005	September	Bean	400 kg ha^{-1} of 05-20-10	90 kg ha^{-1} of urea
2005	December	Cotton	500 kg ha^{-1} of 10-30-10	250 kg ha^{-1} of 20-00-20
2006	October	Soybean	500 kg ha^{-1} of 02-20-18	---------
2007	February	Corn + brachiaria	450 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2007	October	Soybean	450 kg ha^{-1} of 02-20-18	---------
2008	February	Corn + brachiaria	450 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2008	September	Bean	400 kg ha^{-1} of 05-20-10	90 kg ha^{-1} of urea
2008	December	Cotton	500 kg ha^{-1} of 10-30-10	250 kg ha^{-1} of 20-00-20
			NTS[1] (sunflower-millet-soybean-corn)	
2002	August	Millet	---------	---------
2002	October	Soybean	550 kg ha^{-1} of 02-20-18	---------
2003	February	Corn	450 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2003	August	Millet	---------	---------
2003	October	Soybean	550 kg ha^{-1} of 02-20-18	---------
2004	February	Corn	450 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2004	August	Millet	---------	---------
2004	October	Soybean	550 kg ha^{-1} of 02-20-18	---------
2005	February	Corn	450 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2005	August	Millet	---------	---------
2005	October	Soybean	550 kg ha^{-1} of 02-20-18	---------
2006	February	Sunflower	300 kg ha^{-1} of 02-20-20	100 kg ha^{-1} of urea
2006	August	Millet	---------	---------
2006	October	Soybean	500 kg ha^{-1} of 02-20-18	---------
2007	February	Corn	400 kg ha^{-1} of 07-28-14	100 kg ha^{-1} of urea
2007	August	Millet	---------	---------
2007	October	Soybean	500 kg ha^{-1} of 02-20-18	---------
2008	February	Sunflower	300 kg ha^{-1} of 02-20-20	100 kg ha^{-1} of urea
2008	August	Millet	---------	---------
2008	October	Soybean	500 kg ha^{-1} of 02-20-18	---------

1 In the NTS, every month of August of each year (2002-2008), millet was grown for fodder production for soybean in October. Before 2002, no off-season culture was performed or millet was grown. The system remained in rest during the months from May to September, during which plants of the grass family such as guinea grass and brachiaria grew. NTS = no-till system, CLIS = crop-livestock integration system.

The sytems were planted with sunflower in NTS and corn + brachiaria in CLIS at the time of soil sample collection for evaluation. These collections were held in March 2008, being bounded an area around 600 m^2, where four trenches were opened across the plant rows in each system. Layers of 0.0 to 5.0 and 5.0 to 10.0 cm were sampled, with three single samples collected in each trench to form a composite sample. Totaling four replications in each land use system. After collection, the samples were identified, placed in plastic bags and transported to the laboratory, air dried and passed through 2 mm sieve to obtain the air-dried fine soil (ADFS), which was used for the quantification of LOM and FLF of SOM.

For the quantification of LOM, 50 g of ADFS were weighed and placed in a 250 mL beaker added of 100 mL of NaOH 0.1 mol L^{-1}, leaving to rest overnight. After this period, the suspension was stirred with glass rod and the material was passed through 0.25 mm sieve, discarding the silt and clay fraction (ANDERSON; INGRAM, 1989).

Subsequently, the material retained on the sieve (LOM and sand) was quantitatively transferred to the beaker and filled up with water. The floated material was passed through 0.25 mm sieve, taking care to separate the LOM from the sand fraction. Then, water was added to the beaker, manually stirring to resuspend the remaining LOM and slowly pour the material through a 0.25 mm sieve. This operation was repeated until all the material that floated with the stirring in water was removed. The material retained in the sieve (LOM) was transferred to aluminum containers (previously weighed), led to an oven at 65°C until constant weight was reached (72h), the whole material being weighted. Then, the LOM mass was obtained to determine the C and N contents in the LOM mass through the dry combustion method in a C and N autoanalyzer at 900°C (CHN-600 Carlo Erba EA-1110, Italy). The $\delta^{15}N$ and $\delta^{13}C$ values were evaluated using a mass spectrometer (Finnigan Mat Delta Plus, Germany) in the CENA Laboratory of Isotopic Ecology (Centre for Nuclear Energy in Agriculture, Piracicaba, São Paulo State).

The FLF of SOM was obtained according to recommendations described in Sohi et al. (2001) and Machado (2002). Centrifuge bottles of 50 mL were added of 5 g ADFS and 35 mL of sodium iodide solution (NaI) with density of 1.8 (± 0.1 g cm^{-3}). The bottles containing the mixture were manually and slowly shaken for 30 seconds in order to disperse unstable aggregates and allow the FLF flotation in NaI solution and, being then centrifuged at 8000 x g for 30 min. After centrifugation, the FLF on the surface of the NaI solution was aspirated and filtered through a vacuum system using a glass fiber filter with 47 mm in diameter and 2 μm of retention. The retained FLF was carefully washed with distilled water in order to remove excess NaI, being then taken to an oven with forced hot air circulation at 65°C for 72h.

To determine the FLF mass, only the filter was weighed, and after complete drying, the sample was weighed along with the filter. Thus, by subtracting the weight of the filter {(FLF mass = (Mass of filter plus sample) - weight of the filter)}, obtaining the FLF mass, in grams. Subsequently, the C and N contents in the FLF mass were determined through the dry combustion method in a C and N autoanalyzer at 900°C (CHN-600 Carlo Erba EA-1110, Italy).

The results were analyzed for normality and homogeneity of data by means of the Lilliefors and Cochran and Barttlet tests, respectively. Later, it was analyzed as a completely randomized design with three land use systems (NTS, CLIS and Cerrado) with four replications. The land use systems were evaluated under the same soil climatic and topographic conditions, differing only in the land use system. The results were submitted to analysis of variance with application of the F test and the mean values, when significant, were compared by LSD-student test at 5%.

Results and discussion

Light-fraction organic matter in water

The highest LOM mass values were found in the Cerrado at depth from 0.0 to 5.0 cm, with no differences between NTS and CLIS. For the depth from 5.0 to 10.0 cm, the CLIS showed values equal to those of the Cerrado, with lower LOM value for the NTS (Table 2).

Table 2. Light organic matter (LOM) in g kg^{-1}, C and N, g kg^{-1}, C/N ratio and natural abundance of $\delta^{15}N$ (‰) and $\delta^{13}C$ (‰) of LOM in the different land use systems in Montividiu, Goiás State, Brazil.

Variable	Land use system			
	NTS	CLIS	Cerrado	CV(%)
	0.0-5.0 cm			
Mass-LOM	7.44 B	7.24 B	15.12 A	5.81
C- LOM	314.01 B	323.35 B	356.62 A	4.99
N- LOM	17.90 A	17.90 A	16.11 A	8.71
C/N- LOM	17.54 B	18.06 B	22.13 A	5.65
$\delta^{15}N$ (‰)-LOM	2.37 B	3.91 A	2.63 B	3.21
$\delta^{13}C$ (‰)-LOM	-24.06 B	-21.98 A	-29.01 C	4.22
	5.0-10.0 cm			
Mass-LOM	1.98 B	3.44 A	3.88 A	4.11
C- LOM	278.10 B	307.25 A	324.60 A	5.31
N- LOM	16.05 A	15.55 A	13.45 B	4.70
C/N- LOM	17.32 C	19.76 B	24.13 A	6.55
$\delta^{15}N$ (‰)-LOM	2.78 B	3.98 A	2.37 B	4.28
$\delta^{13}C$ (‰)-LOM	-24.40 B	-22.64 A	-28.27 C	4.99

Means followed by same letter on the line do not differ between the systems assessed by the LSD-student test at 5%. CV = coefficient of variation. NTS = no-till system; CLIS = crop-livestock integration system.

These results (Table 2) demonstrate that there is a greater amount of plant material (litter) in the Cerrado when compared with the cultivated systems (0.0-5.0 cm). For the depth from 5.0 to 10.0 cm, between the cultivated systems, CLIS showed higher LOM mass values when compared with the NTS. These differences are due to the higher amount of plant residues in the subsurface through rizo-deposition and renewal of the root system of brachiaria in the CLIS. This contribution when compared with the amount of litter in the Cerrado was more efficient than in the NTS (with millet) in increasing the soil LOM levels. These results are corroborated by those of Pereira et al. (2010), who found higher LOM levels in NTS (0.0-2.5 cm) cultivated with corn and soybean on brachiaria residues when compared with the cultivation of these crops on millet and crotalaria residues in the Cerrado region of Uberaba, Minas Gerais State, Brazil. For other depths studied (2.5-5.0 and 5.0-10.0 cm), no differences were observed between the systems evaluated (PEREIRA et al., 2010).

In relation to the C-LOM levels, higher values were observed in the Cerrado at the depth of 0.0-5.0 cm, and values equal to the CLIS at the depth of 5.0-10.0 cm. Among the cultivated, only the depth of 5.0-10.0 cm showed higher C-LOM levels for the CLIS. These results showed the same pattern for the LOM mass contents, indicating that for the CLIS, which has higher LOM mass amounts, there is a greater supply of substrate used as source of energy for microbial growth. This fact will lead to greater release of nutrients through cycling of microbial biomass, resulting in increased levels of C-LOM, total soil C and macronutrients (N, P, K and Ca), which are significantly higher in the CLIS (LOSS et al., 2011).

For the N-LOM at the depth of 0.0-5.0 cm, no differences were found (F test, $p < 0.05$) and at the depth of 5.0-10.0 cm, the cultivated systems showed higher N-LOM contents compared with the Cerrado. The increased N-LOM levels of cultivated systems may be due to the deposition of plant material with higher N concentrations from the decomposition of brachiaria (CLIS) and millet (NTS) root system, which can extract soil nutrients at greater depths, being subsequently released on the depth 5.0–10.0 cm through rizo-deposition.

For the C/N ratio, the Cerrado showed the highest values, followed by the CLIS at the depth of 5.0-10.0 cm. The highest C/N ratios in the CLIS reflect the quality of the residue, in this case, brachiaria. The highest C/N ratios in the Cerrado may be due to the lower decomposition of plant residues, which may have higher proportions of phenolic compounds and cellulose, with lower N concentrations (PILLON et al., 2011).

The δ^{13}C-LOM values reflect the origin vegetation, being well characterized in the Cerrado, with lower isotopic values, with the sign from -29.01 to -28.27‰, and in the NTS, with intermediate values from -24.06 to -24.40‰, being these values were corresponding to the 0.0–5.0 and 5.0-10.0 cm, respectively. Where for C_3 plants, the isotopic composition (δ^{13}C) ranges from -24 to -34‰, whereas for C_4 plants, the composition in δ^{13}C ranges from -6 to -19‰ (Smith and Epstein, 1971). Therefore, in the Cerrado, the plant material is only from C_3 plants, while in the NTS and CLIS, there is a mixture of plants, where the contribution of C_4 plants is clearly observed, especially millet and corn in the NTS and corn + brachiaria in the CLIS. In relation to δ^{13}C-LOM, the CLIS showed the highest δ^{13}C-LOM values, with sign ranging from -21.98 to -22.64, which allows inferences about greater contribution of C_4 plants in the CLIS (corn + brachiaria) compared to the NTS.

The natural abundance of δ^{15}N-LOM showed small values in all systems and at both depths, which is a pattern resulting from the lower SOM decomposition (PICCOLO et al., 1996). In general, as the SOM decomposition and soil depth increase, higher δ^{15}N values are observed due to the N fractionation through nitrification and denitrification processes (BUSTAMANTE et al., 2004). However, comparing the δ^{15}N-LOM values between systems, it was found that the CLIS had the highest values, which may be related to N fertilization of cultures and brachiaria as well as the planting of legumes such as soybeans and beans (Table 1).

FLF of SOM

The Cerrado showed the highest FLF at the layer of 0.0 to -5.0 cm, and values similar to those observed in the CLIS at the layer of 5.0-10.0 cm (Table 3). Among the systems under cultivation, the CLIS showed higher FLF mass values when compared to the NTS, at both layers assessed. The higher FLF mass values in the Cerrado can be attributed to the absence of human activity and to the presence of larger amounts of plant residues (litter). While among the cultivated systems in the CLIS, the planting of brachiaria (phytomass and root system) resulted in higher FLF mass values when compared with the NTS, in the absence of fodder.

Table 3. FLF (g kg^{-1}), C and N in the FLF of SOM, g kg^{-1} in the different land use systems in Montividiu, Goiás State, Brazil.

Land use systems	Fractions assessed					
	0-5 cm			5-10 cm		
	Mass-FLF	C- FLF	N- FLF	Mass- FLF	C- FLF	N- FLF
NTS	26.88 C	166.68 B	17.42 B	8.11 B	146.82 B	15.72 B
CLIS	32.21 B	195.75 A	19.45 A	20.13 A	179.91 A	16.98 A
Cerrado	78.40 A	155.11 C	14.91 C	21.36 A	170.21 A	15.25 B
CV(%)	4.29	5.77	9.56	6.47	5.12	6.33

Means followed by same capital letter in columns do not differ between systems assessed by the LSD-student test at 5%. CV = coefficient of variation. NTS = no-till system; CLIS = crop-livestock integration system.

A similar study was carried out by Assis et al. (2006), who evaluated the organic compartments of a medium-textured Oxisol in Capinópolis, Minas Gerais State, Brazil, with different land uses and managements. The treatments consisted of NTS for 4 years in corn (silage)/soybean succession; NTS for 4 years with corn/corn/corn/soybean succession; NTS for 3 years followed by Tifton (hay) and soybean in the last year, about 30 years with conventional tillage (corn/soybean), with only soybean in the last four years, and native forest as reference. The depths evaluated were: 0.0-5.0; 5.0-10.0 and 10.0-20.0 cm. The authors observed that the native forest showed higher FLF mass values at all depths probably due to the greater amount of organic residues. The same result was found in this study, in which the Cerrado showed the highest FLF mass values at both depths studied, except for 5.0-10.0 cm, where the Cerrado had values equal to the CLIS.

The larger amounts of FLF mass in the CLIS may be related to the root system of brachiaria (at the time of sample collection, by opening a narrow channel up to 40.0 cm, a good root system distribution of brachiaria was observed). It was found that brachiaria presented good root development, which could reach greater depths. After the death of these roots, all this material remains in the soil profile, thereby raising the SOM levels in various forms, in this case, in the form of FLF. A similar pattern was also observed in the study by Assis et al. (2006), in which the author found that the NTS with the presence of Tifton showed higher FLF values at depths (5.0-10.0 and 10.0-20.0 cm) when compared to other NTS. This result justifies the potential of intercropping and/or rotating forage grasses with Tifton and also brachiaria, for the management of agricultural systems, such as CLIS.

The highest C-FLF levels were found in the CLIS at the layer of 0.0-5.0 cm, and values equal to those of the Cerrado at layer from 5.0 to 10.0 cm. In the topsoil, the cultivated systems showed higher C-FLF levels when compared to Cerrado. The higher C-FLF levels found in cultivated systems in the surface layer are the result of the use of C_4 plants (grasses), while in the Cerrado, only C_3 plants were found. Among the systems under cultivation, the CLIS, for having brachiaria intercropped with corn (both C_4 at the time of sample collection), has higher C-FLF levels when compared to the NTS, which despite having millet and corn rotation, also C_4, differs from the CLIS at the time of sample collection. At this time (collection of samples for FLF analysis), only effect of sunflower cultivation was observed as dominant in the NTS. Among the cultivated systems, the highest C-FLF levels observed on the surface and subsurface of the CLIS reinforce the contribution of the root systems of forage species (grasses) in these systems on subsurface and/or SOM redistribution from surface layers to deeper layers (PILLON et al., 2011).

For the N-FLF contents, a dynamics similar to that of C-FLF was found, with lower N-FLF levels of in the Cerrado at the surface layer, and from 5.0-10.0 cm, the Cerrado did not differ from the NTS, with the highest N-FLF contents being found in the CLIS. The lower N-FLF contents found in the Cerrado may be due to the lower decomposition level of plant residues, which may show higher proportions of phenolic compounds and cellulose, with lower N concentrations. At deeper layers, the oxidation of organic compounds by microorganisms and by-products of microbial decomposition contribute to the higher N-FLF contents (PILLON et al., 2011), which are equal to those of the NTS.

The greater N-FLF contents in the CLIS can be explained by the great capacity of brachiaria of absorbing and accumulating this nutrient (CRUSCIOL; BORGHI, 2007), which is released into the soil from the decomposition of its fodder (plant residues that are quantified as FLF). The use of legumes and N fertilizer used in CLIS must be added to these results (Table 1).

Conclusion

The CLIS increased the mass and the C content of the LOM in water and the FLF of SOM compared to the NTS. Regarding the Cerrado, the CLIS showed equal mass and C and N values of LOM (5-10 cm) and higher C and N values of FLF (0-5 cm).

Acknowledgements

To the Agrisus Foundation for funding the research project, to CNPq and FAPERJ for granting the PhD scholarship to the first author, to the Post-graduation Program in Agronomy - Soil Science (CPGA-CS) for their assistance and to Dr. Adriano Perin and colleagues for their help in collecting soil samples for this study.

References

ANDERSON, J. M.; INGRAM, J. S. I. **Tropical soil biology and fertility**: a handbook of methods. Wallingford: CAB International, 1989.

ASSIS, C. P.; JUCKSCH, I.; MENDONÇA, E. S.; NEVES, J. C. L. Carbono e nitrogênio em agregados de Latossolo submetido a diferentes sistemas de uso e manejo. **Pesquisa Agropecuária Brasileira**, v. 41, n. 10, p. 1541-1550, 2006.

BUSTAMANTE, M. M. C.; MARTINELLI, L. A.; SILVA, D. A.; CAMARGO, P. B.; KLINK, C. A.; DOMINGUES, T. F.; SANTOS, R. V. ^{15}N Natural abundance in woody plants and soils of the savanna in Central Brazil. **Ecological Applications**, v. 14, n. 4, p. 200-213, 2004.

CERRI, C. C.; BERNOUX, M.; MAIA, S. M. F.; CERRI, C. E. P.; COSTA JUNIOR, C.; FEIGL, B. J.; FRAZÃO, L. A.; MELLO, F. F.; GALDOS, M. V.; CARVALHO, J. L. N. Greenhouse gas mitigation options in Brazil for land-use change, livestock and agriculture. **Scientia Agricola**, v. 67, n. 1, p. 102-116, 2010.

COMPTON, J. E.; BOONE, R. D. Soil nitrogen transformations and the role of light fraction organic matter in forest soils. **Soil Biology Biochemistry**, v. 34, n. 7, p. 933-943, 2002.

CONCEIÇÃO, P. C.; AMADO, T. J. C.; MIELNICZUK, J.; SPAGNOLLO, E. Qualidade do solo em sistemas de manejo avaliada pela dinâmica da matéria orgânica e atributos relacionados. **Revista Brasileira de Ciência do Solo**, v. 29, n. 5, p. 777-788, 2005.

CRUSCIOL, C. A. C.; BORGHI, E. Consórcio de milho com braquiária: produção de forragem e palhada para o plantio direto. **Revista Plantio Direto**, v. 100, n. 4, p. 10-14. Passo Fundo, 2007.

EMBRAPA-Empresa Brasileira de Pesquisa Agropecuária. **Sistema Brasileiro de Classificação de Solos**. 2. ed. Brasília: Embrapa Produção de informação; Rio de Janeiro: Embrapa Solos, 2006.

FONTANA, A.; SILVA, C. F.; PEREIRA, M. G.; LOSS, A.; BRITO, R. J.; BENITES, V. M. Avaliação dos compartimentos da matéria orgânica em área de Mata Atlântica. **Acta Scientiarum. Agronomy**, v. 33, n. 3, p. 545-550, 2011.

FRAZÃO, L. A.; SANTANA, I. K. S.; CAMPOS, D. V. B.; FEIGL, B. J. Estoques de carbono e nitrogênio e fração leve da matéria orgânica em Neossolo Quartzarênico sob uso agrícola. **Pesquisa Agropecuária Brasileira**, v. 45, n. 10, p. 1198-1204, 2010.

JANZEN, H. H.; CAMPBELL, C. A.; BRANDT, S. A.; LAFOND, G. P.; TOWNLEY-SMITH, L. Light-fraction organic matter in soils from long-term crop rotations. **Soil Science Society of America Journal**, v. 56, n. 6, p. 1799-1806, 1992.

LOSS, A.; PEREIRA, M. G.; FERREIRA, E. P.; SANTOS, L. L.; BEUTLER, S. J.; FERRAZ-JUNIOR, A. S. L. Frações oxidáveis do carbono orgânico do solo em sistema de aléias sob Argissolo Vermelho-Amarelo. **Revista Brasileira de Ciência do Solo**, v. 33, n. 4, p. 867-874, 2009a.

LOSS, A.; PEREIRA, M. G.; SCHULTZ, N.; ANJOS, L. H. C.; SILVA, E. M. R. Carbono e frações granulométricas da matéria orgânica do solo sob sistemas de produção. **Ciência Rural**, v. 39, n. 4, p. 1067-1072, 2009b.

LOSS, A.; MORAES, A. G. L.; PEREIRA, M. G.; SILVA, E. M. R.; ANJOS, L. H. C. Carbono, matéria orgânica leve e frações oxidáveis do carbono orgânico sob diferentes sistemas de produção orgânica. **Comunicata Scientiae**, v. 1, n. 1, p. 57-64, 2010.

LOSS, A.; PEREIRA, M. G.; ANJOS, L. H. C.; GIACOMO, S. G.; PERIN, A. Agregação, carbono e nitrogênio em agregados do solo sob plantio direto com integração lavoura-pecuária. **Pesquisa Agropecuária Brasileira**, v. 46, n. 8, p. 658-767, 2011.

MACHADO, P. L. O. A. **Fracionamento físico do solo por densidade e granulometria para a quantificação de compartimentos da matéria orgânica do solo**: um procedimento para a estimativa pormenorizada do seqüestro de carbono pelo solo. Rio de Janeiro: Embrapa Solos, 2002. (Comunicado Técnico, 9)).

MAIA, S. M. F.; XAVIER, F. A. S.; OLIVEIRA, T. S.; MENDONCA, E. S.; ARAUJO FILHO, J. A. Organic carbon pools in a Luvisol under agroforestry and conventional farming systems in the semi-arid region of Ceará, Brazil. **Agroforestry Systems**, v. 71, n. 2, p. 127-138, 2007.

PEREIRA, M. G.; LOSS, A.; BEUTLER, S. J.; TORRES, J. L. R. Carbono, matéria orgânica leve e fósforo remanescente em áreas de Cerrado sob plantio direto, MG. **Pesquisa Agropecuária Brasileira**, v. 45, n. 5, p. 1-6, 2010.

PICCOLO, M. C.; NEILL, C.; MELILLO, J. M.; CERRI, C. C.; STEUDLER, P. A. ^{15}N natural abundance in forest and pasture soil of the Brazilian Amazon basin. **Plant and Soil**, v. 182, n. 2, p. 249-258, 1996.

PILLON, C. N.; SANTOS, D. C.; LIMA, C. L. R.; ANTUNES, L. O. Carbono e nitrogênio de um Argissolo Vermelho sob floresta, pastagem e mata nativa. **Ciência Rural**, v. 41, n. 3, p. 447-453, 2011.

PINHEIRO, E. F. M.; PEREIRA, M. G.; ANJOS, L. H. C.; MACHADO, P. L. O. A. Fracionamento densimétrico da matéria orgânica do solo sob diferentes sistemas de manejo e cobertura vegetal em Paty do Alferes (RJ). **Revista Brasileira de Ciência do Solo**, v. 28, n. 4, p. 731-737, 2004.

RANGEL, O. J. P.; SILVA, C. A.; GUIMARÃES, P. T. G.; GUILHERME, L. R. G. Frações oxidáveis do carbono orgânico de Latossolo cultivado com cafeeiro em diferentes espaçamentos de plantio. **Ciência e Agrotecnologia**, v. 32, n. 2, p. 429-437, 2008.

RESCK, D. V. S.; FERREIRA, E. A. B.; FIGUEIREDO, C. C.; ZINN, Y. L. Dinâmica da matéria orgânica no Cerrado. In: SANTOS, G. A.; SILVA, L. S.; CANELLAS, L. P.; CAMARGO, F. O. (Ed.). **Fundamentos da matéria orgânica do solo**: ecossistemas tropicais e subtropicais. 2. ed. Porto Alegre: Metrópole, 2008. p. 359-417.

RUIVO, M. L. P.; AMARAL, I. G.; FARO, M. P. S.; RIBEIRO, E. L. C.; GUEDES, A. L. S.; SANTOS, M. M. L. S. Caracterização química da manta orgânica e da matéria orgânica leve em diferentes tipos de solo de uma topossequência na Ilha de Algodoal/ Maiandeua, PA. **Boletim do Museo Paraense Emílio Goeldi, série. Ciências Naturais**, v. 1, n. 2, p. 227-234, 2005.

SIQUEIRA NETO, M.; PICCOLO, M. C.; COSTA JÚNIOR, C.; CERRI, C. C.; BERNOUX, M. Emissão de gases do efeito estufa em diferentes usos da terra no bioma Cerrado. **Revista Brasileira de Ciência do Solo**, v. 35, n. 1, p. 63-76, 2011.

SMITH, B. N.; EPSTEIN, S. Two categories of $^{13}C/^{12}C$ ratios for higher plants. **Plant Physiology**, v. 47, n. 3, p. 380-384. 1971.

SOHI, S.; MAHIEU, N.; ARAH, J. R. M.; POLWSON, D. S. P.; MADARI, B.; GAUNT, J. L. A procedure for isolating soil organic matter fractions suitable for modeling. **Soil Science Society of America Journal**, v. 65, n. 4, p. 1121-1128, 2001.

SOUZA, E. D.; CARNEIRO, M. A. C.; PAULINO, H. B.; SILVA, C. A.; BUZETTI, S. Frações do carbono orgânico, biomassa e atividade microbiana em um Latossolo Vermelho sob cerrado submetido a diferentes sistemas de manejos e usos do solo. **Acta Scientiarum. Agronomy**, v. 28, n. 3, p. 323-329, 2006.

XAVIER, F. A. S.; MAIA, S. M. F.; OLIVEIRA, T. S.; MENDONÇA, E. S. Biomassa microbiana e matéria orgânica leve em solos sob sistemas agrícolas orgânico e convencional na Chapada da Ibiapaba-CE. **Revista Brasileira de Ciência do Solo**, v. 30, n. 2, p. 247-258, 2006.

Received on September 26, 2011.
Accepted on January 21, 2012.