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GRANULOMETRIC AND HUMIC FRACTIONS CARBON STOCKS OF SOIL ORGANIC MATTER UNDER NO-TILLAGE SYSTEM IN UBERABA, BRAZIL

[RESERVAS DE CARBONO EN LAS FRACCIONES HÚMICAS Y GRANULOMÉTRICAS DE LA MATERIA ORGÁNICA DEL SUELO CON LABRANZA CERO EN UBERABA, BRASIL]

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SUMMARY

The plant cover use preceding grain crops in Cerrado soil can increase the carbon stocks of chemical and physical fractions of soil organic matter (SOM). The present study aimed to quantify the carbon stocks of SOM granulometric and humic fractions in a Cerrado area under no-tillage system with different plant cover, and compare the results with those from conventional tillage and fallow areas, in Uberaba, MG, Brazil. The implemented plant covers were: millet, tropical grass and sunn hemp. Furthermore, an area was used in fallow and another as a control area (conventional tillage). After plant cover removal, the areas were subdivided (subplots) for the corn and soybean plantation. Soil samples were collected in the 0.0-0.025, 0.025-0.05, 0.05-0.10 and 0.10-0.20 m depths, with posterior quantification of total organic carbon (TOC) levels and chemical and granulometric fractionation of SOM. Humic acid carbon (C-HAF), fulvic acids (C-FAF) and humin (C-HUM) were quantified through these fractionations. The granulometric fractions consisted in particulate organic matter (POM) and mineral organic matter (MOM). Using the carbon levels for each fraction, the respective stocks for each depth were calculated, including the 0.0-0.20 m layer. In the depth of 0.0 to 0.025 and 0.025 to 0.05 m, the TOC had the highest stock for the plant covers of tropical grass, fallow and sunn, respectively, with the lowest stoks found under conventional management The highest POM stocks were found for the corn plantation over sunn hemp and the fallow and soybean area over millet and tropical grass (0.0-0.20 m). In relation to the MOM stocks, the highest values were observed in the areas with millet, sunn hemp and tropical grass, all superior to those found in the conventional tillage and fallow areas, independent of evaluated culture (0.10-0.20 m). The highest C-HUM stocks were observed in the area with tropical grass when compared to conventional tillage, independent of evaluated culture (corn and soybean) or the depth (0.0-0.025 and 0.10-0.20 m). The highest C-FAH stocks in the depth of 0.0-0.025 m were found in the areas with plat covers than the conventional tillage and fallow areas. In a general manner, the use of grasses (millet and tropical grass) as plant cover preceding soybean tillage and legumes (sunn hemp) preceding corn tillage, favored a raise in the stocks of humic and granulometric fractions of SOM, especially POM and C-FAH, the fractions most benefitted by this soil management.

Key Words: Cerrado; millet; sunn hemp; tropical grass; plant residues.

RESUMEN

El uso de cultivos de cobertura como un predecesor a los cultivos de grano en el suelo de Cerrado puede aumentar las reservas de carbono de las fracciones químicas y físicas de la materia orgánica del suelo (MOS). Este estudio tuvo como objetivo cuantificar las reservas de carbono y las fracciones granulométricas y húmicas de la MOS en un área del Cerrado bajo labranza cero con diferentes cultivos de cobertura en comparación con un área de labranza convencional y barbecho en Uberaba, MG, Brasil. Los cultivos de cobertura que se establecieron fueron: el milheto, brachiaria, Crotalária juncea, además de ser utilizado en un campo en barbecho y un área de control (labranza convencional). Después de la eliminación de la cobertura vegetal, las parcelas se subdividieron para la siembra de maíz y soya. Se recogieron muestras de suelo a una profundidad de 0,0 a 0,025, 0,025 a 0,05, 0,05-0,10 y 0,10-0,20 m, y se cuantificaron los niveles de carbono orgánico total (COT) y se realizó el fraccionamiento químico y granulométrico de MOS. A través de estos fraccionamientos, se cuantificó el carbono de los ácidos húmicos (C-HAF), ácidos fúlvicos (C-FAF) y huminas (C-HUM). Las fracciones granulométricas consistieron en la materia orgánica particulada (POM) y materia orgánica mineral (MOM). Con el contenido de carbono de cada fracción se calcularon los inventarios correspondientes a cada profundidad y para la capa de 0,0-0,20 m. A la profundidad de 0.0 a 0,025 y 0,025 a 0,05 m, el TOC tuvo las mayores reservas para las coberturas del crotalaria, brachiaria y barbecho, respectivamente, por el contrario, el inventario más bajo se encuentró bajo manejo convencional. Los majores inventarios de MOP se encontraron en los cultivos de maíz sobre Crotalária y barbecho, y soya sobre milheto y brachiaria (0,0 a 0,20 m). Para los inventarios del MOM, los mayores valores se observaron en las parcelas con milheto, crotalaria y brachiaria, sendo todos mayores que las encontradas en él área com labranza convencional y barbecho, independientemente del cultivo evaluado (0.10 a 0.20 m). Las mayores inventarios de C-HUM se encontraron en la parcela con brachiaria, en comparación con el tratamiento convencional, independientemente del cultivo evaluado (maíz y soya) o la profundidad (0.0 a 0.025 y 0.10-0.20 m). Las mayores reservas de C-FAH a una profundidad de 0,025 a 0,05 m, se encuentran en las parcelas con cultivos de cobertura en comparación con el tratamiento convencional y el barbecho. En general, el uso de las gramineas (milheto y brachiaria) como plantas de cobertura predecesores el cultivo de la soya, y las leguminosae (crotalaria) para el cultivo de maíz, favoreció el incremento de las reservas de las fracciones húmicas y granulométricas de MOS, especialmente MOP y C-FAF, como las fracciones que más se benefician de este manejo del suelo.

Palabras clave: Sabana; el mijo; sunn cáñamo; pasto tropical; residuos vegetales.

INTRODUCTION

Studies in the Cerrado biome have been conducted, aiming at developing strategies in order to reduce the impact of the agriculture activities on this environment, where the high temperatures and the more adopted soil management (conventional tillage and usage in monoculture) may lead to a decrease in the stocks of carbon with organic origin (Fontana *et al*., 2006; Moreti *et al*., 2007; Torres *et al*., 2008; Ajayi *et al*., 2010; Pereira *et al*., 2010). Among the different proposed strategies, we can emphasize the no tillage system (NT), also called direct-seeding system in the straw which is a culture practice which focuses the recuperation and/or conservation of the physical, chemical and biological attributes of the soils.

In the State of Minas Gerais, the Cerrado area has an extension of approximately 335.378,7 km^2, corresponding to 57% of the vegetation cover of the state, being submitted to a strong process of anthropization, due to the expansion of the agriculture frontier (Sano *et al*., 2008). In this environment, the conservation and/or increase of the soil organic matter (SOM) grade is of great importance so that the soils productivity potential is maintained. Among the main contributions of the organic matter in the Cerrado environment, we can emphasize: the improvement in the physical properties (aggregation and porosity), in the chemical attributes, with emphasis to the cation exchange capacity (CEC) and in the biological properties.

The SOM is a heterogeneous set of organic materials, differing in the chemical composition, in the degree of availabily for the microbiota and in its function in the environment (Carter, 2001). Many studies of the SOM are based on your fractioning, whether by the employment of chemical extractors or by physical methods (Stevenson and Elliott, 1989).

The different manners of fractioning utilized in the studies of the SOM attempt to reduce the heterogeneity of the humic fractions, trying to separate the homogenous fractions according to its nature, dynamic and function, but, at the same time, ensuring that they are sufficiently different among them (Christensen, 2000). The choice of the fractioning method depends on the nature of the study, i.e. chemical characterization and identification of specif compounds of the SOM, or the quantification or description of the SOM compartment (Collins *et al*., 1997). The combination of the physical separation followed by the chemical extraction has been used with some success to elucidate the SOM dynamic in the soil (Cambardella and Elliott, 1992; Bayer *et al*., 2001).

The chemical fractioning of the SOM consists in the extraction of humic substances of the soil and obtainment of three main fractions: fulvic acids, humic acids and humin (Stevenson, 1982; Swift, 1996; Benites *et al*., 2003). The quantity of organic matter and the proportion of the humic fractions have served as indicators of the quality of the soil, due to the strong interaction of humic substances with mineral material and the management of the soil (Fontana *et al*., 2006; Loss *et al*., 2010a).

The granulometric fractioning of the SOM (Cambardella and Elliott, 1992) consists in the separation of two organic fractions: the particulate organic matter (POM) and organic matter associated to the mineral fraction (MOM). The POM is the SOM fraction separated by dispersion and sieving of the soil, associated to the sand fraction (POM > 53 μm), being characterized as particles derivate from the residues of plant and hyphae with recognizable cellular structures, the permanence of which in the soil is conditioned to the physical protection performed by aggregates (Golchin *et al*., 1994). The MOM is a fraction of the SOM associated to the fractions of silt and clay of the soil (MOM < 53 μm), being defined as the fraction of the SOM which interacts with the surface of the mineral particles, forming the organominerals, being protected through the colloidal stabilization mechanism (Christensen, 1996). The results of granulometric fractioning of the SOM may contribute to the understanding of its dynamics in areas with the use of different cover crops (grasses and legumes) and the POM more responsive to changes brought forward in the management compared to TOC (Loss *et al*., 2009).

This way, the present research work had, as objective, quantify the stocks of humic and granulometric carbon fractions of the SOM in Cerrado area, under no-tillage with different vegetation cover, comparing them to an area of conventional preparation and fallow, in Uberaba, Minas Gerais State, Brazil.

MATERIAL AND METHODS

The experimental area is located at the Federal Technological Education Center of Uberaba (CEFET), in the city of, MG, (19º39’19”S, 47º57’27’’W, at about 795 m of heigth). The annual average precipitation is of 1600 mm; the average annual temperature is of 22.6º C and the air relative humidity is of 68%. The climate is classified as Aw, hot tropical, according to Köppen's classification, presenting dry and cold winter. The experimental area soil was classified as Latossolo Vermelho Distrófico típico, according to Embrapa (2006) and Typic Hapludox, according to Soil Taxonomy (2006). It present the following characteristics in the arable layer (0.0-0.20 m); 180g kg^{-1} of clay, pH H_2O (1:2.5) 6.3 ; 17 mg dm^{-3} of P; 96 mg dm^{-3} of K; 1.9 $cmol_c$ dm^{-3} of Ca^{2+}; 0.6 $cmol_c$ dm^{-3} of Mg^{2+}; 2.0 $cmol_c$ dm^{-3} of H+Al and 16 g dm^{-3} of organic matter. The analyses were carried out according to Embrapa (1997).

The experiment was installed in August 2000, being the following plant cover utilized: millet (*Pennisetum americanum* sin. tiphoydes), tropical grass (*Urochloa brizantha*), sunn hemp (*Crotalarea juncea*), being also utilized an area in fallow and a control area (conventional tillage, where ploughing and grading are carried out). In the area of fallow (seven years: 2000 at 2007) the identification of invading plant was made, being verified the presence of species of various families, with predominance of gramineae (a greater proportion) and also Solanacea, Compositae, Portulacacea, Cyperacea, Rubiacea e Amaranthacea.

The experimental delineation adopted was with random blocks, with four repetitions, with a total of 20 plots (4 x 10 m = 40 m^2) which correspond to five areas (three vegetable covers + conventional tillage + fallow).

After approximately 110 days after seeding the plant cover were desiccated by the application of 1.440 g ha^{-1} of glyphosate + 600g ha^{-1} Paraquat. Fifteen days after desiccation, the plots were subdivided in two areas of 20 m^2, and in November 2002, double hybrid maize AG 1051 and soya MG/BR-46 were planted, being done the treatment of the seeds, blight, diseases and invading plant control, necessary during the cycle of the cultures.

Right after the maize and soya sowing, the seeding of the vegetable covers was done again, in the same locations, and afterwards a new tillage of the cultures of maize and soya. This procedure was carried out continuously after the implementation of the experiment (August/2000) up to the agriculture year of 2007.

The samples for the evaluation of the granulometric and chemical fractioning of the SOM were collected in the depths of 0.0-0.025; 0.025-0.05; 0.05-0.10 and 0.10-0.20 m. In each subplots, in the areas with maize and soya, four composite samples were collected (formed from 10 simple ones), with the employment of trowel, through the opening of trenches of 20 x 40 cm, transversally to the tillage lines, in the area of each vegetable cover, identified and packed in plastic bags. After the sampling, the samples were taken to a laboratory, air dried and harrowed, thus being obtained air dried thin sand. In this material, the following analyses were made:a) Total organic carbon (TOC), determined by oxidation of the organic matter with potassium dichromate 0.2 mol L^{-1} sulfuric media and titration with amoniacal ferrous sulphate 0.1 mol L^{-1} according to Embrapa (1997); b) Granulometric fractioning of the SOM, utilizing the method proposed by (Cambardella and Elliot, 1992) carrying out the dispersion of the sample with a solution of sodium hexametaphosphate (5 g L^{-1}) and the separation of the sand fraction from the silt and clay fractions, with the employment of sieve 53 µm. The material retained in the sieve, which consists of particulate organic matter (POM), associated to the sand fraction was dried in a greenhouse at 50ºC, quantified in relation to its mass, ground in porcelain mortar and pestle and analysed in relation to the total organic carbon(TOC) grade, according to Embrapa (1997). The material that passed through the 53 µm clieve, which consists of organic matter associated to mineral (MOM) of the silt and clay fractions, was obtained by the difference between TOC and POM.

c) Chemical fractioning of the SOM, being the humic substances (humic acids - FAH, fulvic acids - FAF and humin (HUM) identified in accordance with the differential solubility techniques established by the International Humic Substances Society (Swift, 1996), in accordance with a technique adapted and presented by Benites *et al*. (2003). The organic carbon grades were quantified in the fulvic acids fraction (C-FAF), humic acids fraction (C-FAH) and humin (C-HUM) accordind Yeomans and Bremner (1988); and d) Organic carbon stock of the SOM fractions, being utilized the equivalent mass method (Ellert and Bettany, 1995; Sisti *et al*., 2004), according to the equation below,

$$C_S = \sum_{i=1}^{n-1} C_{Ti} + \left[M_{Tn} - \left(\sum_{i=1}^{n} M_{Ti} - \sum_{i=1}^{n} M_{Si} \right) \right] C_{Tn}$$

where:

C_S is the total carbon stock , in Mg C ha^{-1},

$\sum_{i=1}^{n-1} C_{Ti}$ is the sum of carbon from the first (surface) to the last layer in the soil profile in the evaluated treatment (Mg ha^{-1}),

$\sum_{i=1}^{n} M_{Ti}$ is the sum of the soil mass from the first to the last layer in the soil profile in the evaluated treatment (Mg ha^{-1}),

$\sum_{i=1}^{n} M_{Si}$ is the sum of the soil mass from the first to the last layer in the soil profile in the reference treatment (Mg ha^{-1}),

M_{Tn} is the soil mass in the last layer of the soil profile in the evaluated treatment (Mg ha^{-1}),

C_{Tn} is the concentration of carbon in the last layer of the treatment of the evaluated profile (Mg C Mg^{-1} of soil). The area (treatment) was the reference to tropical grass due to smaller mass of soil.

The delineation utilized was of random blocks with subdivided plots, being sunn hemp, millet, tropical grass, conventional tillage and fallow (parcels) and soya and maize (subplots), with four repetitions. For the data of the granulometric and humic franctions of the SOM, in each depth, the evaluation of the normality of data was effected (Lilliefors), homogeneity of the error variances (Teste de Cochran and Barttlet). Subsequently the results were submitted to the analysis of variance with application of the F test and the average values, when significant, compared among them by the Tukey test at 5 % of probability.

When significant interaction between the parcel factors and subplots, for each analysed variable was observed, the unfolding of the interaction was effected. For the variables that did not present significant interaction among these factors, the same were evaluated separately, being its effect verified, when significant, for each factor isolated.

RESULTS AND DISCUSSION

The SOM granulometry fractioning

In the depth of 0.0-0.025 m lower values of POM stocks were observed in the area under conventional management and higher for the area with millet cover, both in the areas of maize (Figure 1).

This pattern may be originated from the higher quantity of vegetable residues found in soil surface produced by the previous culture (millet) and lower and the conventional management areas. In the areas of soya, the fallow differed from the other treatment, presenting the lowest POM stock value. In the area with sunn hemp cover the highest stock of this fraction was observed. Among the cultures, the maize area presented higher POM stocks, when millet was the covering plant preceding the maize seeding, being this pattern also observed in the fallow area. On the other hand, in the soya area higher POM stocks were verified in the area where the cover plant was the sunn hemp and in the conventional management area (Figure 1).

In a study carried out by Bayer *et al*. (2004), about storage of carbon in organic matter labile fractions of a Red Latossoil, the authors found higher organic carbon stocks for the POM in the areas of no-Tillage (NT) when compared to the conventional management, irrespective of the culture rotation system implemented in the depth of 0.0-0.025 m.

In the depth of 0.05-0.10 m (Loss et al., 2010b), higher POM stocks were verified in the fallow area and lower ones in the areas of sunn hemp and tropical grass, in the areas where maize was cultivated. For the soya area, higher stocks were observed in the areas where the tropical grass was the plant cover and in the conventional management. Among the cultures, the areas of sunn hemp and fallow presented higher stocks when the culture of maize was performed. In the depth of 0.10-0.20 m, higher POM stocks were observed in the areas of sunn hemp and fallow (maize) and millet and tropical grass (soya). Among the cultures, the areas of sunn hemp and conventional management, presented higher values when the culture of maize was done, and millet and tropical grass for the soya culture (Figure 1).

In a general manner, it was verified in the evaluated depths that the highest POM grades were found in the areas with association of leguminous and gramineae, being this pattern best evidenced in the layer of 0.0-0.20 m, where the highest POM stocks were observed in the area of soya on millet and tropical grass (leguminous x gramineae) and in the culture of maize on sunn hemp (gramíneae x leguminous).

These results may be due to the balance in the C/N ratio in the cover plant with the cultures, leading to higher POM stocks when compared to the areas where only gramineae occurs(millet on maize) or leguminous(soya on sunn hemp).Increase of POM stocks are verified in the areas with leguminous x gramineae, since the nitrogen biological fixation by the leguminous contributes to the growth of gramineae, which, on their turn react with higher phytomass production and, consequently, higher quantities of dry matter are input into the soil. Part of this material, through the SOM decomposition, will be transformed into POM.

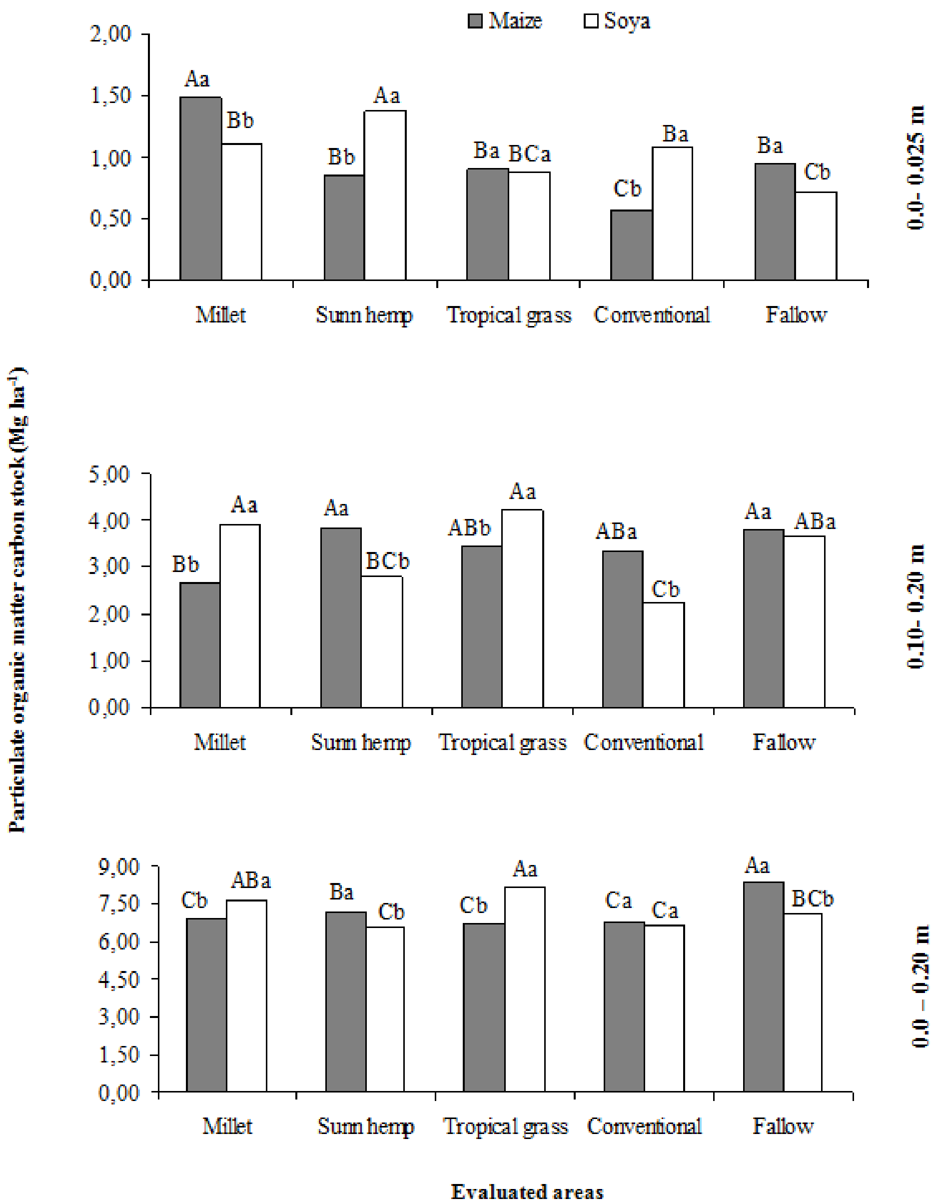

Figure 1. POM carbon stocks under different evaluated areas and cultures of maize and soya. Averages followed by the same capital letter do not differ (Tukey < 0.05) among the areas evaluated for each culture, and same small letters, do not differ (Tukey < 0.05) among the culture of each evaluated area.

In the area of conventional preparation of the soil no differences among the cultures were found, evidencing that the management of the soil with plant of the same family and associated to the practices of plowing and harrowing, promote lower POM stocks. This pattern is evidenced in the area of maize, where millet and tropical grass were the plant cover which promoted the lower POM stocks, being these the same verified in the area of conventional management. In the area of soya the lowest POM values were also observed the sunn hemp cover, being the values the same as the ones quantified in the conventional management area. In the area of fallow, the stocks values found may be due to higher diversity of existing species (Torres *et al*., 2008).

The results found in this study are similar to those verified by Bayer *et al*. (2002), where the authors quantified the POM stocks in the layer of 0-17.5 cm of an Udultsol on the culture systems oat + vetch/maize +cowpea and verified that the NT (9 years) was 36 % higher in relation to the conventional preparation, in promoting the increase of POM stocks, being superior in promoting increase of the POM stocks, being the culture rotation with gramineae and leguminous utilized.

In relation to the MOM stocks, in the depth of 0.0-0.025 m, the fallow area presented the highest value in the area of soya culture. For the culture of maize, in the areas of sunn hemp and millet, the highest and the lowest stocks were respectively verified. Among the cultures, higher MOM stocks were observed in the areas of sunn hemp and conventional management (maize) and in the area of soya, the fallow area presented higher stocks (Figure 2).

For the depth of 0.10-0.20 m, the area of maize, preceded by millet, presented the highest MOM stock and the areas of fallow and conventional management, the lowest stocks. In the area of soya, when the tropical grass was utilized as cover plant, the highest MOM stock was observed, and in the areas of conventional management and fallow, the lowest. Among the cultures, only the tropical grass cover presented differences, with the highest value in the area of soya (Figure 2). The results found allow us to infer that the maize culture on millet and soya on tropical grass increase the MOM stocks when compared to the areas of conventional management and fallow. Therefore the utilization of cover plant (gramineae and leguminous) preceding the planting of grains in Cerrado soil under NT favors the increase of MOM stocks.

In the area of conventional management, the negative effect of the soil preparation (plowing and harrowing) on the aggregates becomes evident, since though their rupture, the MOM which was protected in the inner part, is exposed to the action of micro-organisms. The latter, on their turn, will accelerate the process of the SOM degradation, ending up in a fast mineralization.

SOM chemical fractioning

In the depth of 0.0-0.025 m, in the area of maize, the highest C-HUM stocks were found in the areas which had tropical grass and millet as plant cover. In the culture of soya the highest C-HUM stocks were observed in the areas of tropical grass and sunn hemp. Among the cultures, the areas with sunn hemp and fallow presented the highest stocks for soya, whereas for the culture of maize, this pattern was verified for the millet cover (Figure 3).

In the depth of 0.10-0.20 m, in the area of maize, higher C-HUM stocks were verified in the areas where sunn hemp and tropical grass were the cover plant, whilst in the area of soya, only the fallow area and conventional area differed from the others, presenting the lowest C-HUM stocks. Among the cultures in the areas of maize on sunn hemp and fallow the highest C-HUM stocks were quantified (Figure 3).

When the area with tropical grass and the area under conventional management are compared, it was verified that the tropical grass cover favored higher C-HUM stocks, irrespective of the evaluated culture (maize and soya) or the depth (0.0-0.025 and 0.10-0.20 m). These results indicate that the tropical grass is efficient in increasing the C-HUM stocks in NT under Cerrado soil, through the addition of straw to soil by virtue of its high C/N ratio.

In the conventional preparation of the soil, the carbon grade reduction and consequently the reduction of the humic fractions, is not due only to the decrease of the quantity of residues added, but also to the increase of microbian activity, promoted by better aeration condition, higher temperature and more frequent alternation of moisturing and drying of the soil (Stevenson, 1982), besides the continuous utilization of implement and the losses caused by erosion which are favored in the conventional seeding (Pinheiro *et al*., 2003).

For the C-FAF stocks, in the area of maize, irrespectively of the evaluated depth, no differences were observed (0.025-0.05 and 0.0-0.20 m). In the culture of soya, among the cover plant, higher stocks for the areas with millet (0.025-0.05 m) and millet and tropical grass in the depth of 0.0-0.20 m were verified, being these stocks values identical to the ones observed for the areas of conventional management (0.025-0.05 m) and fallow for the depth of 0.0-0.20 m. Among the cultures, higher C-FAF stocks were verified in the area with soya for the millet and sunn hemp covers and conventional management (0.025-

0.05 m). In the other evaluated depths, only the sunn hemp cover presented differences, with higher values in the area of soya (Figure 4).

These results indicate that the utilizaton of gramineae (millet and tropical grass) as cover plant preceding the leguminous species culture (soya) favors the increase of C-FAF stocks when compared to the utilization of leguminous only (sunn hemp and soya). This pattern may also be due to the benefit of the radicular system of the millets and the tropical grass plant, which can reach higher depths and carry the fulvic acid fraction to higher depths (0.0-0.20 m).

In the area of conventional management, the C-FAF stocks found, identical to the area of millet in the depth of 0.025-0.10 and 0.0-0.20 m and higher than the tropical grass cover (0.025-0.5 m) may be caused by the revolvement of the soil, since the fulvic acid fraction has higher mobility in the soil, when compared to the other fractions.

Evaluating the humic fractions grades in aggregates of a Typic Hapluldox under Cerradão areas and maize culture of 30 years under the conventional system, in the city of Sete Lagoas, MG, Passos *et al*. (2007) higher C-FAF grades were verified in the soil under conventional culture of maize. The authors emphasize the soil revolvement effect, incorportating the maize culture residues, as well as the higher mobility of this fraction, for the highest C-FAF values found.

The C-FAH stocks, in the depth of 0.0-0.025 m, were higher for the areas which had millet, sunn hemp and tropical grass as cover plant, when compared to the conventional management and the fallow area, irrespectively of the evaluated culture (Fig. 5). These results indicate that the increase of the C-FAH stocks depend of the input of vegetable residues originated from the cover plant.

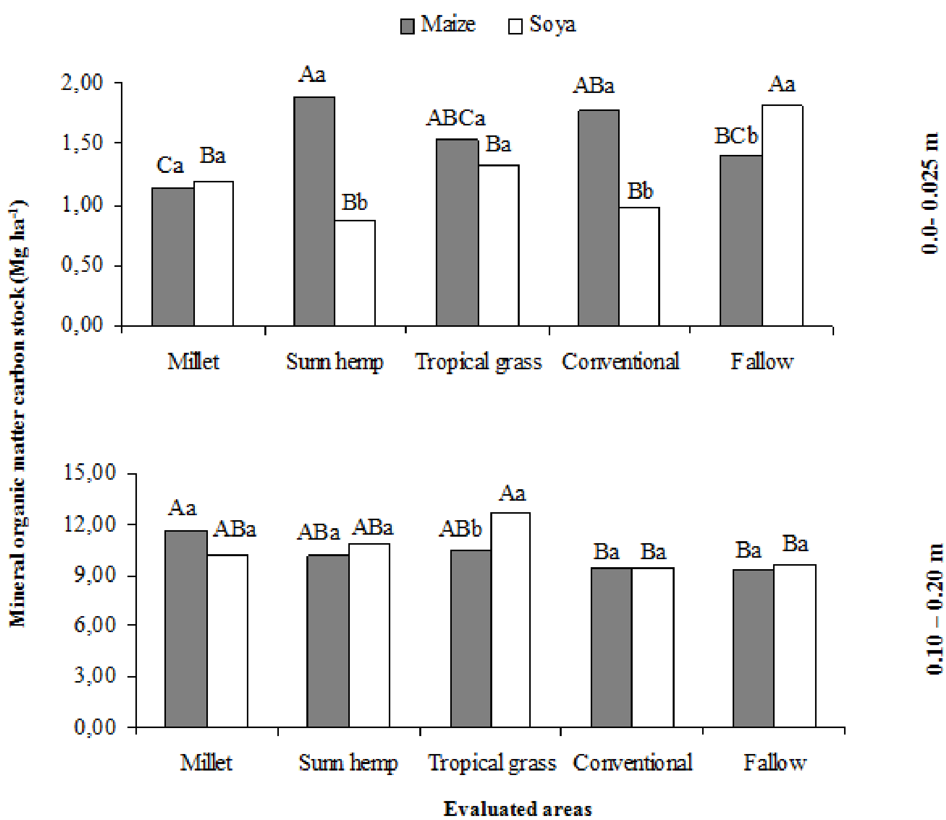

Figure 2. MOM carbon stocks under different evaluated areas and maize and soya cultures. Averages followed by the same capital letter do not differ(Tukey < 0,05) among the evaluated areas for each culture, and averages with the same small letter do not differ(Tukey <0,05) among the cultures for each evaluated area

In the layer of 0.0-0.20 m, higher C-FAH stocks were verified in the areas with tropical grass, conventional management and fallow. In the soya culture, the conventional management presented the highest stock value (Figure 5). These results may be due to the incorporation of the maize and soya culture residues in depth.

Normally, the practices utilized in the conventional preparation of the soil, cause decrease of the humic acid fraction grade (Cunha *et al*., 2001, Loss *et al*., 2010). However, an opposite behaviour in the layer of 0.0-0.20 m was observed. A similar result was observed by Passos *et al*. (2007), evaluating the humic substances grades in aggregates of a Typic Hapluldox under areas of Cerradão and maize culture of 30 years under the conventional system, in the city of Sete Lagoas, MG. The authors found higher C-FAH grades in the soil under conventional culture of maize and attributed this behaviour to the addition of the maize culture residues for 30 years.

In Tables I, the humic fractions stocks are shown for the depths which did not present significant interaction for the evaluated factors. The highest C-HUM stocks (0.025-0.05 m) were found in the area with millet, and the lowest for tropical grass and conventional management. Whereas, in the depth of 0.05-0.10 m, the area under conventional management presented the highest C-HUM stock and the area of tropical grass, the lowest.

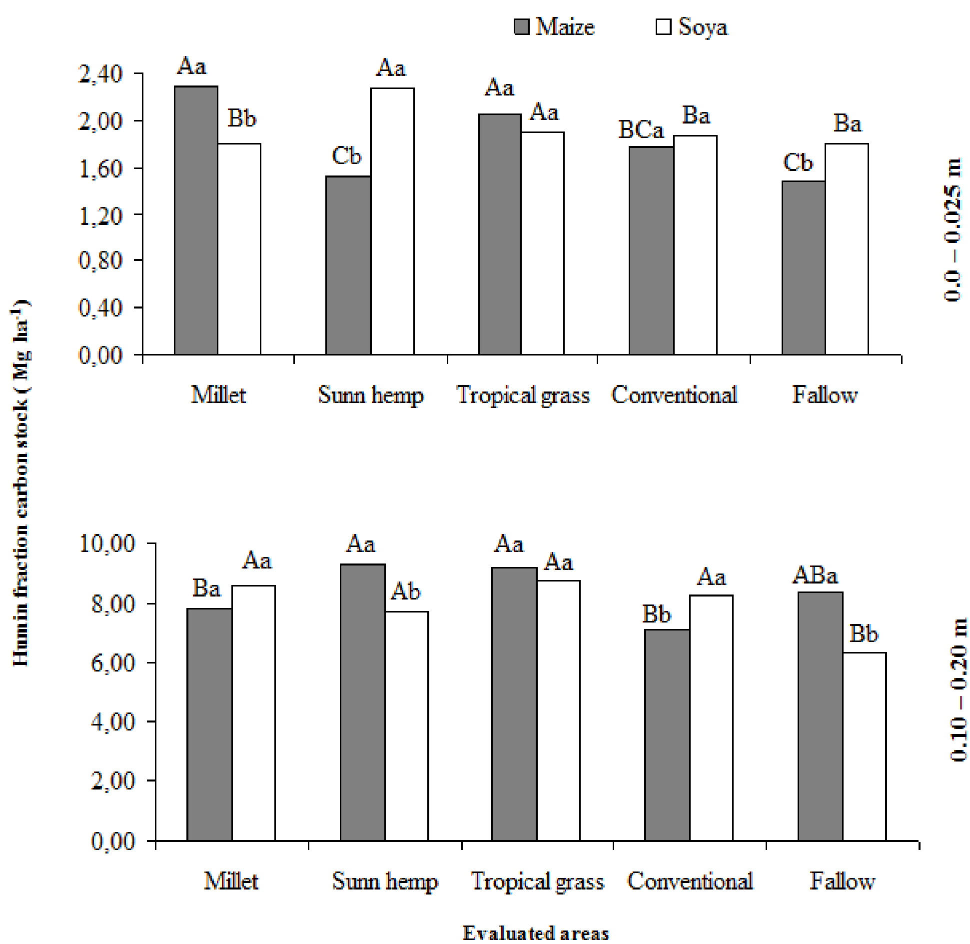

Figure 3. Humin fraction carbons stocks under different evaluated areas and maize and soya cultures. Averages followed by the same capital letter do not differ (Tukey < 0,05) among the evaluated areas for each culture, and the same small letter do not differ (Tukey < 0.05) among the cultures for each evaluated area

This result differs from the one observed by Fontana *et al.* (2006), evaluating the humic fractions under a Typic Hapluldox in the Cerrado of MS, in different culture and rotation systems, being tillage (maize and soya) and pasture (tropical grass). The authors verified that the highest C-HUM grades were found in the area of tropical grass.

The lowest C-HUM stocks in the conventional management, in the surface layer of the soil are due to the preparation of the soil, where the removal of culture residues occurred. Whereas in depth (0.05-0.10 m), the highest C-HUM stocks may be due to the incorporation of vegetable material proceeding from the surface.

For the C-FAF stocks, in the depth of 0.0-0.025 m, no differences were found among the evaluated cover areas. Whilst in the depth of 0.10-0.20 m, the areas of sunn hemp and conventional management presented the lowest values and the area of tropical grass, the highest stock value of this fraction. The C-FAH, in the depth of 0.05-0.10 m, presented the lowest value for the area of millet, whereas in the depth of 0.10-0.20 m, the lowest stock value was observed for the area of sunn hemp (Table I).

For the layer of 0.0-0.20 m, the NT with the use of millet as cover crop to higher average carbon stock over the fallow and sunn areas. However, no differences were found between the areas of tropical grass and conventional tillage when compared to coverage of millet. In conventional tillage, the values of carbon stocks are in agreement with what is expected of soil disturbance, with the incorporation of plant residues on the soil surface into deeper layers.

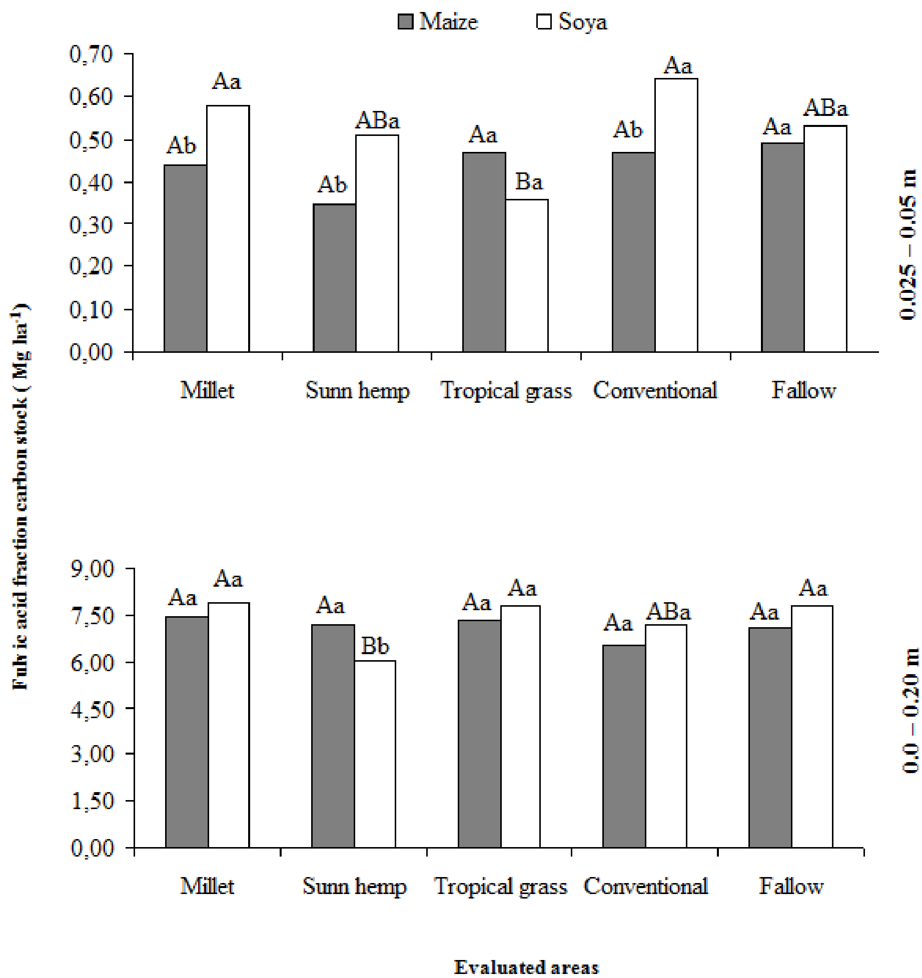

Figure 4. Fulvic acids fraction carbon stocks under different evaluated areas and maize and soya cultures. Averages followed by the same capital letter do not differ (Tukey < 0.05) among the areas evaluated for each culture, and same small letter do not differ (Tukey < 0.05) among the cultures for each evaluated area.

In the NT with millet, the absence of soil disturbance associated with its root system that is able to incorporate carbon capture depth and easily leached nutrients (Foy, 1997) corroborate the highest values were found, and also according to Bayer *et al.* (2004), Wendling *et al.* (2005) and Loss *et al.* (2009).

The results of carbon storage in this study are considered low compared to other studies in literature (Bayer *et al*., 2004; Wendling *et al*., 2005; Blanchart *et al*., 2007; Siqueira Neto *et al*., 2009). However, C accumulation may vary regionally due to climatic conditions (Carvalho *et al*., 2010), soil type, applied to management and, especially, according to the time of implantation of the SPD (Carvalho *et al*., 2009).

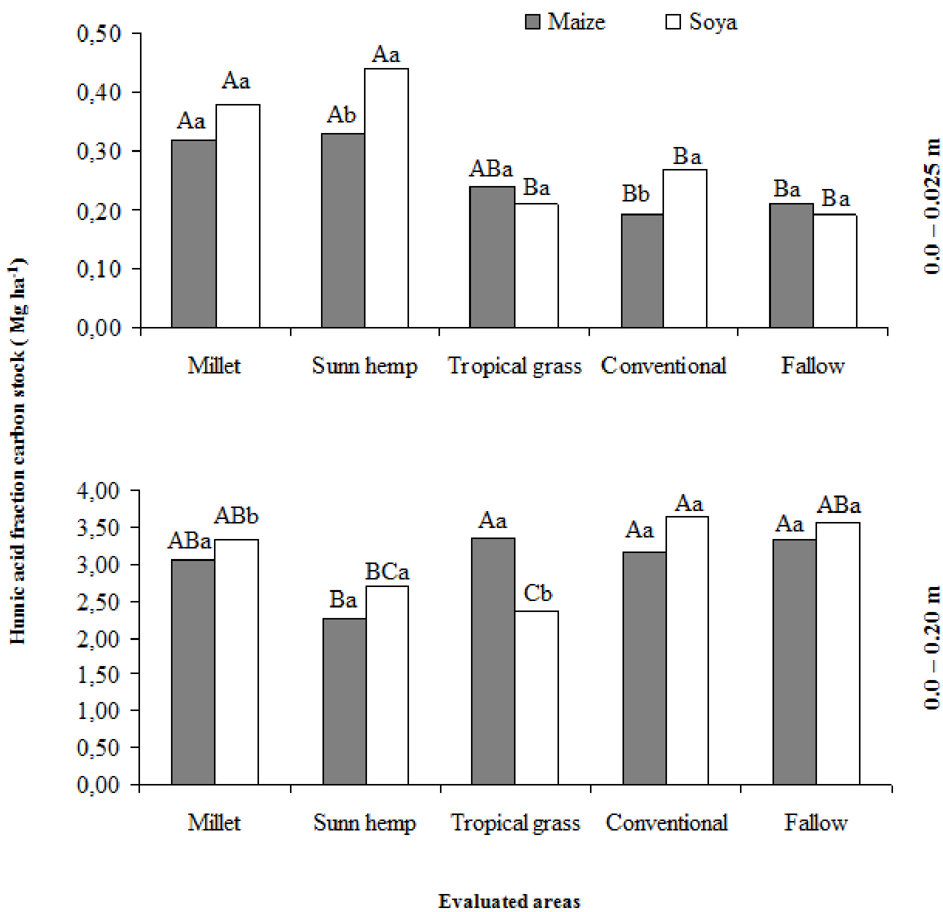

Figure 5. Humic acids fraction carbon stocks under different evaluated areas and maize and soya cultures. Averages followed by the same capital letter do not differ (Tukey < 0.05) among the areas evaluated for each culture, and same small letter do not differ (Tukey < 0.05) among the cultures for each evaluated area.

Table I. Humic fractions stocks and organic carbon stocks which did not present significant alteration among vegetable cover and culture, but were significant (Tukey <0.05) for the vegetable cover factor.

Characteristics Evaluated	**Plant covers**					
	Millet	Sunn hemp	Tropical grass	Conventional	Fallow	CV(%)
C-HUM 0.025 – 0.05 m	2.08 a	1.90 ab	1.69 b	1.61 b	1.90 ab	10,78
C-HUM 0.05-0.10 m	5.42 ab	5.15 bc	4.46 c	5.91 a	5.48 ab	8,33
C-FAF 0.0-0.025 m	0.48 ns	0.46 ns	0.40 ns	0.46 ns	0.45 ns	17,14
C-FAF 0.10 – 0.20 m	4.33 ab	3.91 b	4.70 a	3.83 b	4.38 ab	11,56
C-FAH 0.05-0.10 m	0.96 b	1.11 ab	1.04 ab	1.14 ab	1.30 a	17,84
C-FAH 0.10 – 0.20 m	1.52 a	0.72 b	1.32 a	1.65 a	1.70 a	18,98
COT 0.0 – 0.20 m	27,00 a	25,51 b	26.21 ab	26.37 ab	25.61 b	3,44

Averages followed by the same letter in the line, do not differ among themselves by the Tukey test at 5% of probability. ns= non significant by the F test at 5%. CV= variation coefficient

CONCLUSIONS

The management of the soil under the no-tillage system with plant cover increased the POM stocks when was utilized the maize culture about sunn hemp and soya culture about millet and tropical grass. The utilization of plant cover preceding the grains culture in Cerrado soil under no-tillage system increased the MOM and C-FAH (0.10-0.20 m) stocks when compared to the areas under conventional management and fallow. The tropical grass cover increased the C-HUM stocks in detriment to the conventional management, irrespectively of the evaluated culture (maize and soya) or of the depth (0.0-0.025 e 0.10-0.20 m). The use of grass (millet and tropical grass) as plant cover preceding soybean tillage and legumes (sunn hemp) preceding corn tillage favored a raise in the stocks of humic and granulometric fractions of SOM, especially POM and C-FAH, the fractions most benefitted by this soil management.

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