SOIL CARBON STOCKS AND LABILE ORGANIC MATTER FRACTIONS UNDER DIFFERENTS VEGETATION COVERS IN GURUPI – TO

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Resumo

Estoques de carbono no solo e frações lábeis da matéria orgânica sob diferentes coberturas vegetais em Gurupi – TO. Os solos representam um grande reservatório de carbono (C), de forma que as alterações no uso e manejo podem causar impactos no balanço do C, bem como no controle climático global. O estudo teve como objetivo determinar o efeito das mudanças de coberturas vegetais nos estoques de C do solo e frações lábeis no bioma Cerrado na região sul do Tocantins. O trabalho foi desenvolvido em áreas de *Eucalyptus* sp., pastagem, agricultura e Cerrado stricto sensu, localizadas na fazenda experimental da Universidade Federal do Tocantins. As amostras de solo foram coletadas em trincheiras de 70 x 70 cm nas profundidades 0-10, 10-20, 20-30, 30-40 e 40-50 cm, com seis repetições. A análise estatística foi realizada por meio do teste de normalidade, análise de variância e comparação das médias pelo teste Tukey a 5% de significância. A área com *Eucalyptus* sp. com 11 anos apresentou teores de carbono do solo superiores aos da vegetação de mata nativa, pastagem e agricultura. Os teores de carbono lábil (C-lábil) e matéria orgânica leve foram 26,80 e 41,58 % maiores para a área de *Eucalyptus* sp. em comparação com Mata Nativa, 25,75 e 35,76 % para a pastagem, e 48,39 e 9,50 % para a agricultura respectivamente. Dentre as diferentes áreas avaliadas, foi verificado que o *Eucalyptus* sp. possui grande potencial em aumentar o armazenamento de carbono no solo, C-lábil e matéria orgânica leve.
Palavras-chave: mudança no uso do solo; Plintossolos; Cerrado

Abstract

Soils represent a large carbon reservoir (C), and changes in its use and management can impact C balance and global climate control. This study aimed to determine the effect of changes in vegetation cover on soil C stocks and labile fractions in the Cerrado biome in the southern region of Tocantins. The work was developed in areas of *Eucalyptus* sp., pasture, agriculture and Cerrado stricto sensu at the experimental farm located at the Federal University of Tocantins. Soil samples were collected in trenches of 70 x 70 cm and depths of 0-10, 10-20, 20-30, 30-40 and 40-50 cm, with six replicates. Statistical analysis was performed using the normality test, analysis of variance and comparison of means by the Tukey test at 5% significance. On Eucalyptus stands, soil carbon was higher than native forest vegetation, pasture and agriculture. The contents of labile carbon (C-labile) and light organic matter (LOM) were 26.80 and 41.58% higher for *Eucalyptus* sp. compared to native forest, 25.75 and 35.76% for pasture, and 48.39 and 9.50% for agriculture, respectively. Among the different areas evaluated, it was found that *Eucalyptus* sp. has great potential to increase soil carbon storage, C-labile and light organic matter.
Keywords: land use change; Plintossolos; Cerrado

INTRODUCTION

All over the world, soils stock four times more C than the biosphere and two to three times more C than the atmosphere. Thus, small changes in land use and management can cause major impacts on C balance, promoting implications for global climate control (CHEN *et al*., 2019).

Forest ecosystems are important for the global C cycle due to their great potential to store C and their large biomass volume. Tropical forests are the most productive ecosystems in capturing C, confirming the great importance of forests in the global C cycle (NAVARRETE-SEGUEDA *et al*., 2018). Changes in land use in the Brazilian Cerrado lead to a decrease in soil organic carbon (SOC) in the adoption of inappropriate management techniques, such as monocultures or unfertilized crops (OLIVEIRA *et al*., 2016).

There are several soil organic matter (SOM) fractions with varying decomposition degrees and stability. These fractions are useful in the study of short and long-term influences of land use and management on the SOC dynamics (BLAIR *et al*., 1995). Total organic carbon (TOC) is composed of labile and non-labile SOC forms and has different sensitivity levels in different systems and management practices (ARAUJO FILHO *et al*., 2018), emphasizing carbon labile (C-labile) and light organic matter (LOM) forms.

Thus, knowing the effects of land use on carbon stocks is important for controlling CO_2 emissions, because it can change mitigation policies, involving incentives to adopt practices that potentialize C sequestration. In this context, this study aimed to determine the effect of changes in vegetation cover on soil C stocks and labile fractions in the Cerrado biome in the southern region of Tocantins.

MATERIAL AND METHODS

Study Area

The work was conducted at the experimental farm located at the Federal University of Tocantins, municipality of Gurupi, state of Tocantins at the following geographical coordinates: 11º46'25” S and 49º02’54” W (Figure 1).

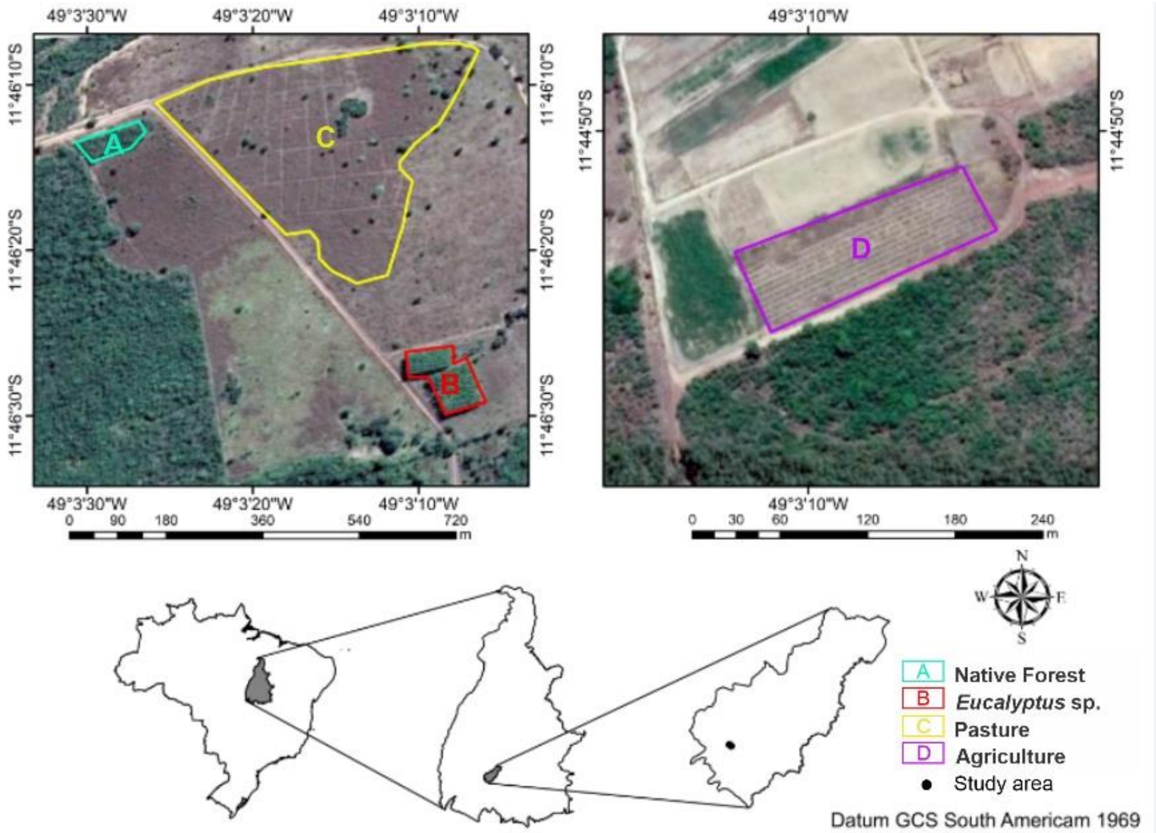

Figure 1. Location of experimental areas with native forest, *Eucalyptus* sp., pasture and agriculture.
Figura 1. Localização das áreas experimentais com mata nativa, *Eucalyptus* sp., pastagem e agricultura.

According to Thornthwaite, the climate of the region is B1wA'a' type, which has two well-defined seasons, with about six months of drought comprising the winter period and six months of rain during the summer. The average annual temperature is 27 ºC and the average annual precipitation is 1,500 mm (SEPLAN, 2017). The soil was classified as a Plintossolos Pétrico (SANTOS *et al*., 2018). The areas under study were composed of *Eucalyptus* sp. stands, pasture, agriculture and Cerrado stricto sensu native forest as witness. Each area had the following characteristics:

Cerrado stricto sensu native forest: the area covers 22.82 ha aged over 60 years. The vegetation was characterized by five species of higher importance value: *Myrcia splendens* (Sw.) DC. (13.04%), *Qualea multiflora* Mart. (9.87%), *Protium heptaphyllum* (Aubl.) Marchand (7.53%), *Magonia pubescens* A.St.-Hil. (5.35%), *Qualea grandiflora* Mart. (5.02%) (BENDITO *et al*., 2018).

***Eucalyptus* sp.:** the area has 0.65 ha aged 11 years and its implementation was carried out through deforestation with crawler tractor and front blade, then plowing and harrowing was carried out. Seedlings with 25 cm in height were planted in pits with dimensions of 0.4 x 0.4 x 0.4 m with the help of diggers, with 3 x 2 m spacing. Then, fertilization was carried out with 100 g of simple superphosphate at the bottom of the pit and partially buried, then 150 g of NPK per pit^{-1} were added in the 5-25-15 formulation.

Pasture: the area has 11.25 ha with native pasture and predominance of Andropogon grass aged 40 years. Other Poaceaes species have been recorded such as: *Paspalum notatum* Flügge, *Eragrostis bahiensis* Schrad, *Axonopus affinis* Chase, *Bothriochloa laguroides* (DC.) Herter, *Schizachyrium microstachyum* (Desv. ex Ham) Roseng, *Paspalum dilatatum* Poir., *Sporobolus indicus* P.Beauv., *Rhynchospora* sp., *Andropogon ternatus* (Spreng.), *Panpalumis* sp.

Agriculture: The area has 0.95 ha and soil preparation was performed using leveling harrow and disc plow. Weeds were controlled by manual weeding associated with full-action herbicides such as Glyphosate, when necessary. Over the past 6 years, corn crop was grown in the area, which was annually planted in the period between February and March at average spacing of 0.2 x 0.8 m. For sowing, manual planter-fertilizer was used, which enabled basic fertilization. The nutrients applied at the time of corn sowing consisted of nitrogen in the form of ammonium sulphate (45% N), phosphorus in the form of triple superphosphate (42% P_2O_5) and potassium in the form of potassium chloride (58% of K_2O), corresponding to 120, 170 and 140 kg ha^{-1}, respectively of N, P and K, with N applied 50% at 25 days and 50% at 45 days after sowing.

Soil samples

Six trenches randomly selected, about 30 m equidistant from each other, with dimensions of 70 x 70 cm and depth of 50 cm were opened. Samples were collected in the dry period in October 2018 at depths of 0-10, 10-20, 20-30, 30-40 and 40-50 cm. Deformed soil samples were air dried at room temperature and passed through 2 mm sieve to perform physical and chemical analyses. Non-deformed samples were collected and submitted to soil density analysis.

Physical and Chemical Analysis

Soil density was determined by the volumetric cylinder method and granulometric analysis was performed using the pipette method (DONAGEMMA *et al*., 2017).

Soil samples and light organic matter - LOM obtained by the method adjusted by Fraga and Salcedo (2004), were macerated in porcelain mortar and pistil until forming a fine powder and passed through 150 µm mesh sieve. Soil carbon and light fraction determination was carried out using this fine powder, by the dry combustion method (CHNS / O) in elementary analyzer (Model PE-2400 Series II Perkin Elmer). Labile carbon (C-labile) was determined by oxidation with 0.033 mol L^{-1} potassium permanganate ($KMnO_4$) solution (BLAIR *et al*., 1995).

C concentrations were converted into soil carbon stock (SCS) in Mg ha^{-1} for each sampled depth as follows (ARAUJO FILHO *et al*., 2018):

$$\text{Stock C} = (\text{Cc x Sd x VSD})\text{x } 1000$$

Where, Stock C is the carbon stock in the soil layer, in (Mg ha^{-1}); Cc is the carbon concentration in the soil sample, in (kg Mg^{-1}); Sd is the soil density in the layer, in (Mg m^{-3}) and VSD is the sampled depth volume, in (m^3). Total C stock at depth from 0 to 50 cm was calculated by adding values obtained in each sampled layer.

Statistical Analysis

Parameters C concentrations and stocks, light organic matter and labile soil fraction were submitted to Shapiro-Wilk normality tests and then to analysis of variance to assess differences among land uses in soil depths. Comparison of means was performed by the Tukey test at 5% significance using the SISVAR statistical software (FERREIRA, 2011).

RESULTS

Soil grain size analysis showed predominance of sandy fraction (fine and coarse sand), since silt fractions, clay, and sandy fraction did not show great variations with increases in soil depth or with changing vegetation cover. Thus, it is classified as sandy-clay-loam texture at all soil depths (Table 1).

Table 1. Physical Cerrado soil characteristics in different vegetation covers at five depths in Gurupi-TO.
Tabela 1. Características físicas do solo do Cerrado nas diferentes coberturas vegetais em cinco profundidades em Gurupi-TO.

Vegetation Cover	Coarse Sand	Fine Sand	Silt	Clay	Soil Density	Texture
	(%)				g cm^{-3}	
Depth 0-10 cm						
Native forest	57.50 ±2.85	6.33 ±1.89	8.44 ±1.32	27.73 ±3.01	1.45 ±0.06	Sandy-clay-loam
Eucalyptus sp.	54.85 ±3.12	9.98 ±2.99	9.19 ±1.23	25.98 ±2.38	1.40 ±0.05	
Pasture	55.59 ±1.79	13.44 ±1.63	6.64 ± 0.57	24.33 ±1.21	1.55 ±0.08	
Agriculture	56.71 ±1.59	9.41 ±3.71	7.86 ±0.80	26.02 ±3.32	1.37 ±0.06	
Depth 10-20 cm						
Native forest	59.96 ±2.03*	4.71 ±2.12	8.51 ±2.33	26.82 ±2.24	1.51 ±0.05	Sandy-clay-loam
Eucalyptus sp.	56.04 ±2.24	9.09 ±1.90	6.85 ±2.17	28.02 ±1.91	1.53 ±0.07	
Pasture	57.84 ±1.32	10.55 ±1.84	7.26 ±1.75	24.35 ±1.76	1.59 ±0.05	
Agriculture	57.84 ±1.86	8.92 ±2.09	7.54 ±1.19	25.70 ±2.90	1.49 ±0.08	
Depth 20-30 cm						
Native forest	59.30 ±2.36	4.67 ±3.09	8.47 ±1.44	27.56 ±2.66	1.55 ±0.03	Sandy-clay-loam
Eucalyptus sp.	55.62 ±1.56	7.53 ±1.81	8.38 ±1.48	28.47 ±1.08	1.57 ±0.05	
Pasture	58.31 ±1.02	8.98 ±1.39	7.10 ±0.80	25.61 ±1.36	1.62 ±0.07	
Agriculture	57.67 ±2.23	8.28 ±3.47	6.56 ±0.73	27.49 ±2.70	1.51 ±0.07	
Depth 30-40 cm						
Native forest	58.43 ±3.23	4.43 ±2.89	8.68 ±1.55	28.46 ±2.33	1.62 ±0.03	Sandy-clay-loam
Eucalyptus sp.	55.89 ±1.68	8.75 ±2.08	8.82 ±1.68	26.54 ±2.36	1.65 ±0.04	
Pasture	58.16 ±1.44	9.44 ±2.17	6.23 ±1.46	26.17 ±1.81	1.64 ±0.06	
Agriculture	57.39 ±2.22	7.44 ±3.78	6.74 ±1.00	28.43 ±4.05	1.57 ±0.03	
Depth 40-50 cm						
Native forest	58.46 ±3.16	5.52 ±4.19	8.38 ±1.78	27.64 ±2.00	1.65 ±0.03	Sandy-clay-loam
Eucalyptus sp.	55.95 ±1.62	7.93 ±1.62	8.85 ±1.47	27.27 ±2.98	1.68 ±0.02	
Pasture	57.57 ±1.54	8.78 ±2.75	6.85 ±1.13	26.80 ±2.65	1.69 ±0.04	
Agriculture	57.04 ±2.45	6.89 ±2.55	7.23 ±0.45	28.84 ±3.64	1.61 ±0.07	

* Standard Deviation (SD)

Soil carbon concentrations, light organic matter (C-LOM) and labile carbon (C-labile) decreased with increasing depth for all vegetation cover areas analyzed, showing significant differences (Figure 2).

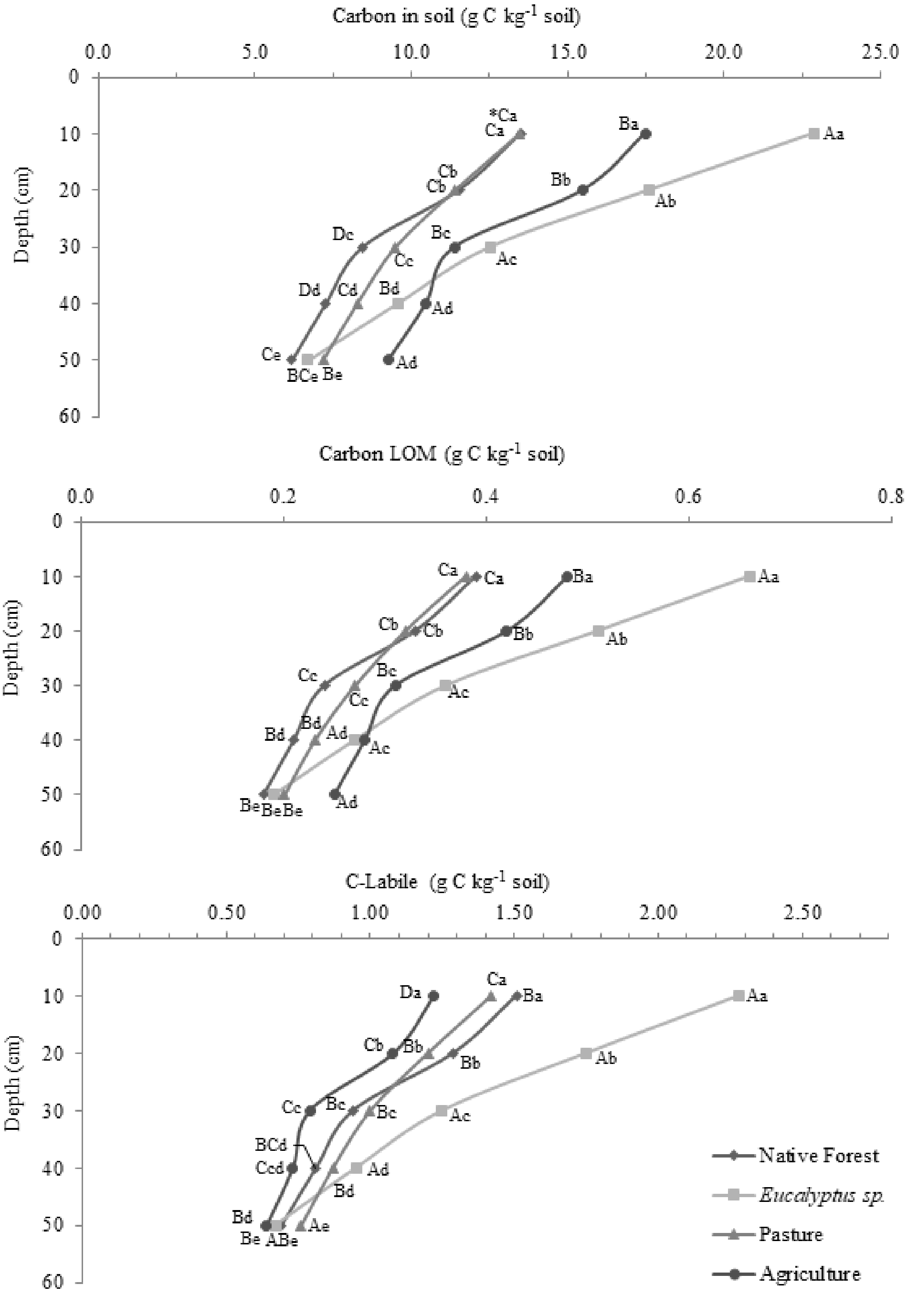

Figure 2. Soil carbon concentrations, light and labile organic matter in the different vegetation covers in Gurupi-TO.

Figura 2. Concentrações de carbono no solo, matéria orgânica leve e lábil nas diferentes coberturas vegetais em Gurupi-TO.

* Significant differences are indicated by different letters by the Tukey test at 5% significance level (P ≤ 0.05). Capital letters indicate differences among vegetation covers and lower letters indicate differences among soil layers.

Evaluated areas showed significant differences in soil carbon stocks, showing significant reduction with increasing soil depth (Figure 3).

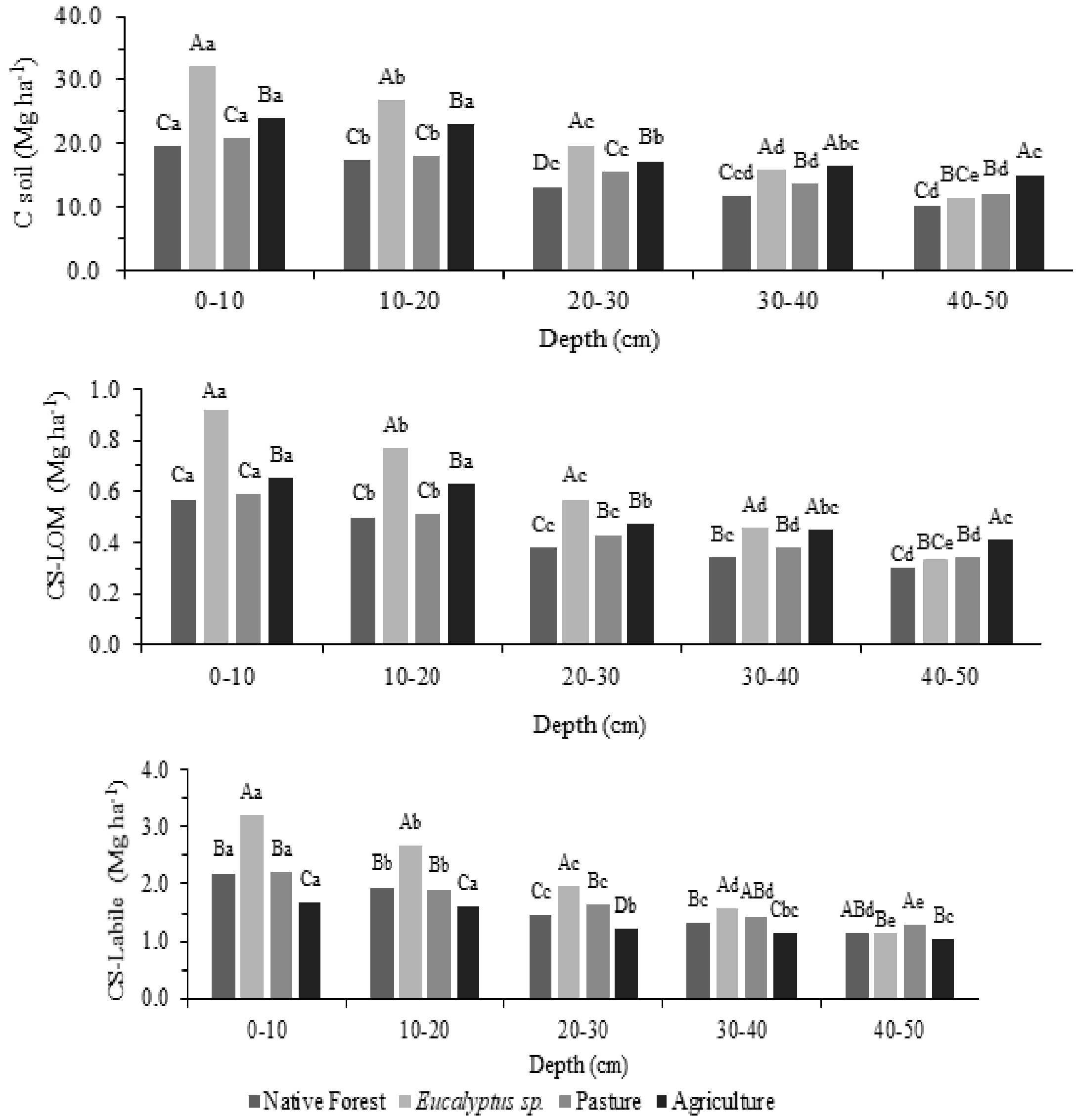

Figure 3. Carbon stocks in soil, light organic matter and C-labile in the different vegetation covers in Gurupi-TO.
Figura 3. Estoques de carbono no solo, matéria orgânica leve e C-lábil nas diferentes coberturas vegetais em Gurupi-TO.

* Significant differences are indicated by different letters by the Tukey test at 5% significance level ($P \leq 0.05$). Capital letters indicate differences among vegetation covers and lower letters indicate differences among soil layers.

DISCUSSION

The grain size test performed in physical analyses showing sand predominance indicates that the soil has low nutrient adsorption capacity due to the size of its relatively large aggregates, which makes them less capable of retaining water, not adhering to one another (MARINHO-JUNIOR *et al*., 2019). Soil density did not vary widely among land use types (Table 1), and increase was observed as soil depth increased, which is attributed to the weight of superficial layers. For MARINHO-JUNIOR *et al*. (2019), the removal of vegetation cover can cause soil compaction, due to the impact of rain drops and soil structure.

Regarding soil carbon concentrations, *Eucalyptus* sp. stands presented the highest concentrations, with higher average values compared to native forest, pasture and agriculture. According to Santos *et al.* (2019), this difference was due to the greater volume of roots in superficial layers, indicating that most soil organic matter comes from root residues. In contrast, lower average values were found in the 40-50 cm layer, with 6.71 g kg^{-1} *Eucalyptus* sp. and 6.78 g kg^{-1} native forest. Gmach *et al*. (2018) evaluated the effect of changes in carbon through land use in the Cerrado biome of Piauí and found similarities, as the evaluated soil showed decrease in soil C concentrations with increasing depth, and also found maximum value of 23.8 g kg^{-1} in the layer of 0-10 cm and minimum value of 5.2 g kg^{-1} in the deepest layer of 30-40 cm.

Eucalyptus sp. stands, pasture and agriculture, show C concentrations higher (+) or lower (-) than the reference area (native forest), respectively, + 69.2%; -2.6% and + 23.1% in the 0-10 cm layer, + 54.5%; -3.0% and + 27.3% in the 10-20 cm layer, + 50.0%; + 12.5% and + 29.2% in the 20-30 cm layer, + 28.6%; + 9.5% and + 33.3% in the 30-40 cm layer and + 5.6%; + 11.1% and + 38.9% in the 40-50 cm layer (Figure 2). Apparently, there was significant reduction of C-LOM in *Eucalyptus* sp. area and lower loss of C-LOM for agriculture in deeper layers. Since the highest C concentrations in light organic matter in the 40-50 cm layer are found in this area.

Although soil preparation favors soil carbon losses, this phenomenon can be explained by Araujo Filho *et al*. (2018), who attributed this lower C-LOM reduction in conventional corn planting to the high C/N ratio and to the fact that corn is a C4 plant with efficient photosynthetic metabolism to fix carbon, making carbon more present in underground soil.

Loss et al. (2019) evaluated the impact of soil cover change on soil organic matter in the Cerrado biome of Goiás and found significant differences in C-LOM concentrations in native Cerrado (4.77 g kg-1), pasture (1.44 g kg -1) and crop-livestock integration (0.91 g kg-1) at depth of 0-10 cm, which result could be attributed to the amount of litter in the soil. Despite the higher values compared to those of this study, this factor may explain the higher C-LOM content obtained in *Eucalyptus* sp.

The C-labile content, on average, represented 9.7% of total carbon concentration and was found at higher concentrations in the topsoil due to the greater presence of biomass, reducing with soil depth (Figure 2). Agriculture area had the lowest labile-C levels, below 23.8% in relation to native forest. Similar conditions were found in the study by Buongiorno et al. (2019), who reported that in conventional crops, soil disturbance due to tillage, low supply of biomass and loss of nutrients generate decreases in C-labile contents.

The labile-C proportion related to total soil C presented small variation among vegetation covers, being more representative in the native forest area, on average 11.2% of TOC, Pasture and *Eucalyptus* sp. 10.5%, and agriculture 7.0%. Coser *et al*. (2018) evaluated carbon accumulation in pastures for an agricultural system in the Brazilian Cerrado and found similar results, where the C-labile fraction accounted for 4.40 to 10.44% of TOC.

Regarding soil carbon stocks, *Eucalyptus* sp. stands presented the largest carbon reservoirs compared to others areas. Gomes *et al*. (2019) estimated that 50% of C, around 36.0 PgC is stored in the first 30 cm of soil. Guedes *et al*. (2016) found similar results in *Pinus* and *Eucalyptus* stands, where they obtained higher carbon stocks compared to native forest, attributing to the greater organic matter deposition on the soil and the C/N ratio. Long-term planting favors greater soil protection and OM accumulation, contributing to larger soil carbon stock.

Native forest had the lowest stocks at all depths, which corroborates the fact that changes in land use generate increase in LOM carbon (Figure 3). Studies by Moraes Sá *et al*. (2014) indicate that the light fraction is a sensitive indicator of land use change. The superiority in CS-LOM in the first 30 cm of soil for *Eucalyptus* sp. may be associated with high amounts of litter available to the soil. Soil organic matter light fraction is sensitive to the effects of the interaction of management systems, type of vegetation; organic waste deposited on the soil surface and thin root biomass in the topsoil (LUO *et al*., 2019).

CS-LOM was largely responsible for increases in the total organic carbon stock (TOCS) in the superficial and subsurface soil layers. According to Marques *et al*. (2015), about 60% of soil C contained in the top layer is associated with light free soil fraction. Guareschi and Pereira (2013) evaluated carbon and light organic matter in alley systems and concluded that the availability of organic matter from pruning resulted in increase in the LOM carbon content in the topsoil.

C-labile stocks showed significant differences with changes in land use, with reduction in stocks with increasing soil depth (Figure 3).

Brito *et al*. (2019) evaluated CS-labile in response to land conversions in the Brazilian Cerrado after change in land use and found significant reductions in CS-labile, representing -16% in conversion to Pasture and -14% in conversion to *Eucalyptus* stands. The low soil C-labile levels may indicate low availability of organic material, generating low decomposition of organic residues. The low values found in C-labile stocks for the agriculture area can be attributed to little or no soil cover at certain times of the year.

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CONCLUSIONS

- Labile soil organic matter fractions contributed to carbon stock and concentrations in the soil in the evaluated areas.
- *Eucalyptus* sp. stands and agriculture have shown great potential to increase soil carbon levels;
- *Eucalyptus* sp. stands proved to be the most appropriate land use strategy, with potential to increase carbon reservoirs.
- *Eucalyptus* sp. stands showed increase in soil C concentrations and stocks, possibly due to the lack of soil preparation after implantation, climatic conditions and clay contents.

REFERENCES

ARAUJO FILHO, R. N.; FREIRE, M. B. G. S.; WILCOX, B. P.; WEST, J. B.; FREIRE, F. J.; MARQUES, F. A. Recovery of carbon stocks in deforested caatinga dry forest soils requires at least 60 years. **Forest Ecology and Management**, Amsterdam, v. 407, p. 210-220, jan. 2018.

BENDITO, B. P. C.; SOUZA, P. A.; FERREIRA, R. Q. S.; CÂNDIDO, J. B.; SOUZA, P. B. Espécies do Cerrado com potencial para recuperação de áreas degradadas, Gurupi (TO). **Revista Agrogeoambiental**, Pouso Alegre, v. 10, n. 2, p. 99-110, jun. 2018.

BLAIR, G. J.; LEFROY, R. D. B.; LISLE, L. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. **Crop and Pasture Science**, Australia, v. 46, n. 7, p. 1459-1466, 1995.

BONGIORNO, G.; BÜNEMANN, E. K.; OGUEJIOFOR, C. U.; MEIER, J.; GORT, G.; COMANS, R. Sensitivity of labile carbon fractions to tillage and organic matter management and their potential as comprehensive soil quality indicators across pedoclimatic conditions in Europe. **Ecological Indicators**, Netherlands, v. 99, n.1, p. 38-50, abr. 2019.

BRITO, G. S.; BAUTISTA, S.; LÓPEZ-POMA, R.; PIVELLO, V. R. Labile soil organic carbon loss in response to land conversion in the Brazilian woodland savanna. **Biogeochemistry**, Netherlands, v. 144, p. 31-46, mai. 2019.

CHEN, S.; ARROUAYS, D.; ANGERS, D. A.; MARTIN, M. P.; WALTER, C. Soil carbon stocks under different land uses and the applicability of the soil carbon saturation concept. **Soil and Tillage Research**, Amsterdam, v. 188, p. 53-58, mai. 2019.

COSER, T. R.; FIGUEIREDO, C. C.; JOVANOVIC, B.; MOREIRA, T. N.; LEITE, G. G.; CABRAL-FILHO, S. L. S. Short-term buildup of carbon from a low-productivity pastureland to an agrisilviculture system in the Brazilian savannah. **Agricultural Systems**, Netherlands, v. 166, p. 184-195, out. 2018.

DONAGEMMA, G. K.; VIANA, J. H. M.; ALMEIDA, B. G.; RUIZ, H. A.; KLEIN, V. A.; DECHEN, S. C. F. **Manual de métodos de análise de solo**. 3. ed. Brasília: Embrapa, 2017. 573 p.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, Lavras, v. 35, n. 6, p. 1039-1042, nov./dec. 2011.

FRAGA, V. S.; SALCEDO, I. H. Declines of organic nutrient pools in tropical semiarid soils under subsistence farming. **Soil Science Society of America Journal**, United States, v.68, n.1, p.215-224, jan. 2004.

GMACH, M. R.; DIAS, B. O.; SILVA, C. A.; NÓBREGA, J. C. A.; LUSTOSA-FILHO, J. F.; SIQUEIRA-NETO, M. Soil organic matter dynamics and land-use change on Oxisols in the Cerrado, Brazil. **Geoderma Regional**, Amsterdam, v. 14, n.1, e00178, set. 2018.

GOMES, L. C.; FARIA, R. M.; SOUZA E.; VELOSO, G. V.; SCHAEFER, C. E. G. R.; FERNANDES-FILHO, E. I. Modelling and mapping soil organic carbon stocks in Brazil. **Geoderma**, Amsterdam, v. 340, n.1, p. 337-350, abr. 2019.

GUARESCHI, R. F.; PEREIRA, M. G. Carbono, matéria orgânica leve e frações oxidáveis do carbono orgânico sob sistemas de aleias. **Pesquisa Florestal Brasileira**, Colombo, v. 33, n. 74, p. 109-114, abr./jun. 2013.

GUEDES, B. S.; OLSSON, B. A.; KARLTUN, E. Effects of 34-year-old *Pinus taeda* and *Eucalyptus grandis* plantations on soil carbon and nutrient status in former miombo forest soils. **Global Ecology and Conservation**, Netherlands, v. 8, p. 190-202, out. 2016.

LOSS, A.; PEREIRA, M. G.; BEUTLER, S. J.; PERIN, A.; PICCOLO, M. C.; ASSUNÇÃO, S. A. The impact of agricultural systems in the soil organic matter content in brazilian Cerrado. **International Journal of Research**, Granthaalayah, v. 7, n. 8, p. 220-244, ago. 2019.

LUO, Y.; LI, Q.; SHEN, J.; WANG, C.; LI, B.; YUAN, S. Effects of agricultural land use change on organic carbon and its labile fractions in the soil profile in an urban agricultural area. **Land Degradation and Development**, England, v. 30, n.1, p. 1875-1885, jun. 2019.

MARINHO-JUNIOR, J. L.; OLIVEIRA, M. D.; DIAS, J. L. A.; ARAÚJO-FILHO, R. N.; MELO NETO, J. O.; GONÇALVES, S. B. Physical Attributes of Soil in Different Forest Cover in South of Tocantins. **International Journal of Plant and Soil Science**, India, v. 31, n. 2, p. 1-7, dez. 2019.

MARQUES, J. D. O.; LUIZÃO, F. J.; TEIXEIRA, W. G.; SARRAZIN, M.; FERREIRA, S. J. F.; BELDINI, T. P. Distribution of organic carbon in different soil fractions in ecosystems of central Amazonia. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 39, n. 1, p. 232-242, jan./fev. 2015.

MORAES SÁ, J. C.; TIVET, F.; LAL, R.; BRIEDIS, I.; HARTMAN, D. .C; SANTOS, J. Z. Long-term tillage systems impacts on soil C dynamics, soil resilience and agronomic productivity of a Brazilian Oxisol. **Soil and Tillage Research**, Amsterdam, v. 136, n.1, p. 38-50, mar. 2014.

NAVARRETE-SEGUEDA, A.; MARTÍNEZ-RAMOS, M.; IBARRA-MANRÍQUEZ, G.; VÁZQUEZ-SELEM, L.; SIEBE, C. Variation of main terrestrial carbon stocks at the landscape-scale are shaped by soil in a tropical rainforest. **Geoderma**, Amsterdam, v. 313, n.1, p. 57-68, mar. 2018.

OLIVEIRA, W. R. D. de; RAMOS, M. L. G.; CARVALHO, A. M. de; COSER, T. R.; SILVA, A. M. M.; LACERDA, M. M. Dynamics of soil microbiological attributes under integrated production systems, continuous pasture, and native Cerrado. **Pesquisa Agropecuária Brasileira**, v. 51, n. 9, p. 1501-1510, set. 2016.

SANTOS, C. A. dos; REZENDE, C. de P.; PINHEIRO, É. F. M.; PEREIRA, J. M.; ALVES, B. J. R.; URQUIAGA, S. Changes in soil carbon stocks after land-use change from native vegetation to pastures in the Atlantic forest region of Brazil. **Geoderma**, Pequim, v. 337, p. 394-401, mar. 2019.

SANTOS, H. G.; JACOMINE, P. K. T.; DOS ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R. **Sistema Brasileiro de Classificação de Solos**. 5. ed., rev. e ampl. − Brasília: Embrapa, 2018.

SEPLAN - SECRETARIA DE PLANEJAMENTO E ORÇAMENTO. GERÊNCIA DE INDICADORES ECONÔMICOS E SOCIAIS (GIES). **Projeto de Desenvolvimento Regional Integrado e Sustentável. Zoneamento Ecológico-Econômico do Estado do Tocantins**. Diagnóstico Ecológico-Econômico do Estado do Tocantins. Palmas: Seplan/GIES, 2017. 522p.

SRINIVASARAO, C.; KUNDU, S.; SHANKER, A. K.; NAIK, R. P.; VANAJA, M.; VENKANNA, K. Continuous cropping under elevated CO_2: Differential effects on C4 and C3 crops, soil properties and carbon dynamics in semi-arid alfisols. **Agriculture, Ecosystems and Environment**, Netherlands, v. 218, p. 73-86, fev. 2016.