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Research Article

Carbon stocks and lability in land use and management systems in southwestern Goiás, Brazil[1]

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ABSTRACT

The southwest region of the Goiás state, Brazil, is suitable for several agricultural activities, even in more fragile soils such as Typic Quartzipsamments. This study aimed to evaluate the carbon stocks and lability of a Typic Quartzipsamment under land use and management systems in southwestern Goiás. The experiment was conducted in a completely randomized design and consisted of areas subjected to five land use and management systems [native Cerrado vegetation (Brazilian Savanna), pasture under intensive grazing, pasture under extensive grazing, soybean and maize rotation, and eucalyptus]. Soil samples were collected at the 0-0.1 and 0.1-0.2 m layers. The land use and management systems affected the carbon stocks and quality. In the 0-0.2 m layer, the carbon stocks ranged between 15.9 and 29.2 Mg ha^{-1}. The areas with eucalyptus and under intensive grazing promoted increases in the carbon stocks that ranged between 72 and 84 %, when compared to the areas with Cerrado vegetation and soybean and maize rotation. The carbon contents in the F1, F2 and F4 fractions were higher in the areas with eucalyptus and under intensive grazing. In the 0-0.1 m soil layer, the areas with eucalyptus and under intensive grazing had an increase in the carbon management index by 33 and 36 %, respectively, when compared to the reference area with native Cerrado vegetation.

KEYWORDS: Soil organic matter, carbon quality, carbon management index.

RESUMO

Estoques e labilidade de carbono em sistemas de uso e manejo do solo no sudoeste goiano

O sudoeste do estado de Goiás apresenta elevada vocação para diversas atividades agropecuárias, mesmo em solos considerados mais frágeis, como os Neossolos Quartzarênicos. Objetivou-se avaliar os estoques e a labilidade de carbono em sistemas de uso e manejo de um Neossolo Quartzarênico, no sudoeste goiano. Utilizou-se delineamento inteiramente causualizado, constando de áreas submetidas a cinco sistemas de uso e manejo do solo (Cerrado nativo, pastagem intensiva, pastagem extensiva, plantio de soja com sucessão de milho, e eucalipto). Foram coletadas amostras nas profundidades de 0-0,1 e 0,1-0,2 m. Os sistemas de uso e manejo do solo alteraram os estoques e a qualidade do carbono. Na camada de 0-0,2 m, os estoques de carbono variaram entre 15,9 e 29,2 Mg ha^{-1}. As áreas com eucalipto e sob pastejo intensivo proporcionaram incrementos variando entre 72 e 84 % nos estoques de carbono, em relação às áreas de Cerrado e soja-milho. Os teores de carbono nas frações F1, F2 e F4 foram superiores nas áreas com eucalipto e sob pastejo intensivo. Na camada de 0-0,1 m, as áreas com cultivo de eucalipto e sob pastejo intensivo incrementaram o índice de manejo de carbono em 33 e 36 %, respectivamente, quando comparadas à área de referência com Cerrado nativo.

PALAVRAS-CHAVES: Matéria orgânica do solo, qualidade de carbono, índice de manejo de carbono.

INTRODUCTION

Agricultural activities increased by 1.3 % in 2019, reaching a 5.2 % share of the Brazilian gross domestic product (IBGE 2019). Several economic activities are developed in the Goiás state, mainly agricultural ones, making it the ninth economy of Brazil. The agricultural sector in Goiás includes soybean, maize, sugarcane, beef and dairy cattle, and, in recent years, wood production, mainly eucalyptus.

Different land use and management systems affect the soil quality (Silva et al. 2016, Souza et al. 2016). The conversion of native areas to agricultural areas, such as those of the Cerrado (Brazilian

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Savanna) biome, may lead to changes in the soil carbon (C) stocks, as reported for Oxisols (Latossolo Vermelho) after a no-tillage chronosequence (Souza et al. 2016) and under land use and management systems (Silva et al. 2016). In areas of well-managed rotational grazing, carbon stocks can be increased over time (Ribeiro et al. 2022). In addition, in areas cultivated with eucalyptus, after 7 years, carbon stocks can equal the native areas of the Cerrado in the superficial layers, and even be higher in the deeper soil layers (Fialho et al. 2019). Soil is the largest terrestrial C storage compartment, containing almost four times more C than vegetation, and about 3.3-fold the C in the atmosphere (Machado 2005). Therefore, land use and management systems that promote the maintenance or even increases in the soil C are important for the maintenance of soil quality.

Evaluations of total organic C stocks alone often do not indicate short-term variations. Thus, evaluations of labile fractions of the organic matter are usually carried out to monitor the impact of short-term use and management systems. Oxidizable fractions also have been used to assess the soil quality in some studies (Chan et al. 2001, Benbi et al. 2015). Oxidizable carbon fractions are divided into F1, F2, F3 and F4, corresponding to sulfuric acid concentrations of 3, 6, 9 and 12 mol L^{-1}, respectively.

The use of poultry waste and plant residues in a rice and wheat cropping system resulted in higher C stocks in the F1 fraction and lower in the F4 fraction (Benbi et al. 2015). Therefore, monitoring carbon stocks and oxidizable fractions is important to determine soil quality. Thus, this study aimed to evaluate carbon stocks and lability in a Typic Quartzipsamment under land use and management systems in southwestern Goiás state, Brazil.

MATERIAL AND METHODS

The study was conducted in 2020, in Mineiros, Goiás state, Brazil. The region presents a mean annual temperature of 24.2 ºC; mean rainfall depth of 1,700 mm; and an Aw, tropical wet and dry, climate, with a rainy summer and a dry winter, according to the Köppen classification.

The predominant soil in the area is classified as Typic Quartzipsamment (USDA 2014) or Neossolo Quartzarênico (Santos et al. 2018), with sandy texture (56 g kg^{-1} of clay, 17 g kg^{-1} of silt and 927 g kg^{-1} of sand) in the 0-0.2 m layer (Teixeira et al. 2017), which was originally occupied by Cerrado vegetation. The soil samples were collected in May 2020 to determine the carbon contents and, subsequently, the carbon stocks. The samples were collected from the 0-0.2 m soil layer for chemical characterization (Teixeira et al. 2017) (Table 1).

The study was conducted in a completely randomized design, consisting of 5 treatments, with 4 replications. Samples were collected from the 0-0.1 and 0-0.2 m soil layers, at eight points of each experimental unit (forming one composite sample per plot), in May 2020, using a Dutch auger to determine the carbon contents and oxidizable fractions. The collections were carried out in four agroecosystems and in one preserved natural ecosystem, according to the following description: pasture under intensive grazing, pasture under extensive grazing, soybean and maize rotation, eucalyptus and native Cerrado vegetation (Figure 1). The areas presented similar topographic and edaphoclimatic conditions, differing only in land use (Table 2). All the areas were in the same rural property and exposed to the same conditions within a radius of approximately 3.5 km.

The total organic carbon was determined using about 0.5 g of soil, which were weighed and placed in an Erlenmeyer flask containing 10 mL of a 0.0667 mol L^{-1} $K_2Cr_2O_7$ solution, and then heated to boiling and rested for 5 min. After cooling, 80 mL of distilled water, 2 mL of orthophosphoric acid and three drops of 0.025 mol L^{-1} Ferroin indicator were added, and the mixture titrated with 0.05 mol L^{-1} of ammoniacal ferrous sulfate (Teixeira et al. 2017).

The total organic carbon stocks were calculated by the equivalent soil mass method. The samples with

Table 1. Soil chemical characterization (0-0.2 m layer) of the experimental area.

pH	OM	P	K	Ca	Mg	Al	H + Al	SB	CEC	BS
$CaCl_2$	g dm^{-3}	mg dm^{-3}		cmol$_c$ dm^{-3}						%
4.0	18.7	1.02	22	0.76	0.25	0.56	2.47	1.07	3.54	30.2

OM: organic matter; SB: sum of bases; CEC: cation exchange capacity; BS: base saturation.

Table 2. Description and history of the studied areas.

Treatment	Description
Cerrado vegetation	Area with natural Cerrado vegetation without anthropogenic interference.
Soybean and maize rotation	Area of 80 ha used for extensive grazing until 2004. In 2005, it was converted to cropping area, with limestone application to increase the base saturation to 50 %. A rotation of summer soybean and second-crop maize was used. In subsequent years, liming was applied to avoid the base saturation to decrease to 40 %; thus, limestone was applied to increase the base saturation to 60 %. Applications of 80 to 90 kg ha^{-1} of P_2O_5 and K_2O were carried out for both crops. Approximately 100 kg ha^{-1} of N were applied using urea for the second crop maize, in addition to fertilizers containing P and K.
Degraded pasture	Area of 10 ha used for beef cattle grazing in extensive system for at least 15 years, without fertilization and soil acidity correction. The species used was *Paspalum notatum* Fluegge.
Pasture under intensive grazing	Area of 5 ha used for rotational grazing, cultivated with Mombasa grass. Dolomitic limestone (3 Mg ha^{-1}) and turkey litter (10 Mg ha^{-1}) were applied in early December 2010. The grass was planted in mid-2011. Turkey litter (10 Mg ha^{-1}) was applied in October 2011 and poultry litter (6 Mg ha^{-1} year^{-1}) in October, from 2012 to 2014. Poultry litter (4 Mg ha^{-1} year^{-1}) was applied between 2015 and 2017 and dolomitic limestone (2 Mg ha^{-1}) in 2015. No chemical or organic fertilizers were applied between 2018 and 2020. Fertilizers and limestone were applied to the soil surface, without incorporation. The average stocking rate was 6 to 7 animal units (450 kg) per hectare from 2011 to 2016, and 3 animal units (450 kg) per hectare from 2017 to 2020. In addition to poultry waste, 100 kg ha^{-1} of N fertilizer were applied using urea, in all years.
Eucalyptus plantation	Area of approximately 4 ha with eucalyptus (*Eucalyptus grandis*) plantations, implemented in December 2008.

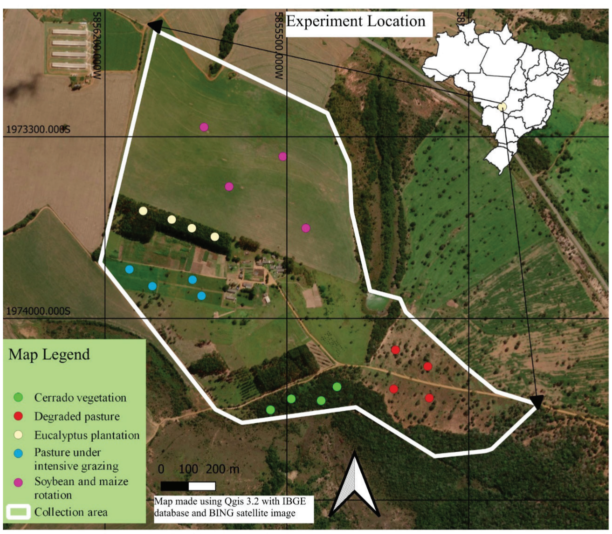

Figure 1. Photo of the experimental area in Mineiros, Goiás state, Brazil.

the lowest apparent density were used as reference in the treatments for each layer. Thus, soil densities of 1.23 and 1.3 kg dm^{-3} were used for the 0-0.1 and 0.1-0.2 m layers, respectively. The total organic carbon (TOC) stocks of each sampled layer were summed to determine the total TOC stocks (0-0.2 m layer) (Sisti et al. 2004), and calculated based on the following equation: TOC = (OC x Ds x t)/10, where TOC is the total organic carbon stock in the evaluated soil layer (Mg ha^{-1}); OC the total organic carbon contents in the sampled layer (g kg^{-1}), Ds the soil density (kg dm^{-3}) and t the layer thickness (cm).

Chemical fractionation was then carried out according to the methodology by Chan et al. (2001), with adaptations of Mendonça & Matos (2017): the soil samples were sieved through a 0.2-mm-mesh sieve, using approximately 0.5 g; 10 mL of 0.167 mol L^{-1} $K_2Cr_2O_7$ were added in a 250-mL Erlenmeyer flask, followed by increasing amounts of H_2SO_4 (2.0, 5.0 and 10 mL) for each soil sample, totaling four analyses of oxidable fractions, corresponding to the oxidizable fractions F1, F2, F3 and F4, respectively. Oxidation was performed without external heat source, and extracts were titrated with a 0.5 mol L^{-1} solution of $Fe(NH_4)_2(SO_4)^2.6H_2O$. Four fractions were obtained through decreasing degrees of C oxidation: Fraction 1 (F1): C oxidized by $K_2Cr_2O_7$ in acidic medium of 2.5 mol L^{-1} of H_2SO_4; Fraction 2 (F2): difference between C oxidized by $K_2Cr_2O_7$ in acidic medium with 5 and 2.5 mol L^{-1} of H_2SO_4; Fraction 3 (F3): difference between C oxidized by $K_2Cr_2O_7$ in acidic medium with 10 and 5 mol L^{-1} of H_2SO_4; Fraction 4 (F4): difference between TOC and carbon oxidized by $K_2Cr_2O_7$ in acidic medium with 10 mol L^{-1} of H_2SO_4.

The carbon management index (CMI) and its components were calculated according to the original proposal of Blair et al. (1995). The F1 fraction was used to determine the labile carbon contents (L). Non-labile carbon (NLC) was obtained by the sum F2 + F3 + F4 (Chan et al. 2001). Considering the variations in TOC contents in the soil of the reference area (native Cerrado vegetation) and the other treatments, the following indexes were calculated: carbon compartment index (CCI) = $TOC_{cultivated}/TOC_{reference}$; lability index (LI) = $L_{cultivated}/L_{reference}$; and carbon management index (CMI) = CCI × LI × 100.

The treatments were compared as it follows: the results of the chemical analyses were subjected to analysis of variance, and the means of the treatments compared by the Tukey test at 5 % of probability. The data of the variables were described and analyzed simultaneously, using a biplot chart to verify the overall variability of the experiment and trends of the multivariate. The analyses were carried out in the Rbio software with interface of the R software (Bhering 2017).

RESULTS AND DISCUSSION

The carbon stocks and contents in the 0-0.1, 0.1-0.2 and 0-0.2 m soil layers were affected by the land use and management systems. In the 0-0.1 m layer, the highest stocks (Figure 2) were found in the areas with eucalyptus plantation and intensive grazing, which were higher than those in the areas with Cerrado vegetation, extensive grazing, and soybean and maize rotation. Areas with eucalyptus plantation and intensive grazing presented increases in carbon stocks of 66-80 % in the 0-0.1 m layer, when compared to the areas with extensive grazing, Cerrado vegetation, and soybean and maize rotation.

In the 0.1-0.2 m layer, the area with eucalyptus had higher carbon stocks than the areas with Cerrado vegetation and soybean and maize rotation, representing increases of 68 and 88 %, respectively. In the 0-0.2 m layer, the carbon stocks ranged between 15.9 and 29.2 Mg ha^{-1} and the eucalyptus plantation resulted in increases of 72 and 84 %, when compared to the areas with Cerrado vegetation and soybean and maize rotation, respectively.

Silva et al. (2016) observed decreases in carbon stocks in a clayey Oxisol with land use and management systems, when compared with a native Cerrado vegetation area. However, the use of different crops associated with the no-tillage system can contribute to increases in the soil carbon stocks in clayey Oxisols (Ferreira et al. 2022). This is corroborated by the results found in the present study, which showed that the adoption of eucalyptus plantation and intensive grazing contributed to increases in the soil carbon stocks.

The increase in the carbon stocks in areas with intensive grazing is probably connected to the proper management of soil amendments and fertilizers, as the use of poultry waste (poultry litter and turkey litter), which may have contributed to increases in carbon stocks in the intensive grazing area. Applications of poultry waste were efficient in increasing the carbon stocks in areas with rotational grazing, with application of 16 and 30.9 Mg ha^{-1} (Pinto et al. 2012). Conservationist management is important for increasing soil carbon stocks, mainly in soils with sandy textures and poorly structured (Ferreira et al. 2022).

The higher carbon stocks found in the eucalyptus area is probably connected to the high carbon assimilation by eucalyptus plants - each 5-year-old plant fixes approximately 39 kg of C in its shoots (Silva et al. 2015). This large carbon fixation by eucalyptus plants can contribute to increases in the carbon stocks in the 0-0.1 m soil layer. Soares et al. (2019) found an increase of 128 % in the carbon stocks in areas managed with eucalyptus for 13 years, after one year of a new planting, when compared to an area with native vegetation. These studies corroborate the results found in the present study, which showed the highest carbon stocks for areas cultivated with eucalyptus and under intensive grazing. The deposition of residues on the soil and

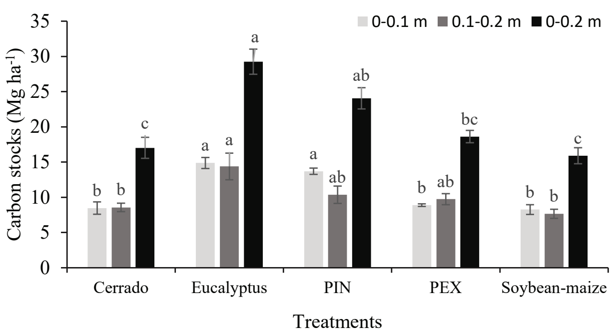

Figure 2. Carbon stocks in the 0-0.1, 0.1-0.2 and 0-0.2 m layers of a Typic Quartzipsamment under land use and management systems. PIN: pasture under intensive grazing; PEX: pasture under extensive grazing. Bars with different letters are statistically different from each other by the Tukey test at 0.05 of probability.

the increase in the organic matter contents on the soil surface have several positive effects, such as nutrient cycling, aggregation, microbial activity, water storage and gas exchange with the atmosphere, which may favor the soil sustainability and, consequently, result in higher crop yields (Bayer et al. 2004).

The oxidizable C fractions F1, F2 and F4 were affected by the land use and management systems only in the 0-0.1 m layer, except for the F4 fraction, which was also affected in the 0.1-0.2 m layer (Table 3). In the 0-0.1 m layer, the highest carbon contents in the F1 fraction were found in the areas with eucalyptus plantation, intensive grazing, and soybean and maize rotation, and were higher than those found in the Cerrado vegetation and extensive grazing areas. The carbon contents in the F2 fraction were higher in the areas with eucalyptus and intensive grazing and lower in the Cerrado vegetation area, followed by the area with extensive grazing. The carbon contents in the F4 fraction in the 0-0.1 m layer were higher in the areas with eucalyptus plantation and intensive grazing and lower in the areas with Cerrado vegetation, extensive grazing, and soybean and maize rotation. In the 0.1-0.2 m layer, the carbon contents in the F4 fraction were higher in the area with eucalyptus and lower in the areas with Cerrado vegetation and soybean and maize rotation, with intermediate values in the treatments with intensive and extensive grazing.

The increases in carbon contents in the F1, F2 and F4 fractions, in the areas with eucalyptus, intensive grazing, and soybean and maize rotation, when compared to areas with Cerrado vegetation and extensive grazing, are probably connected to the high deposition of materials of greater lability from the shoots of eucalyptus trees, poultry waste and residues of grass not consumed by animals. The results of the present study corroborate those by Ribeiro et al. (2022), who found that the use of a poultry waste rate of 69.24 Mg ha^{-1} accumulated over 9 years contributed to increases in contents of total organic carbon and particulate organic carbon (labile carbon fraction) by 21 and 43 %, respectively, in the 0-0.05 m soil layer. In addition, the recovery of pastures using *Urochloa brizantha* intercropped with maize after eight years in the Amazon region in the Maranhão state, Brazil, proved to be efficient in recovering carbon contents in the F1 fraction in the 0-0.1 m soil layer. In an area with soybean and maize crops, increases in the F1 fraction were attributed to the contribution of the crop rotation, as the inclusion of legumes for biological nitrogen fixation increases the soil organic matter quality (Silva et al. 2016) and is important for maintaining the sustainability of agricultural systems.

Increases in the F1 and F2 fractions are important, because they are easily oxidizable carbon fractions and represent the active organic carbon due to their strong relationship with microbial biomass and mineralizable carbon (Benbi et al. 2015). Therefore, they are important for maintaining a higher soil biological activity, as occurred in areas with eucalyptus and intensive grazing. The F1 and F2 fractions have a greater lability, while F3 and F4 are considered more resistant to decomposition (Loss et al. 2010, Benbi et al. 2015). Therefore, maintaining

Table 3. Oxidizable carbon fractions in the 0-0.1 and 0.1-0.2 m layers of a Typic Quartzipsamment under land use and management systems.

Treatments	F1	F2	F3	F4
	g kg^{-1}			
		0.0-0.1 m		
Cerrado vegetation	3.79 b*	2.26 bc	0.88^{ns}	4.48 b
Eucalyptus	5.35 a	3.75 a	1.04	9.45 a
Intensive grazing	5.37 a	3.55 a	0.85	8.46 a
Extensive grazing	3.53 b	1.76 c	0.73	4.72 b
Soybean-maize	4.72 a	3.11 ab	0.84	4.15 b
		0.1-0.2 m		
Cerrado vegetation	3.90^{ns}	2.23^{ns}	0.62^{ns}	4.23 b
Eucalyptus	4.04	2.20	0.60	8.61 a
Intensive grazing	4.24	2.46	0.63	5.55 ab
Extensive grazing	4.04	2.48	0.85	5.08 ab
Soybean-maize	3.77	2.11	0.69	3.89 b

* Means followed by different letters in the columns are statistically different from each other by the Tukey test at 0.05 of probability.

a balance among these fractions is important for an equilibrium related to their respective functions: F1 and F2 are responsible for availability of nutrients, and F3 and F4 represent physical and chemical protection (Loss et al. 2010).

The carbon management index was affected by the land use and management systems in the 0-0.1 and 0-0.2 m layers (Figure 3). In the 0-0.1 m layer, the carbon quality increased by 36 and 33 %, respectively in the areas with intensive grazing and eucalyptus, when compared to the areas with native Cerrado vegetation. A similar result was found for the 0-0.2 m layer, in which increases in the carbon management index were 20 % in the areas with intensive grazing and eucalyptus, when compared to the area with native Cerrado vegetation.

A high carbon management index (CMI) means a higher soil quality, whereas a low CMI indicates low soil quality (Assmann et al. 2014). A high CMI also indicates a high lability of organic matter and is positively correlated with various chemical, physical and biological soil attributes (Zanatta et al. 2019). The evaluated areas with Typic Quartzipsamment under vegetation with eucalyptus and intensive grazing can not only increase the carbon stocks, but also the soil quality in the 0-0.1 and 0-0.2 m layers, in comparison to the native Cerrado vegetation area. It is probably connected to increases in soil fertility due to the planting of eucalyptus and an adequate pasture management, in addition to direct C increases from the poultry waste used between 2010 and 2017.

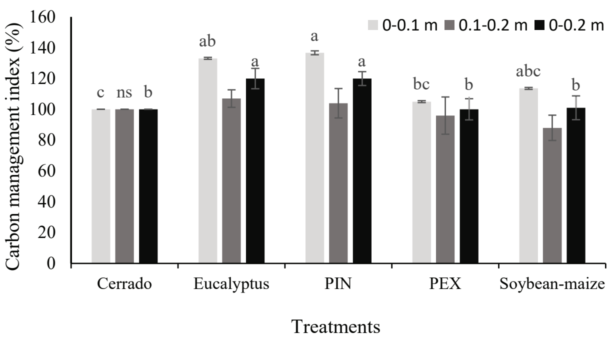

Figure 3. Carbon management index in the 0-0.1, 0.1-0.2 and 0-0.2 m layers of a Typic Quartzipsamment under land use and management systems. PIN: pasture under intensive grazing; PEX: pasture under extensive grazing. Bars with different letters are statistically different from each other by the Tukey test at 0.05 of probability. [ns] not significant.

The biomass production by the Mombasa grass shoots and roots is another factor that may have contributed to increases in CMI in the intensive grazing area. The lower CMI results found in the areas with extensive grazing are probably connected to the low biomass production in these areas due to the absence of fertilization. The lower CMI results found in the Cerrado vegetation area are probably connected to the high levels of lignified materials produced by the native Cerrado vegetation. Silva et al. (2016) evaluated different land use and management systems and found a reduction in increases of CMI in areas under no-tillage with 18 years of implementation, when compared to the native Cerrado vegetation area. In the present study, CMI in areas with soybean and maize rotation with 16 years of implementation were similar to those of the native Cerrado vegetation area; therefore, soybean and maize crops may resemble areas with native Cerrado vegetation, even for soil with sandy texture.

Canonical variates analysis is a multivariate statistical technique that maximizes the variation between treatments, in relation to the residual variation. In the present study, this analysis (Figure 4) was used to assess the contribution of each variable to the difference between treatments of land use and management systems.

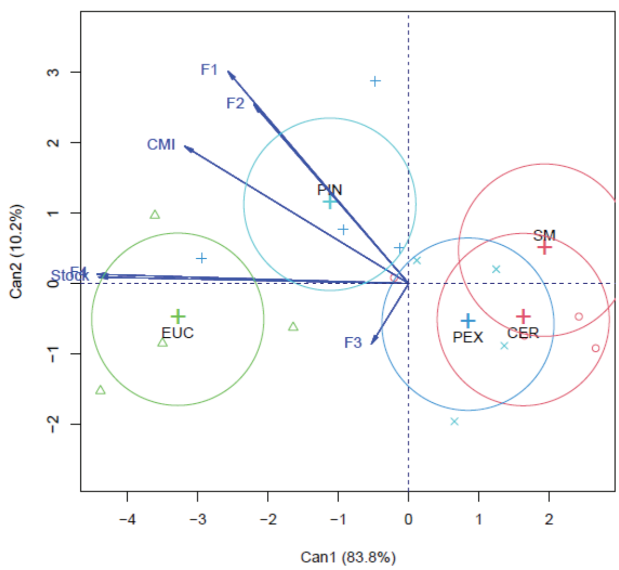

Figure 4. Canonical variates analysis for carbon stock (Stock); carbon management index (CMI) and oxidizable carbon fractions (F1, F2, F3 and F4), in the 0-0.2 m layer of a Typic Quartzipsamment. EUC: eucalyptus plantation; CER: native Cerrado vegetation; PIN: pasture under intensive grazing; PEX: pasture under extensive grazing; SM: soybean and maize rotation.

This is a technique similar to the principal component analysis; however, it should be used when the study is composed of an experimental design with replications (Baio et al. 2018). The accumulation of variances in the first two variables corresponded to 94 %, which is higher than that recommended: at most 80 % (Mingoti 2005). Therefore, canonical variates could be used in the present study for an accurate interpretation.

The eigenvectors in Figure 4 show that the variables F1, F2 and CMI are close to the treatment with intensive grazing. The proximity of the variables F1, F2 and CMI to the area with intensive grazing is probably connected to the proper soil management by using soil amendments and fertilizers, in addition to application of poultry waste, which can contribute to increases in more labile carbon fractions (Benbi et al. 2015). The carbon stocks and the oxidizable carbon fraction F4 are close to the treatment with eucalyptus plantation areas. The high carbon stocks near areas with eucalyptus and intensive grazing are probably connected to the high deposition of residues from plant shoots and organic residues from their root systems. The proximity of areas with eucalyptus to the oxidizable carbon fraction F4 is probably because 74 % of the carbon in the dry matter of eucalyptus shoots is from wood (Silva et al. 2015), what may contribute to more recalcitrant fractions of carbon in the soil. The F3 fraction remained isolated and was not close to any treatment. The treatments with extensive grazing, soybean and maize rotation, and native Cerrado vegetation areas were close, but no variable was associated with these treatments. The proximity among these treatments is probably connected to the similarity among the variables evaluated in the present study.

CONCLUSIONS

1. Intensive agricultural activities, including correct plant species and soil management such as supply of nutrients and conscious use of agricultural implements, results in an environment conducive to increases in carbon stocks, mitigating the greenhouse effect through decreases in gas emissions, combined with a greater atmospheric carbon sequestration;
2. Areas with Typic Quartzipsamment cultivated with eucalyptus and intensive grazing can promote increases of 12.223 and 7.027 kg ha^{-1} in carbon stocks in the 0-0.20 m soil layer, when compared to native Cerrado vegetation. In addition, land use and management systems affect oxidizable carbon fractions, mainly in the 0-0.1 m layer. Carbon contents in the F1, F2 and F4 fractions were higher in the areas with eucalyptus plantation and intensive grazing;
3. The carbon management index can be increased by 20 % in areas with intensive grazing and eucalyptus, when compared to native Cerrado vegetation. Agricultural systems using rotation of summer soybean and second crop maize can maintain the soil carbon quality, when compared to native Cerrado vegetation areas.

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