CARBON AND NITROGEN STOCKS IN THE SOIL IN INTEGRATED CROP-LIVESTOCK-FOREST SYSTEMS

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ABSTRACT
The integrated crop-livestock-forest system (ICLF) is a sustainable production strategy that integrates agricultural, livestock and forestry activities. The intensification of land use through systems integrated with trees provides income diversification for the farmer, thermal comfort for animals and the offsetting of greenhouse gas emissions - GHG. The objective of this work is to evaluate the effect of the ICLF system on the stocks of carbon and nitrogen in the soil, with a focus on dairy farming. The carbon stock in the 0-100 cm soil layer under ICLF system was 10.4% higher than the carbon stock in the same layer under integrated crop-livestock system (ICL). The nitrogen stock in the soil under ICLF system was 19.5% higher than the ICL. The ICLF system has great potential for storing carbon through the soil and trees and consequently mitigating GHG emissions.
Key words: integrated systems; dairy cattle; eucalyptus

INTRODUCTION

The crop-livestock-forest integration (ICLF) is a sustainable production strategy, which integrates agricultural, livestock and forest activities carried out in the same area, in intercropped cultivation, in succession or rotation, and seeks synergistic effects between the components of the agro-ecosystem, contemplating environmental adequacy, valuing man and economic viability (BALBINO et al., 2011, VILELA et al., 2011, KLUTHCOUSKI et al., 2015). It is a production system conducive to achieving satisfactory productivity and offsetting GHG emissions from agricultural activity, providing a positive carbon balance (OLIVEIRA et al., 2017). The high content of organic matter on the soil surface is one of the main benefits of integrated systems, when associated with soil management and conservation practices. This is because these practices improve the physical, chemical and biological conditions of the soil, while the cultivation of monoculture under the conventional system for some years causes the loss of organic matter and, consequently, compromises the quality of the soil (ASSAD et al., 2019). In addition, promoting the accumulation of organic matter in the soil is an excellent way to store carbon by removing it from the atmosphere, providing greater sustainability of the agricultural system. As part of the commitments to reduce GHG emissions assumed by the country through the Agricultural Low Carbon (ABC Plan), a goal was adopted for the adoption of four million hectares of ILPF systems with an estimated mitigation potential of 18 to 22 million Mg CO_2 eq (BRAZIL, 2012). In this way, the adoption of ICLF systems aiming at sustainable intensification can converge to a more efficient agricultural production strategy in relation to the carbon footprint, both by increasing the organic matter of the soil and by fixing carbon in the plant biomass of the forest component. The objective of this work is to evaluate the effect of the ICLF system on the carbon and nitrogen stocks in the soil in an ICLF area with a focus on dairy cattle.

MATERIAL AND METHODS

An experimental area of approximately 16 hectares with two systems: crop-livestock integration (ICL) and crop-livestock forest integration (ICLF), with a focus on milk production, was implemented in 2013 in Brasília, DF, at the Dairy Zebu Technology Center (CTZL), Embrapa Cerrados (15º 57' 09''S, and 48° 08' 12" W), altitude of 998 m. The soil of the experimental area is a typical dystrophic Red Latosol. The region's climate is Aw, with an average annual air temperature of 21.1 ° C and an average annual capacity of 1,668 mm, distributed predominantly from November to April. The area of each system is approximately eight hectares. In this work, the ICL system will be considered as a control treatment. The ICLF was implanted with eucalyptus seedlings in February 2013, through 13 simple rows, with spacing of 1.5 m between plants and 25 m between rows, associated with the cultivation of grains and or pasture, totaling about 2000 trees in the total area and about 267 trees per hectare. The fertilization of the implantation of the eucalyptus seedlings was carried out with 300 g of 4-30-16 + Zn, and in June 2013 it was projected in the total area of 2 t/ha of dolomitic limestone, without incorporation. In the experimental area, in February 2013, the sorghum was planted, in 2014 *Brachiaria brizantha* BRS Piatã was planted, in 2015/2016 soy was introduced and in 2017, a species of forage in the areas of ICL and ICLF it was *Panicum maximum* cv. Mombaça that remains in the area today. With the exception of trees, the ICL and ICLF areas suffered the same cultural treatments. The ICLF area comprises 13 lines of eucalyptus, 11 lines of the *Eucalyptus urograndis* hybrid (*E. urophylla* x *E. grandis*) (clone GG100) and a border containing two lines of the *E. urocam* hybrid (E. *urophylla* x *E. camaldulensis*). As for the animal component, in the first three years (2013 to 2015) heifers of the Zebu breed (girolando and gir) were introduced to the area, from the fourth year onwards lactating cows (girolando and gir) were introduced in rotated pasture. In 2018, due to the shading of the trees that hinder the development of forage, thinning of the trees in the area was carried out, with a removal of about 50% of them. For the assessment of soil carbon and nitrogen stocks, three samples of soil up to 1 m deep in the 0-5 cm layers were collected in June 2019; 5-10 cm; 10-20 cm; 20-30 cm; 30-40 cm; (from 20 simple samples); 40-60 cm; 60-80 cm and 80-100 cm (from 5 simple samples). The samples were air-dried and subjected to chemical and physical analysis. For the evaluation of the apparent density of the soil (AD), undisturbed samples were collected in the same layers mentioned above, by opening trenches 120 cm deep. The samples for AD were taken in duplicate in each layer (in the middle of the interval), using two alternating walls of the trench, with thin-walled stainless steel cylinders, 4 to 5 cm in diameter and 5 to 8 cm in diameter. length, according to the Embrapa soil analysis manual procedure (EMBRAPA, 1997). The AD data were used to calculate the carbon and nitrogen stocks. The soil samples for analysis of C and N were ground, passed through a 0.150 mm mesh sieve, and subjected to the determination of the total carbon (C) and total nitrogen (N) content by elementary analysis with dry combustion on Elementar's Macro Vario Cube equipment. The accumulated C and N stock, in each layer of the soil profiles, was calculated using the equivalent soil mass method (SISTI et al., 2004). The analysis of the contents and stock of C and N were carried out using the Mixed procedure of the statistical program SAS 9.4. The means of the ICLF and ICL systems were estimated using the LSMEANS command and were compared using Fisher's least significant difference (LITTELL et al., 2006). The level of significance was set at $P < 0.05$.

RESULTS AND DISCUSSIONS

The stock of C up to 30 cm deep for the ICLF system was 83.4 Mg ha^{-1} and in the 30 to 100 cm layer it was 99.7 Mg ha^{-1}, that is, on average 45% of the carbon was stored in the 0 to 30 cm layer and 55% of the carbon was stored in the 30 to 100 cm layer. Oliveira (2015) studying carbon stocks in ICLF systems in the municipality of Nova Canaã do Norte, MT, found that the 0 to 30 cm layer was responsible for storing an average of 47% of the soil's carbon, while the stock in the 30 to 100 cm was approximately 53%. The results of the present study are similar to the data found by Oliveira (2015). Thus, although the Intergovernmental Panel on Climate Change (IPCC) requires, for carbon credit projects under the Kyoto protocol, the assessment of soil carbon stocks up to a depth of 30 cm, considering a layer of at least 100 cm is important when assessing carbon stocks, especially in areas where tree and grass species with a deep root system are present (OLIVEIRA, 2015). In the ICL system of the present study, results similar to those found in the ICLF system were observed in terms of the percentage of carbon storage in the layers, where 47.5% of the carbon was stored up to 30 cm deep and 52.5% of the carbon was stored in the layer from 30 to 100 cm. The carbon stock in the ICLF system in the 0 to 100 cm layer was 10.4% higher than the carbon stock in the ICL system (Figure 1). The higher accumulation of C in the ICLF system, found in the present study, may have been favored by the high deposition of eucalyptus litter in the soil. Villa Nova et al. (2003) reports that greater spacing allows greater accumulation of nutrients in eucalyptus leaves and branches in relation to trunk biomass. Pulrolnik et al. (2015) studying the ICLF and ICL systems in the Cerrado area at three and five years after the implantation of the system, observed that at three years of age, the C stock values were 137.85 Mg ha^{-1} for ICL and 139.61 Mg ha^{-1} for ICLF and at five years of age the C stock values for ICL were 146.76 Mg ha^{-1} and 146.33 Mg ha^{-1} for ICLF, in both evaluations (at 3 and 5 years of age) there were no significant differences between the two systems. Macedo et al. (2015) found a higher total accumulation of C in the soil in ICL systems after six years, when it obtained higher carbon values compared to ICLF systems with single or double lines of trees, concluding that the ICL system (without trees) had less competition for light, water and nutrients, allowing greater increase of organic matter than the ICLF system. The ICLF experiment under study, however, has the largest spacing, with about 130 trees per hectare, that is, with less competition for water, light and nutrients than the ICLF system of the study by Macedo et al. (2015). The nitrogen stock in the ICLF system was 19.5% higher than that found in the ICL system (Figure 1). However, in his study Oliveira (2015) found a decrease in the N stock in the ICLF with one tree line and an increase in the ICLF system with three tree lines, compared to pasture, both in the 0 to 30 cm layer and in the layer from 0 to 100 cm. Sacramento et al. (2013) observed that the ICLF provided, after 13 years of cultivation, the lowest losses of N in the soil, followed by the ICL and monocultures under a conventional system.

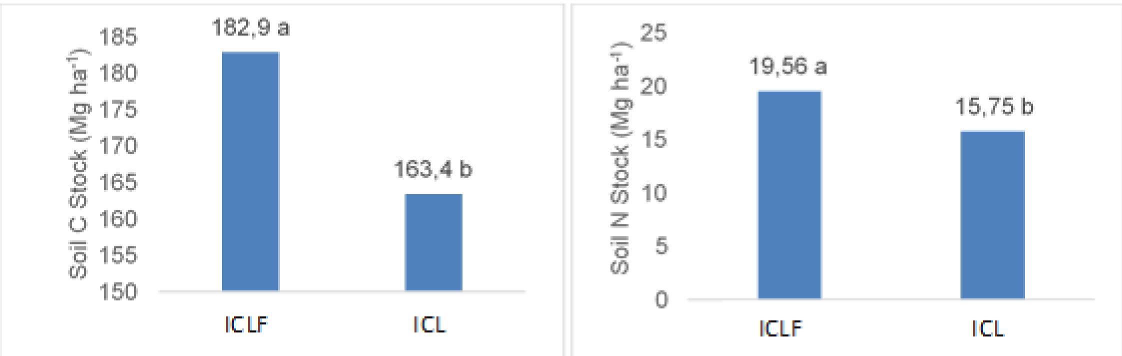

Figure 1. Stocks of soil carbon (C) and soil nitrogen (N) in the 0-100 cm layer in the ICLF and ICL experimental area. Bars followed by different lowercase letters indicate significant differences between systems ($p < 0.05$).

CONCLUSIONS

The carbon stock in the soil under ICLF system up to a depth of 0-100 cm, was 10.4% higher than the carbon stock in the ICL system and the nitrogen stock in the ICLF system was 19.5% higher than the ICL system. In this study, the ICLF system was more efficient in storing nitrogen and carbon through storage in the soil. These results confirm the ICLF system's greatest potential in mitigating greenhouse gas emissions. However, it is important that measurements continue to be carried out in order to assess changes in C and N stocks over time.

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