Carbon in pasture soil: stock change factor for the land-use and carbon sequestration rate due to the adoption of better management

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Abstract - In Brazil, agriculture contributes to the emission of greenhouse gases, but has great power to sequester carbon (C) in the soil. The objective of this research was to quantify the C stock in the soil due to land use change (LUC) from forest (Atlantic Forest biome) to *Urochloa brizantha* pasture, obtaining LUC factors; as well as determining C sequestration rates resultant of the adoption of better pasture management practices. The soil C stocks with the change of land use from forest to pasture was investigated in two locations, one with Dystrophic Red Oxisol and Dystrophic Red Argisol, and the other with Dark Red Oxisol, in the cities of Nova Odessa and Pirassununga, both in the State of São Paulo. Soil C stocks were obtained from soil sampling in pits with an auger, in different layers, down to 100 cm deep. The LUC factor was calculated from the ratio between the C stock in the forest soil and the C stock in the soil under pasture, for each location and soil type. The intensification of pasture management was studied in Pirassununga, resultant ofnitrogen fertilization and deferred or rotated grazing, while in Nova Odessa nitrogen fertilization and intercropping between *U. brizantha* and *Macrotyloma axillare* were tested. Soil sampling to obtain initial C stocks and after two years of implementing the new management was carried out in a similar way to that mentioned for LUC, but only considering the soil downto 30 cm deep. The factors for LUC varied between 0.76 and 0.98, demonstrating that inadequate management can affect the C stock in the soil in relation to the forest (standard IPCC value of 1), but that these factors increased when an appropriate management was applied, varying between 1.04 and 1.18, when compared to the IPCC factor standard value of 1.17. Furthermore, management practices resulted in C sequestration rates ranging between 1.2 and 4.4 t C ha^{-1} $year^{-1}$, relatively high values that demonstrate the high potential of soils under pasture for C sequestration.

Key words: Atlantic Forest, fertilization, global climate change, grass-legume intercropping soil, organic matter

Introduction

Pastures occupy around 160 million hectares in Brazil and are the main land use in the country. Understanding the change in carbon (C) stock in the soil due to the land use change (LUC) from native vegetation to pasture is important in understanding the impact of the livestock sector on the emission/removal of greenhouse gases. No less important is determining the impact of adopting good pasture management practices and grazing systems on the sequestration and stabilization of C in the soil Data will support sectoral, regional, and national C accounting, allowing the evaluation of greenhouse gases reduction targets, improving market competitiveness. In this context, the objective of the research is to quantify the variation in soil carbon stock due to LUC from forest to pasture and determine C sequestration rates in the soil resultant of the adoption of better pasture management practices.

Methods

The research was carried out in areas of the Institute of Animal Science (IZ), in the city of Nova Odessa, SP, and the University of São Paulo (USP), in the city of Pirassununga, SP. The forest areas evaluated are from the Atlantic Forest biome and the pastures are formed with *Urochloa brizantha* cv. Marandú.

The effect of LUC from forest to pasture on C stock in the soils was evaluated in three areas: (i) soil classified as a typical Dystrophic Red Oxisol, in Nova Odessa (RO-NO); (ii) soil classified as Dystrophic Red Argisol, in Nova Odessa (RU-NO); and (iii) soil classified as a typical Eutrophic Dark Red Oxisol, in Pirassununga (RO-Piras).

The quantification of C stock in the soils under forest and pasture was carried out in samples from four trenches per area. Undisturbed samples, for density evaluation, and auger samples (deformed soil samples) were collected to evaluate the C content in the soil. The layers (depth) sampled were: 0-5, 5-10, 10–20, 20–30, 30–40, 40–60, 60–80 and 80–100 cm. Soil density was determined using the gravimetric method after drying at 105°C for 48 hours. The deformed soil samples were dried at 38°C, sieved through a 2 mm mesh and sub-samples of 5 to 8 g were ground and passed through a 0.150 mm sieve to quantify the total C content using dry combustion in a CN elemental analyzer.

Carbon stocks were calculated using soil density and C content. Carbon stocks in pasture soils were corrected using the equivalent mass method, according to Wendt & Hauser (2013), using the soil under forest as a reference.

Statistical comparisons were carried out using mean values and confidence intervals at 95% probability. LUC factors, considering each location and soil type, were obtained by the ratio between the soil C stock in the forest and the soil C stock in the pasture, based on the IPCC Guidelines (2006).

The adoption of better management practices and grazing systems were evaluated in Nova Odessa (MS-NO) and Pirassununga (MS-Piras).

In Pirassununga, *U. brizantha* pastures were fertilized with nitrogen, under four grazing systems: deferred pasture; deferred pasture + protein supplement for the animals; rotational grazing and rotational grazing + protein supplement.

In Nova Odessa, the treatments were: *U. brizantha* pasture fertilized with mineral N; *U. brizantha* pasture fertilized with mineral N and protein supplement; and the consortium of *U. brizantha* and the legume *Macrotyloma axillare*.

Soil C stocks, in layers 0-5, 5-10, 10-20, 20-30 and 30-40 cm, were quantified initially (baseline) and after two years of adopting the managements, using the same procedures used in the LUC assessments. Sample preparation and analysis also followed what was already described, however, for correction by equivalent mass, the baseline soils were used as a reference.

The initial and final stocks for each grazing system and/or management practices were compared using a 95% probability t-test and, in the case of significance, the respective C sequestration rates were calculated.

Results and Discussion

Considering LUC in RO-NO, there was no difference between forest and pasture (Table 1) in any of the soil layers. The RU-NO and RO-Piras differed in the 0-30 cm layers, where the forest surpassed the pasture in both places. In the 0-100 cm layer, the forest differed from the pasture in RU-NO and RO-Piras, what can be explained by the short time since the change in land use, insufficient for forage inputs to overcome the impact of C loss caused by the removal of trees and often by the use of fire and/or some level of mechanical tillage of the soil. The factor for LUC was 0.87, 0.76, and 0.98 in RU-NO, RO-Piras and RO-NO, respectively, when compared to the IPCC default value of 1 (IPCC, 2006). These factors are a reflection of pastures that do not have an adequate management system, resulting in less vegetation, fewer species diversity, and greater soil disturbance, damaging the carbon stock in the soil compared to a forest, where there is greater dynamic balance.

The accumulated C values in the 0-100 cm layer differ from the sum of the 0-30 cm and 30-100 cm C layers due to differences in the composition and distribution of organic carbon in the soil at different depths, such as decomposition, input of organic material, climatic factors, erosion and transport, type of vegetation and land use, and geological processes, among others.

Table 1. Results of accumulated C stocks in layers 0–30, 30-100, and 0-100 cm in RO-NO, RU-NO, and RO-Piras and Factors of Land Use Change (F-LUC) in layer 0–30 cm.

Place	Pasture	Forest	Pasture	Forest	Pasture	Forest	F-LUC
	0-30 cm		30-100 cm		0-100 cm		
RO-NO	67,4±71,8	69,0±76,3	115,6±156	67,1±133,1	183±226,7	136,1±207,6	0,98
RU-NO	55,2±59,2	63,8±71,5	52,5±57,8	74,8±82,3	104±112	138,6±149,9	0,87
RO-Piras	62,6 ±64,5	82,3±88,9	77,4±82,5	93,2±103,5	135,8±143,7	175,5±191,2	0,76

Considering management systems, MS-NO resulted in the sequestration of 4 t C ha^{-1} $year^{-1}$ in the grass treatment, standing out in relation to the grass and legumes and grass and protein treatments which had sequestration rates of 3.2 and 2.4 t C ha^{-1} $year^{-1}$, respectively. The superiority of the grass treatment can be explained by the presence of the animals and the lowering of the pasture, allowing a renewal of the root systems in the area, increasing the biomass, and contributing to the sequestration of carbon, what was potentiated by an adequate management of the pastures. In MS-Piras, the rotational and deferred pastures treatments had a C sequestration rate of 3.3 and 3.6 t C ha^{-1} $year^{-1}$, respectively. Rotational grazing and supplemented pastures treatments had a C sequestration rate of 4.4 t C ha^{-1} $year^{-1}$, which can be explained by the bovine contribution to the soil-plant system, in constant renewal, associated with protein supplementation and bovine excreta contributing to increase the organic matter content in the soil.

Table 2. Carbon sequestration rate and factors for each treatment in MS-NO and MS-Piras Management Systems in the 0-30 cm layer.

Place	Treatment	C Rate (t $ha^{-1}year^{-1}$)	Management system factors
MS-NO	Grasses	+4	1,18
MS-NO	Grasses and Legumes	+3,2	1,08
MS-NO	Grasses and Protein	+2,4	1,10
MS-Piras	Deferred	+3,6	1,13
MS-Piras	Deferred and Supplement	+1,2	1,04
MS-Piras	Rotated	+3,3	1,10
MS-Piras	Rotated and Supplement	+4,4	1,14

The factors for MS resulted in values that varied between 1.04 and 1.18, being below the default value of 1.17 estimated by the IPCC (IPCC, 2006). This shows the importance of sustainable management in pastures, associated with forage quality, cattle feed, soil conservation, and nutrient cycling, in the mitigation of climate change.

Conclusions and/or Implications

The land use change from forest to pasture resulted in carbon emissions into the atmosphere, which can be recovered with an adequate management system, combined with the application of fertilizers, consortium with legumes and an adequate grazing system, which resulted in high rates of carbon sequestration per year, ranging from 1.2 to 4.4 t C ha^{-1} yr^{-1}.

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