SOIL CARBON STOCKS OF INTENSIVE GRAZING AND SILVOPASTORAL SYSTEMS

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ABSTRACT
Soil has a great potential to accumulate carbon; deforestation and the different managements tend to decrease the soil carbon (C) and generate loss of soil quality and increase CO_2 emission. The intensification of grazing management with fertilization, adequate cattle stocking rate, as well as the systems integration such as livestock and forest (silvopastoral) can increase the soil C stock. In this study were evaluated the soil C stocks at depths of 0—30 and 0—100 cm in pastures with irrigation and high stocking rate (IHS), rainfed pasture with high stocking rate (RHS), rainfed pasture with moderate stocking rate (RMS), degraded pasture under continuous grazing (DP) and a silvopastoral system with native trees. The RHS and RMS showed higher C stocks (139 and 165 Mg ton ha^{-1}, respectively) concerning the other evaluated systems, which was able to incorporate C equally a native forest (148 Mg ton ha^{-1}) and more than the degraded pasture (103 Mg ton ha^{-1}) and silvopastoral system (114 Mg ton ha^{-1}). The results suggest that the intensification of grazing systems can stock more C in the soil than integrated systems.
Key words: Soil carbon storage; Pastures; Integrated systems

INTRODUCTION

The concentration of gases that causes the greenhouse effect (GHG) has increased in the atmosphere, since the industrial revolution, which is associated with the upsurging in the Earth's surface temperature, melting of glaciers and increasing of ocean levels, among other environmental deregulations (IPCC, 2018). The soil has great potential to stock carbon (C) in the organic form, originated from the input of animal residues and plant tissues (LAL, 2004). Deforestation to create different systems for crop and animal production as well as the soil management causes a loss of carbon in the soil, decreasing the quality and productivity. The intensification of grazing systems with adjustment of the stocking rate, use of correctives and fertilizers can influence the quantity and quality of the accumulated C and contribute to stock C and mitigate GHG emissions (FREITAS et al., 2020). In addition to intensive grazing systems, the integration of systems, such as livestock and forest (silvopastoral) can contribute to increase soil carbon storage due to the different C sources in the system.

This study aimed to evaluate the C stock of intensive grazing systems and at a silvopastoral system (SP), in relation to a degraded pasture and an area of native vegetation.

MATERIAL AND METHODS

Five different grazing systems were evaluated, replicated twice for each area: 1) irrigated pasture with high stocking rate (IHS), 2) rainfed pasture with high stocking rate (RHS), 3) rainfed pasture with moderate stocking rate (RMS), 4) degraded pasture (DP), and 5) silvopastoral system with moderate stocking rate (SP). In addition, a semideciduous forest, Atlantic Rainforest Biome, without signs of anthropogenic disturbance was evaluated. Pastures in DP and RMS were established in 1996 with *Brachiaria brizantha* and *Brachiaria decumbens*. Pastures in IHS and RHS were established in 2002 with *Panicum maximum*. The pasture in SP was established with *Brachiaria decumbens* and wooded with native forest species in 2008. Each pasture of the DP consisted of a single paddock (3.3 ha) maintained in continuous grazing and was not managed, limed or fertilized (SEGNINI et al., 2019). The IHS and RHS were divided into 12 paddocks (0.14 to 0.15 ha each) grazed for three days under a rotational grazing system with 33 days of rest. The RMS pasture was divided into six paddocks (0.55 ha each) grazed for six days, and under a rotational system (30 days rest). SP was divided into six paddocks of 0.6 ha each, grazed for six days and with 30 days of rest. The trees in the SP system were native species such as “angico-branco” (*Anadenanthera colubrina*); “canafístula” (*Peltophorum dubium*); “ipê-felpudo” (*Zeyheria tuberculosa*); “jequitibá branco” (*Cariniana estrellensis*) and “pau-jacaré” (*Piptadenia gonoacantha*). Furthermore, “mutambo” (Guazuma ulmifolia) and “capixingui” (Croton floribundus) were planted in an alternating sequence to ensure that these species mentioned above grew straight boles with a minimum of lower branches. The trees were planted in sets of three corridors (distance between trees of 2.5 m), and each corridor in a distance of 17 m, which resulted in 545 trees per ha. In July 2016, trees were thinned, which consisted in cutting 50% of the trees in each external corridor, resulting in 350 trees ha^{-1}.

The soils were sampled in trenches in 2020, in a total of six trenches per area, in a depth of one meter with segmented fractions: 0-5, 5-10, 10-20, 20-30, 30-40, 40-60 and 80-100 cm. In the SP system, the trenches were open in the corridors with tree (referred to as SP T) and between the tree corridors (8.5 m) referred to as SP M. To calculate the C stock, the density of the soil was determined by the volumetric ring method and the total C content by an elemental analyzer (model 2400, PerkinElmer, USA).

The C stocks (Mg ha^{-1}) were calculated by multiplying soil C content (%), bulk density (Mg m^{-3}) and soil thickness (cm). Once soil bulk density of the agricultural systems treatments was higher compared to the forest area, non-corrected C stocks would be systematically overestimated in these treatments. Then, the stocks were corrected by equivalent soil mass, considering native vegetation as a reference, according to the method proposed by Ellert and Bettany (1995).

RESULTS AND DISCUSSIONS

Figure 1 shows the carbon stocks in the depth of 0-30 cm (a) and 0-100 cm (b), which the majority of the accumulated carbon is in depth. Both RHS and RMS pastures showed the capacity to increase carbon storage in relation to DP. The irrigation was not favorable to distinguish the C stock between IHS, RHS, and DP systems. May the abundance of water promoted by irrigation limited the growth of roots, decreasing C entry into the soil (MUDGE et al., 2017; SCOTT et al., 2012). The RMS showed the most potential area to accumulate carbon (165 Mg ton ha^{-1}), which at both depth 0-30 and 0-100 had the same stock of forest. The *Brachiaria* pasture may have influenced a greater entry of vegetal tissues in the soil and vegetation cover, generating a greater C accumulation in relation to the *Panicum maximum* pasture. *Brachiaria* has a high root growth and improves the soil’s physical, chemical, and biological properties with its vegetal cover (BIELUCZYK et al., 2020). Horrocks et al. (2019) demonstrated that *Brachiaria* pasture increased the amount of C in the soil compared to *Panicum maximum* pasture. Although the RHS showed a lower C stock (139 Mg ton ha^{-1}), it is not statistically different from RMS, maybe with time the differences will be more highlighted.

Silvopastoral system did not show any statistical difference in the C stock in proximity to trees (SP T) or between the tree corridors (SP M), in both evaluated depths of 0-30 and 0-100 cm, which suggest that pasture and trees can have the same contribution for C accumulation in the soil. Furthermore, both depths of 0-30 and 0-100 cm showed a C stock inferior to native vegetation, and equally to DP. Thus, in 12 years of native trees integration in the pasture, there was no increase in the C stocked in the soil in relation to DP. Considering the C stocks of all systems, intensive grazing systems (RHS and RMS) shown a greater potential for C accumulation in the soil. Of course, the C accumulated in the trees’ growth is not being considered, and just the C accumulated in the soil.

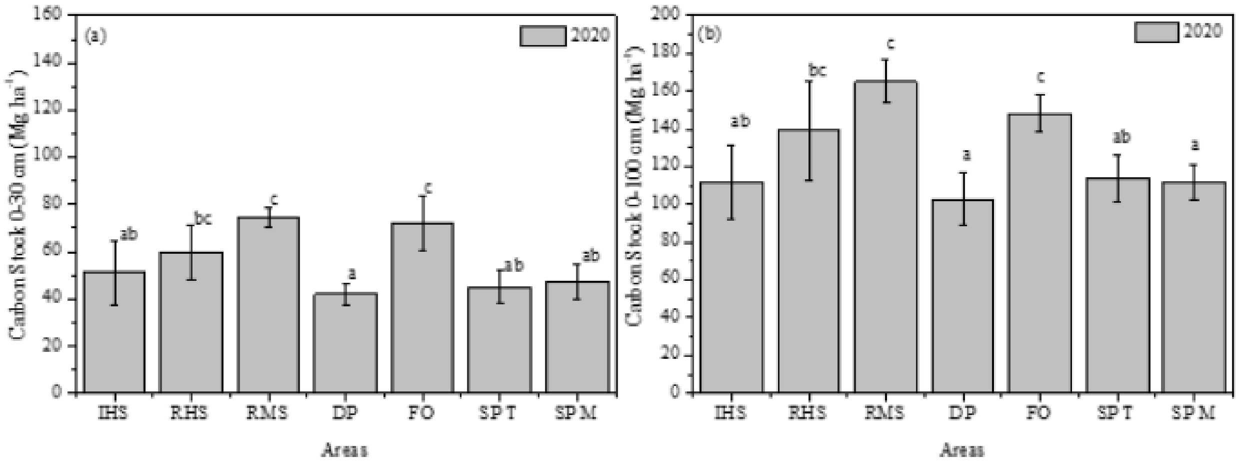

Figure 1. Carbon stocks at a depth of 0-30 cm (a) and 0-100 cm (b) in the different evaluated areas corrected by a native forest area. Different letters mean statistical difference at a level of $p<0.05$ by Tukey pos-hoc test.

Table 1 shows each storage carbon system capacity per year. C stock rates were obtained by a subtraction between stocks from each area in relation to FO and DP, and normalized by the time (years) of each experiment. The C stocks rates data obtained of RHS and RMS systems has shown that were the only one that presented capacity to increase C in relation to FO, while all the evaluated areas showed C stock rates higher than DP.

Table 1. Carbon stock rates (Mg ton ha^{-1} $year^{-1}$) in relation to forest and degraded pasture.

Management System	**Carbon stock (Mg ton ha^{-1} $year^{-1}$) in relation to forest area**	**Carbon stock (Mg ton ha^{-1} $year^{-1}$) in relation to degraded pasture**
IHS	-1.51^{cd}	1.03^{ab}
RHS	0.15^{ad}	2.69^{b}
RMS	0.79^{ab}	2.70^{b}
SP T	-2.90^{c}	0.99^{ab}
SP M	-3.49^{c}	0.32^{a}

*different letters mean statistical difference at a level of $p<0.05$ Tukey pos-hoc test.

CONCLUSIONS

Both high and moderate cattle stocking rate and the different pasture type (*Panicum maximum* and *Brachiaria brizantha)* did not change the C stock between RHS and RMS systems. Furthermore, the irrigation did not help increasing the C stock, as expected.

Intensive grazing systems proved to be more effective in accumulating C in soil than a silvopastoral system with native trees, in which, both RHS and RMS were able to accumulate C in the soil equally to an area of native vegetation.

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