IV International Symposium on Integrated Crop-livestock Systems
ICLS
And
III Congresso Brasileiro de Sistemas Integrados de Produção Agropecuária
VII Encontro de Sistemas Integrados de Produção Agropecuária no Sul do Brasil

SOIL FERTILITY EVOLUTION IN INTEGRATED CROP-LIVESTOCK-FORESTRY SYSTEM ON SANDY SOIL OF BAHIA'S CERRADO[1]

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Abstract:
The Integrated Crop-Livestock-Forestry System (ICLF) emerged as alternative to recover degraded pastures, as well as to improve production systems' efficiency, in order to make agriculture more sustainable. Research study was implemented in 2018 to assess soil fertility evolution under ICLF system in sandy soil of Bahia State's Cerrado. Soil fertility assessments were carried out from 2019 to 2022; Cerrado soil was used as basis for initial fertility comparison purposes. Improvement in soil chemical properties was observed after ICLF system implementation in comparison to the Cerrado soil, or to the initial soil condition, since agricultural intensification helped improving nutrient cycling in the system.
Keywords: Western Bahia State, Intensification, Nutrient cycling.

Introduction

Brazil stands out in farming activities worldwide, mainly due to the size of its fields and production. Thus, it's essential developing sustainable production processes to guarantee productive efficiency and to win global markets.

However, most of the country's pasture areas remain subjected to low technological level. Consequently, according to the Image Processing and Geoprocessing Laboratory (https://atlasdaspastagens. ufg.br/map), approximately 41% of the total Brazilian pasture area recorded in 2021 (159 million hectares) presented intermediate degradation level, whereas 22% of it presented severe degradation level.

Therefore, recovering these areas is a great opportunity to help the country increase its plant and animal production, as well as to meet the significantly increased world's demand for food, without deforesting new areas (Sene & Bacha, 2024).

The agricultural intensification, based on integrated production systems, has emerged as technological alternative to help recovering these degraded areas through several

arrangements involving plants, such as integrated crop-livestock-forestry (ICLF), which integrates plant, animal and tree components in the same area (Balbino et al., 2011).

Benefits deriving from this system take place due to complementarity, diversification and synergy among its components. These benefits comprise better soil physical, chemical and biological properties; improved yield and animal welfare; "earth-saving" effect; carbon sequestration; among others (Balbino et al., 2011; Assis et al., 2019, Sene & Bacha, 2024).

Thus, the aim of the current study was to assess soil fertility evolution in a sandy soil area subjected to ICLF system, at Trijunção Farm, *Cerrado* biome, Bahia State.

Methodology

The study site is located at Trijunção Farm, Jaborandi County, Western Bahia State. It was covered with degraded pasture belonging to species *U. brizantha* cv. Marandu, which was replaced by crops and eucalyptus trees, after ICLF system implementation, in 2018. Eucalyptus trees were planted in 15 rows (400 m, in length), at 2-m spacing between plants and 25-m spacing between rows; the total planted area covered 15 ha. Crops and pasture (*U. brizantha* cv. Piatã) were sown in the middle of eucalyptus rows - based on recommendations - in the 2018/2019 and 2019/2020 crop seasons, in compliance with schedule and input dosages (Table 1).

The soil of the experimental area was a sandy soil, which was classified as typical Oxisol, with 110 g kg^{-1} clay, 10 g kg^{-1} silt and 880 g kg^{-1} sand contents. Cerrado "*strictu sensu*" was the original vegetation growing in it.

Table 1. Soil correction and fertilization carried out in the study site.

Time	Culture	Product	Quantity	Application form
Aug/2018	Marandu[1]	limestone (TRNP 76%)	5 t ha^{-1}	broadcasting and incorporated
Oct/2018		Gypsum	700 kg ha^{-1}	broadcasting and incorporated
Oct/2018		MAP (11-52-00)	290 kg ha^{-1}	broadcasting and incorporated
Dec/2018	Eucalyptus	03-18-05	200 g pl^{-1}	furrow
Dec/2018	Crops[2]	MAP (11-52-00)	200 kg ha^{-1}	furrow
Jan/2018	Crops[2]	urea + KCl	120 + 100 kg ha^{-1}	broadcasting in topdressing
Nov/2019	Crops[3]	11-33-11+ FTEBR12 + Ulexite	400 + 30 + 30 kg ha^{-1}	furrow
Dec/2019	Eucalyptus	11-33-11 + FTEBR12 + Ulexite	150 + 20 + 20 g pl^{-1}	broadcasting in topdressing
Jan /2020	Crops [3]	20-00-30 + KCl	500 kg ha^{-1}	broadcasting in topdressing
Nov/2020	Piatã[4]	11-33-11 + FTE BR12	200 + 30 kg ha^{-1}	furrow
Jan/2021	[4]	20-00-20	250 kg ha^{-1}	broadcasting in topdressing
Apr/2021	Eucalyptus	MAP + FTEBR10 + KCl	150 + 22 + 50 g pl^{-1}	broadcasting in topdressing
Nov/2021	[4]	20-00-20	150 kg ha^{-1}	broadcasting in topdressing

Dec/2021	****	FTE BR10	50 kg ha^{-1}	broadcasting in topdressing
Jan/2022	****	Urea	100 kg ha^{-1}	broadcasting in topdressing

Marandu[1] - *U. brizantha* cv. Marandu; Crops[2] - sunflower, cowpea bean, forage sorghum and soybean; Crops[3] - millet, sorghum, Sudan grass, intercropped with *U. brizantha* cv. Piatã, Piatã[4] - *U. brizantha* cv. Piatã

Soil assessments were carried out before crops' planting, in November 2019, and after crops' harvesting, in April 2020, 2021 and 2022. They were compared to soil samples collected in the *Cerrado* area close to the experimental site, which was considered as time 'zero'.

Soil samplings were carried out at layers 0-10 cm and 10-20 cm. In total, 5 simple samples were collected from each layer and from each 1-ha area, in order to form one compost for each 5 ha (15-ha area was split in 3 blocks).

Chemical fertility analyses have followed the methodology described by Teixeira et al. (2017). Results were subjected to mean-comparison test at 5% probability level.

Results and Discussion

Overall, as expected, the ICLF increased fertility levels in terms of pH, P, K, Ca, Mg, CEC pH7,0 and BS (base saturation) and decreased the values of Al^{3+} and H+Al in comparison to that of *Cerrado*, which represented the original soil condition, or time zero (Table 2). However, the increase or reduction observed in fertility values in comparison to *Cerrado* did not follow a chronological sequence, although it would be expected to happen due to both liming and fertilizations applied, overtime (Table 1). But, it is also necessary taking into consideration the nutrient extraction process happening at crop harvesting or forage grazing time, as well as the faster dynamics of sandy soils due to lower buffering capacity (Assis et al., 2019). The highest chemical property values were recorded in November 2019 - which was the assessment period closest to the initial soil correction that, in its turn, comprised limestone, gypsum and fertilizers' application - and in April 2022, after soil fertility management was carried out based on the demand identified after the soil analysis performed in April 2021 (Table 2).

Table 2. Chemical properties of sandy soil at time zero-Cerrado (0-Cer) and at the other assessment times.

Time	pH	P	K	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	CEC pH7,0	BS	OM

	H_2O	---mg dm^{-3}---		----------$cmol_c$ dm^{-3}----------					---------%---------	
0-10 cm										
0-Cer	4.8c	1.9c	8.6b	0.02c	0.02d	0.5a	2.2a	2.3c	2.9c	0.82ab
Nov/19	7.3a	21.0a	18.3b	1.9a	0.60c	0.0b	0.3c	2.9a	89.1a	0.79ab
Apr/20	7.1a	14.8b	10.8b	1.5b	0.64bc	0.0b	0.4bc	2.5bc	82.8ab	0.96a
Apr/21	6.0b	17.7ab	14.4b	1.4b	0.69b	0.0b	0.5bc	2.7ab	81.4b	0.64b
Apr/22	6.7b	15.6ab	31.6a	1.4b	0.78a	0.0b	0.7b	2.9a	76.6b	0.80ab
10-20 cm										
0-Cer	4.6d	1.4c	5.7 b	0.01d	0.02d	0.4a	2.0a	2.0b	1.8d	0.70b
Nov/19	7.2a	13.2a	10.8b	1.64a	0.57b	0.0b	0.5c	2.7a	82.2a	0.75ab
Apr/20	6.7b	7.7b	9.9b	1.12c	0.45c	0.0b	0.8b	2.4b	67.4c	0.82a
Apr/21	6.5c	9.0ab	11.7b	1.16bc	0.52b	0.0b	0.6bc	2.3b	73.4b	0.53b
Apr/22	6.6bc	10.7ab	25.4a	1.27b	0.68a	0.0b	0.8b	2.8a	73.3b	0.75ab

Means followed by the same letter in the column did not significantly differ from each other at 5% probability level.

Overall, one of the main soil properties – i.e., organic matter content - did not differ between *Cerrado* (time zero) and the years of ICLF system; this finding corroborated the study by Stieven et al. (2018).

Conclusions

The ICLF system was capable of improving soil chemical properties in comparison to *Cerrado*, or to the initial soil condition, because the agricultural intensification enabled by it improved nutrient cycling in the system.

Acknowledgement

The authors are grateful to Embrapa, Faped and Trijunção Farm for the support.

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