

Artigos

Soil microbiological activity under different vegetation coverages in the Cerrado biome of Tocantins state

Atividade microbiológica do solo sob diferentes coberturas vegetais no Cerrado tocantinense

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ABSTRACT

The microbial activity is very sensitive to changes in soil cover, making it an important indicator of soil quality. The study aimed to assess changes in soil microbiological activities under different vegetation coverings in the Cerrado biome of Tocantins state. The work was developed in areas of *Eucalyptus* sp., Pasture, agriculture and Cerrado sensu stricto in the experimental farm of the Federal University of Tocantins. The soil samples were collected in trenches of 70 x 70 cm at depths 0-10 and 10-20 cm, with six replications. The variables evaluated were: concentration and stock in the microbial biomass carbon, basal soil respiration, metabolic quotient and microbial quotient. The statistical analysis was performed using the normality test, analysis of variance and comparison of means by the Tukey test at 5% significance. The area with *Eucalyptus* sp. at 11 years of age, he had a stable soil microbiological activity, showing stocks in microbial biomass carbon 57.32% higher than that native forest vegetation, 84.29% that pasture and 290.91% that agriculture. The soil microbiological activities are affected by the variation of the soil vegetation cover, being efficient as an indicator of soil quality.

Keywords: Bioindicators; Soil respiration; Metabolic quotient; Microbial biomass carbon

RESUMO

A atividade microbiana se mostra bastante sensível a mudanças da cobertura, tornando-se um importante indicador de qualidade do solo. O estudo teve como objetivo avaliar as alterações nas atividades microbiológicas do solo sob as diferentes coberturas vegetais no cerrado do Tocantins. O trabalho foi desenvolvido em áreas de *Eucalyptus* sp., pastagem, agricultura e cerrado sensu stricto na fazenda experimental da Universidade Federal do Tocantins. As amostras de solo foram coletadas em trincheiras de 70 x 70 cm nas profundidades 0-10 e 10-20 cm, com seis repetições. As variáveis avaliadas foram: concentração e estoque de carbono na biomassa microbiana, respiração basal do solo, quociente metabólico e quociente microbiano. A análise estatística foi realizada por meio do teste de normalidade, análise de variância e comparação das médias pelo teste Tukey a 5% de significância. A área com *Eucalyptus* sp. com 11 anos apresentou uma atividade microbiológica do solo estável, apresentando estoques de carbono na biomassa microbiana superiores em 57,32 % aos da vegetação de mata nativa, 84,29 % ao da pastagem e 290,91 % ao da agricultura. As atividades microbiológicas do solo são afetadas pela variação da cobertura vegetal do solo, sendo eficiente como indicador de qualidade do solo.

Palavras-chave: Bioindicadores; Respiração do solo; Quociente metabólico; Carbono da biomassa microbiana

1 INTRODUCTION

In ideal conditions, the topsoil shows a great capacity to store carbon, this capacity being closely related to the soil microbial activity. In Brazil, about 50% of the soil organic carbon (SOC) is stored in the first 30 cm of the soil, and the global average of SOC accumulation for the topsoil is around 35% (BATJES, 2016).

The microbial activity, as it distinguishes between the types of land use, becomes an indicator of quality, being directly related to SOC concentrations (MOGHIMIAN *et al.*, 2019). The biggest changes in soil microbial biomass (SMB) are concentrated in the superficial layers. The soil organic matter (SOM) also plays an important role in the soil microbiota, with the presence of SOM regulating soil microbial activity and directly related to the mobilization of nutrients such as nitrogen and phosphorus and, consequently, the soil fertility (MUSHINSKI; GENTRY; BOUTTON, 2019).

Thus, it emphasizes the importance of knowing the quality indicators of the activity of soil microorganisms (MOGHIMIAN *et al.*, 2019). BMS and basal soil respiration (BSR) when evaluated in sets are good microbial indicators (MOSCATELLI *et al.*, 2007). The ratio between BSR and SMB, per unit of time results in the metabolic quotient (qCO_2) which is

the amount of CO₂ released by SMB as a function of time, being considered the specific respiration of soil microorganisms. And the microbial quotient (qMIC) is the relationship between microbial biomass carbon (MBC) and SOC (MOSCATELLI *et al.*, 2007). These indicators highlight the importance of the microbial activity in the global carbon cycle and in soil quality control, in different forest ecosystems (MOGHIMIAN *et al.*, 2019).

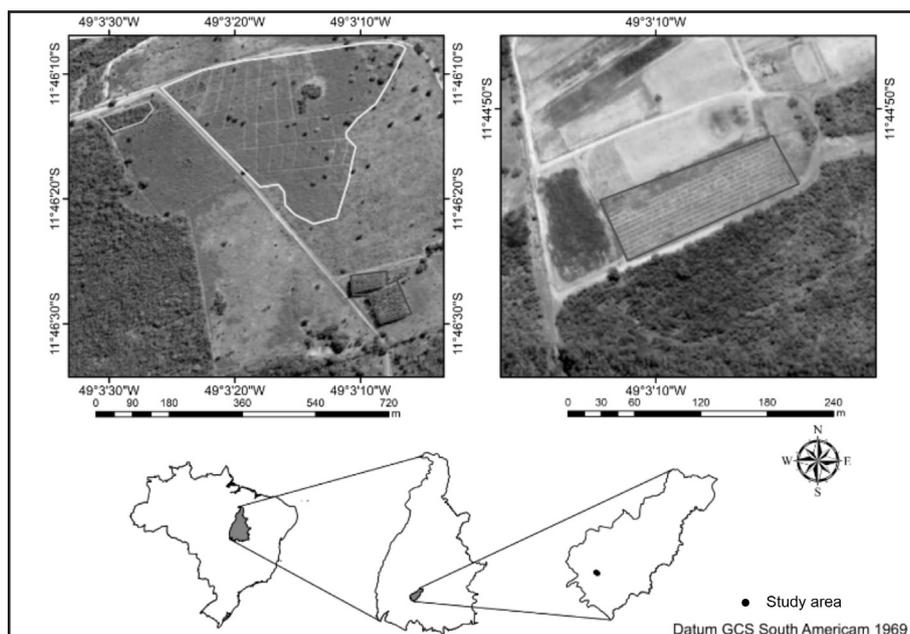
The knowledge of changes in vegetation cover in soil microbial activity is of great importance for the control of CO₂ emissions (SOLEIMANI *et al.*, 2019). In the view of the above, the objective of this study was to evaluate changes in soil microbiological activities under different vegetation coverings in the Cerrado of Tocantins.

2 MATERIAL AND METHODS

2.1 Study area

The work was conducted at the experimental farm of “Universidade Federal do Tocantins”, municipality of Gurupi, state of Tocantins, in the geographical coordinates 11°46'25" S and 49°02'54" W (Figure 1).

Figure 1 – Location of experimental areas with native forest, *Eucalyptus* sp., pasture and agriculture in Gurupi, Tocantins state



Source: Authors (2020)

The climate of the region according to Thornthwaite is of the B1wA'a' type, having two well-defined seasons, with about six months of drought, comprising the winter period and six months of rain that correspond to the summer. The average annual temperature is 27°C and the average annual precipitation is 1,500 mm (TOCANTINS, 2017). The soil was classified as a petric Plinthosol (SANTOS *et al.*, 2018). The studied areas were with *Eucalyptus* sp., Pasture, Agriculture and Native Forest as a witness. Each area had the following characteristics:

- Native forest: the area covers 22.82 ha, aged over 60 years, without recent burns or cuts of vegetation in the area. The ground cover had a large amount of litter and the vegetation was characterized by five species of higher importance values *Myrcia splendens* (Sw.) DC. (13.04%), *Qualea multiflora* Mart. (9.87%), *Protium heptaphyllum* (Aubl.) Marchand (7.53%), *Magonia pubescens* A. St.-Hil. (5.35%), *Qualea grandiflora* Mart. (5.02%) (BENDITO *et al.*, 2018).

- *Eucalyptus* sp.: the area is 0.65 ha and 11 years old and its implementation was carried out through deforestation with a bulldozer and front shovel, followed by plowing and harrowing. Seedlings 25 cm high were planted in pits in the dimensions of 0.4 x 0.4 x 0.4 m with the help of excavators and 3 x 2 m spacing. Then, fertilization was carried out with 100 g of simple superphosphate at the bottom of the pit and partially buried, then 150 g per pit⁻¹ of NPK were added in formulation 5-25-15. After its implantation, the thinning was not carried out on the trees and the ground cover was made up of leaves and small branches of *Eucalyptus* sp.. The manual weeding is also carried out in the area to control weeds.

- Pasture: the area has 11.25 ha with native pasture and predominance of *Andropogon* grass over 40 years old, without animals present. Other species of poaceas have been recorded such as: *Spalum notatum*, *Eragrostis bahiensis*, *Axonopus affinis*, *Bothriochloa laguroides*, *Schizachyrium microstachyum*, *Paspalum dilatatum*, *Sporobolus indicus*, *Rhynchospora* sp., *Andropogon ternatus*, *Panpalumis* sp.

- Agriculture: The area has 0.95 ha and the soil preparation was done using a leveling harrow and disc plow, and the weeds were controlled by manual weeding associated with the use of full-action herbicides such as Glyphosate, operations adopted when necessary. Over the past 6 years the corn crop was grown in the area, planted annually in the period between February and March at an average spacing of 0.2 x 0.8 m. For sowing, a manual planter-fertilizer was used, which enabled the basic fertilization. The nutrients applied at the time of corn sowing consisted of nitrogen in the form of ammonium sulphate (45% N), phosphorus in the form of triple superphosphate (42% P₂O₅) and potassium in the form of potassium chloride (58% of K₂O), corresponding to 120, 170 and 140 kg ha⁻¹, respectively of N, P and K, with N applied 50% at 25 days and 50% at 45 days after sowing. At other times of the year, no cultivation of any kind was carried out in the area, with corn stubble being the only soil covering.

2.2 Soil samples

Six trenches selected at random equidistant from each other around 30 m, were opened with dimensions 70 x 70 cm and depth of 20 cm in each area. The soil samples were collected at depths 0-10 and 10-20 cm, and the deformed samples were dried in air at room temperature and passed through a 2 mm sieve to perform physical analysis. The non-deformed samples were collected and submitted to soil density analysis.

2.3 Physical analysis

The soil density was determined by the volumetric cylinder method and granulometric analysis was performed using the pipette method (DONAGEMMA *et al.*, 2017).

2.4 Microbiological analysis

For the microbiological analysis, soil samples were subjected to basal soil respiration (BSR) (ISERMEYER, 1952), microbial biomass carbon (MBC) by the irradiation extraction method using a microwave oven (frequency of 900 W and 2450 MHz) , according to the method described by Islam and Weil (1998), and the C extracts were determined from irradiated and non-irradiated samples using colorimetry method (BARTLETT; ROSS, 1988), metabolic quotient (qCO_2), obtained by dividing the baseline respiration per unit of MBC (ANDERSON; DOMSCH, 1989), and microbial quotient (qMIC), obtained by dividing MBC by soil carbon. In the determination of carbon from soil microbial biomass, the irradiation extraction method was used, which analyzes the extractable microbial biomass in aqueous K_2SO_4 solution 0.5 mol L^{-1} .

The C concentrations were converted into carbon stock in soil microbial biomass (S-SMB) in Mg ha^{-1} for each depth sampled as follows, Equation (1):

$$MBC \text{ Stock} = (MBC \times S_d \times VSD) \times 1000 \quad (1)$$

Where: MBC Stock is the stock in microbial biomass carbon in the soil layer, in (Mg ha^{-1}); MBC is the concentration in the microbial biomass carbon in the soil sample, in (kg Mg^{-1}); S_d is the soil density in the layer, in (Mg m^{-3}) and the VSD is the volume sampled depth, in (m^3). The total stock of C in the microbial biomass at a depth of 0 to 20 cm was calculated by adding the values obtained in each sampled layer.

2.5 Statistical analysis

The parameters evaluated concentrations and stocks of C in the microbial biomass were subjected to normality tests Shapiro and Wilk, then performed the analysis of variance to evaluate the differences between the uses of the soil in the depths. The comparison of means was performed by the Tukey test at 5% significance and using the statistical software SISVAR (FERREIRA, 2011).

3 RESULTS AND DISCUSSION

In general, the granulometric composition of the soil showed a predominance of medium texture, being classified as sandy-clay-loam in all soil depths of the analyzed areas (Table 1).

Table 1 – Physical characteristics of Cerrado soil in different vegetation coverings in Gurupi, Tocantins state, Brasil

Vegetal Cover	Coarse Sand	Fine Sand	Silt	Clay	Soil Density	Texture
	%				g cm ⁻³	
Depth 0-10 cm						
Native Forest	57.50 ±2.85	6.33 ±1.89	8.44 ±1.32	27.73 ±3.01	1.45 ±0.06	Sandy-clay-loam
<i>Eucalyptus</i> sp.	54.85 ±3.12	9.98 ±2.99	9.19 ±1.23	25.98 ±2.38	1.40 ±0.05	Sandy-clay-loam
Pasture	55.59 ±1.79	13.44 ±1.63	6.64 ± 0.57	24.33 ±1.21	1.55 ±0.08	Sandy-clay-loam
Agriculture	56.71 ±1.59	9.41 ±3.71	7.86 ±0.80	26.02 ±3.32	1.37 ±0.06	Sandy-clay-loam
Depth 10-20 cm						
Native Forest	59.96 ±2.03	4.71 ±2.12	8.51 ±2.33	26.82 ±2.24	1.51 ±0.05	Sandy-clay-loam
<i>Eucalyptus</i> sp.	56.04 ±2.24	9.09 ±1.90	6.85 ±2.17	28.02 ±1.91	1.53 ±0.07	Sandy-clay-loam
Pasture	57.84 ±1.32	10.55 ±1.84	7.26 ±1.75	24.35 ±1.76	1.59 ±0.05	Sandy-clay-loam
Agriculture	57.84 ±1.86	8.92 ±2.09	7.54 ±1.19	25.70 ±2.90	1.49 ±0.08	Sandy-clay-loam

Source: Authors (2020)

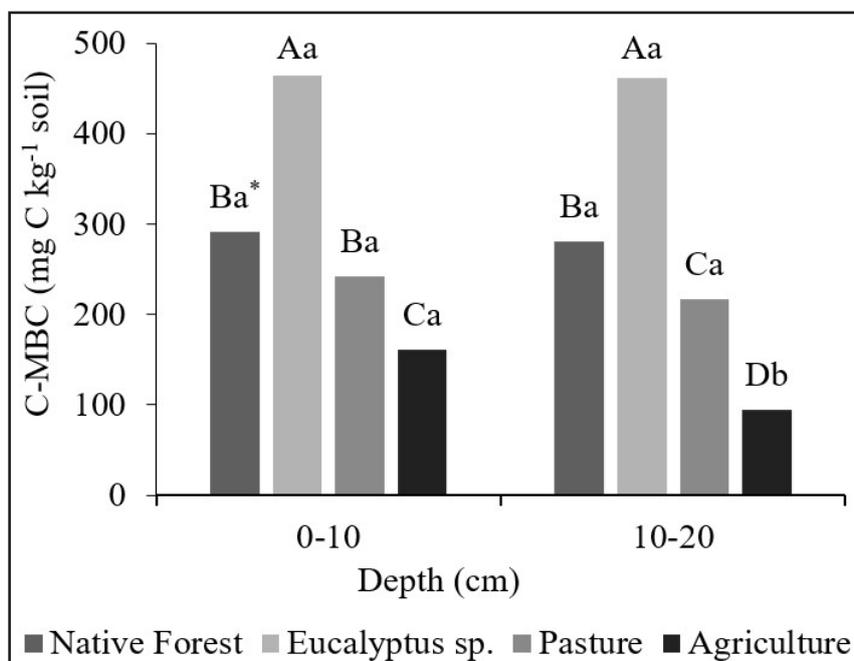
The predominance of sand indicates that soil has a low capacity for nutrient retention (ARAÚJO FILHO et al., 2017). In general, the soil density did not vary widely among the types of land use. For Marinho Junior *et al.* (2019), the removal of vegetation cover can cause physical changes in the soil, due to the impact of rain drops that fall directly on the exposed soil.

Soil microbiological indicators: carbon concentration in microbial biomass (C-MBC), basal soil respiration (BSR), microbial quotient (qMIC), metabolic quotient (qCO₂) and carbon stock in microbial biomass (S-MBC) showed significant differences in the different soil coverages analyzed. The interaction of litter and microorganisms has a fundamental role in the formation of the microbial metabolic activity of the soil,

making the effect change of vegetation cover on the microbial activity more intense in the superficial layer of the soil than in greater depths (SOLEIMANI *et al.*, 2019).

The C-MBC showed a variation of (161.58 to 463.49 mg C kg⁻¹ soil) in the 0-10 cm layer and (94.99 to 461.50 mg C kg⁻¹ soil) in the layer 10-20 cm where, in general, there were no significant losses between the soil layers, except for the agricultural area (Figure 2).

Figure 2 – Carbon concentration in soil microbial biomass in different vegetation coverings in Cerrado, in Gurupi, Tocantins state, Brazil



Source: Authors (2020)

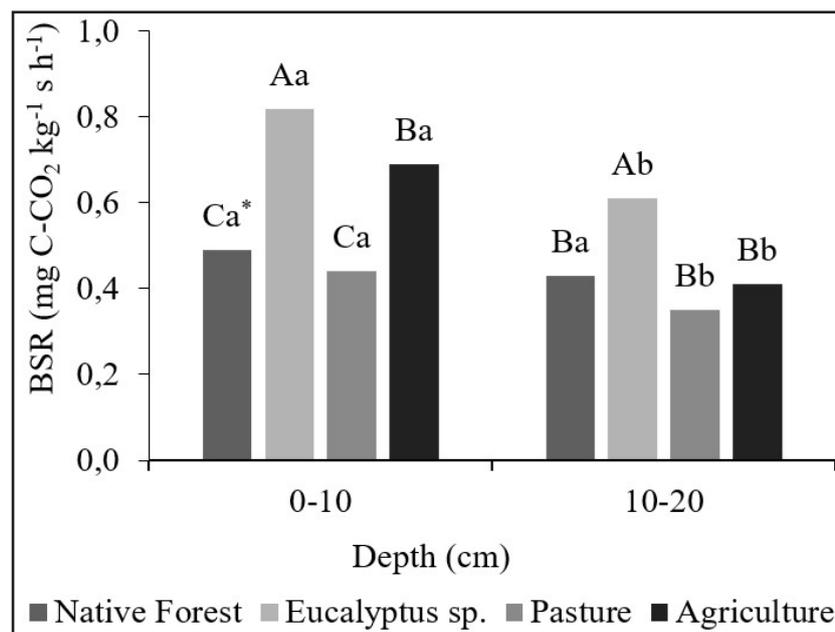
In where: *Significant differences are indicated by different letters by the Tukey test at 5% significance level ($p \leq 0.05$). Capital letters indicate differences between vegetation cover and lower letters indicate differences between soil layers.

Studies by Kaschuk, Alberton and Hungria (2010), evaluating the soil microbial biomass for three decades in Brazilian ecosystems, found values ranging from (46 to 1386 mg C kg⁻¹ soil) in different soil coverings in the Cerrado biome. Probably the low supply of organic matter in agriculture area has reduced the activity of soil

microorganisms and consequently reduced the C-MBC in contrast to the greater availability of organic matter mainly via litter for native forest area and *Eucalyptus* sp. area, and via thin root system for pasture area has ensured a more stable microbial activity and possibly a higher MBC content.

The BSR obtained a variation of (0.44 to 0.82 mg C-CO₂ kg⁻¹ s h⁻¹) from 0-10 cm and (0.35 to 0.61 mg C-CO₂ kg⁻¹ s h⁻¹) 10-20 cm, showing a variation similar to that of C-MBC among the evaluated areas and in the soil layers except for the agricultural area (Figure 3).

Figure 3 – Basal soil respiration in different vegetation coverings in Cerrado in Gurupi, Tocantins state, Brazil



Source: Authors (2020)

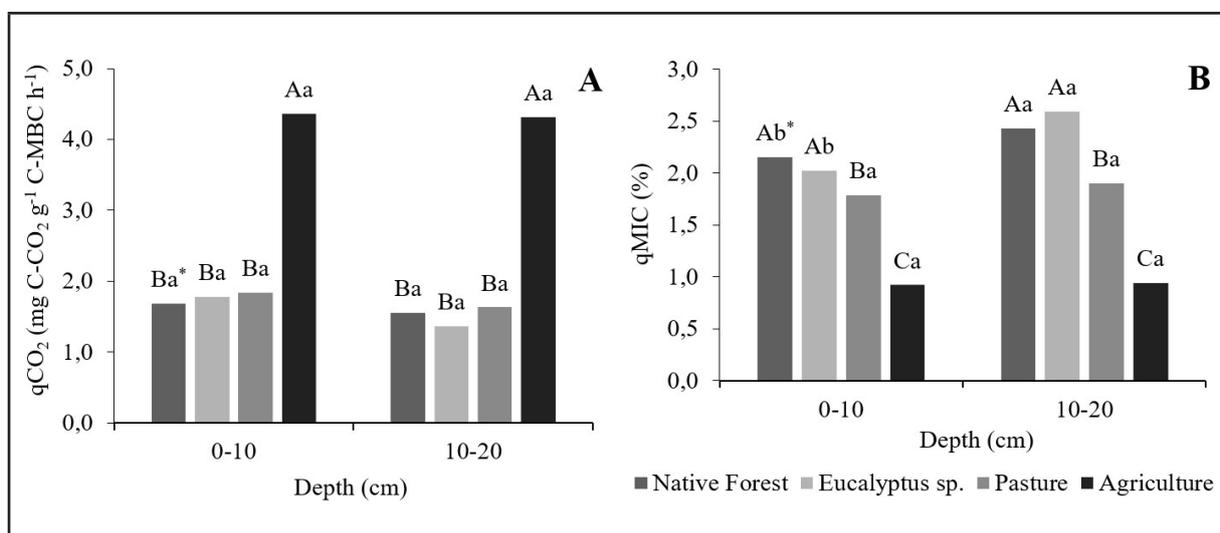
In where: *Significant differences are indicated by different letters by the Tukey test at 5% significance level ($p \leq 0.05$). Capital letters indicate differences between vegetation cover and lower letters indicate differences between soil layers.

According to Brito *et al.* (2019) attributes the variation in BSR to an ecological imbalance, as in his study evaluating BSR did not found no clear pattern in response to the change of the land use. According to Frazão *et al.* (2010), only BSR as soil microbial

activity indicator can not explain its different behaviors among the evaluated areas. However, it is known that soil microbial activity is sensitive to substrate availability, humidity and temperature (ČAPEK *et al.*, 2019). Studies by Oliveira *et al.* (2016), evaluating microbiological attributes in different uses of soil in Cerrado found great variation of BSR among the evaluated areas, being that the highest values were found in areas with greater presence organic matter (mainly labile), and warmer and dry periods.

The qCO_2 and $qMIC$ of soil are shown in Figure 4. The qCO_2 evaluated soil showed a variation of (1.68 to 4.36 mg C-CO₂ g⁻¹ C-MBC h⁻¹) in layer 0-10 cm and (1.55 to 4.31 mg C-CO₂ g⁻¹ C-MBC h⁻¹) in layer 10-20 cm, without significant difference between native forest, *Eucalyptus* sp. and pasture areas, being the largest values found in agriculture area in both depths.

Figure 4 – Metabolic quotient and microbial quotient of soil in different vegetation coverings in Cerrado in Gurupi, Tocantins state, Brazil



Source: Authors (2020)

In where: *Significant differences are indicated by different letters by the Tukey test at 5% significance level ($p \leq 0.05$). Capital letters indicate differences between vegetation cover and lower letters indicate differences between soil layers.

Higher qCO_2 values indicate soils under stress or disturbance related to quality

or quantity of the substrate and/or to unfavorable environmental conditions such as adverse microclimate or soil compaction (BRITO *et al.*, 2019). The low qCO_2 values are related to more stable areas with low degree of disturbance, indicating less loss of C in CO_2 form through respiration per unit of biomass (YAGHOUBI KHANGHAHI *et al.*, 2019), according to the results found in an area with native forest, *Eucalyptus* sp. and pasture where there is less or no disturbance. The high qCO_2 index is caused by higher metabolic activity per unit of biomass that stimulates the greater consumption of soil organic matter without its transformation into MBC and indicating less environmental sustainability (GRAZZIOTTI *et al.*, 2017).

The $qMIC$ showed a variation 0-10 cm (0.92 to 2.15 %) and 10-20 cm (0.94 to 2.59 %) showing that there was significant difference between areas and layers evaluated (Figure 4B).

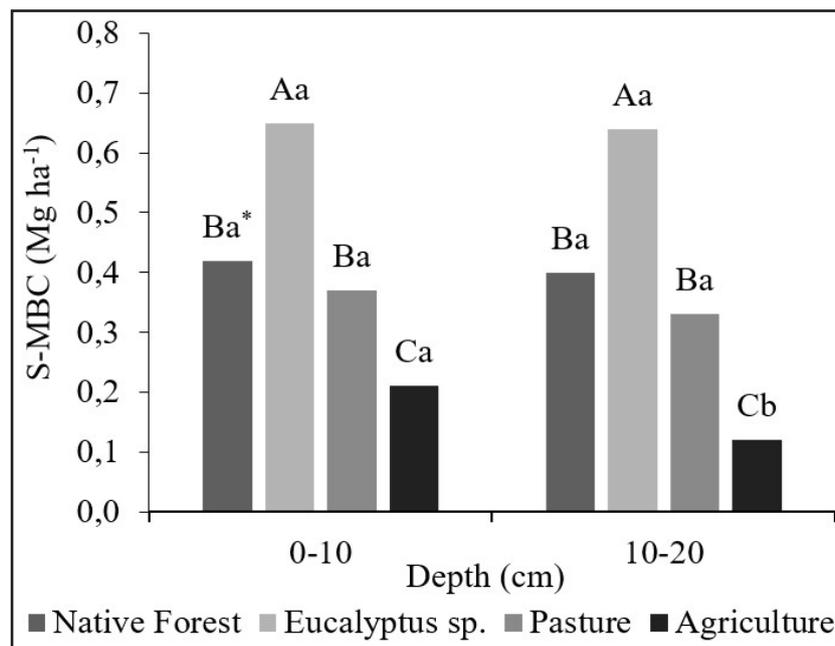
Lower values $qMIC$ in agriculture area compared to the other areas indicate that there are lower proportions of labile organic matter and stable soil organic matter (MGANGA; RAZAVI; KUZYAKOV, 2016). $qMIC$ values below 1.0 indicate a slower process for mineralization of OM in these systems (NUNES *et al.*, 2018). Another interesting factor is that in 10-20 cm layer $qMIC$ was superior in all evaluated areas, which may indicate a better quality of SOM, or even a better efficiency of microorganisms in the use of organic compounds in this depth soil. Nunes *et al.* (2018), evaluating microbiological attributes in different monocultures in the Cerrado of Piau  state, found a $qMIC$ that varied from (1.06 to 2.66 %). Data that corroborate with presented in this study.

Carbon stock in microbial biomass (S-MBC) varied between (0.21 to 0.65 $Mg\ ha^{-1}$) in 0-10 cm and (0.12 to 0.64 $Mg\ ha^{-1}$) in 10-20 cm, showing significant differences between the vegetation cover analyzed (Figure 5).

There is a maintenance S-MBC with an increase in depth, without significant differences in the soil layers evaluated, except in the agricultural area, which showed 42.86 % reduction in S-MBC in 10-20 cm layer in relation to the surface layer 0-10 cm (Figure 5). Studies by Brito *et al.* (2019) evaluating S-MBC in response to land conversions

in the Brazilian savannah, after changing the land use, found significant reductions in S-MBC, representing (-56%) in conversion to pasture and (-39%) in conversion to *Eucalyptus* plantation.

Figure 5 – Carbon stocks in microbial biomass in different vegetation coverings in Cerrado in Gurupi, Tocantins, Brazil



Source: Authors (2020)

In where: *Significant differences are indicated by different letters by the Tukey test at 5% significance level ($p \leq 0.05$). Capital letters indicate differences between vegetation cover and lower letters indicate differences between soil layers.

The S-MBC low level can indicate low microbiological activity soil, and/or low disposition of organic material, generating low decomposition of the organic residues. The low values found in the MBC stocks for agricultural area can be attributed to little or no soil coverage at certain times of year, causing a reduction in the microbiological activity. For Ramesh *et al.* (2019), this result can also be attributed to high C/N ratios found in agricultural systems that significantly reduce the MBC content and consequently reducing the mineralization process. On other hand, there was a superiority in MBC

stocks in soil of *Eucalyptus* sp. not showing significant losses between the evaluated layers, which can be attributed to the great availability of organic matter in the form of litter.

The results found in soil microbial activity corroborate with S-MBC found, indicating great stability of evaluated area reflecting in a greater capacity to store carbon in soil. According to Soleimani *et al.* (2019), reforested areas are effective in increasing organic carbon content in soil and microbial biomass carbon compared to the natural forest.

The high BSR, C-MBC and S-MBC found in *Eucalyptus* sp. may represent a stable microbial activity justified by large amount of organic matter in this area. In the agricultural area, results were found contrasted with other areas in indicators of C-MBC, S-MBC, qCO_2 and $qMIC$, which may indicate a lower stability of the microbial activity in this soil, due to the low availability of organic matter in certain times of year. In the areas of pasture and native forest, which presented average results in most indicators and similar results to *Eucalyptus* sp. area in indicators such as qCO_2 and $qMIC$, it can be attributed to greater stability in those areas that do not have recent anthropic interference, which ensure a large amount of organic matter in soil and consequently a stable microbial activity.

4 CONCLUSIONS

The vegetation area of *Eucalyptus* sp. showed minor changes in the microbiological activities.

C-MBC, BSR and S-MBC were significantly higher in *Eucalyptus* sp. area, and lower in agriculture, pasture and native forest area.

The activities mediated by microorganisms were affected by the change in the soil cover.

Microbiological activities proved efficient to be used in the control and analysis of degraded areas.

ACKNOWLEDGEMENTS

The authors would like to thank CAPES for the grant of a master's scholarship, Universidade Federal de Pernambuco (UFRPE), Universidade Federal de Sergipe (UFS) and Universidade Federal de Pernambuco (UFPE), for their availability, facilities, cooperation and assistance.

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How to quote this article

Marinho Junior, J. L.; Piscoya, V. C.; Cunha Filho, M.; Fernandes, M. M.; Pedrotti, A.; Pisco-ya, T. O. F.; Gomes Filho, R. R.; Campos, F. S.; Holanda, F. S. R.; Castro, J. B.; Roncal, J. L. P.; Araújo Filho, R. N. Soil microbiological activity under different vegetation coverages in the Cerrado biome of Tocantins state. *Ciência Florestal*, Santa Maria, v. 31, n. 3, p. 1494-1511, 2021. DOI 10.5902/1980509847922. Available from: <https://doi.org/10.5902/1980509847922>. Accessed: xx abbreviated-month. 2021.