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INDICADORES FÍSICO-HÍDRICOS DO SOLO CULTIVADO COM SOJA ORGÂNICA NO CERRADO

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1 RESUMO

A qualidade de um solo envolve aspectos biológicos, químicos e físicos, que se aplicam para a avaliação da degradação ou melhorias em suas capacidades funcionais de manutenção dos sistemas agrícolas, incluindo sistemas de produção orgânica. O objetivo desta pesquisa foi avaliar as propriedades físico-hídricos do solo em cultivo orgânico de soja no sudoeste goiano. O estudo foi realizado na Fazenda Panorama, no município de Santa Helena de Goiás. Considerou-se cinco áreas (quatro áreas sob cultivo orgânico e uma área de vegetação nativa). As amostras de solo foram coletadas na safra 2022/23, na fase de colheita da soja, nas camadas de solo de 0 a 10, 10 a 20 e 20 a 30 cm. O solo sob cultivo orgânico acerca do indicador porosidade total sofreu nenhuma ou pouca alteração devido ao revolvimento ou tráfego de máquinas. O cultivo orgânico na área em que a braquiária permaneceu por mais tempo no esquema de rotação de culturas (SO1) apresentou vantagens quanto a redução da densidade do solo, tornando-a semelhante às demais áreas de referência, vegetação nativa e pastagem consolidada, associado a um aumento do teor de carbono orgânico do solo.

Keywords: densidade do solo, carbono orgânico do solo, braquiária

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PHYSICAL-HYDRIC INDICATORS OF SOIL CULTIVATED WITH ORGANIC SOYBEANS IN THE CERRADO

2 ABSTRACT

Soil quality involves biological, chemical, and physical aspects, which are applied to the evaluation of degradation or improvements in its functional capacity for maintaining agricultural systems, including organic production systems. The objective of this research was to evaluate the physical–hydric properties of soil under organic soybean cultivation in

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southwestern Goiás. The study was conducted at Fazenda Panorama, in the municipality of Santa Helena de Goiás. Five areas were considered (four areas under organic cultivation and one area of native vegetation). Soil samples were collected during the 2023/24 growing season, at the soybean harvest stage, in the 0 to 10, 10 to 20, and 20 to 30 cm soil layers. The soil under organic cultivation showed little or no alteration in terms of total porosity because of tillage or machine traffic. Organic farming in the area where brachiaria grass remained for the longest time in the crop rotation scheme (SO1) showed advantages in terms of reducing soil density, making it similar to the other reference areas, native vegetation and consolidated pasture, associated with an increase in the soil organic carbon content.

Keywords: soil density, soil organic carbon, brachiaria

3 INTRODUCTION

Climate change presents itself as a phenomenon capable of generating often irreversible impacts, especially on natural resources, particularly under anthropogenic influences (Wu *et al*., 2020). The water crisis is challenging because of the effects it can cause on numerous systems, whether natural, urban, or agricultural, and has already resulted in a decrease in water availability for numerous regions of the world (D'Odorico *et al*., 2020). Agriculture is an economic activity that is dependent on climate and water availability and therefore more strongly affected in the context of the water crisis (Pereira; Rodriguez, 2022) because of recurring prolonged drought periods, generating negative consequences in relation to the production of many agricultural crops and repercussions on the quality of life of the population. The search for strategies aimed at reducing the impacts caused by the water crisis is crucial for strengthening the agricultural sector in this scenario of climate change.

Salton, Morais, and Lohmann (2021) suggest, as management practices that favor the direct or indirect tackling of the water crisis in agricultural production, the use of water deficit-tolerant varieties, conservationist soil and water management, the use of cover crops, irrigation, and the adoption of green manure, for example. Therefore, the organic farming system is based on ecological balance, which favors soil fertility and biological cycles, allowing not only good-quality food production but also the conservation of natural resources such as soil and water (Ifoam, 2009).

In the absence of pesticide use, organic agriculture is on the rise because it encompasses economic, environmental, and social issues in its management proposal (Oliveira; Bertolini, 2022; Pugliesi *et al*., 2021). In addition to defending the right to health and life of consumers and producers, organic agriculture is a practice of a solidarity economy, considering that small producers end up contributing to their independence. In addition, it highlights important aspects, such as environmental preservation, sustainability, respect for local knowledge, and avoiding the waste of food and resources (Soares *et al*., 2021).

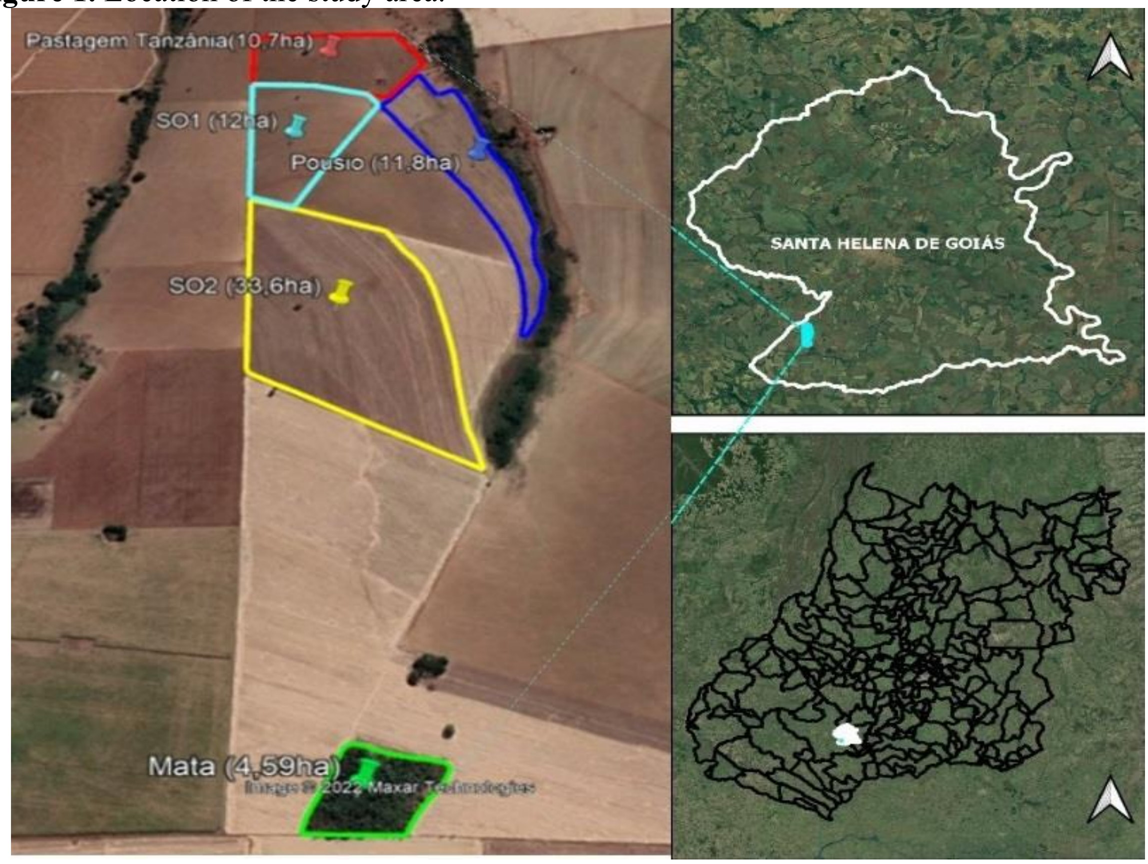
Recently, there has been great interest in evaluating the physical quality of soil in various production systems because it is considered a fundamental component in maintaining the sustainability of agricultural production systems. This quality results from both intrinsic and extrinsic factors related to the soil (Schossler). *et al* ., 2018). According to Topp *et al*. (1997) and Xiao *et al*. (2024), the most widely used attributes as indicators of physical-hydric soil quality are those that consider the effective rooting depth, total porosity and the distribution and size of pores, particle size distribution, soil density, soil resistance to root penetration, optimum water range, compression index and aggregate stability. For Evanylo *et al*. (2008) soils that have been subjected to organic cultivation show better physical soil conditions for subsequent crops.

Given this, few studies have evaluated the effects of cropping systems on the physical-hydric quality of soils under organic soybean cultivation, especially in the Cerrado region and in the largest soybean-producing region in the state of Goiás, the southwestern region. Thus, in this study, the physical–hydric properties of a dystrophic Red Latosol under different rotation schemes for organic soybean cultivation were evaluated.

4 MATERIALS AND METHODS

The study was conducted in the municipality of Santa Helena de Goiás, Fazenda Panorama, located at 17° 54'22” S and 50° 39'56” W, at an altitude of 625 meters, in the southwestern region of Goiás (Figure 1). The region has a climate classified as Aw (Alvares *et al.,* 2013), with annual rainfall distributed in two well-defined seasons: a dry season or winter (May–October) and a rainy season or summer (November–April). The soil in the region is a Dystrophic Red Latosol with a clayey texture (Santos *et al*., 2025).

Figure 1. Location of the study area.



Source: (Authors, 2025)

The assessments were carried out in five crop areas during the growing season (three areas under organic grain cultivation; one area of already consolidated pasture; one area of native vegetation) and three soil layers (0–10; 10–20 and 20–30 cm) in a split-plot design. Soil sampling occurred during the soybean harvest phase, at reproductive stages R8 and R9, in the 2023/2024 agricultural season (sowing in November 2023). In each area, 5 points were sampled, totaling 15 samples per area. The history of agricultural use for each study area is presented in Table 1. The areas under organic cultivation have been under this management since 2018, when they were certified.

Table 1. Historical land use areas under organic farming.

Areas under organic farming	**SO1 (organic system 1)**: in 2018, lime was applied and corn and brachiaria grass were intercropped, followed by brachiaria grass in 2019 and 2020, and soybean (BRS 511) planting in the summer of 2021. In 2022 it was left fallow, and in the 2023/24 crop season soybeans were cultivated (Location: 17° 54' 25” S and 50° 39' 59” W).
	SO2 (organic system 2): in 2018 limestone was applied and brachiaria grass was planted in 2019 and 2020, followed by soybean and second-crop corn planting in 2020, and soybean (BRS 511) was planted in the summer of 2021. Grain sorghum was cultivated in 2022 and soybean was cultivated in the 2023/24 season. (Location: 17° 54' 48” S and 50° 39' 55” W).
	Fallow: In 2018, rock dust with microorganisms was applied. In the 2019/20 growing season, harrowing and cultivator passes were carried out to control weeds, in preparation for soybean cultivation in the summer of 2021 and 2022, leaving the land fallow in the 2023/24 growing season. (Location: 17° 54' 30” S and 50° 39' 42” W).
	Pasture (Tanz): Limestone, manure, and rock dust were applied in 2018, and in the 2021/2022 season, humic and fulvic acids were applied to the pasture area established in 2008. (Location: 17° 54' 15” S and 50° 39' 56” W)
	Native Vegetation (NV): area of native forest used as a reference. (Location: 17° 55' 33” S and 50° 39' 54” W)

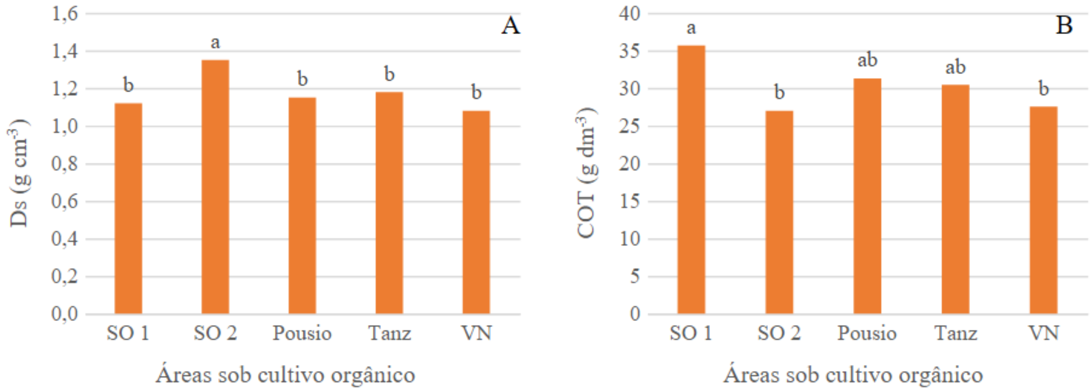
Source: Authors (2025)

To assess the physical-hydric quality of the soil, the following indicators were evaluated: 1- soil density (Ds); 2- percentage volume of micropores (Micro) and macropores (Macro); 3- total porosity (PT); and 4- total organic carbon in the soil (COT), according to the methods described by Teixeira *et al*. (2017). For the statistical analysis of the data, the areas were considered plots, and the subplots were considered the sampled soil layers. The data were subjected to analysis of variance associated with the F test at 5% probability. If significant, the means were compared using Tukey's test at 5% probability. The statistical software SISVAR (Ferreira, 2019) was used.

5 RESULTS AND DISCUSSION

With respect to the soil density indicator, only one of the organic soybean areas, SO2, differed from the others with a 5% probability, indicating that it was a denser soil (Figure 2A). This is because the area was possibly compacted by agricultural machinery (Lima *et al*., 2012), considering the conventional preparation in grain crop areas associated with corn straw, which is less dense than the brachiaria straw present in the SO1 area. Silva *et al*. (2026) evaluated the density in areas under different sugarcane cycles in the Quirinópolis-GO region and reported values higher than 1.8 g dm $^{-3}$ in the third cut, which was attributed by the authors to the traffic of agricultural machinery and implements, as well as the intense oxidation of organic matter during the first years of cultivation.

Figure 2. Soil density (Ds) (A) and total soil organic carbon (TOC) (B) under organic farming systems in Santa Helena de Goiás in the 2023/2024 crop season.



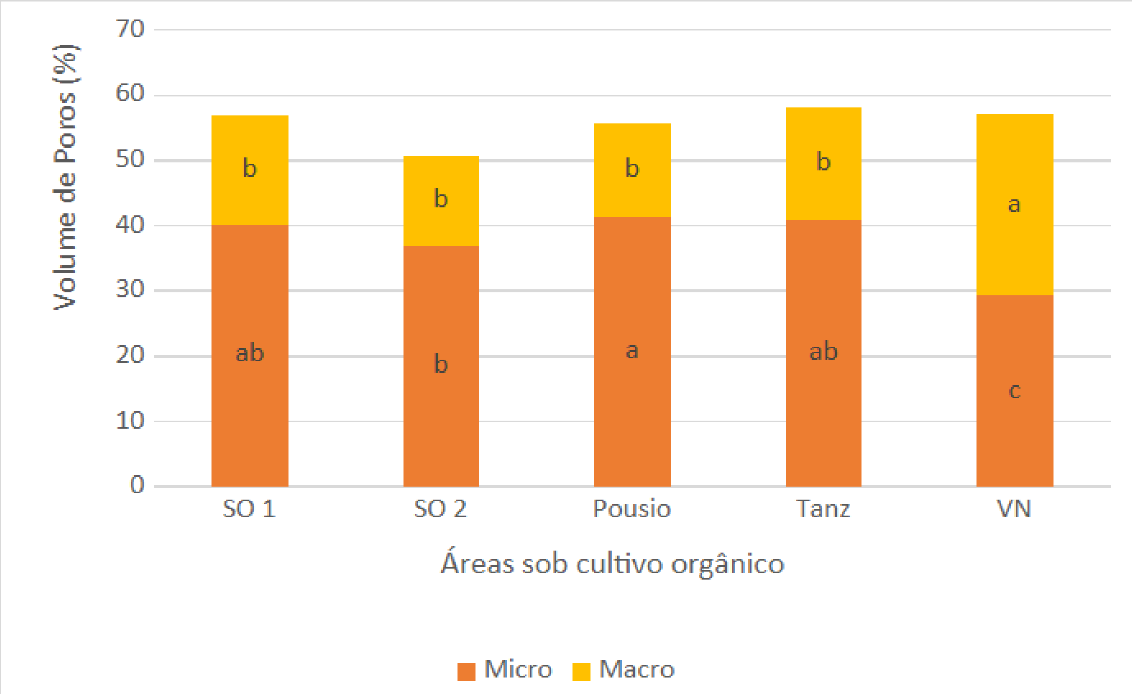
*Means followed by the same letter across columns do not differ from each other according to Tukey's test at the 5% significance level.
SO1: organic system 1; SO2: organic system 2; Tanz: consolidated Tanzanian pasture; VN: native vegetation.
Source: (Authors, 2025)

The total organic carbon (TOC) differed between the organic cultivation areas, with a higher SO1 content and a value close to 35 g dm $^{-3}$ (Figure 2B). This can be explained by the fact that since 2018, the area has been sown with brachiaria grass, as its use as a soil cover adds organic matter. Grasses, being C4 plants, contribute to increasing and maintaining organic matter content and, consequently, organic carbon in the soil, since their root system provides a high supply of carbon in the subsoil, contributing to its stabilization and increasing its content in the most recalcitrant fraction of the soil (Barreto *et al*. 2008). In addition, the carbon:nitrogen ratio of brachiaria grass is high, which results in a relatively slow decomposition rate of its residues, similar to those in native vegetation areas. In this area, soil properties are less affected because of the greater accumulation of diverse plant residues on the soil surface and organic carbon in the surface layers, as well as less anthropogenic disturbance, as reported by Castioni *et al*. (2018) and Silva *et al*. (2026).

In the fallow area, the TOC was approximately 30 g dm^{-3}, which did not differ from that in the SO1 area and did not differ from that in the Tanzania pasture area. One of the reasons may be that this area has had pasture established on the site since 2008, modifying the area compared with the fallow area, which had only pasture during the last growing season. According to Santos *et al*. (2024), when pastures are adopted in degraded areas, improvements in soil properties and ecosystem services are expected, since the presence of plant residues and pasture roots can increase carbon levels and thus improve aeration conditions and water infiltration capacity, as grasses, such as Brachiaria, have an extensive and constantly renewed root system. In the VN reference area, COT was an average of 26 g dm $^{-3}$, which was lower than that in the SO1 area (Figure 3B), reinforcing the capacity of the organic farming system to store carbon in the soil as a function of the management adopted.

This research revealed that the increased soil density in the study areas promoted changes in properties related to soil aeration, such as the percentage volume of macropores (Macro), micropores (Micro), and total porosity (PT), as shown in Figure 3. These results corroborate those presented by Silva *et al.* (2026).

Figure 3. Percentage volume of micropores (Micro), macropores (Macro) and total porosity (PT**) of soil under organic farming systems in Santa Helena de Goiás in the 2023/2024 crop season.



*Means followed by the same letter across columns do not differ from each other according to Tukey's test at the 5% significance level.
SO1: organic system 1; SO2: organic system 2; Tanz: consolidated Tanzanian pasture; VN: native vegetation. **PT: total porosity = sum of the percentage volume of macro- and micropores.
Source: (Authors, 2025)

The micropore values ranged from 29.26% to 41.35%, with the lowest value occurring in the reference area (native vegetation) and the highest value observed in the fallow area (Table 1). Compared with the fallow area, all the areas had different values. Compared with the other areas, the fallow area tends to have a larger water reservoir because of the greater presence of micropores, which play a fundamental role in water storage in the soil. In their research, Oliveira, Silva and Mello (2020) reported that the higher the percentage of micropores is, the greater the water reservoir in the soil profile.

With respect to total porosity (TP), only the SO2 area differed from the others. The values ranged from 50.84% to 58.09% of the soil composition (Figure 4). According to Oliveira, Lima, and Verburg (2015), the total pore volume is directly linked to land management and is among the most important indicators of soil quality. In the area under native vegetation, soil properties were less affected, which can be attributed to the greater accumulation of plant residues on the soil surface and organic carbon in the surface layers, as well as less anthropogenic disturbance, as also indicated by Silva *et al*. (2026).

6 CONCLUSION

The inclusion of brachiaria grass in crop rotation within an organic soybean farming system allows significant improvements in the physical and hydrological properties of the soil. A reduction in density and an increase in organic carbon content are observed, resulting in a soil profile similar to that of the reference area.

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