PHYSICAL CHARACTERIZATION OF THE SOIL IN A RURAL SETTLEMENT AREA IN SOUTHEASTERN PARÁ

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ABSTRACT
Rural settlements in Brazil, initiated in the 1980s by INCRA, aim to redistribute land to mitigate agrarian conflicts, but face challenges such as production conditions and environmental preservation. The study at PDS Porto Seguro, in Marabá-PA, analyzed the physical properties of the soil in areas of legal reserve, agroforestry system (AFS) and cassava cultivation, highlighting that AFS and preserved areas have better soil quality compared to intensive cultivation.

Keywords: Rural settlements. Agroforestry systems.

INTRODUCTION

Rural settlements are a set of agricultural units resulting from the distribution of territories previously belonging to a single owner and redistributed to landless families, a process carried out by INCRA (National Institute of Colonization and Agrarian Reform) (BRASIL, 2017). In Brazil, these settlements officially originated in the 1980s. They are the result of agrarian issues in the country and arose with the intention of solving, or at least mitigating, conflicts related to land tenure (FREITAS et al., 2014). However, many of these still face obstacles in terms of production and marketing conditions, political and social organization, both internal and external, and the organization and preservation of natural resources (VASCONCELLOS et al., 2016).

Family farming is one of the main agricultural activities in the Southeast of Pará, offering opportunities for family farmers, whose properties have origins from rural settlements (PEREIRA et al., 2023). In general, families invest in the most varied production agroecosystems because they understand that in this system the soil and natural resources of their properties are used more efficiently (ASSMANN; SOARES; ASSMANN, 2008).

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Sustainable development projects (PDS) consist of a modality of agrarian reform that contemplates the objectives of promoting sustainable development, this concept has been explored and studied in order to combat various problems in rural areas, whether social, environmental, political and economic.

Therefore, one of the methods that has been used are the Agroforestry Systems (SAF's), which for environmental recovery are production systems that can be based on ecological succession, analogous to natural ecosystems, optimize land use by reconciling environmental preservation with food production, conserving the soil and reducing the pressure for land use for agricultural production, and can be used to restore forests and recover degraded areas (EMBRAPA, 2019).

In addition, soil quality (QS) encompasses important factors, such as: physical, chemical and biological. Therefore, physical indicators can diagnose the quality of that soil, through density, porosity, compaction, conductivity, etc. These indicators, when used together, can indicate the changes that have occurred in soil management systems (TORRES et al., 2015).

The adoption of management systems that maintain soil protection by the continuous contribution of organic waste is essential for the maintenance and/or improvement of soil structure, as monitoring changes in the physical, chemical and biological properties of the soil is extremely important, as they can provide information that helps in the evaluation of production systems, with the aim of making them sustainable (JÚNIOR et al., 2016).

OBJECTIVE

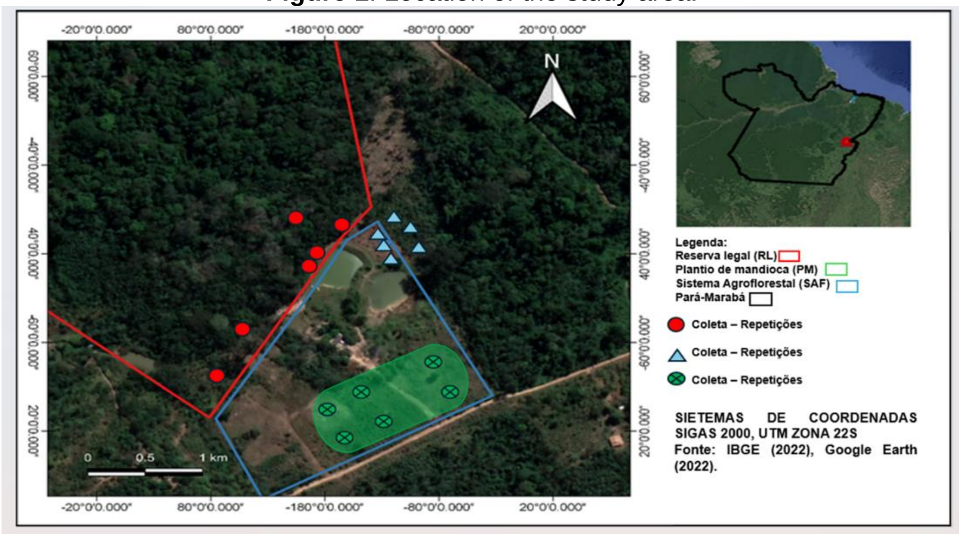
Thus, the objective of this study was to characterize the physical properties of the soil in three distinct areas, such as the legal reserve, agroforestry system and cassava cultivation, using the technique of determining the physical characteristics of the soil by the volumetric ring method

METHODOLOGY

FIELD OF STUDY

The Sustainable Development Project (PDS) Porto Seguro, study area (figure 1), is located on the BR-155 highway, Km 14, in the rural area of the municipality of Marabá, Pará. The total area of the PDS is 1,069 hectares, which includes 37 lots. with longitude of 049° 02.041 (W) and latitude of 05° 28.134 (S) from Greenwinch, average altitude of 85m, with tropical climate, classified as Aw climate according to Köppen and Geiger (DA SILVA et al., 2023).

Figure 1: Location of the study area.



Source: prepared by the authors, 2025.

COLLECTION OF SAMPLES

Samples were collected in three distinct areas (Figure 1), with a total of 18 samples, in each study area (Treatments) at a depth of 0-5 cm, 5-10 cm, and 10-15cm, randomly on February 11, 2024. The study areas were in soils with vegetation cover in the legal reserve area (RL - Testemunha), cassava cultivation (Manihot esculenta) and agroforestry system (AFS) with an age of five years, productive stage crops such as annatto (Bixa orellana), banana (Musa spp.), açaí (Euterpe oleracea) and Brazil nut (Bertholletia excelsa).

Soil collection using cylinders of known volume at the depths described. Subsequently, the samples were taken to the Environmental Quality laboratory of the State University of Pará (UEPA), Marabá campus. Therefore, to determine the physical properties of the soil, whether they are: soil density, particle density, volumetric moisture, and porosity, the volumetric ring (AVM) method was used (EMBRAPA, 2017).

STATISTICAL ANALYSIS

The data from the soil chemical analyses were submitted to the Shapiro-Wilk normality test ($p > 0.05$). Once this assumption was met, an analysis of variance (ANOVA) was performed and, in case of a significant difference ($p < 0.05$), the means were compared using Tukey's test at 5% probability of error. Statistical analyses and graphs were performed using the statistical program Minitab version15 (CHARLES-PIERRE, 2020).

RESULTS AND DISCUSSION

The soils of the legal reserve showed greater structural stability and greater porosity (Table 1), with the values of soil density (SD) with 1.2 g.cm3 and porosity (Ps) with 53.9%, which can be explained by the presence of organic matter and low compaction. In cassava cultivation, more compacted soils (1.36 g.cm3) are found, due to machine traffic or preparation of an area with animal traction, characterizing soil trampling. The agroforestry system showed intermediate properties, with the second compaction value (1.29 g.cm3) and better structure, such as a good porosity (30.35%), due to the presence of forest elements such as trees and less mechanical intervention.

Table 1 - Physical properties of the soil in the treatments studied.

TREATMENT*	Average values				
	DEPTH(cm)	Soil Density	Particle Density	Volumetric Humidity	Porosity (%)
		g.cm3			
RL	0-5	1,2	2,57	0,35	53,9
SAF	5-10	1,29	2,03	0,35	30,35
MN	10-15	1,36	2,25	0,34	34,43

*RL – legal reserve; SAF – agroforestry system and MN – cassava cultivation.
Source: prepared by the authors, 2025.

Muniz et al., (2023), observed a notable variation in soil density (SD) between the different proven areas, with results indicating that the highest SD values were found in the first 10 centimeters of depth, with emphasis on an area that is intended for cattle farming, a behavior that suggests that the constant trampling of animals in this area may have contributed to the higher density observed.

Regarding porosity, no major variations were observed between the areas studied, however, when analyzing porosity in general, the cassava area stood out, where the crop presented higher porosity indices in the surface layer. This indicates that crop treatments and good soil cover played an important role in maintaining this attribute (MUNIZ et al., 2023).

Soil moisture basically refers to the water content in the soil and its amount stored at a given depth, usually a depth at which the root system effectively absorbs water. Since this physical factor is of vital importance for the vegetation, it is possible to identify that the values for LR and AFS oscillated in comfortable averages for the vegetation (Table 1), and the lowest values were found in the MN treatment, as it is an area of agricultural practice, thus being more subject to evaporation.

Porosity is an extremely important factor for the soil, it is a volumetric fraction of the soil occupied by water and air, important components for root growth (BUSKE, 2013). The same author also states, among the soils they vary from 30 to 60%, and the saturated soil is the one filled by water and the dry by the air, in this context the porosity is greatly influenced by soil management, being affected by compaction.

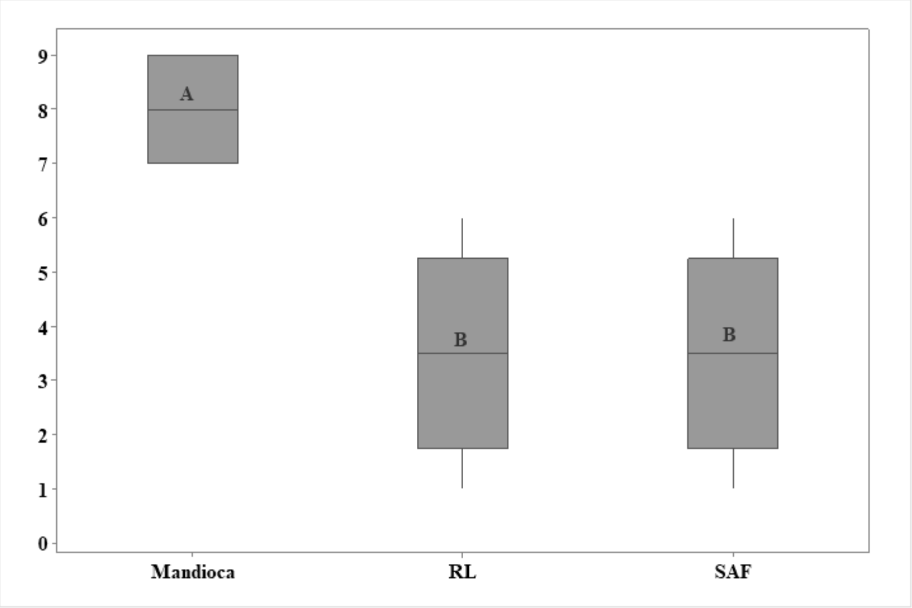
Consequently, the highest values of soil porosity were found at the collection points of the native forest, oscillating in 50%, on the other hand there is a decrease in porosity in the SAF's, indicating alert levels for compaction, presenting low values that may indicate dry soil. Porosity is closely related to soil density, so it is also affected by the level of soil compaction, because the higher the density values, the smaller the pore space (Oliveira et al., 2010).

The factors that cause soil degradation are related to the removal of the vegetation cover that protects it; overgrazing that induces its compaction; agricultural activities without their proper management; the overexploitation of vegetation for domestic use and (bio)industrial activities, among others (FAO; ITPS, 2015; FAO, 2019). According to the UN (2019), it is estimated that around the world an amount of soil equivalent to a football field is lost every 5 seconds and, if the exploitation of this land continues at the current rate, by 2050 more than 90% of the soils of the entire planet Earth will become degraded.

In relation to all the treatments studied (Figure 2), from the data analyzed on the density of the soil analyses, it is possible to identify that in the points referring to the different depths, there were no significant changes and/or differences (*p= 0.0001). Figure 2 shows the variance of soil density (SD), concomitant with the comparison of the values obtained in the three distinct areas (Treatments: Cassava - MN, RL and SAF) of this study, recorded by Tukey's test in all areas of the research. It is observed that SD demonstrates uniformity in the two areas studied (LR and APS), it was found that there were no significant differences between them (p= 0.0001), however with significant variability in relation to the NM treatment (p= 1.0).*

Soil is a dynamic structure, endowed with particles, fluids, gases and liquids, arranged in a certain way that promotes its sustainability and an efficient soil-plant relationship. Therefore, as agricultural practices are adopted, the physical characteristics of the soil are altered, causing an adverse environment for vegetation, this is evidenced when soils in use of agricultural practices are compared with soil still under natural vegetation (ASSIS et al., 2015; BUSKE, 2013; STEFANOSKI et al., 2013).

Figure 2 - Average values for the treatments studied with the physical properties of the soil in the Porto Seguro PDS, Marabá – PA.



Means followed by the same letter in the column do not differ from each other by Tukey's test ($p<0.05$).
Source: prepared by the authors, 2025.

In relation to the area used for agricultural production in the AFS format, there is a greater variation in the analysis of densities, most likely because the soil is at different levels of compaction at each collection point. This compaction happens by managing the soil for planting, involving the removal of organic matter and the green layer, thus causing a drop in the root process that in RL was very visible due to the fact that the soil is in natural or regeneration conditions.

Soil density values vary according to soil type, when classified as sandy clay in inhomogeneous concentrations (STEFANOSKI et al., 2013). The highest concentration of clay soil was also identified in the area of SAF's, which explains the lower density, characteristic of clay soils, as well as the lower presence of roots, since the density value indicates moderate levels of soil compaction (ALVES, 2021).

The constituent material of the soil has a great influence on the density value, as well as the systems of use, management and the type of vegetation cover. In general, soil density values tend to increase with depth, given the reduction in organic matter content, soil aggregation and porosity, as well as due to increased compaction (DE LIMA et al., 2021).

Therefore, the physical structure of the soil is a good indicator of soil quality, because of the changes that management practices cause to it. Thus, a soil maintained under native vegetation has physical factors, such as density, porosity and humidity suitable for the normal development of plants. On the other hand, the soil used for agricultural practices gradually suffers wear and tear, and it is necessary to monitor these properties so that management can be carried out that promotes soil sustainability.

FINAL CONSIDERATIONS

Soil management in the three areas significantly implied the results found. In this sense, the legal reserve area (LR) that was still with vegetation cover while remaining conserved and the area of the agroforestry system (AFS) obtained better results compared to cassava cultivation (MN).

Physical soil characterization is an essential tool to promote sustainable management in rural settlements. The expected results show that the agroforestry system can offer better conditions for maintaining soil quality, while the intensive cultivation of cassava tends to degrade its physical properties. Thus, the adoption of conservation practices and sustainable management techniques is recommended.

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