Evaluation of the physical and chemical quality of the soil in different land uses, Frutal, MG

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ABSTRACT

Soils in areas of agricultural production, in the Cerrado region, when under intense cultivation, can present alterations in the chemical and physical constitution. This work aimed to evaluate the physical and chemical quality of the soil, at different depths in different land use systems (SUT): sorghum, rubber tree, pasture and native Cerrado in the municipality of Frutal-MG. In each SUT area, three samples were collected, at two depths. The design used was completely randomized 4x2, with four cropping systems and two depths, in three areas with the same SUT. The native forest system at a depth of 20-40 cm showed better values for electrical conductivity. For soil moisture the depth 0-20 cm were higher in the pasture, native forest and rubber tree systems, and 20-40 cm was native forest, between the depths the pasture system was greater in 0-20 cm. SUTs pasture showed higher soil density at depth 0-20 cm within and between depths. In the chemical analysis of the soil, regardless of the depth, the native forest has higher acidity. The copper content in the 20-40 cm depth, within the SUTs and depths, is higher for pasture, native forest, and rubber trees. In the sum of the bases within the 0-20 cm depth, the SUTs with the highest value were pasture, native forest and sorghum.

Keywords: Macro and micronutrients, Land use system, Agricultural sustainability.

1 INTRODUCTION

Grain production in Brazil may break records in the 2022/2023 harvest, with production of 312.2 million tons, 40.8 million tons more than in the 2021/22 harvest, representing a 15% increase in production, with the state of Minas Gerais being one of the largest grain producers in the country with an expected increase of 8.5% (CONAB, 2023). On the other hand, the areas destined for pastures have decreased, but productivity has been increasing, reaching 149.7 million hectares (IBGE, 2018).

Planted forests in Brazil extend over about 7 million hectares, and the state of Minas Gerais leads in planted area, with 1.49 million hectares, the main species being: pine, eucalyptus and rubber tree (CNA, 2020). These production areas are mostly located in areas that were originally Cerrado.

These soils, under natural conditions and corrected acidity, reveal favorable conditions for agriculture and livestock through their physical attributes. However, when under intense cultivation, they undergo changes in their chemical constitution (nutrients, organic matter, pH) and physical constitution (texture, structure, density, porosity). Thus, soils submitted to different management systems will tend to a new stable state, which may present a reduction in soil quality (SILVA, 2013; D'ANDRÉA, 2018).

The effects on the physical and chemical attributes of the soil in each management system depend on the type of tillage, the intensity of turning, the traffic of machinery, the types of equipment used, the management of plant residues and the soil moisture conditions at the time of tillage (VIEIRA; MUZILLE, 1995).

In general, the intensity of cultivation with soil turning has been observed by several authors as the main responsible for the increase in soil density and resistance to penetration and reduction of porosity (ALVARENGA; DAVIDE, 2009; D'ANDRÉA, 2018). The degradation of soil structure leads to a reduction in soil quality, consequently reduces plant development and increases the predisposition to accelerated water erosion, leading to loss of organic matter.

With the adoption of the appropriate cultivation system, seeking soil conservation and improvement of the system, conventional cultivation techniques are changed. Among these, the non-turning of the soil is always the first to be adopted. However, the absence of soil turning after several years under conventional management (plowing and harrowing) leads to a greater face-to-face rearrangement of soil mineral particles, resulting in a less favorable condition for cultivation than the conventional system previously adopted, since there will no longer be a mechanical increase in soil porosity due to turning (SANTOS et al., 2018b).

However, depending on the sustainable management practices adopted and the climatic conditions of the site, results are observed that indicate improvements in soil quality in the system after 3 to 4 years of implementation (MATA et al., 2021), such as increased porosity and carbon stock, in addition to reduced soil density and resistance to penetration.

Thus, it is important to continuously monitor these changes in order to produce information that supports interventions in these systems, aiming at improving soil quality with a consequent increase in crop productivity.

The objective of this study was to evaluate the physical and chemical quality of the soil at different depths in different land use systems (SUTs): sorghum, rubber tree, pasture and native Cerrado in the municipality of Frutal-MG.

2 THEORETICAL FRAMEWORK

The study of the variation of soil attributes over time allows us to quantify the magnitude and duration of changes caused by different management systems (SILVEIRA et al., 2011). These attributes are important to establish whether there has been degradation or improvement of soil quality in relation to a given management system (REICHERT et al., 2009).

The physical properties of the soil are of paramount importance due to the fact that they are linked to root growth; storage and supply of water and nutrients, gas exchange, and biological activity (ARSHAD; MARTINS, 2002). With the mechanization of labor in the field, soil compaction has become much more intense due to the fact that the machines have a large mass concentrated in small points (wheels), thus making it necessary to manage the soil with appropriate implements for soil decompaction.

However, agricultural machinery and implements, depending on soil moisture can increase compaction, this is also linked to the type of management and crop to be applied in the area, so it is necessary to study the cultivation environment, indicators and soil attributes.

The main physical indicators that have been used and recommended are texture; thickness (A horizon; solum); soil density; resistance to penetration; porosity; water holding capacity; hydraulic conductivity; and aggregate stability (ARAÚJO et al. 2012).

In the agricultural areas that are used for the first time, the soil has favorable conditions for the cultivation of plant species and presented an excellent production result. With the passage of time and the frequent use of the area, in addition to physical changes, the soil will also present chemical changes, causing productivity to reduce, no longer being interesting for the producer. In order for this not to happen, the owner must alternate crops (crop rotation/succession) so that the nutrients and properties of the soil are not depleted.

Knowledge about the particle size distribution of solid soil particles is essential in several situations, such as in the determination of texture, in studies on compaction and water movement and, consequently, for understanding the erosive processes that involve transport and deposition of particles, including nutrients essential to the development and productivity of plants (SILVA; FILE; ZUCOLOTO, 2011).

Soil attributes influence plant development, such as soil density, texture, porosity and stability of soil aggregates (MONTANARI *et al.,* 2015). The main changes are evidenced by the decrease in gas exchange, the rate of water infiltration into the soil and the increase in penetration resistance (DALCHIAVON *et al.,* 2014). Thus, these attributes can be considered as indicators of soil quality.

To improve the physical, chemical and biological quality of the soil, it is essential to know the damage caused by the different management systems, Soares et al. (2016) report that the inappropriate use of the soil, such as excessive turning or the use of poor conservation practices, can cause an increase in density, a decrease in macroporosity and total porosity, among other damages. Different soil attributes have been employed to characterize the modifications resulting from the adoption of different soil management. The commonly used parameters are soil density and porosity (CARVALHO et al., 2014), soil resistance to penetration (TAVARES et al., 2014), soil moisture (LIMA et al., 2015), nutrient accumulation and organic matter (MARTINS et al., 2015; GOMES et al., 2015), particle density (BATISTA et al., 2017).

3 MATERIALS AND METHODS

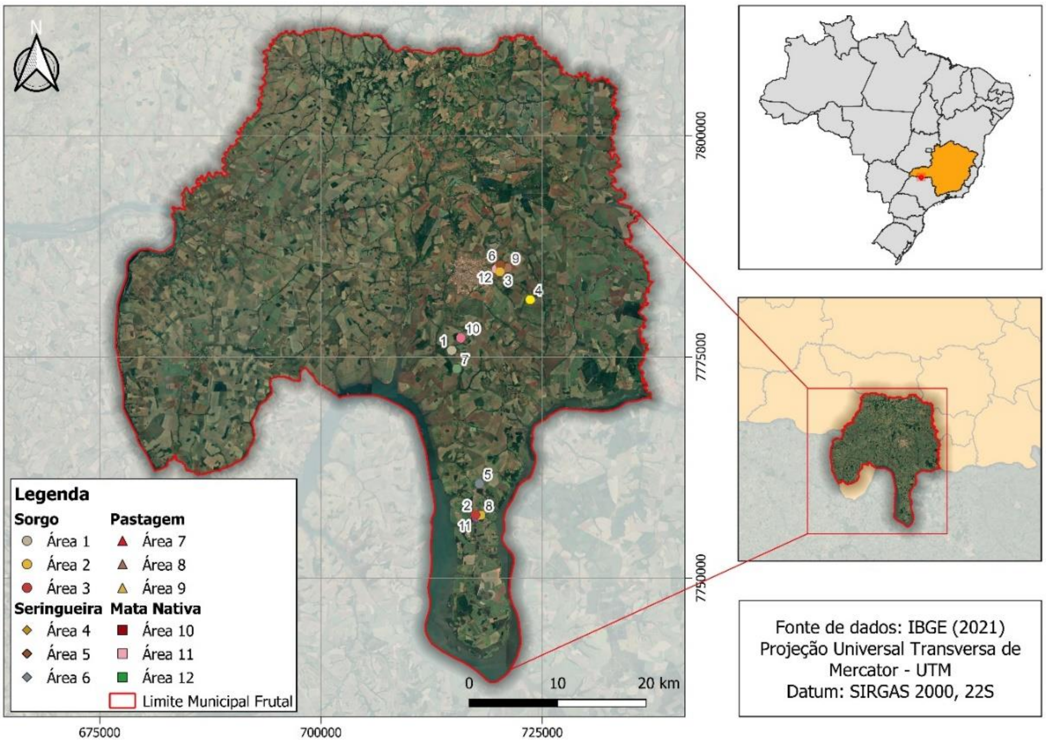
3.1 AREA OF STUDY

The study was carried out in the municipality of Frutal, in the Triângulo Mineiro region of the State of Minas Gerais. The climate of the region is defined as Aw, according to the Köppen-Geiger classification, tropical with the dry and cold season occurring in winter, and summer presents the season with the highest rainfall indices (DUBREUIL et al., 2018), with average annual temperature and precipitation of 23.8ºC and 1626.9 mm, respectively, with precipitation concentrated between the months of November and April.

Samples were collected in four land use systems (SUT): pasture, rubber tree, sorghum and native savannah, totaling 12 areas (Figure 1). Each system had three replicates with areas at least 1.0 km apart. In each replica of the system, a 300 m transect was traced with three equidistant points at 100 m, maintaining a distance of 50 m from the edges of the area.

In the areas, an analysis of the landscape that is occupied in the ecosystem was carried out, where it was verified that it is in the Cerrado biome, convex, low slope and production area without trees and shrubs, with the exception of the legal reserve areas.

Figure 1. Location map of the experimental areas, municipality of Frutal-MG.



Source: Prepared by the authors, 2023.

3.2 CHARACTERIZATION OF LAND USE

The characterization and classification of soils in land use systems followed that proposed by Santos et al. (2018a). The spatial data of the locality were recorded with GPS and processed in the QGIS 3.22.7 software (QGIS Development Team, 2020). The classification of land use cover was carried out using the database of the Annual Project for Land Use and Mapping of the Brazilian MapBiomas - Collection 7, with a collection at a scale of 1:250,000 and the standardized RGB legend (MapBiomas, 2021). The platform is based on Landsat satellites (5-TM, 7-ETM+ and 8-OLI), with a spatial resolution of 30 m.

3.3 EXPERIMENTAL DESIGN

The experimental design was completely randomized (DIC) 4x2, with four cropping systems and two depths, in three areas with the same SUTs, with three replications in each area. Soil samples were collected during the cultivation of the systems, at depths of 0-20 and 20-40 cm. For the collections in each SUT, nine mini-trenches (considered as repetitions) were opened between the rows of each selected management system at random points.

After the collections, the soils were sent to the Soil Physics Laboratory of the State University of Minas Gerais – Fruiting Unit, where it underwent a sieve process to obtain the air-dried fine earth (TFSA), where they were later used for soil physics and chemical analyses. The samples were manually de-disturbed and spread on 180 g m-2 kraft paper trays and placed in a dry and ventilated place, exposed to the sun, until complete air desiccation.

3.4 PHYSICAL CHARACTERIZATION OF THE SOIL

For the determination of soil density (Ds) (g cm-3), by the volumetric ring method, undisturbed samples were collected with a *Uhland* sampler in cylinders with an average volume of 79 cm3 and for particle density (Dp) (g cm-3) the deformed samples were made with the Dutch auger. The total porosity (PT) of the soil was calculated by the soil density/particle density ratio using the formula adapted by the authors: PT = (Ds-Dp)/Ds x 100 (TEIXEIRA et al., 2017).

Following the methodology of the previous author, soil texture was analyzed by the textural triangle, after the separation of the fractions: sand, silt and clay, by means of particle size sieves and symphonization.

Electrical conductivity (EC) and humidity (U) were measured in situ using the *Moisture Probe Meter* (MPM-160-B 12-bit) developed by *ICT International Pty Ltd*.

To determine the soil color of the respective samples, the classical method was used by Munsell®'s Color Chart, in which it is expressed in three components: hue, value and chroma (MUNSELL, 1994).

3.5 CHEMICAL CHARACTERIZATION OF THE SOIL

The pH and organic carbon analyses were performed at the UEMG soil laboratory, where they were performed according to Teixeira et al. (2017). The carbon stock (EstC) was calculated using the expression proposed by Costa et al. (2009): EstC = (COtotal * Ds * e)/10; where: EstC: organic carbon stock in the studied layer (Mg ha-1); COtotal: total organic carbon in the studied layer (g kg-1); Ds: bulk density of the studied layer (kg dm-3); e: thickness of the studied layer (cm). The carbon balance was determined by the formula: BC= (EstCCN - EstC)/TC, where BC: carbon balance (Mg ha-1 year-1); EstCCN: carbon stock of each system studied (Mg ha-1); TC: cultivation time (years).

For the chemical analysis of the soil, potassium (K) was read in the B 262 micronal flame photometer, phosphorus (P) in the Ultraviolet Analytik Jena and calcium (Ca), magnesium (Mg), aluminum (AL), hydrogen (H), zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) in the Atomic Absorption Spectrometer (Perkin-Elmer Corp) and organic matter (MO) following the methodology of Teixeira et al. (2017).

3.6 DATA ANALYSIS

The effect of depth, land use system and system-depth interaction was analyzed by analysis of variance, and qualitative data were evaluated by Tukey's test at the level of 5% probability, using the statistical program SISVAR (FERREIRA, 2009).

4 RESULTS

The soils of the study areas were classified as a typical dystrophic Red Latosol, with dark reddish-brown colors (Table 1).

About the Red Latosol, cropping systems were studied under different land use systems, found in the region, always compared with the reference system, which in this study was considered the characteristic native Cerrado in the region.

Table 1. Staining of soil collection points by Munsell's color chart.

Area	Depth	Cor (Munsell)	Cor Manual tec. IBGE	Color (reference)
Sorghum				
1	0-20 cm	2.5YR 3/3	Dark reddish bruno-brown	🟫
	20-40 cm	2.5YR 3/3	Dark reddish bruno-brown	🟫
2	0-20 cm	2.5YR 2.5/3	Dark reddish bruno-brown	🟫
	20-40 cm	2.5YR 2.5/3	Dark reddish bruno-brown	🟫
3	0-20 cm	2.5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 2,5/4	Dark reddish bruno-brown	🟫
Rubber tree				
4	0-20 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
5	0-20 cm	2,5YR 2,5/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 2,5/4	Dark reddish bruno-brown	🟫
6	0-20 cm	2,5YR 2,5/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
Grass				
7	0-20 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
8	0-20 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 2,5/4	Dark reddish bruno-brown	🟫
9	0-20 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
Native Bushes				
10	0-20 cm	2.5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
11	0-20 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫
12	0-20 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫

	20-40 cm	2,5YR 3/4	Dark reddish bruno-brown	🟫

Legend: Color (Munsell) = Color determined according to the Munsell chart; Color Manual Tec. IBGE = Color described according to IBGE (2015); Color (reference) = colors obtained by RGB.

Source: Prepared by the authors, 2023.

The soil texture in the sorghum, rubber tree and pasture areas was predominantly sandy clay loam, while in the native forest the texture was loam (Table 2). These variations in soil texture in different areas may be related to natural, topographic, or even erosive processes that have occurred over the years (FROZZI et al., 2018). As highlighted by Alifa et al. (2020), this variation indicates a homogeneity in soil pedogenetic processes and their approximation to the source materials.

Table 2. Description of soil texture according to fractionation, at different depths and areas on the cultivation of sorghum, rubber tree, pasture and native forest, municipality of Frutal-MG.

Area	Depth	Medium Sand	Medium Clay	Silte Media	Texture
Sorghum					
	...... cm......		**................................%................................**		
1	0-20	70,4	15,4	14,2	Sandy loam
	20-40	76,1	20,2	3,7	Argyl-sandy loam
2	0-20	63,7	26,8	9,4	Argyl-sandy loam
	20-40	63,0	24,2	12,8	Argyl-sandy loam
3	0-20	42,7	15,9	41,5	Franca
	20-40	47,8	16,5	35,7	Franca
Rubber tree					
4	0-20	75,9	20,4	3,7	Argyl-sandy loam
	20-40	65,1	12,8	22,1	Sandy loam
5	0-20	44,9	18,8	36,3	Franca
	20-40	50,4	19,2	30,3	Argyl-sandy loam
6	0-20	63,2	24,5	12,4	Argyl-sandy loam
	20-40	48,2	19,2	32,5	Franca
Grass					
7	0-20	75,5	20,7	3,8	Argyl-sandy loam
	20-40	42,5	9,3	48,3	Franca
8	0-20	68,2	23,4	8,4	Argyl-sandy loam
	20-40	67,1	25,2	7,7	Argyl-sandy loam
9	0-20	45,0	31,2	23,7	Argyl-sandy loam
	20-40	47,2	29,6	23,2	Argyl-sandy loam
Native Bushes					
10	0-20	64,6	21,7	13,7	Argyl-sandy loam
	20-40	67,6	16,2	16,2	Sandy loam
11	0-20	64,3	16,1	19,7	Sandy loam
	20-40	49,5	17,2	33,3	Franca
12	0-20	48,7	19,6	31,7	Franca
	20-40	50,4	17,8	31,8	Franca

Source: Prepared by the authors, 2023.

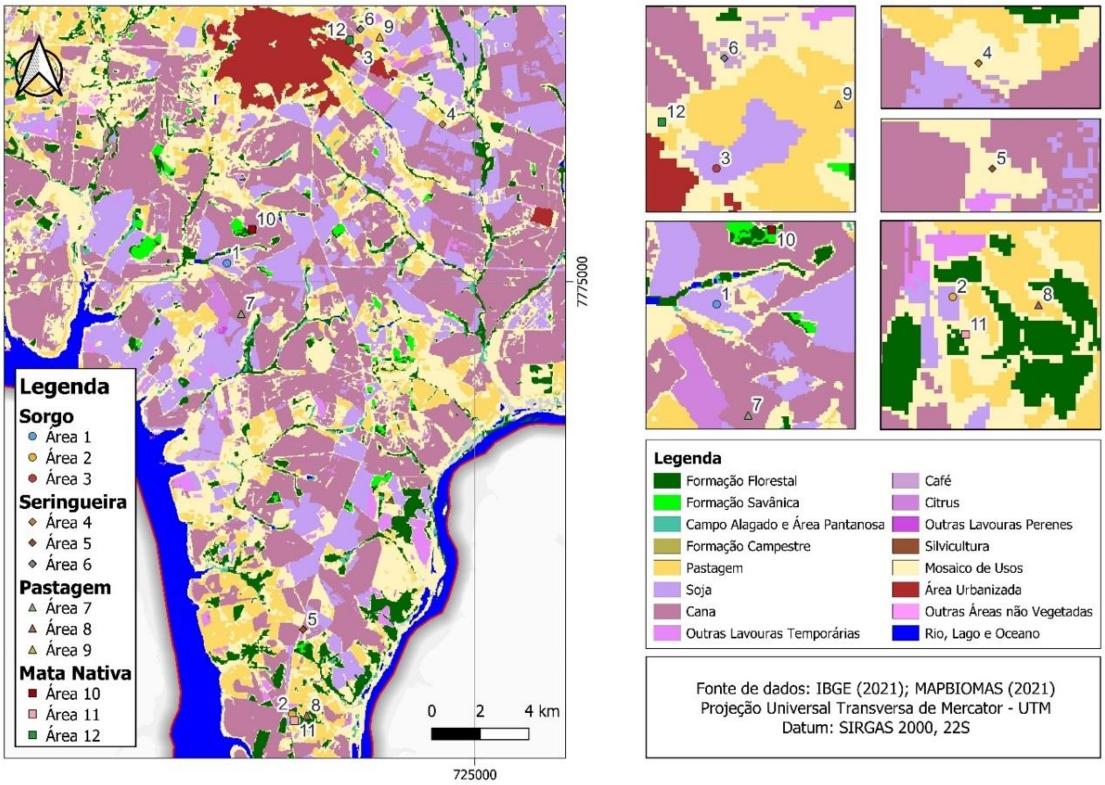
Figure 2 shows the map of land use and occupation, areas 1, 2 and 3, the occupation is soybean (eudicot), however the three SUTs met with the sorghum crop, being also an annual crop, however a monocot. In areas 4, 5 and 6 with occupation mosaic of uses (cultivated vegetation), being rubber tree SUTs, considered a cultivated vegetation.

For area 7 with sugarcane, 8 and 9 with pasture, all three having a pasture SUTs, as much as sugarcane and pastures are monocots, their size and management and cultivation system are very different. And areas 10 savannah formation (Cerrado biome), 11 and 12 use mosaic (Cerrado biome), these with SUTs Native Forest (Cerrado biome).

Although the images were taken in the same year of the study, there are divergent readings between the land use and occupation map with the on-site collection of the SUTs, where this is due to the crop rotation/succession and area renewal, since the survey soil collection may have occurred in different months from the image collected.

However, it is verified that the soils of the cultivated areas in use and occupied are suitable for the growth and development of crops.

Figure 2. Location map of the experimental areas, municipality of Frutal-MG.



Source: Prepared by the authors, 2023.

The physical properties of the soil are of paramount importance because they are linked to root growth, storage and supply of water and nutrients, gas exchange and biological activity (ARSHAD; MARTINS, 2002).

There was no significant difference for the variables particle density and soil porosity between SUTs and depths (Table 3). However, differences were observed for electrical conductivity (EC), moisture (U) and soil density (SD) (Table 3).

For the EC variable at the depth of 20-40 cm, the native forest presented the highest value. The decomposition of organic compounds present in the soil results in the release of organic salts into the soil, which may explain this result. Electrical conductivity (EC) is used to measure, by means of electric current, the amount of salts present in the soil solution, and the greater the amount of salts present in the solution, the higher the EC value obtained (BRANDÃO; LIMA, 2002).

Regardless of the ions present, excessive accumulation of salts in the root zone of plants can impair plant germination, development, and productivity. This accumulation causes the plant to expend more energy to be able to absorb water (due to the osmotic effect), impairing its essential metabolic processes (MAIA, 2017). It is important to note that each plant species has a maximum level of tolerance to excess salts.

Analyzing soil moisture at depth 0-20 cm, the SUTs with the highest values were native forest, pasture and rubber tree, and at depths 20-40 cm was native forest. When checking the humidity at the different depths in each SUT, it was found that pasture has the highest humidity in the 0-20 cm layer. Among the systems, the humidity showed higher values in the native forest, this can be justified by the existence of litter covering the surface layer of the soil, which helps to maintain moisture, in addition, it helps to increase the rates of organic matter over time, thus retaining greater moisture (GONÇALO FILHO et al., 2018).

For SD, higher values were observed for pasture, rubber and sorghum at the depth of 0-20 cm. When comparing the depths in the pasture system, the greatest increase was in the 0-20 cm layer. Through the statistical analysis, it was possible to demonstrate that the native forest areas expressed lower SD, pointing out that the existence of vegetation and soil cover helped in the increase of humidity, causing a decrease in density, certainly due to the greater contribution of organic matter.

It is important to highlight that higher SD values demonstrate that the area is compacted and, according to Mioto et al. (2020), the compaction process is one of the fundamental reasons for soil degradation. Similar results were found by Custódio et al. (2015) and Bezerra et al. (2019) in pasture areas, where there was an increase in SD when compared to native forest and other systems. Compaction in pasture is associated with the topmost layer of the soil, however, it is not even considered a limiting factor for plant development (BONETTI et al., 2015).

According to Kiehl (1979), the larger the SD, the smaller its physical structure will be and in general less permeable, in which it may present limitations for the growth and development of plants.

Table 3. Average values of physical attributes in pasture, native forest, rubber tree and sorghum systems in the municipality of Frutal-MG.

Cultivation systems	**CE1**		**U1**		**DP1**		**DS1**		**PO1**	
	.... mv........		**........% ....**		**................ g cm^{-3}................**				**.........%.........**	
	.. Depth (cm)									
	0-20	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**	**0-20**	**20-40**
Grass	175,67aA	153,00bA	3,07aA	1,86bB	2,95	2,62	3.17abA	2.40aB	39,56	47,66
Native Bushes	216,56aA	235,78aA	4,81aA	4,97aA	2,66	2,56	2,52bA	2,70aA	36,02	36,84
Rubber tree	192,75aA	188,80bA	3,16aA	3,21bA	2,59	2,76	2.74abA	2,60aA	39,15	37,94
Sorghum	191,22aA	192,44bA	2,98bA	2,89bA	2,80	2,81	2.85abA	2,75aA	35,87	31,07
CV (%)	17,32		37,26		19,90		18,73		14,94	
Causes of variation	Fc									
SUTs.	10,36**		0,79ns		0,51ns		0,61ns		1,35ns	
Prof.	0,05ns		12,55**		0,20ns		3,02ns		0,04ns	
SUTs. X Prof.	1,20ns		1,15ns		0,66ns		2,76*		0,59ns	
Prof. X SUTs.	1,20ns		1,15ns		0,66ns		2,76**		0,59ns	

[1]Means compared in the columns (lowercase letters) and row (uppercase letters) with the same letter do not differ from each other, by Tukey's test, at the level of 5% probability. * and ** significant at 5 and 1% probability, respectively. ns – not significant. CV – Coefficient of variation. Prof. – Depth; SUTs - System.

Source: Prepared by the authors, 2023.

In the variables in Table 4, there is a significant difference for pH, SB and Cu. For pH, the crops do not differ from each other, but all differ from the Native Forest (NM), because in crops of economic interest, there is alkalinization of the soil through the mechanical application of lime and gypsum; Looking at the depths, there is not a significant difference between them. However, there is a difference between each depth when comparing the SUTs at the depth 0-20 cm, the highest values were found for rubber trees, with a pH of 5.98. At a depth of 20-40 cm, pasture, rubber tree and sorghum had a pH of 5.63; 5.56 and 5.11, respectively.

In general, in the most superficial layer (0-20 cm) the areas of agricultural cultivation obtained higher pH values, this fact can be justified as highlighted by Oliveira et al. (2001) due to the soil being subjected to deep plowing with greater turnover, thus bringing a higher concentration of bases to the surface.

For the variable Copper (Cu), there is a difference within the depth of 20-40 cm in the SUT, with higher values for pasture, native forest and rubber tree, while among the depths there are higher values at the depth of 20-40 cm in native forest. This is evident that SUTs are able to modify the amount of this element in the soil. This behavior differs from the study carried out by Silva et al. (2016), where the concentration of Cu was higher in cultivated soils than in areas with natural vegetation, however the author corroborates when he found that Cu increased at greater soil depths.

Regarding the sum of the bases (SB), there was a significant difference in depth of 0-20 cm between the SUTs, with higher values for the pasture, native forest and sorghum systems. It is justified that at this depth these SUTs presented lower amounts of Ca, Mg and K in the soil. Carvalho et al. (2002) and Bernadi, Rassani and Ferreira (2012) point out that the values of BS in most Oxisols are generally low in the deeper layers, when comparing the superficial layers. The authors' statement is confirmed in this study, since at the depth of 20-40 cm, the BS values were lower than those found at the depth of 0-20 cm.

To improve the physicochemical quality of the soil, it is essential to know the damage caused by the different management systems, Soares et al. (2016) report that the inappropriate use of the soil, such as excessive turning or the use of poor conservation practices, can cause an increase in density, a decrease in macroporosity, total porosity, alteration in the amount of minerals in the soil, among other damages.

The study of the variation of soil physical and chemical attributes over time allows us to quantify the magnitude and duration of changes caused by different management systems (SILVEIRA et al., 2011). These attributes are important to establish whether there has been degradation or improvement in soil quality in relation to a given management system (REICHERT et al., 2019).

Table 4. Average values of the chemical attributes of the soils pasture, native forest, rubber tree and sorghum systems at different depths, in the municipality of Frutal-MG.

ATRIBUTO S1	CV (%)	.... LAND USE SYSTEMS – SUTs								FV		
		Grass		Native Bushes		Rubber tree		Sorghum		Fc		
		.... Depth (cm)...										
		0-20	20-40	0-20	20-40	0-20	20-40	0-20	20-40	Prof	SUTs	Prof X SUTs
pH (H_2O)	11,13	5,53bA	5,63aA	4,43bA	4,78bA	5,98aA	5,56aA	5,55bA	5.11abA	0,54ns	$13,34^{**}$	1,98ns
MO (g dm^{-3})	17,54	4,52aA	13,98aA	5,58aA	16,74aA	13,19aA	10,67aA	8,92aA	7,32aA	1,38ns	0,25ns	1,04ns
P (mg dm^{-3})	303,52	8,16aA	26,43aA	3,91aA	19,43aA	6,79aA	4,09aA	9,32aA	3,55aA	0,70ns	0,17ns	0,74ns
K ($mmol_c$ dm^{-3})	128,39	2,15aA	2,60aA	1,31aA	1,94aA	1,19aA	1,07aA	1,67aA	1,58aA	0,14ns	1,02ns	0,15ns
Ca ($mmol_c$ dm^{-3})	93,61	22,33aA	11,95aA	10,37aA	9,61aA	8,14aA	10,56aA	12,54aA	11,41aA	0,96ns	1,70ns	1,02ns
Mg ($mmol_c$ dm^{-3})	76,00	4,33aA	2,99aA	3,18aA	2,87aA	2,51aA	4,66aA	2,91aA	2,54aA	0,01ns	0,67ns	1,59ns
Al ($mmol_c$ dm^{-3})	105,00	0,83aA	3,06aA	3,72aA	3,33aA	3,75aA	4,50aA	3,00aA	3,89aA	1,28ns	1,35ns	0,39ns
H+Al ($mmol_c$ dm^{-3})	41,77	13,44aA	13,56aA	20,56aA	19,33aA	17,38aA	18,90aA	17,22aA	15,89aA	0,01ns	2,67ns	0,16ns
COrg (g dm^{-3})	17,66	4,43aA	6,40aA	5,56aA	5,51aA	3,45aA	6,75aA	3,08aA	5,28aA	2,54ns	0,28ns	0,36ns
SB ($cmol_c$ dm^{-3})	76,70	28,80aA	17,54aA	14.86abA	14,42aA	11,84bA	16,29aA	17.11abA	15,53aA	0,59ns	$1,79^{*}$	1,10ns
T ($cmol_c$ dm^{-3})	55,22	29,64aA	20,59aA	18,58aA	17,75aA	15,59aA	20,79aA	20,11aA	19,42aA	0,31ns	1,48ns	1,98ns
T ($mmol_c$ dm^{-3})	39,50	42,25aA	31,09aA	35,42aA	33,75aA	29,24aA	35,19aA	34,34aA	31,42aA	0,64ns	0,36ns	1,19ns
V (%)	53,08	64,00aA	55,59aA	34,14aA	39,39aA	40,76aA	42,28aA	45,10aA	43,48aA	0,02ns	$2,98^{*}$	0,27ns
M (%)	109,61	4,68aA	23,46aA	35,70aA	26,28aA	29,99aA	28,40aA	23,12aA	33,41aA	0,51ns	1,38ns	0,88ns
Zn (mg dm^{-3})	85,33	0,27aA	0,30aA	0,25aA	0,16aA	0,31aA	0,21aA	0,24aA	0,28aA	0,42ns	0,46ns	0,64ns
Cu (mg dm^{-3})	84,82	0,18aA	0.17abA	0.19aB	0,36aA	0,14aA	0.17abA	0,16aA	0,15bA	1,39ns	$2,19^{*}$	$1,38^{*}$
Fe (mg dm^{-3})	35,87	105,06aA	112,71aA	127,96aA	105,24aA	127,33aA	103,36aA	113,52aA	122,32aA	0,17ns	0,60ns	0,89ns

Mn (mg dm^{-3})	54,31	2,03aA	1,83aA	2,14aA	1,80aA	1,17aA	1,76aA	1,98aA	1,59aA	0,15ns	0,90ns	0,94ns
EstC (Mg ha^{-1})	13,74	15,15aA	17,35aA	13,48aA	13,48aA	9,04aA	17,92aA	9,60aA	16,01aA	1,63ns	0,20ns	0,34ns

[1]Means compared with lowercase letters on the line at the same depths between the SUTs, uppercase letter on the same line between the depths in each SUTs, do not differ from each other, by Tukey's test, at the level of 5% probability. * and ** significant at 5 and 1% probability, respectively. ns – not significant. Fc – F calculated. CV – Coefficient of variation. Prof. – Depth.

Source: Prepared by the authors, 2023.

5 CONCLUSION

The soil class was a typical dystrophic Red Latosol with dark reddish haze, and the predominant texture in the areas of sorghum, rubber tree and pasture was sandy clay loam, and loam texture for native forest.

The native forest system at a depth of 20-40 cm showed better values for electrical conductivity. For soil moisture, the depth 0-20 cm was greater in the pasture, native forest and rubber tree systems and 20-40 cm was native forest, among the depths the pasture system was greater in 0-20 cm. The pasture SUTs showed higher soil density at the depth 0-20 cm within and between the depths.

In the chemical analysis of the soil, regardless of the depth, the native forest presents higher acidity. The copper content at the depth of 20-40 cm, within the SUTs and depths, is higher for pasture, native forest and rubber trees. In the sum of the bases within the depth 0-20 cm, the SUTs with the highest value were pasture, native forest and sorghum.

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REFERENCES

ALIFA, M.; CLAUTILDE, M.; CHRISTOPHE, H. L.; KESEL, R.; OUMAR, O. M. Restoration of soil physical parameters by an ecological Revitalization Technology (ReviTec) in Maroua, Far North Region, Cameroon. International Journal Advanced Research in Bioliological Sciences, v.7, n.3, p.139-151, 2020.

ALVARENGA, M. I. N.; DAVIDE, A. C. Características físicas e químicas de um Latossolo Vermelho – Escuro e a sustentabilidade de agroecossistemas. Revista Brasileira de Ciências do Solo, Viçosa, v. 23, n. 4, p. 933 – 942. 2009.

ARAÚJO, E. A. KER, J. C.; NEVES, J. C. L.; LANI, J. L. Qualidade do solo: conceitos, indicadores e avaliação. Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias, Guarapuava-PR, ano 12, v. 5, n. 1, ed. 1, p. 187-206, 2012.

ARSHAD, M.A.; MARTIN, S. Identifying critical limits for soil quality indicators in agro-ecosystems. Agriculture, Ecosystems and Environment, v.88, n.2, p.153-160, 2002.

BATISTA, P. H. D.; ALMEIDA, G. L. P.; TAVARES, U. E.; NASCIMENTO, V. N.; SARMENTO, R. M. Variabilidade espacial de atributos físicos do solo sob colheita mecanizada de capim-buffel no agreste Pernambucano. Enegenharia na Agricultura, v. 25, n. 4, p. 307-317, 2017.

BEZERRA, C. B.; SOUZA JUNIOR, A. J.; CORRÊA, M. M.; LIMA, J. R. S.; SANTORO, K. R.; SOUZA, E. S.; OLIVEIRA, C. L. Latossolo húmico sob pastagem com diferentes intensidades de usos: atributos químicos e físico-hídricos. Revista Brasileira de Ciências Agrárias, Recife, v. 14, n. 1, p. 1-9, 2019.

BERNARDI, A. C. C.; RASSINI, J. B.; FERREIRA, R. P. Teores de potássio no solo, estado nutricional e produção de matéria seca de alfafa em função de doses e frequência da adubação potássica após dois anos de cultivo. São Carlos, SP: Embrapa Pecuária Sudeste, 2012. 25 p. (Embrapa Pecuária Sudeste. Boletim de Pesquisa e Desenvolvimento, 33). Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/72342/1/PROCI-2012.00195.pdf. Acesso em: 13 fev. 2023.

BONETTI, J. D. A.; PAULINO, H. B.; SOUZA, E. D. D.; CARNEIRO, M. A. C.; SILVA, G. N. D. Influência do sistema integrado de produção agropecuária no solo e na produtividade de soja e braquiária. Pesquisa Agropecuária Tropical, Goiânia, v. 45, n. 1, p. 104-112, 2015.

BRANDÃO, S. L.; LIMA, S. C. pH e condutividade elétrica em solução do solo, em áreas de pinus e cerrado na Chapada, em Uberlândia (MG). Caminhos de Geografia, v. 3, n. 6, p. 46-56, 2002.

CARVALHO, L. A.; NOVAES, L. P.; MARTINS, C. E.; ZOCCAL, R.; MOREIRA, P.; RIBEIRO, A. C. C.; LIMA, V. M. Sistema de produção de leite (cerrado). 2002. Disponível em: http://sistemasdeproducao.cnptia.embrapa.br/FontesHTML/Leite/LeiteCerrado/introducao.html. Acesso em: 13 fev. 2023.

CARVALHO, M. A.; RUIZ, H. A.; COSTA, L. M.; PASSOS, R. R.; ARAUJO, C. A. S. Composição granulométrica, densidade e porosidade de agregados de Latossolo Vermelho sob duas coberturas do solo. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, PB, v.18, n.10, p.1010-1016, 2014.

Confederação da Agricultura e Pecuária do Brasil (CNA). O Brasil é um dos maiores produtores de Florestas Plantadas do mundo. Brasília: CNA Brasil. 2020. Disponível em:

https://www.cnabrasil.org.br/noticias/o-brasil-e-um-dos-maiores-produtores-de-florestas-plantadas-do-mundo. Acesso em: 21 out. 2021.

Companhia Nacional de Abastecimento (CONAB). Levantamento da Safra de Grãos 2022/2023. Brasília: Conab. v.1, n.1. 2023.

CUSTÓDIO, G. D.; RIBON, A. A.; FERNANDES, K. L.; HERMÓGENES, V. T. L.; BARROS, L. R. Densidade do solo e densidade relativa-indicadores da qualidade física de um latossolo amarelo sob diferentes manejos de pastagens e mata nativa. Campo Digital, v. 10, n. 1, p. 50-62, 2015.

D'ANDRÉA, A. F. Atributos indicadores da qualidade do solo em sistema de manejo no Sul de Goiás. 2018. Dissertação (Mestrado em Solos e Nutrição de Plantas). Universidade Federal de Lavras, Lavras – MG.

DALCHIAVON, F. C.; CARVALHO, M. P.; MONTANARI, R.; ANDREOTTI, M.; BEM, E. A. D. Inter-relações da produtividade de cana soca com a resistência à penetração, umidade e matéria orgânica do solo. Revista Ceres. v.2, p.255-264. 2014.

DUBREUIL, V.; FANTE, K. P.; PLANCHON, O.; SANT'ANNA NETO, J. L. Os tipos de climas anuais no Brasil: uma aplicação da classificação de köppen de 1961 a 2015. Confins, *[S. l.]*, n. 37, p. 1-20, 2018.

FERREIRA, D. F. SISVAR Sistema para análise de variância. Lavras: Universidade Federal de Lavras (Departamento de Ciências Exatas DEX), (CD-ROM). 2009.

FROZZI, J. C.; BERGAMIN, A. C.; CUNHA, J. M.; CAMPOS, M. C. C.; LIMA, A. F. L.; BRITO, W. B. M.; LOURENÇO, I. H.; SILVA, W. L. M. Atributos do solo e dimensão fractal em ambientes naturais e transformados na região amazônica. Revista Ibero Americana de Ciências Ambientais, v. 9, n.2, p. 231-243, 2018.

GOMES, R. L. R.; SILVA, M. C.; COSTA, F. R.; JUNIOR, A. F.L.; OLIVEIRA, I. P.; SILVA, D. B. Propriedades físicas e teor de matéria orgânica do solo sob diferentes coberturas vegetais. Revista Eletrônica Faculdade Montes Belos, v. 9, n. 1, 2015.

GONÇALO FILHO, F.; FERREIRA NETO, M.; FERNANDES, C. S.; DIAS, N. S.; CUNHA, R. R.; MESQUITA, F. O. Efeitos do manejo sustentável da Caatinga sob os atributos físicos do solo. Pesquisa Florestal Brasileira, Colombo, v. 38, p. 1-5, 2018.

IBGE - Instituto Brasileiro de Geografia e Estatística. Censo agropecuário: resultados preliminares 2017. Rio de Janeiro: IBGE. v.7. 2018.

KIEHL, E. J. Manual de edafologia: Relações solo-planta. São Paulo-SP, Ceres, 1979. 262p.

LIMA, R.P.; SILVA, A.R.; OLIVEIRA, D.M.S. Análise de trilha de atributos físicos na resistência à penetração de um latossolo amarelo. Revista de Agricultura Neotropical, Cassilândia, MS, v.1, n.1, p.65-74, 2015.

MAIA, P. M. E. Cultivo de hortaliças em substrato de fibra de coco sob estresse salino e aplicação foliar de ácido ascórbico. 2017. 96 p.

MARTINS, E. C. A.; PELUZIO, J. M.; DE OLIVEIRA JUNIOR, W. P.; TSAI, S. M.,NAVARRETE, A. A.; MORAIS, P. B. Alterações dos atributos físico-químicos da camada superficial do solo em resposta à agricultura com soja na várzea do Tocantins. Biota Amazônia, v. 5, n. 4, p. 56-62, 2015.

MATA, J. F.; MAGALHÃES, J. C. S.; SIEBENEICHLER, S. C.; SILVA, R. R.; PEREIRA, M. A. B.; MARTINS, H. L. Urochloa brizantha E Andropogon gayanus em monocultivo e consórcio sob diferentes níveis de adubação. Desafios - Revista Interdisciplinar da Universidade Federal do Tocantins, Palmas, v. 8, n. 3), p. 22–29, 2021.

MIOTO, L. S.; ARAÚJO, M. A.; SERON, C. C.; LAVANHOLI, R.; BATISTA, M. A.; USHIWATA, S. Y. Resistência mecânica do solo à penetração avaliada em área de segundo ano de implantação da cultura da mandioca (Manihot esculenta CRANTZ). Revista Brazilian Journal of Development, v. 6, n. 1, p. 4601-4620, 2020.

MONTANARI, R.; CARVALHO M. P.; ANDREOTTI M.; DALCHIAVON, F. C.; LOVERA L. H.; HONORATO; M. A. O. Variabilidade espacial da produtividade de sorgo e de atributos do solo na região do ecótono Cerrado - Pantanal, MS. Revista Brasileira de Ciência do Solo. v. 39, p. 385-396. 2015.

MUNSELL, A. H. Munsell soil color charts. New Windsor, 1994. Revised edition.

Projeto MapBiomas – Coleção 7 da Série Annual de Mapas da Cobertura e Uso do Solo do Brasil. Disponível em: https://storage.googleapis.com/mapbiomas-public/brasil/collection-6/lclu/coverage/brasil_coverage_2021.tif. Acesso em: 9 jan. 2023.

QGIS Development Team. QGIS Geographic Information System. Open Source Geospatial Foundation Project. 2020. http://qgis.osgeo.org.

OLIVEIRA, I. P.; KLUTHCOUSKI, J.; SANTOS, R. S. M.; FANCELLI, A. L.; DOURADO NETO, D.; FARIA, C. D. Concentrações residuais de cobre, ferro, manganês e zinco em latossolo roxo eutrófico sob diferentes tipos de manejo. Pesquisa Agropecuária Tropical, Goiânia, v. 31, n. 2, p. 97-103, 2001.

REICHERT, J. M.; KAISER, D. R.; REINERT, D. J.; RIQUELME, U. F. B. Variação temporal de propriedades físicas do solo e crescimento radicular de feijoeiro em quatro sistemas de manejo. Pesquisa Agropecuária Brasileira, v.44, n.3, p.310-309, 2009.

SANTOS, H. G.; JACOMINE, P. K. T.; ANJOS, L. H. C.; OLIVEIRA, V. A.; LUMBRERAS, J. F.; COELHO, M. R.; ALMEIDA, J. A.; ARAUJO FILHO, J. C.; OLIVEIRA, J. B.; CUNHA, T. J. F. Sistema Brasileiro de Classificação de Solos. Brasília: Embrapa. 5. ed. 2018a. 356 p.

SANTOS, R. A.; SILVA, S. M. C.; CARNEIRO, V. A.; OLIVEIRA, A. L. R.; MILHOMEM, A. V. Sistema de Plantio direto: conservação e manutenção da capacidade produtiva dos solos do Cerrado Goiano. Revista Sapiência: Sociedade, Saberes e Práticas Educacionais, Iporá, v. 7, n. 2, p. 230 – 255, jan./jul. 2018b.

SILVA, L. S.; GALINDO, I. C. L.; NASCIMENTO, C. W. A.; GOMES, R. P.; CAMPOS, M. C. C.; FREITAS, L.; OLIVEIRA, I. A. Heavy metal contents in Latosols cultivated with vegetable crops. Pesquisa Agropecuária Tropical, Goiânia, v. 46, n. 4, p. 391-400, 2016.

SILVA, R. R. Qualidade do solo avaliada através dos atributos físicos em sistemas de manejo na região Campos das Vertentes, Bacia do Alto do Rio Grande – MG. Lavras, UFLA, 2013. Cap. 2, p. 39. Dissertação (Mestrado em Solos e Nutrição de Plantas).

SILVA, S. A.; LIMA, J. S. S.; ZUCOLOTO, M. Distribuição espacial das frações granulométricas em um Latossolo Vermelho amarelo utilizando krigagem indicativa. Engenharia na Agricultura, Viçosa, v. 19, n. 3, p. 195-202, 2011.

SILVEIRA, P. M.; SILVA, J. H.; LOBO JUNIOR, M.; CUNHA, P. C. R. Atributos do solo e produtividade do milho e do feijoeiro irrigado sob sistema integração lavoura-pecuária. Pesquisa Agropecuária Brasileira, v.46, n.10, p.1170-1175, 2011.

SOARES, M. D. R.; CAMPOS, M. C. C.; OLIVEIRA, I. A.; CUNHA, J. M.; SANTOS, L. A. C.; FONSECA, J. S.; SOUZA, Z. M. Atributos físicos do solo em áreas sob diferentes sistemas de usos na região de Manicoré, AM. Revista de Ciências Agrárias, v. 59, n. 1, p.9-15, 2016.

TAVARES, U. E.; MONTENEGRO, A. A. A.; ROLIM, M. M.; SILVA, J. S. S.; VICENTE,T. F. S.; ANDRADE, C. W. L. Variabilidade espacial da resistência à penetração e da umidade do solo em Neossolo Flúvico. Water Resources and Irrigation Management, Cruz das Almas, BA, v.3, n.2, p.79-89, 2014.

TEIXEIRA, P. C.; DONAGEMMA, G. K.; FONTANA, A.; TEIXEIRA, W. G. (ed.). Manual de métodos de análise de solo. 3. ed. rev. e ampl. Brasília, DF: Embrapa, 2017. 574 p.

VIEIRA, M. J.; MUZILLI, O. Características físicas de um Latossolo Vermelho – Escuro sob diferentes sistemas de manejo. Pesquisa Agropecuária Brasileira, Brasília, v. 19, n.7, p. 873 – 882, jul. 1995.