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Abstract

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1. Introduction

The quality of the soil is variable to its formation, textural composition and type of adopted management, which determines its behaviour against some anthropic activity. According to [1], there are some diagnostic attributes that classify the types of existing soils, including organic material, mineral material (inorganic compounds), clay fraction activity, capacity to exchange cations, saturation of bases, silt: sand ratio, textural grouping and skeletal constitution of the soil, among others.

Oxisols are developed under hot and humid tropical environments, characterized by intense and long-lasting weathering. These environments can provide nutrient deficiency and a relatively uniform texture throughout the profile. Oxisols make up the largest geographic area of Brazil, occupying around 300 million hectares [2]. Their wide distribution typically occurs in flattened to smooth undulating reliefs; a small fraction of these soils occur in mountainous reliefs [3]. They are considered soils of more complex management for agriculture due to their low nutrient content. As such, technological advances are necessary, as is the use of correctives and fertilizers. When using these processes, understanding the behaviour of the physical and chemical properties of the soil is crucial. These soils are also present at great depth, friability, porosity and good internal drainage, allowing for mechanization and irrigation [4]. These soils are composed of mineral materials, featuring oxic B horizon, which is preceded by any type of horizon A within 200 cm from the soil surface or within 300 cm if the horizon A features more than 150 cm thick [1].

After Oxisols, Ultisols are the most extensive order among the Brazilian soils, making them particularly important. They cover a huge range of soils, with high and low nutrient contents (eutrophic, dystrophic, alic and aluminium), shallow to very deep depths, abrupt or not, with or without gravel and with fragipan and/or solodic character. This large range makes it difficult for a generalized appreciation for the soils of this order [3], as they form a very heterogeneous class, presenting a marked differentiation in depth due to the accumulation of low or high activity clay. This clay is conjugated with low base saturation or with aluminium character in most of the horizon B [3], [1].

Ultisols mainly occur associated with the Oxisols, since they also grow under humid tropical environmental conditions. The occurrence relief is also variable from mountainous to soft wavy soil. The susceptibility of Ultisols to erosion is aggravated when the texture of the surface horizon is sandy. Most of the Ultisol are acidic and nutrient-poor, requiring adequate use of correctives and fertilizers in order to adequately develop agriculture [2].

The understanding of the physical behaviour of a soil is of utmost importance because it guides the appropriate activities that must be performed in the system in order to reach an adequate development of the cultures. This diagnosis involves textural composition, particle and pore arrangement, soil bulk density, aggregation structure, mechanical penetration resistance, soil water infiltration and water availability to plants [5]. This study aimed to understand the attributions and limitations of two types of highly weathered soils in the extreme west of São Paulo, as well as the additional factors associated with the resilience of the studied areas, their physical attributes and soil organic matter.

2. Material and Methods

2.1 Experimental site

The experiment was developed in the extreme west region of São Paulo, in the municipality of Dracena (SP) (21° 28' 57" S and 51°31'58" W), with an average altitude of 400 m. The climate is type Aw (tropical humid), classified according to [6], with average temperature of 22.1°C and average annual precipitation of 1.200 mm. Soil samples are shown in Figure 1.

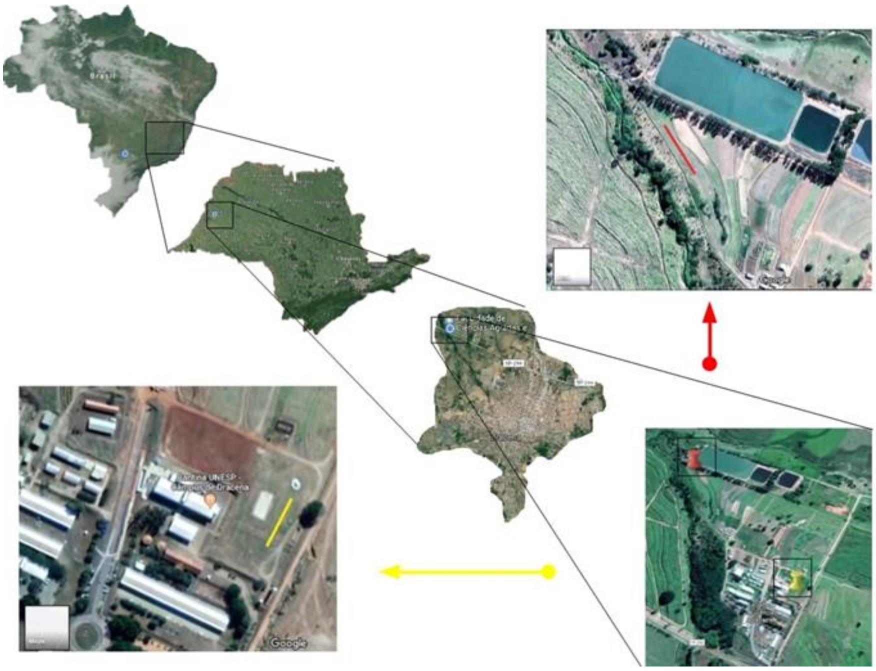

Figure 1. Experimental field in Dracena (SP). Image of the study area of the Oxisol (yellow pin and yellow arrow) and the Ultisol (red pin and red arrow) sampling sites. Source: Google Maps (2018).

The studied areas were uncultivated for at least 14 years and only covered by spontaneous undergrowth.

2.2 Experimental design

The experimental design was completely randomized, consisting two different soil treatments: Red-Yellow Oxisol and one Red-Yellow Ultisol at three depth ranges: 0.00-0.10, 0.10-0.20 and 0.20-0.40 m with 10 replicates. The analyses per plot were done in triplicate.

2.3 Evaluations of the attributes of the soil

Soil texture: the collected samples were submitted to a particle size analysis to quantify of the distribution of the size of the individual soil particles, according to the methodology of [7]. This methodology focuses on the mechanical dispersion and stabilization of the sample by means of a Wagner shaker in a suitable dispersing solution. This step is followed by separation of the fractions through sieving and sedimentation. Then, the fraction measurements are separated by weighing after oven drying (standard method).

Volumetric and gravimetric humidity: direct methods consist of the direct measurement of the water content of a sample by means of its removal. The gravimetric humidity method is standard, presenting good accuracy and a relatively low cost. This method consists of drying a sample in an oven at a temperature of 110 ± 5 ºC, for a period of 24 hours [8], [9], [10].

The mass of water present in the sample was obtained through calculating the difference. The undeformed samples for determination of soil density were treated in the same manner as described for the deformed samples. For the moisture-gravimetric and volumetric determinations, we used the procedure described by [7].

Infiltration of water in the soil: the samples for analysis were determined with the aid of a mini-disk tension infiltrometer [11]. The procedure was started by filling the equipment with water. The equipment was then placed in contact with the soil surface. The equipment readings were carried out to verify the amount of water lost during 30 second intervals; readings were taken with at least three constant readings. Subsequently, the values were organized and equated to obtain concrete values [12].

Soil density: undisturbed samples were collected with 100 cm^3 volumetric rings embedded in the three layers of soil (0-0.10, 0.10-0.20 and 0.20-0.40 m) with the aid of an extractor and a hammer. The toilette was placed in the samples so that the collected soil volume was equal to the volume of the ring used. The samples were taken to a greenhouse (105 °C) until a constant mass was obtained. The soil density is expressed in $g.cm^{-3}$[7].

Soil porosity (macroporosity, microporosity and total): the total porosity was determined by the saturation of the soil (total pore volume of the soil occupied by water). The macroporosity was determined by the tensile table method with a water column of 0.060 kPa. Microporosity was calculated as the difference between total porosity and macroporosity, according to [7].

Distribution and stability of aggregates: the distribution and stability of aggregates in water; The weighted average diameter of the aggregates was determined by the method of [13].

Penetration resistance and soil moisture: the mechanical resistance to penetration was performed by the PenetroLOG Falker model at different points of data collection. Soil samples for soil moisture analysis were collected along with the penetration resistance, in accordance with the method of classical weighing [7]. Organic matter content: was determined by the colorimetric method using the methodology proposed by [14].

2.4 Data analysis

The data were subjected to analysis of variance by F test, at $p \leqslant 0.05$. When significant, the parameters were submitted to the Tukey test ($p < 0.05$). All statistical analyses of the data were performed using routines developed in the software R, [15].

3. Results and Discussion

Texture is a key indicator of the quality and productivity of soils, interfering with the dynamics of adhesion and cohesion and consequently, in the physical, chemical, biological and hydrological attributes of the soil [16]. Texture can be used as an environmental factor by determining ecological processes [17].

When analysing the textural diagnosis of the studied areas (Table 1), a sand prevalence was verified in both soils, mainly in the superficial layers. Soils with sandy texture are considered light, with a high capacity of infiltration and water loss by percolation. In addition, they have low potential for water retention and organic matter content. This kind of soil is highly susceptible to erosion and loss of productive capacity when compared to clayey soils, thus requiring adequate management and conservation practices [7].

The percentage of inorganic solids in the two types of soils (Table 1), shows that the Oxisol exhibits homogeneity in the clay content with depth. This result contrasts with the Ultisol, which revealed a clay increment with depth, characterizing the clay eluviation with the genesis of the horizon B textural, giving this soil type a high water storage with depth, due to the retention by the presence of this inorganic solid.

The amount of organic matter found was similar in the different layers evaluated of both types of soils. This is due to the same soil cover (spontaneous vegetation), since the management of the area is 14 years without cultivation, with only spontaneous undergrowth. Therefore, there is no modification in the inorganic composition of the soil, a chemical attribute in which it is significantly altered by management. At the same time, the inorganic composition can directly or indirectly influence the physical, chemical and biological attributes of the soil.

Soil acts as a water reservoir, providing plants according to the needs of the moment and consisting of particles of different size fractions or textures. Soils with sandy textures are light, well drained and with a lower water retention capacity [18].

Table 1. Average values of the granulometry of the studied soils. Dracena - SP.

Layers	Sand		Silt		Clay		M.O.	
Meters	OX	UL	OX	UL	OX	UL	OX	UL
	---------------------------%-------------------------						---g dm^{-3}---	
0.00-0.10	91	94	3	3	7	3	14	12
0.10-0.20	89	86	5	10	6	4	9	12
0.20-0.40	80	87	4	6	6	7	9	10

The soil water content, when referring to volumetric and gravimetric moisture (as shown in Figure 2 A-B), revealed a higher retention of water in the Oxisol layers when compared to Ultisol, except in the layer between 0.20 and 0.40 m, due to the density of clay at depth in the Ultisol. Similar results were found by [19], who showed that the soil layers studied showed a slight variation of soil moisture between the studied soil recovery treatments. However, contrary results were reported by [20], who found the highest moisture levels at depth in response to the advance of the wetting front.

The higher volumetric moisture in the surface layer of the Oxisol can be influenced by precipitation on the day of collection. [21], who also faced these conditions, found them to be one of the factors leading to greater infiltration of water in the soil and resulting in no formation of the seal surface.

In the studied soils, there was pasture present in the soil cover. In addition, the Oxisol had a higher water content than the Ultisol up to the layer of 0.10-0.20 m. According to [22], organic matter is important in the retention of water in the soil, besides being dependent on the texture. Therefore, in sandy textured soils, water retention is more sensitive to the amount of organic matter than the more clayey soils, which have finer texture.

The infiltration of water in the Ultisol was superior to that found in the Oxisol (Figure 2 C-D). This behaviour is due to the sandier layer, due to the eluviation of clay for the horizon B textural. According to [12], who point out that in the tropical climate and Brazilian cerrado soils, where iron and aluminium oxides predominate in relation to silicate clays, the soil structure has more influence on the infiltration than the texture.

These values are in the average for this soil textural class, according to [12]. According to [23], the values are a consequence of three main effects: no preparation during the grazing cycle, the presence of a dense root system, which acts as a soil aggregating agent and increased macrofaunal activity in the soil.

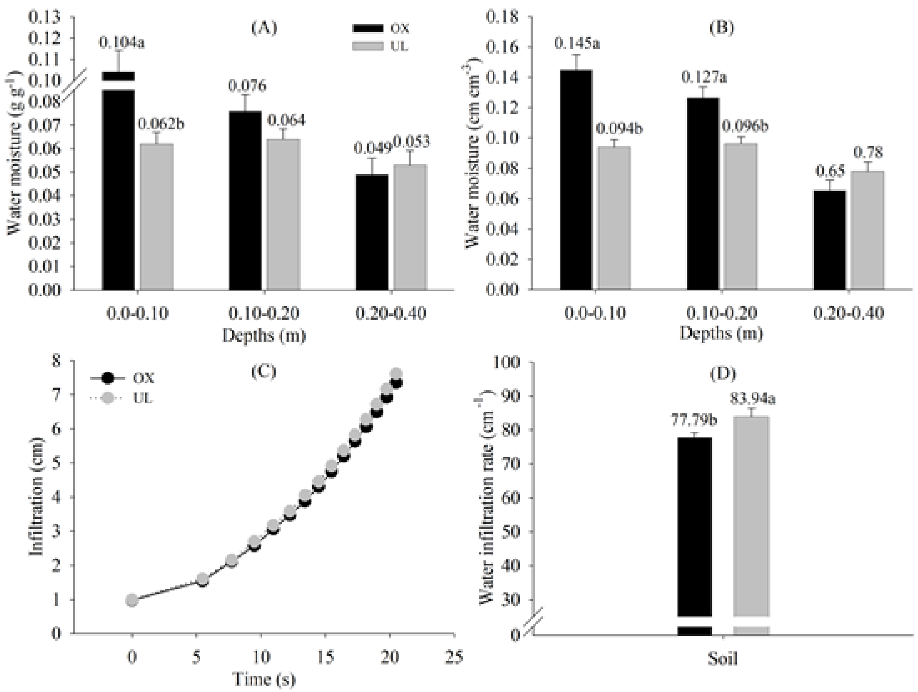

Figure 2. Gravimetric moisture (A), volumetric moisture (B), infiltration curve (C) and water infiltration rate (D) in response to different soils for each dephts. Different letters present statistical difference according to the Tukey test ($p < 0.05$). Bars on the vertical represent the standard error ($n = 10$).

The density of the soil is given by the relation mass and volume of the soil; that is, the volume occupied by soil particles in a given volume depends on the structure and management of the area, where it allows variations for the same type of soil [24]. The soil content influences the water retention of the soil and water available to the plants, aeration and resistance to penetration [25].

The observed density values (Figure 3 A) are close to those recommended by the literature as ideal (1.25 to 1.60 $g.cm^{-3}$) for sandy soils. In the layer of 0.0 to 0.10 m, the Ultisol presented a lower value, which can be explained due to the lack of texture homogeneity, when compared to Oxisol. The porosity of the soil has proper values in both soils, in the different analysed layers. The Ultisol presented higher value of macropores only in the layer of 0.0 to 0.10 m. On the other hand, the Oxisol presented higher value of micropores in the 0.10 to 0.20 m and 0.20 to 0.40 m layers (Figure 3 B). A higher percentage of macropores, which facilitate water percolation by gravity, should be above 10-15% to be considered suitable for growth and productivity of most crops, according to [26].

The variance in water storage of the studied soils can be related to the influence of the structure and composition of the materials in terms of organic matter and clay as well as the changes in the quantity and distribution and size of the pores, since micropores are important in maintaining moisture since they retain and store infiltrated water [27].

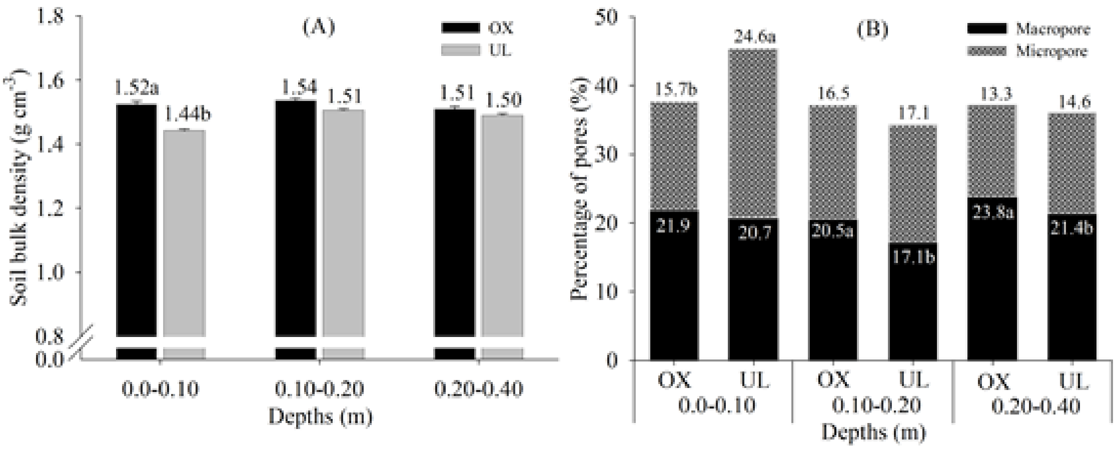

Figure 3. Density of the soil (A), pores percentage (B) in response to different soils for each dephts. Different letters show statistical difference according to Tukeys test ($p < 0.05$). Bars on the vertical represent the standard error (n = 10).

Soil structure is one of the most important physical aspects, since it provides information about the size, shape and arrangement of the aggregates, which are organized by the union of primary particles in separable units and are thus sensitive to the changes according to the management. The stability of the aggregates allows for greater resistance to the erosive process, thus protecting organic matter and the microbial population [28]. When considering the aggregate stability data (Figure 4 A), both soils showed remarkable particle structuring, with values more representative in the 0.10-0.20 m layer. According to [29], the values of average diameter weighted values for sandy soils should be no greater than 2 mm. On the surface, the Oxisol presented a lower aggregation, due to its higher density on the surface, which provides a greater compaction in this layer, when compared to the other soils (Figure 4A). The Ultisol in the layers of 0.20-0.40 m had a lower value, since this type of soil is characterized by clay density at depth (Figure 4A).

The layer of 0.10-0.20 m with better structuring showed lower resistance to root penetration (Figure 4 B). Values found in this work are below the limit considered critical according to [30], who considers values greater than 2 Mpa restrictive to root growth. Soil compression is one of the main causes of degradation because it determines the performance of the soil physical attributes and alters nutrient uptake [31]. The physical quality of the soil is derived from the quality of the environment that interferes with the productive system and degradation of the area. The moisture analysed together with the resistance to penetration (Figure 4 B), refers to the field capacity of each soil; adequate values are observed for the availability of water for the crops.

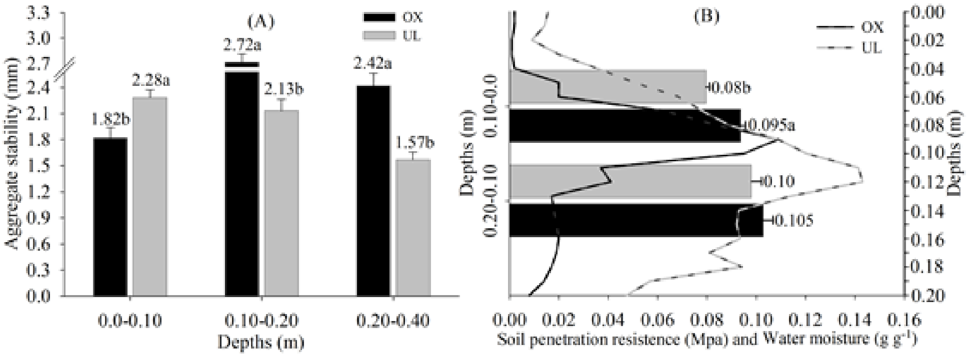

Figure 4. Aggregate stability (A) and resistance to penetration and soil moisture (B) in response to different soils for each dephts. Different letters present statistical differences according to the Tukey test ($p < 0.05$). Vertical error bars represent the standard error ($n = 10$).

4. Conclusion.

Oxisol and Ultisol soils have a good structure and organic matter content, sandy texture and are susceptible to erosion.

The studied soils are not compressed and their soil densities are optimal. As such, pore distribution and infiltration rate were good indicators of quality in this study.

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