Physical attributes of a Dystroferric Red Latosol (Oxisol) under different management systems

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Abstract

The relationship of management and soil quality may be evaluated by the behavior of soil physical, chemical and biological properties. In the assessment of soil structure, it is sought attributes in the view of measuring the porosity and the distribution of pores by size and its implication to permeability and rigidity of the pores, as well as the stability of the units that composes soil structure. The aim of this research was to assess the structure of a Dystroferric Red Latosol (Oxisol) under conventional corn crop, conventional coffee crop, eucalyptus crop and an equilibrium reference (native vegetation), by the determination of the particle density, bulk density, calculated total porosity, microporosity, macroporosity, moisture saturation, determined total porosity, blocked pores and aggregated stability. Soil under native vegetation presented the lowest values of particle density, probably due to the greatest soil organic matter content in this environment. It was verified a tendency of increasing blocked pores and decreasing bulk density. As expected, bulk density varied from 0.87 to 1.03 g cm^{-3}, showing an inversely proportional distribution related to total porosity. The largest values of geometric mean diameter presented by the soil under native vegetation are due to the greater structuration degree of this soil, which contributes to the stabilization of the aggregates in this environment. The native vegetation environment presented a better soil physical quality in relation to other land uses.

Keywords: Bulk density. Porosity. Aggregate stability.

Introduction

Soil structure is one of the most important attributes for evaluating soil quality, and it can be used as an indicator of soil compaction, soil crusting and soil susceptibility to soil erosion, subsidizing control of productivity loss and environmental degradation (FERREIRA, 2010). This soil attribute is related to aggregation and suffers alteration due to inadequate land-use and land-cover, and these alterations may be transient or prolonged for several years (WENDLING et al., 2005).

Better physical quality is represented, in a wide textural range, by lower bulk density, higher total porosity and macroporosity (BLUM et al., 2014). In this sense, the use of soil physical attributes to study its quality presents advantages related to low cost, simple and fast methodologies and direct relationship with other chemical and biological attributes of the soil (SALES et al., 2016).

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Ingaramo (2003) suggests that, for adequate evaluation of soil quality, properties and physical factors to describe it are: porosity, pore size distribution, bulk density, mechanical strength, hydraulic conductivity, particles, size distribution and depth at which roots grow. In addition, particle density, although considered to be quite stable, may reflect physical changes in the soil, especially when they cause a reduction in the amount of organic matter.

Based on the above, this research aimed to assess, by soil physical attributes, the structure of a Dystroferric Red Latosol (Oxisol) under four different land uses: maize plantation, coffee plantation, eucalyptus plantation and native forest.

Material and methods

The study area is located at 21°34'46.04' S and 44°58'40.40'' W South of Minas Gerais State, Brazil, with an average altitude of 920 m. The relief is predominantly undulated, with an average slope of 16 %. The climate is Cwa, according to Köppen classification system, characterized as semitropical with dry winters, hot and rainy summers, with an annual rainfall average of 1,450 mm.

Soil samples (undisturbed and disturbed samples) were collected from a Dystroferric Red Latosol (Oxisol) with four different land uses (the treatments): maize plantation (1.22 ha), coffee plantation (0.25 ha), eucalyptus plantation (0.32 ha) and a reference area with native forest (5.8 ha). The area under maize plantation has a history of alternating annual crops (maize and beans), with maize being planted in the rainy season of the year (October to March) and beans, under irrigation, in the dry season (April to September). The area under eucalyptus has in its history past cultivation of annual crops such as maize, beans and potatoes. The area under coffee plantation was implanted more than 15 years ago.

Sampling depth used was only 0-20 cm, in a completely randomized block, experimental design with three replicates per soil depth in each profile opened. Particle density (PD) was determined by the Pycnometer Method (Blake and Hartge, 1986a). Bulk density (BD) was determined according to Blake and Hartge (1986b). Microporosity (MIC) was determined by a porous plate apparatus (RICHARDS, 1948) and corresponds to the moisture retained up to a tension of 0.006 MPa (KIEHL, 1979; DANIELSON; SUTHERLAND, 1986). Total porosity (TP) was calculated from the values of BD and PD, using the equation (EMBRAPA, 2017):

$$VTP = 1 - BD/PD \qquad (1)$$

Macroporosity (MAC) was calculated from the difference between total porosity (TP) and MIC.

Aggregate stability was determined from a sample of 25 g with diameter from 4.76 to 7.93 mm obtained from the previously sieving of soil samples. These aggregates were submitted to slow moistening and put in a set of sieves with diameters 2; 1; 0.5; 0.25; 0.10 mm and shaken in Yoder mechanical oscillator (YODER, 1936).

After sieving in water, the aggregates of each sieve were transferred to Becker of 100 mL and heated at 105-110°C for 24 hours, the weight of aggregate was obtained in each size class, expressing it as a percentage of the initial sample.

The data were subjected to analysis of variance (ANOVA), and the means compared by the Scott-Knott test at 5 %, using SISVAR software (FERREIRA, 2014).

Results and discussion

By analyzing Table 1, it can be seen the native forest condition had lower values of particle density (PD), and this can probably be attributed to the higher organic matter (OM) of this type of environment, since the mass is less than the other constituents of the solid phase (FERREIRA, 2010), considering that both environments are under the same soil (particle size distribution). Thus, it was inferred that, with the soil management, there was a reduction of OM and the consequent increase of PD for other uses of the soil.

Table 1. Averages for bulk density (BD), microporosity (MICRO), macroporosity (MACRO), particle density (PD), calculated total porosity (CTP), determined total porosity (DTP), blocked pores (BP) and geometric mean diameter (GMD) of a Dystroferric Red Latosol in function of the different uses.

Land-use	PD	BD	MICRO	MACRO	CTP	DTP	BP	GMD
	g cm^{-3}		cm^3 cm^{-3}		%		(cm^3 cm^{-3})	(mm)
Maize	2.68a	0.95b	0.37a	0.27a	64.0a	59.0b	0.05a	2.09c
Native forest	2.54c	0.87c	0.34a	0.32a	66.0a	59.0b	0.07a	4.75a
Eucalyptus	2.70a	1.03a	0.34a	0.28a	62.0a	59.0b	0.02a	1.82c
Coffee	2.62b	0.95b	0.35a	0.28a	63.0a	63.0a	0.00a	3.21b
CV	2.4	6.0	3.5	6.7	2.3	2.9	76.9	38.9

Note: Means followed by the same letter, within each land use, did not differ by the Scott-Knott's test ($P < 0.05$). CV: Coefficient of variation (%).

Source: Elaborated by the authors (2018).

According to Ferreira (2010), PD is a very stable attribute, whose magnitude depends exclusively on the composition of the solid particles, and in this context, it depends on the relative proportions of the organic and mineral fractions (mineralogical composition of the soil). As the organic matter has a specific mass around 1.2 g cm^{-3}, greater relative amounts mean lowering the value of PD. Thus, it is reasonable to assume soil management can modify the value of PD over time if there is a significant reduction in soil organic matter content by this management.

According to Table 1, it can be observed the native forest environment presented better physical quality of the soil in relation to other uses, easily observed by the set of physical attributes evaluated. This fact is due to the greater contribution of organic matter in this environment and absence of anthropization. This environment presents lower BD values, higher MACRO and a more balanced relationship between MACRO and MICRO around 0.90. Oliveira et al. (2003) found a higher MACRO/MICRO ratio for a Dystroferric Red Latosol under Cerrado (1.08) compared to no-tillage (0.59) and disk plowing (0.66), a result of man's interference by using machines and equipment that altered soil properties in these two systems of planting.

The BD of the forest showed a significant difference on the other land uses, presenting a lower value compared to other due to the influence of litter (OM) (TABLE 1), indicating the homogeneity of this soil property in its natural condition, without layers of impediment or accumulation of clay.

The results of this study are in agreement with those found by Araújo et al. (2004), who found a higher BD under cultivated area (1.70 g cm^{-3}), compared to the native forest (1.48 g cm^{-3}), in a Dystroferric Red Latosol.

The higher BD in the cultivated soils is related to soil compaction by traffic of machines and implements, with the reduction of OM and lower stability of soil structure (BRAGA et al., 2015; PAIS et al., 2013).

Regarding MACRO and DTP, unlike this study, Araújo et al. (2004) observed lower values of MACRO and DTP in cultivated Dystroferric Red Latosol compared to the same soil under native forest. It is verified the lowest value of BD corresponds to the larger volume of MACRO within the native forest environment, emphasizing the physical quality of this soil when natural. However, for MICRO, the same authors did not find differences relating to micropores within the two systems studied.

Another aspect that should be considered is the amount of pores blocked in the soil, especially in environments under forest and maize. These pores are potentially occupied by water but they are found only with air, even when the soil is saturated.

According to Table 1, it is observed the native forest environment presents higher GMD, followed by the use of soil with coffee.

Possibly, the higher values of GMD presented by the forest are due to the higher degree of structure of this soil, conditioned by the greater presence of roots that release exudates and raise organic matter contents from soil through biochemical cycling (formation, death and decomposition of roots), contributing to the stabilization of aggregates (BRAGA et al., 2015).

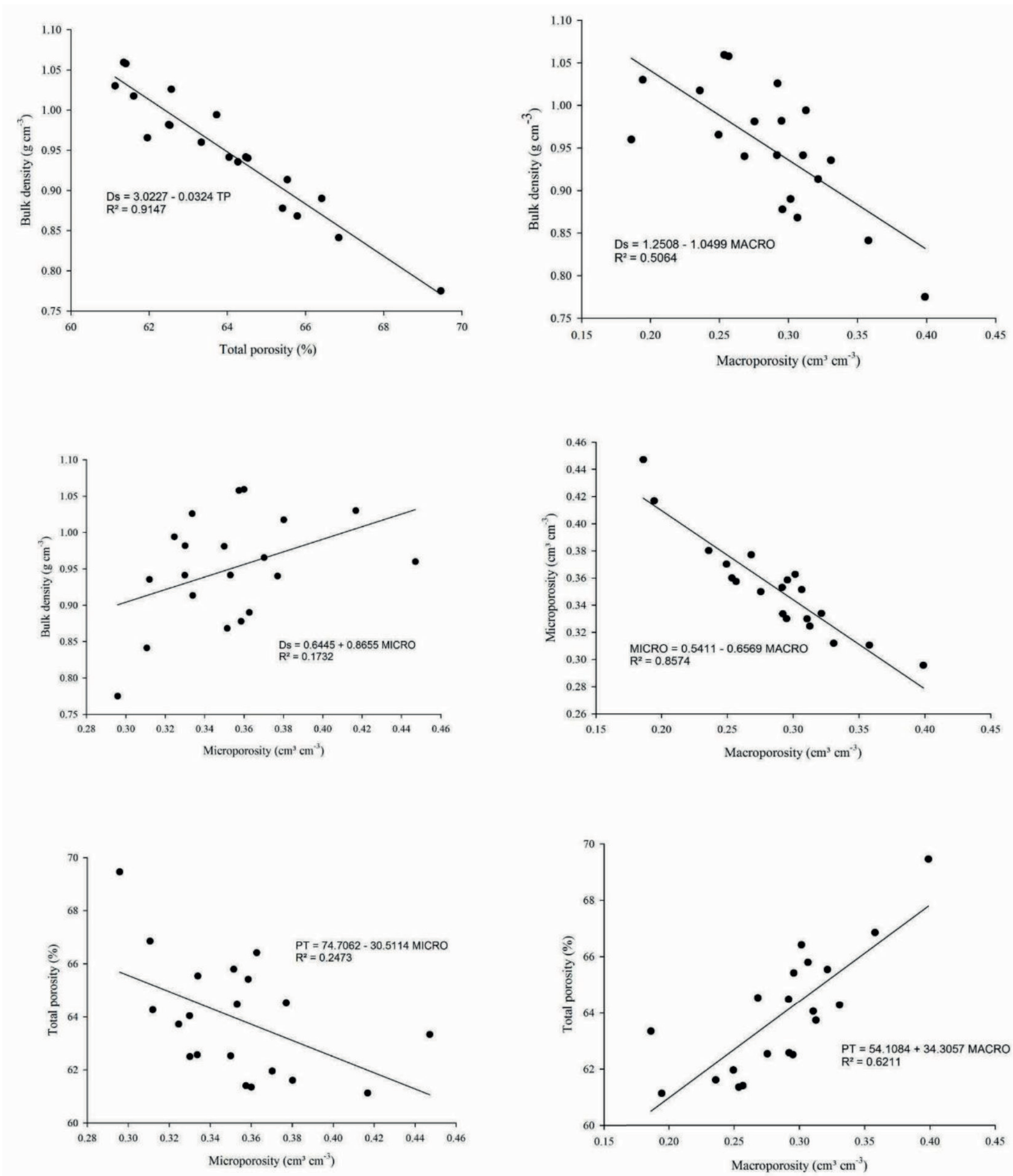
The lower values of GMD were found in the eucalyptus and maize areas, probably due to soil structure damage, caused by conventional tillage, with soil disturbance and consequent soil structure degradation and lower organic matter content when compared to native forest.

Martins et al. (2002) also found lower GMD values for soils with eucalyptus (2.72 mm), pinus plantation (2.44 mm) and rubber tree (2.04 mm), due to soil structure damage caused by management of these soils, they found soil under cultivation of eucalyptus had low organic matter contents when compared to native forest (GMD of 4.07 mm). Also, Bochner et al. (2008) found higher values for GMD (2.9 mm) in the 0 to 10 cm layer in secondary forest area when compared to other areas under conventional tillage.

Considering GMD values verified in this study and those found by Braga et al. (2015) in a Dystroferric Red Latosol under forest (4.88 mm) and by Martins et al. (2002) also in a Dystroferric Red Latosol under forestry (mean of 2.4 mm), it can be assumed the use of soil changes aggregates stability considerably. According to Table 1, there is a tendency for an increase in BP with decreasing BD. Dörner et al. (2010), in a study of soil structure on porosity functionality, found results of BP tending to decrease with increasing BD.

Figure 1 shows linear correlation analysis among total porosity (TP), bulk density (BD), macroporosity (MACRO) and microporosity (MICRO) of the area analyzed in this study.

Figure 1. Relationship between total porosity (TP), bulk density (BD), macroporosity (MACRO) and microporosity (MICRO) in Dystroferric Red Latosol.



Source: Elaborated by the authors (2018).

Linear correlation analysis (FIGURE 1) indicated TP and MACRO correlated positively, whereas TP and MICRO had a low negative correlation. TP has a strong negative correlation with BD as BD with MACRO; however, for this one, the correlation was not so strong.

These results corroborate Braga et al. (2013), who emphasize this behavior demonstrates soil structure is more associated with macropores; therefore, an increase in BD implies a decrease in MACRO and an increase in MICRO.

As expected, bulk density varied from 0.87 to 1.03 g cm^{-3}, showing an inversely proportional distribution related to total porosity (FIGURE 1). Therefore, modifications caused in the soil by different management systems may have an impact on bulk density and soil porosity, influencing root growth and productivity of crops (TAVARES FILHO et al., 2010).

For BD and MICRO, it was also found a negative linear correlation to MACRO, with coefficients 0.5 and 0.8 for BD and MICRO, respectively. Braga et al. (2013) also found a negative linear relation for these attributes; however, the values were 0.89 for BD and 0.01 for MICRO. These results show MACRO decreases with increasing BD and MICRO.

This correlation can contribute to the evaluation of soil structure in cropping systems. According to Cavenage et al. (1999), in compacted layers, the increase in BD resulting from the increase of solids comparing to volume of pores causes a predominance of micropores. Therefore, the movement of water and air is hampered, which diminishes the internal drainage of the soil commanded by the structure.

Total porosity had a positive linear relationship with MACRO, meaning total porosity values increased with the increase in MACRO. According to Kiehl (1979), total porosity distribution of soil for agricultural cultivation should be of one-third percentage for macropores and two-thirds for micropores.

Conclusions

Soil under native forest had the lowest values of BD because native forest environment provides greater contribution and conservation of organic matter to the soil.

There was a tendency for increasing blocked pores with decreasing BD.

The highest values of GMD presented by soil under forest are due to the higher degree of structuring of this soil. The lowest values of GMD were found for eucalyptus and maize areas as a result of disintegration of soil aggregates caused by conventional soil preparation.

Considering all the analyses, it was observed a reduction for physical quality of soil when submitted to conventional preparations and used in agricultural or forestry species.

Atributos físicos de um Latossolo Vermelho Distroférrico sob diferentes sistemas de manejo

Resumo

A relação entre o manejo e a qualidade do solo pode ser avaliada pelo comportamento das propriedades físicas, químicas e biológicas do solo. Na avaliação da estrutura do solo, buscam-se atributos como a porosidade e a distribuição de poros por tamanho no solo e suas implicações na permeabilidade e rigidez dos poros, bem como a estabilidade das unidades que compõem a estrutura do solo. O objetivo desta pesquisa foi avaliar a estrutura de um Latossolo Vermelho Distroférrico sob cultivo convencional de milho, café, eucalipto e uma referência de equilíbrio (vegetação nativa), pela determinação da densidade de partículas, densidade do solo, porosidade total calculada,

microporosidade, macroporosidade, umidade saturada, porosidade total determinada, poros bloqueados e estabilidade de agregados. O solo sob vegetação nativa apresentou os menores valores de densidade de partículas, provavelmente devido ao maior teor de matéria orgânica do solo nesse ambiente. Verificou-se uma tendência de aumento de poros bloqueados e diminuição da densidade do solo. Como esperado, a densidade do solo variou de 0,87 a 1,03 g cm^{-3}, mostrando uma distribuição inversamente proporcional à porosidade total. Os maiores valores de diâmetro médio geométrico apresentado pelo solo sob vegetação nativa se devem ao maior grau de estruturação deste solo, o que contribui para a estabilização dos agregados nesse ambiente. O ambiente de vegetação nativa apresentou melhor qualidade física do solo em relação a outros usos do solo.
Palavras-chave: Densidade do solo. Porosidade. Estabilidade de agregados.

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