GLOBAL SCIENCE AND TECHNOLOGY (ISSN 1984 - 3801)

CHANGE IN PHYSICAL PROPERTIES OF CERRADO OXISOL UNDER CROP-LIVESTOCK INTEGRATION IN THE STATE OF TOCANTINS, BRAZIL

Saulo de Oliveira Lima1*, Luiz Paulo Figueredo Benício1, André Fróes de Borja Reis1, Ariádila Gonçalves de Oliveira1

Abstract: The purpose of this study was to evaluate some physical attributes of a Red Oxisol under different types of uses. The study was conducted at Fazenda Palmeiras, in the city of Aparecida do Rio Negro, State of Tocantins, Brazil. Two areas were evaluated: a) the first area is native Cerrado vegetation; and b) the second is a farming area under no till cultivation, with crop rotation and grazing. The design was completely randomized in a 2x3 factorial. The properties evaluated were soil bulk density, total porosity, macroporosity, microporosity, and soil resistance to root penetration. The area under cultivation had lower density than the natural area, and the highest density occurred in the deeper layers and consequently a decrease in total porosity. From 10 cm depth the values of resistance to penetrations found in the soil under cultivation are above the critical level for cultivated soils.

Keywords: macroporosity, microporosity, soil resistance to root penetration.

ALTERAÇÃO DE PROPRIEDADES FÍSICAS DE UM LATOSSOLO VERMELHO SOB INTEGRAÇÃO AGRICULTURA-PECUÁRIA NO TOCANTINS

Resumo: O presente trabalho objetivou avaliar diferentes atributos físicos em um Latossolo Vermelho distroférrico, sob diferentes usos. O trabalho foi realizado na Fazenda Palmeiras, no município de Aparecida do Rio Negro – TO. Foram avaliadas duas áreas: a) uma área sobre vegetação do Cerrado; e b) uma área sob cultivo com plantio direto, rotação de culturas e pastejo. O delineamento utilizado foi o inteiramente casualizado no esquema fatorial 2x3. As propriedades físicas avaliadas foram: densidade do solo, porosidade total, macroporosidade, microporosidade e resistência do solo à penetração. A área sob cultivo apresentou menor densidade do solo em comparação a área sob vegetação do Cerrado, os maiores valores de densidade ocorreram nas camadas mais profundas e consequentemente a diminuição da porosidade total. A partir dos 10 cm de profundidade os valores de resistência a penetração encontrados no solo sob cultivo estão acima do nível crítico para solos cultivados.

Palavras-chave: macroporosidade; microporosidade; resistência a penetração, sistema de uso e manejo.

Received at: 03/08/11 Aprovado em: 17/11/11.

1Universidade Federal do Tocantins, Campus Universitário de Gurupi, Agronomia. Rua Badejós, chác. 69/72, Lt.07, Zona rural, Caixa-Postal: 66, Gurupi (TO). CEP: 77402-970. *E-mail: saulolima@uft.edu.br. Autor para correspondência.
INTRODUCTION

The state of Tocantins has approximately 83,000 km$^2$, or 30% of the territory in an area of cerrado physiognomy with potential use for annual cycle crops or intensive livestock. From that tillable land, we can establish as the most important soils in order of occurrence in the state: 22% Oxisols, 18.9 % Quartzipsamments and 10% Ultisols (SEPLAN, 2005). These soils have very different characteristics between classes, but they all have high weathering process.

According to Albuquerque et al. (2001), soil compaction caused by heavy traffic, agricultural machinery and cattle stepping has been identified as a major cause of degradation of cultivated areas in crop-livestock integration. The compression process reduces the soil macroporosity, increases its density and the resistance for root growing under low humidity conditions, and reduces its oxygen when wet. In compacted soil, the root system is concentrated near the surface (MÜLLER et al., 2001), making the plant more susceptible to water deficits and limited ability to absorb nutrients in subsurface layers.

The agricultural systems affect the soil over time, causing disorder in its properties (MARTINEZ et al., 2008), as the removal of native vegetation and implementation of crops coupled with inappropriate management practices promote the disruption of the balance between soil and the environment, limiting its use (CENTURION et al., 2001). In response to this process of deterioration, new conservation-oriented systems such as minimum tillage and no-tillage have been developed for the subtropical conditions in order to reduce soil tillage (LLANILLOS et al., 2006).

The no-tillage system (NT) is a technique of land use intended to cause less impact on the soil and its properties. In agriculture, the need to preserve the soil, which is the basis of the entire production system, combined with the need to reducing production costs and increasing productivity resulted in the implementation of the No-tillage System. Currently, this system reaches about 14 million hectares in Brazil, especially in the Cerrado region (SALTON et al., 2002). The effectiveness of this system is related to the quantity of vegetal waste produced by cover crops, among other factors (TORRES, 2003).

Several studies have shown the beneficial effects of cover crops on soil properties. The soils on NT associated to crop rotation presents high quality levels, especially those including tropical legumes, because of the supply of Nitrogen and Carbon from their residues. (AMADO et al., 2007). The association of no-tillage system with crop-livestock integration has contributed satisfactorily to the increased levels of soil quality in Brazil (KLUTHCOUSKI et al., 2003).

In crop-livestock integration, areas of perennial pasture and annual crops are alternated every two or three years using NT. In this case, grass allows permanent covering of soil, the increase in organic matter content and improvements in other soil properties. The concern with the weed control is basically reduced to the control of forage plants. Pasture remains productive because of fertilizer and soil biological activity stimulated by annual crops. In this context, the grain yield and production of pastures and meat is improved (SALTON et al., 2002). Besides the economic advantages, the use of this system is beneficial to soil physical properties such as greater aggregate stability, better water infiltration, decreased density, increased porosity, and consequently a better root system (SALTON et al., 2001).

Soils used in crop-livestock integration under NT have lower densities and micropores, and a higher amount of macropores similar to soils under native vegetation (SPERA et al., 2009). The penetration of the roots compresses the soil particles. Thereafter their death and tissue decomposition form the biopores that...
contribute for the improvement of soil physical conditions (FOLONI et al., 2006).

Considering that soil physical quality is key to sustainability of agricultural systems, the use of variables as density and porosity of the soil, mechanical resistance to penetration are adequate tools to compare management systems and also to study the effects of conversion of native areas into cropland and / or pasture (LEÃO et al., 2006).

In addition, this study aimed to evaluate physical changes in a Red Oxisol managed under crop-livestock system in no-tillage in the state of Tocantins.

MATERIAL AND METHODS

The study was conducted at Palmeiras Farm, in the country side of Aparecida do Rio Negro, in the State of Tocantins, Brazil, in March 2011. The soil under study is a clayey Oxisol. The climate is classified as tropical warm (Aw) according to Köppen classification, and altitude of 385 meters above mean sea level.

The area originally covered by native vegetation of the Cerrado which was replaced for the first time in 1993 for implementation of pasture, was maintained until 2005. After that the grass was removed and annual soybean crop was implemented with integrated livestock farming. In 2006/2007, 2007/2008 and 2008/2009 there was a succession soybean / millet, grown under no-tillage system. In 2007 subsoiling was done in the area at a depth of 30 cm. In 2009/2010 and 2010/2011 there was a succession soybean / Brachiaria ruziziensis grass. By the end of 2009/2010 the subsoiling was performed again, and in the 2010/2011 crop was planted in NT.

The study was based on a factorial 2x3 design fully randomized with two areas, one the cultivated area and an area of native cerrado x three depths 0-10cm, 10-20cm and 20-30 cm.

Evaluations consisted of five soil physical properties, as follows: soil bulk density (BD), total porosity (TP), macroporosity (MACP), microporosity (MICP) and soil resistance to root penetration (SRP). For BD, TP, MICP, MACP assessments undisturbed soil samples were collected with 50 cc volume metal rings. The samples were collected at depths of 0-10, 10-20 and 20-30 cm, and in order to determine moisture levels they were weighed immediately after collected. For quantification of TP, MICP, MACP, nylon screens were fixed at the bottom of the cylinders and the samples were wet by placing them on a tray containing 1 cm of water until saturation. Then, the set was placed in suction plate apparatus corresponding to 60 cm of water column (6 kPa) following the methodology described by Embrapa (1997). After removing the cylinder plate apparatus, they were taken to the oven and dried for 24 hours at a temperature of 105 ° C. This procedure provided the determination of the BD by the ratio mass / volume.

An impact penetrometer model IAA / Planalsucar-Stolf was used to determine soil resistance to root penetration. It was proceeded with the random sampling of 12 points to a depth of 40cm, to find the values of RP used the methodology described by Stolf (1991).

The values of BD, TP, MACP, MICP and SRP were submitted to analysis of variance and means were compared by Tukey's test at a significance level of 5% using the SISVAR software for the statistical analysis. The software MYSTAT 12 was used to perform the Pearson correlation test in the errors in order to verify the relationship between the variables chosen in the resarch.

RESULTS AND DISCUSSION

The results obtained on bulk density and porosity are shown in Table 1. For soil bulk density there is no significant interaction area x depth. In cultivated area, the values of density found were 1.09, 1.10 and 1.15 g cm$^{-3}$ for the respective layers of depth 0-10, 10-20 and 20-30 cm, with no significant difference between them. For native vegetation of the...
cerrado area values found were 1.23, 1.20 and 1.25 g cm$^{-3}$ 0-10, 10-20 and 20-30 cm respectively, also with no difference according F-test.

In relation to the observed depths for both areas, the density values increased throughout the profile (Table 1), these results are similar to those obtained by Bergamin et al. (2010) who got the highest values densities in the deeper layers of a clayey Oxisol. The highest densities were observed in the 20-30 cm depth in both the native vegetation of cerrado, and on the ground under cultivation (Table 1). A likely explanation for this similarity between both uses of soil is that this soil has a natural characteristic of higher density in the mentioned depth.

The dense layer found in both soils can also be generated by different causes - in the soil under cultivation the increased density is caused by machine traffic, and in the forested area the increased density may be a pedogenetic characteristic. Tormena et al. (1998) found an average increase of 10% in soil microporosity in areas with and without machinery traffic, showing that natural density was equivalent. The soil density decreases with soil tilling or scarification operation, however this property tends to return to its original condition over time, due to the natural density of the particles (MARCOLAN et al., 2007) and it is a probable explanation for a higher soil density in forest areas than in areas under cultivation.

The area of native cerrado presented a density value greater than the area under cultivation in all evaluated depths; this is due to the treatment used in the cultivated area. Operations such as ripping and subsoiling were always performed in the last two years in addition to planting of Brachiaria ruziziensis, a plant that has the aggressive root system (CALONEGO et al., 2011) that can help reducing the density. Kanno et al. (1999) reported that the Brachiaria grass is the best option to be introduced into crop-pasture rotation to improve soil quality. Calonego et al. (2011) concluded that Brachiaria ruziziensis is a species with high potential for structure of compacted soils because its root system characteristics. The lower densities observed in the surface depth may be related to the roots of crops used (REINERT et al., 2008).

Oxisols with lower clay contents are less susceptible to compaction than those with predominance of clay. Thus, soils that have potentially higher structural quality, associated to a lower density, will be the most susceptible to degradation. Therefore, great care is needed regarding the use and management to maintain the physical quality of soils to optimize crop productivity (IMHOFF, 2002).

The total porosity values did not present significant difference between the observed areas, and between layers (Table 1). For the cultivated soil and the soil under cerrado, the lowest total porosity was found at a depth of 20-30 cm, confirming the higher density at this depth even though no significant difference in total porosity. The area of cerrado had lower TP value, thus confirming a higher BD in this area, as occurred in greater depths. The fact that the BD and TP were higher in cerrado than in the cultivated area is puzzling because most studies found indicate the opposite situation, however this can be explained by the management applied to the cultivated area, the subsoiling and ripping made in recent years in the cultivated area may have influenced the increase in soil porosity and consequently in a lower density. No-tillage and crop succession may also have helped in improving the physical properties with the addition of organic matter from different materials to the system.

In assessing the physical attributes of an Oxisol, cultivated for 10 years in systems with chisel tilling (0.30 m) a soybean/corn succession and alternating with soybean / wheat rotation in the first case, and no-tillage of corn / wheat / soybean / oats / soybean / oilseed radish in the second case, Tormena et al. (2004) found that subsoiling increased total porosity, but both systems had adequate porosity. Due to the small granulometry of the clay in some specific
cases such as soil dryness and natural high density, the clayey Oxisoil favors the formation of hard consistency (Pereira et al., 2010).

Table 1 - Bulk density (BD) and total porosity (TP) of an Red Oxisol under native vegetation of the cerrado and farming

<table>
<thead>
<tr>
<th>Bulk density (Mg cm(^{-3}))</th>
<th>Area</th>
<th>Depth (cm)</th>
<th>Under Cultivation</th>
<th>Native Cerrado</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-10</td>
<td>1.09 aB</td>
<td>1.23 aA</td>
<td>1.16 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-20</td>
<td>1.10 aB</td>
<td>1.20 aA</td>
<td>1.15 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-30</td>
<td>1.15 aB</td>
<td>1.25 aA</td>
<td>1.20 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>1.11 B</td>
<td>1.23 A</td>
<td>1.20 a</td>
</tr>
<tr>
<td></td>
<td>CV (%)</td>
<td></td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Porosity (m(^3) m(^{-3}))</th>
<th>Area</th>
<th>Depth (cm)</th>
<th>Under Cultivation</th>
<th>Native Cerrado</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-10</td>
<td>0.4695 aA</td>
<td>0.4329 aB</td>
<td>0.4512 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-20</td>
<td>0.4487 aA</td>
<td>0.4526 aA</td>
<td>0.4506 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20-30</td>
<td>0.4377 aA</td>
<td>0.4364 aA</td>
<td>0.4370 a</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Average</td>
<td>0.4519 A</td>
<td>0.4406 A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CV (%)</td>
<td></td>
<td>6.44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Averages followed by the same lowercase letters in columns, and uppercase in rows, did not differ from each other by Tukey test at 5%.

The values of macroporosity and microporosity (MACP and MICP) are shown in Table 2. The area under native cerrado showed the average macroporosity of 0.2339 m\(^3\) m\(^{-3}\), higher than that under cultivation where the average was 0.2223 m\(^3\) m\(^{-3}\) but the two areas showed no significant difference between them. The effect of soil management on the total porosity and their distribution has been emphasized in several studies. Secco et al. (1997) in an Red Clay Oxisol at Cruz Alta (RS), found a decrease in both MACP and PT, while an increase in the MICP when comparing conventional tillage (CT) with no-tillage (NT), while Costa et al. (2003), in Oxisols at Guarapuava (PR) and Albuquerque et al. (1995), in Oxisol (RS) did not observe these differences. Costa et al. (2009) concluded that the management of grazing in crop-livestock integration in no-tillage system, does not significantly change the physical properties of soil, and that transition from native pasture for the system of crop-livestock integration in no-tillage system preserves the physical quality soil when compared to conventional tillage.

There was a decrease in the MACP along profile, where the depth of 00-10 was 0.2840 m\(^3\) m\(^{-3}\), differing from the layer of 10-20 and 20-30 where the values were 0.2106 m\(^3\) m\(^{-3}\) and 0.1897 m\(^3\) m\(^{-3}\) respectively. This reduction in macroporosity along the soil profile occurred in both areas. These results corroborate the soil bulk density and porosity, since they are soil properties that have a direct relationship, thus confirming the natural increase of density throughout the soil profile. The increased in the bulk density occur at same with MICP increase, reduction in total volume of pores and macropores (MACHADO et al., 2010; SANT'ANNA et al., 2009).

Observing the MICP in both areas (Table 2), the cultivated soil had an average of 0.2296 m\(^3\) m\(^{-3}\) while the native vegetation of the cerrado 0.2067 m\(^3\) m\(^{-3}\) of the total volume, with no significant differences between the two areas. For greater depths under analysis, the average micropores percentage found was 0.2473 m\(^3\) m\(^{-3}\) in 20-30 cm depth, significantly differing only from 0-10 cm depth, where the microporosity was 0.1672 m\(^3\) m\(^{-3}\). The increase of microporosity...
in deeper soil demonstrated increase of soil bulk density in deeper layers.

In the Pearson correlation test it was observed significant correlation between TP and MICP 0.432 and between TP and MACP 0.803 (Table 3). This correlation is positive, showing that the increase in total pore volume also causes the increase of macro and micropores. Silva et al. (2005) found similar results studying different management systems on an Ultisol. The total porosity is directly influenced by the macro and micropores, since it depends on the interaction of both (BERTOL et al., 2000).

The correlation between MICP and MACP was negative (Table 3), this behavior is natural in soils, as these properties are inversely proportional.

Table 2 - Macroporosity and microporosity of a Red Oxisol under cultivation and native cerrado

<table>
<thead>
<tr>
<th>Area</th>
<th>Under Cultivation</th>
<th>Native Cerrado</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth (cm)</td>
<td>MACROPOROSITY (m³ m⁻³)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>0.2842 aA</td>
<td>0.2838 aA</td>
<td>0.2840 a</td>
</tr>
<tr>
<td>10-20</td>
<td>0.2182 abA</td>
<td>0.2030 bA</td>
<td>0.2106 b</td>
</tr>
<tr>
<td>20-30</td>
<td>0.1646 bA</td>
<td>0.2148 abA</td>
<td>0.1897 b</td>
</tr>
<tr>
<td>Average</td>
<td>0.2223 A</td>
<td>0.2339 A</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>26.64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 - Pearson's correlation between the properties evaluated

<table>
<thead>
<tr>
<th>BD(3)</th>
<th>MICP</th>
<th>MACP</th>
<th>TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS</td>
<td>0.085 ns(2)</td>
<td>-0.190 ns</td>
<td>0.803 **</td>
</tr>
<tr>
<td>MICP</td>
<td>0.035 ns</td>
<td>0.432 *(1)</td>
<td>0.103 ns</td>
</tr>
<tr>
<td>MACP</td>
<td>-0.034 ns</td>
<td>0.103 ns</td>
<td>0.074 ns</td>
</tr>
</tbody>
</table>

(1)** correlation is significant at the 0.01 level. (2)Correlation no significant. (3)BD: bulk density; MICP: microporosity; MACP: macroporosity; SRP: soil resistance to root penetration

In tests of soil resistance to root penetration (SRP) values ranged from 1.30 to 2.76 MPa in the cultivated area, and from 1.57 to 2.31 MPa in the native Cerrado (Figure 1) all obtained with average humidity of 24% in both areas. This result can be considered high if compared to those found by Marchão et al. (2007) also in an Oxisol. High values of SRP may restrict the percolation of water and prejudice the root growth with consequences on crop productivity. Keeping in view the intrinsic variability of this attribute, there is no consensus on the value above which there are restrictions. However, SRP values greater than 2 MPa have been strongly considered restrictive to the growth of plant roots (LIMA et al., 2010). In view of this author's
statement, the two uses of this soil, may present problems for the plants development starting from the 10 cm layer, since the values of SRP are above the ordinary.

In 0-10cm layer of soil under agricultural use had a lower resistance to penetration the cultivated soil had higher penetration resistance values, a probable cause for this behavior is the traffic of machines and animal trampling. The fact that the area under cerrado has obtained a lower resistance to penetration may be explained by the accumulation of soil organic matter over the years, leaving the soil less cohesive. Organic matter has contradictory effects on the soil resistance to compaction, increased bond strength between the mineral particles, and change in the arrangement of particles (porosity) (HORN & LIBERT, 1994). In fact, organic matter can increase or decrease the resistance of the soil, depending on their joint effect on density, shear parameters, capillary tension, and degree of saturation of water (ZHANG et al., 1997). When there is a predominance of the effects of density reduction by increasing porosity, the compressive strength decreases.

![Figure 1 - Soil resistance to root penetration achieved through impact penetrometer performed in native Cerrado (■) and soil under agricultural use (●).](image)

Even showing a lower density, the cultivated soil had a higher SRP. The physical degradation of soil by compression also depends on the intensity of traffic. It is important to be acknowledged that the number of passes of the machinery on the one hand reduces the soil porosity and the nominal diameter of the pores, but on the other hand...
its effect decreases in each pass (Zhang et al. 2005). However these relations are highly dependent on soil conditions, especially moisture, consistency, initial porosity and macroporosity (FIGUEIREDO et al., 2009).

The adoption of crop rotation systems, particularly in the NT, has been recommended for physical, chemical and biological soil management. From the standpoint of soil physics, has been stimulated the adoption of the rotation to maintain and / or increase levels of soil organic matter, creating biological pores, improve soil structure and maintain enough straw on the soil surface.

CONCLUSIONS

1 - The ripping and subsoiling operations in recent years have reduced the density of the soil in the area under cultivation in relation to the Cerrado conditions.

2 – Land use for cultivation has not changed the behavior of the BD, TP, MICP and MACP, where for both areas there is growth of BD and decrease of TP, MICP and MACP in parallel to the increase of the depth of the soil.

3 - From 10 cm of depth, the RP values in the crop soil are above the critical level for cultivated soils.

REFERENCES


Change in physical…  9


