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Soil Characteristics under Three Management Systems in an Agricultural Property at the Cerrado-Brazil

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Abstract: The present work aimed to characterize the chemical, physical and organic matter attributes on three land use systems (No Tillage System-NTS, Livestock Forestry Integration-LFI and Native Forest-NF), adopted in an agricultural property. Soil deformed samples were collected for texture and chemical analysis. For density, particle density and soil density analysis, undisturbed samples were collected at different depths. As for texture, the NTS was characterized as clayey and the LFI and NF systems as sandy. For the Particle Density (Pd), the systems did not differ statistically at the depth of 0-5 cm, and the other depths differed significantly only between NTS and NF. As for the Soil Density Sd, the LFI and NF systems did not differ from each other and showed the highest value. In macroporosity, at depths of 0-5 cm and 5-10 cm, there was a significant difference only between NF and LFI systems. In NTS the microporosity, the levels of Ca, Mg, P and K and O.M (0-10cm) were higher. For the O.M the NTS and NF presented similar values. The evaluated characteristics were influenced by the soil texture and not by the adopted system. The producer makes use of that information to implement the appropriate system.

Keywords: No-Tillage, Livestock Forest Integration, Native Forest, Agroecology

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1. INTRODUCTION

For many years, rural producers maintained agricultural practices that did not prioritize soil conservation techniques. However, these practices can increase environmental impacts and, consequently, decrease the productivity of implanted crops (Giro, A. *et al.*, 2019). One of the main problems identified in these practices were the long-standing use of the conventional cultivation system, where changes in the physical and chemical characteristics of the soil have been proven (Levinski-Huf, F., & Klein, V. A. 2018; Nascimento, P. C. D. *et al.*, 2014). Each time the soil preparation is done in a conventional manner, its structure is damaged, leading to the destruction of aggregates, causing surface sealing and compaction, reducing the infiltration of rainwater and reducing the availability of water stored in the soil, also favoring erosion (da Silva, P. L. F. *et al.*, 2019).

The mulching harnessed in the integration systems can maintain adequate levels of organic matter in the soil, which has great benefits for the physical characteristics of the soil, such as the improvement of its structure with the formation of macro and micropores (Sales, L. E. D. O. *et al.*, 2010; Aikins, K. A. *et al.*, 2019; & Wang, H. *et al.*, 2020). That improvement is due to the root synthesis of organic material, associated with the configuration and proportion of lateral roots (da Luz, F. B. *et al.*, 2019). Good levels of carbon in the soil also benefit the retention and availability of nutrients for plants, which can be accentuated with the use of crop rotation or succession, which can increase the productivity of the implanted crops (Bu, R. *et al.*, 2020; Schmidt, M. P., & Martínez, C. E. 2019).

In the Brazilian Cerrado region, tax incentives and the high value of the land resulted in the occupation of soils with low aptitude without the assessment of this capacity, resulting in the adoption of inadequate management systems. To circumvent this situation, farmers have implemented integrated agricultural production systems (IAPS) in those areas to recover nutrient cycles, improve biodiversity and increase the resilience of agricultural operations (Smart, A. J. *et al.*, 2021). Associated with a minimum cost, using techniques such as better spacing between crops planted in the area and minimum tillage (Giro, A. *et al.*, 2019). Thus, the integration systems intensify the use of the soil, having as basis the spatial and temporal integration of the components of this productive system, in order to have higher quality in production, environmental quality and competitiveness (Cortner, O. *et al.*, 2019).

In this context, Livestock-Forest Integration systems may have lesser impacts on land use, recovery of degraded areas and alternatives for areas unqualified to plant crops, such as sandy soils (Du-Pont, T. *et al.*, 2020; Nyberg, Y. *et al.*, 2020; & Cortner, O. *et al.*, 2019). However, that information indicates, in turn, the need to assess soil characteristics and the environment in general, with an emphasis on their limitations and potential, for the establishment of agricultural activities (Lilburne, L. *et al.*, 2020). The present work aimed to characterize the physical, chemical and organic matter attributes in three land use systems (No Tillage System-NTS, Livestock Forest Integration -LFI and Native Forest -NF), adopted in an agricultural property.

2. Material and Methods

This work was carried out at the São Paulo farm, located at the municipality of Brasnorte, in the State of Mato Grosso at a Latitude: -13 06 '49.19173", Longitude: -57 56' 48.91738" and Altitude: 442.56 m (Fig. 1). The prevailing climate is the tropical super-humid monsoon, with annual rainfall above 2,000 mm.

At the property, three land use systems were evaluated, namely, No Tillage System (NTS), Livestock Forest Integration (LFI) and Native Forest (NF) (Fig. 2).

On the No Tillage area (Fig 2A) a crop succession with soybean occurs on the first cycle and the corn crop planted after the soybean harvest. After the corn harvest, the straws remains on the soil and that will serve as cover for the next soybean harvest. In the Livestock Forest Integration (Fig 2B), there was the plantation of *Brachiaria brizantha Marandu* pasture and eucalyptus lines, emphasizing that the eucalyptus was about five years old and the cattle was raised in the area. The Native Forest was used as a reserve area for the farm. It is worth mentioning that in this area a large amount of plants litter was observed in the most superficial fraction of the soil (Fig 2C).

For the collection of undisturbed samples, an area of 600 m^2 was defined, in which five transverse trenches were cut across the sowing lines at each area (Loss, A. *et al.*, 2014).

Deformed and undisturbed soil samples were collected. The deformed samples were collected with the aid of a hoe, at depths of 0-20 cm for texture and 0-10 for organic matter. That choice of differentiated depth sampling for organic matter was due to its superficial accumulation on the surface.

For porosity analysis (macro and micropores), particle density and soil density, undisturbed samples were collected with the Kopecky ring, at depths of 0-5, 5-10 and 10-15 cm.

The deformed samples were air-dried and passed through a 2.0 mm sieve (Air-Dried Fine Earth) for particle size analysis, particle density and soil fertility analysis. The undisturbed samples were initially saturated in plastic trays with distilled water, at a height of about ¾ height of the cylinder for 24 h. After filling the pores by capillarity, the samples were submitted to a tension table to obtain micro, macroporosity and total porosity. After carrying out the tests, the samples were dried in a kiln at 105ºC for 48 hours to determine the soil density (Sd).

The physical and chemical analysis were based on a soil analysis methodology (Donagema, G. K. *et al.*, 2011) and performed at the Soil Laboratory of the University of the State of Mato Grosso (UNEMAT).

All data were subjected to variance analysis ($P < 0.05$) and the Tukey average test at 5%, using the computer program ASSISTAT was performed.

Fig. 1 Location of the municipality of Brasnorte - Mato Grosso (Brazil) and identification of the São Paulo farm. 1-No-Tillage System (NTS); 2 –Livestock Forest Integration (LFI) and 3-Native Forest (NF)

Fig. 2 Systems evaluated at the São Paulo farm. A-No-Tillage System; B – Forest Livestock Integration and C-Native Forest

3. Results and Discussion

The granulometric analysis of the areas of LFI and NF presented low clay contents, being in LFI 17% and in NF 9%, thus characterizing the soil present in those systems within the sandy class. In the NTS there was a high clay content, reaching 60% of which characterizes it as soil within the clay textural class (Table 1).

Table 1. Soil texture values for depth of 0-20 cm.

Soil use systems	Granulometry (%)		
	Sand	Silt	Clay
NTS	22	18	60
LFI	75	8	17
NF	87	4	9

According to Table 2, it was found that there was no significant difference on particle density at the depth of 0-5 cm; however, in the others there were differences. At a depth of 5-10cm, the NF system showed the highest density value, followed by LFI, which did not differ from NTS. At the depth of 10-15 cm, NF and LFI stood out with higher values in relation to NTS.

Table 2. Particle density (Pd), soil density (Sd), macroporosity (Ma), microporosity (Mi) and total porosity (Tp).

Soil use systems	Pd	Sd	Ma	Mi	Tp
	g/cm³		cm³/cm³		
	0-5 cm				
NTS	2,34 ns	1,03 b	0,087 ab	0,477 a	0,552 a
LFI	2,43 ns	1,30 a	0,062 b	0,377 b	0,440 b
NF	2,40 ns	1,24 a	0,107 a	0,310 b	0,417 b
VC (%)	2,61	7,32	22,73	11,24	8,73
	5-10 cm				
NTS	2,36 b	1,16 b	0,100 ab	0,445 a	0,545 a
LFI	2,44 ab	1,33 a	0,075 b	0,397 b	0,472 b
NF	2,51 a	1,29 a	0,130 a	0,312 c	0,442 b
VC (%)	1,73	3,30	19,40	5,51	7,07
	10-15 cm				
NTS	2,30 b	1,15 b	0,075 b	0,452 a	0,527 a
LFI	2,47 a	1,42 a	0,067 b	0,360 b	0,432 b
NF	2,51 a	1,35 a	0,117 a	0,310 b	0,427 b
VC (%)	2,14	4,52	18,24	7,39	7,14

Means followed by the same letter do not differ by the Tukey test (P <0.05). Means followed by ns show no significant difference.

Particle density is an inherent attribute of the soil; therefore, its variation occurs due to mineralogy (Rossi, C. Q. *et al.,* 2015). These values may indicate the predominance of a specific mineral; however, as the soils are formed of mixtures of different primary minerals, such as quartz and secondary minerals such as kaolinites and iron oxides, it cannot be assumed just by this variable, the mineralogical composition of the analysed soils (Kiehl, E. J. 1979; Vilela, E. F. *et al.,* 2019; & Chaparro, M. A. *et al.,* 2020). The real density has an indirect effect on plant growth, as it represents the weighted average of the real density of all its mineral and organic components (Kiehl, E. J. 1979).

As for the soil density (Sd), at the three analyzed depths, the LFI and NF systems did not differ statistically from each other, presenting the highest density value compared to the NTS, corroborating the results in Table 1. This occurs due to the systems LFI and NF presented sandy soils, which are denser than clay soils, due to the presence of quartz. (Loss, A. *et al.*, 2019) in their studies found that the reduction of Sd values are associated with a constant supply of organic matter in cultivation areas such as in the NTS. (Luciano, R. V. *et al.*, 2012) evaluating the granulometry of predominant soils in the Southern Plateau of the State of Santa Catarina, concluded that the maximum compaction density increases in soils with total sand and fine sand content and reduces in soils with higher clay contents.

The higher density found in sandy soils, such as those found in this work, does not present restrictions for the implantation of commercial crops, as this only occurs in values above 1.65 g cm^3 (Reinert, D. J. *et al.*, 2008). Soils with a density between 1.70 to 1.80 g.cm-3 can hinder the penetration of the roots; however, there is no consensus on the limit values of soil density to consider whether there is compaction or not (Lima, I. M. A. *et al.*, 2013).

According to the data referring to macroporosity, it can be verified that at the depths of 0-5 and 5-10 cm, there was a significant difference only between the NF and LFI systems. At those depths, it was observed that there was no significant difference between the NTS and NF systems between both NTS and LFI. These results can be explained due to the clay contents and the higher aggregation that occur in clayey soils (Kiehl, E. J. 1979).

At a depth of 10-15 cm in clayey soils, naturally show greater compaction, due to the reduction of the pores, due to the pressure exerted by the soil mass of the surface, as shown in the Sd values present in Table 2. The macroporosity has its importance for being responsible for aeration and for the greatest contribution to the infiltration of water into the soil (Reinert, D. J. *et al.*, 2008). Soils with a sandy texture have higher values of macroporosity, due to the larger size of their particles (Rigatto, P. A. *et al.*, 2005). In the experiment, it can be observed this greater macroporosity in the NF at that depth. The largest amount of sand (Table 1) can be verified for this management area.

It was observed in Table 2 that the microporosity was higher at the three depths in the NTS. The constant supply of organic matter in cultivation areas such as the NTS may have promoted a higher root density, which favors the approximation of particles and the formation of aggregates by the faster decomposition of crops that have a lower C: N ratio such as soybean. According to (Dalchiavon, F. C., 2011), the content of organic matter can directly influence the values of soil microporosity. Microporosity is responsible for the retention and storage of water in the soil (Rigatto, P. A. *et al.*, 2005). At the depths of 0-5 cm and 10-15 cm, the LFI and NF systems did not differ statistically, with lower values. This characteristic was directly influenced by the texture, since the microporosity is strongly influenced by the texture of the different soils (Barbosa, L. C. *et al.*, 2018).

Regarding total porosity, as it is inversely proportional to the soil density, the same relationship was observed, where the highest values of soil density followed with the lowest values of total porosity. The total porosity had a statistical difference between all analyzed depths, with highlighting on the NTS system, which obtained the highest value at all depths. The LFI and NF systems that did not differ statistically from each other with the lowest values. These data are explained according to the clay soil texture in the NTS and sandy soil in the IFP and NF. According to (Rigatto, P. A. *et al.*, 2005) in general, the soils with a clay texture showed higher values of total porosity, while in soils with higher levels of sand, due to the arrangement of these solid particles, the total porosity is lower.

The highest values of macroporosity at the superficial layers are influenced by the organic matter in the aggregation of the soils (Pereira, M. G. *et al.*, 2020; do Nascimento, D. M. *et al.*, 2019; & Holthusen, D. *et al.*, 2018).

The levels of Ca, Mg, P, K, O.M, Al and pH showed differences between the different uses of the soil, as well as in the different evaluated depths (Table 3).

The pH values (H2O) in NF soils obtained the lowest means compared to the other systems at the three different evaluated depths. (Diel, D. *et al.*, 2014) obtained the same result of lowest pH, in NF soils. According to the authors, these values occur because the NF preserves the natural conditions of the soil, with no correction with liming. At a depth of 0-10 cm, the LFI system obtained the best mean followed by the NTS. At a depth of 10-20 cm the result was inverted, with the soil in the NTS having the best average, whereas for the depth of 20-40 cm the values obtained for the NTS and LFI soils did not differ significantly.

Table 3. Means values and variation coefficients (V.C.) of data on organic matter (O.M), pH, P, Al, K, Ca, Mg and sum of bases (S.B.) in different soil use systems.

Soil use systems	pH	P	Al	K	Ca	Mg	S.B.	O.M.
	H_2O	mg dm^{-3}		cmolc dm^{-3}				%
	0-10 cm							
NTS	6,09 b	11,72 a	0,0 b	0,14 a	4,87 a	1,28 a	6,30 a	0,28 a
LFI	6,44 a	6,94 b	0,0 b	0,04 b	3,26 b	1,72 a	5,03 b	0,22 b
NF	4,46 c	2,37 c	1,7 a	0,03 b	0,18 c	0,14 b	0,36 c	0,23 ab
VC (%)	2,22	18,07	16,64	19,03	9,54	23,12	10,78	10,98
	10-20 cm							
NTS	6,15 a	2,47 b	0,0 b	0,11 a	3,00 a	0,71 b	3,83 a	0,25 ns
LFI	5,67 b	3,45 a	0,0 b	0,03 b	1,27 b	0,92 a	2,26 b	0,19 ns
NF	4,65 c	1,77 c	1,53 a	0,03 b	0,26 c	0,05 c	0,36 c	0,20 ns
VC (%)	3,44	10,15	77,35	23,09	26,32	15,84	17,55	17,09
	20-40 cm							
NTS	5,76 a	1,70 a	0,0 b	0,04 ns	1,39 a	0,34 a	1,77 a	0,21 ns
LFI	5,76 a	1,01 b	0,0 b	0,03 ns	0,79 b	0,39 a	1,22 b	0,19 ns
NF	4,96 b	1,87 a	0,87 a	0,02 ns	0,02 c	0,14 b	0,19 c	0,19 ns
VC (%)	2,35	10,69	29,69	44,16	12,9	26,86	5,14	26,21

Means followed by the same letter do not differ by the Tukey test at 5%; (ns) not significant NTS: No-till; LFI: Livestock Forest integration; NF: Native forest.

The presence of Al+3 only in the soils of NF where the pH is below 5.5 has a probable explanation for being an area where no type of agricultural management has been carried out, whereas for the area of NTS and LFI the liming was carried out. According to (Zambrosi, F. C. B. *et al.,* 2007) liming carried out in these systems increases the pH and neutralizes the levels of exchangeable aluminum.

The NTS soil obtained the highest means for the Ca values at the three different evaluated depths, followed by the LFI soil; the NF soil had the lowest mean. This is due to the liming performed in the areas of NTS and IFP. The application of lime (liming) in addition to increasing the pH positively influences the contents of Ca, Mg and the sum of bases, thus it is possible to observe the best means in the soil of NTS followed by that of LFI (Bispo, D. F. A. *et al.,* 2017; Leite, L. F. *et al.,* 2010; & Prado, R. D. M., & Natale, W. 2004).

The Mg values did not differ in the NTS and LFI soils at a depth of 0-10; 20-40 cm, on the other hand for the depth of 10-20 cm the LFI soil obtained the best average. The lowest average was observed in NF soil. This result can be explained by the fact that the liming process provides Mg to the soil. The Mg contents obtained in the NF soil were the natural contents of the soil.

The soil of the NTS obtained the best P content at a depth of 0-10 cm, since the producer performs superficial broadcasted fertilization on the agricultural crops, which justifies this result. The LFI area was fertilized to implant the forage species, but that fertilization it is not carried out every year, this may justify the smaller amount present in the soil for that system, contrariwise for NF there is no management in order to increase P in the soil. At a depth of 10-20 cm, the LFI soil obtained the best average; according to (Bispo, D. F. A. *et al.,* 2017) the dynamics of phosphorus are altered by the constant coverage of the soil causing an increase in the concentration of the nutrient in the topmost layer of the soil.

The K values were higher in the NTS since fertilization was carried out more regularly. According to (Santini, J. M. K. *Et al.,* 2019) correction fertilization, maintenance, gradually builds soil fertility, providing phosphorus and / or other nutrients according to the necessary fertilizer dose. Fertilization can explain not only the highest levels of K in the soil of NTS but also those of P.

The O.M contents varied according to the different land use systems evaluated. The content of O.M at the depth of 0-10 cm in the soils of NTS and NF did not differ among themselves, these data can be explained by the fact that the surface layer of the soil of NF is composed of plants litter. (Araújo, R. *et al.,* 2007) found in a Pinus reforestation area that despite the large volume of plant litter, the organic matter content was low, probably due to the small specific surface and the high C: N ratio, that is, the large amount of plants litter found in the NF soil did not influencede the O.M content of the soil. (Di Lonardo, D. P. *et al.,* 2018) comparing the carbon dynamics in forest soils and cultivated soils, found that the C respiration rate from plants litter is lower when compared to agricultural soils.

In the work presented by (Wood, S. A. *et al.,* 2019) the authors comment that, the studies show that the areas of annual crops, without the use of conservationist management, have great falls in the contents of organic matter.

The O.M content found in the LFI soil did not differ from the NF soil; these data can be explained by the fact that areas of well-managed pastures can provide a greater supply of biomass to the soil (Jackson, R. D. *et al.,* 2019). (Alvarenga, M. I. N., & Davide, A. C. 1999) found that the pasture areas did not differ significantly from the native Cerrado areas. There were no significant differences in the O.M content in the three different land uses for the depths of 10 -20 and 20-40cm. This result can be explained due to the greater supply of organic matter on the soil surface (Cotching, W. E. 2018).

According to (Jiménez-González, M. A. *et al.*, 2020) the rate of O.M decomposition varies according to the conditions of temperature and humidity, however even in similar conditions of climate, humidity and management, it is common to observe variations. This is because the soils have different capacities of retention and protection to the decomposition of the O.M depending on their specific surfaces. (Wang, H. *et al.*, 2020) found that the levels of organic matter are related to the texture of the soil, as long as they are similar in climate, management and drainage. As noted in Table 2, it is possible to verify that the soils of NF and LFI have a sandy texture and therefore a smaller specific surface, leaving the O.M more unprotected from the decomposing microorganisms.

The content of O.M in the soil presented in the NTS can be explained by its more clayey texture. This clay has a greater capacity to protect the soil's organic matter stock. (Loss, A. *et al.,* 2019) described that the the silt and clay fraction particles can join or adsorb O.M particles, being the main aggregation agent of soil particles, responsible for the stabilization of macroaggregates, consequently greater preservation of soil organic matter.

(Adams, A. M. *et al.,* 2020) found that the use of conservation systems for a long period has been shown to be efficient in increasing the levels of N, P and organic carbon and thus improving soil fertility and increasing the productivity of implanted crops.

The present work confirms that the results were influenced by the soil texture and not by the systems used on the farm. However, it demonstrates that the producer uses information on texture, organic matter and physical characteristics of the soil to implement the management system that is most appropriate for each area. Using the soil aptitude land use system, the results show that the producer has implanted the main crop in the area that has 60% clay, with higher content of organic matter and nutrients. While the textured soil, which has 17% clay, used as a pasture and planting area for tree species and in the more sandy area the use given was as a reserve area.

(Juhos, K. *et al.,* 2019) demonstrated that the parameters of soils texture, organic matter and nutrient availability were those that had the greatest influence on the selection of land use.

4. CONCLUSION

The texture had a direct influence on the organic matter and in all chemical and physical analyzes evaluated. Thus, it cannot be justified that the differences found in the analysis results were due to the different land use systems;

The levels of O.M are directly influenced by the soil texture, so it is not possible to state that the land use system influenced the values of O.M obtained in this work;

The areas with clayey texture and higher levels of nutrients and organic matter are used for the main crop and the other areas are used for the LFI and preservation area.

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