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PHYSICAL ATTRIBUTES OF SOIL IN AN AGROFORESTRY SYSTEM WITH OIL PALM

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ABSTRACT

Currently, there is a lack of related studies on the impacts of management in diversified cultivation with oil palm, on the attributes of the soil. Thus, this work aimed to evaluate whether the management affects the physical attributes in different positions within an agroforestry system with oil palm. The research was carried out at an experimental site, in the county of Tomé-Açu, Brazil. The system is called the Biodiverse Agroforestry System (AFS-BIO), with oil palm as the species with the greatest economic value. We collected soil samples with preserved structure in the weeded circle oil palm (WED); harvest path (HAR); leaf pile (PIL) and diversified strip (DIV) in depths 0-5; 5-10; 10-20 and 20-30 cm from the soil, to determine aggregation and bulk density. In management zones without machine traffic, soil aggregation is greater and the density of the soil is lower compared to the harvest path. Machine traffic decreased aggregation and promoted values of bulk density above the ideal (1.4 g cm^{-3}), for sandy loam soils, in the harvest path. The organic management and the presence of mulch on the soil contributed to a higher physical quality, while the heavy machinery traffic in the harvest path causes soil compaction.

Key words: Management zones; Physical quality; Soil management

INTRODUCTION

Physical attributes (bulk density, aggregate, porosity and resistance to penetration) are considered the main indicators of physical soil quality in integrated agricultural production systems (POLANÍA-HINCAPIÉ et al., 2021). The management practices carried out in the systems with or without oil palm, can cause changes in the carbon content of the soil (CARVALHO et al., 2014; DLAPA et al., 2020), that influences physical components, such as bulk density, porosity and water storage (MACHADO et al., 2008; MORADI et al., 2015) and, consequently, can affect plant growth (MORAES et al., 2016).

Oil palm is considered the most economically valuable oilseed and has the highest productivity per harvested area (SEDAP, 2021). One of the characteristics of the production system of this agricultural commodity is the spatial variation of the soil due to management, which conditions the emergence of management zones (NELSON et al., 2015). The studies by Frazão et al. (2013) and Ramos et al. (2017) found spatial variation for soil carbon content in monoculture and agroforestry systems with oil palm, respectively, mainly due to the management carried out in these use systems.

Agroforestry systems with oil palm are land-use systems that can provide more ecosystem services compared to conventional farming systems (monoculture) (GOMES, 2019). In these production systems, the impacts of management on the physical components of the soil have not yet been reported. The most recent studies on physical attributes have been carried out in monoculture systems (FERREIRA et al., 2019; SATO et al., 2017; ZURAIDAH, 2019). However, related studies on diversified oil palm systems lacking.

Therefore, the objective of this work was to evaluate whether the management influences the physical attributes of soil in different positions (management zones) within an agroforestry system with oil palm, in the eastern Amazon.

MATERIAL AND METHODS

The research was carried out at an experimental site, which is located in the county of Tomé-Açu, eastern Amazon, Brazil. The soil in the area is characterized as a medium textured dystrophic yellow Oxisol with a predominance of the sand fraction (EMBRAPA, 2018). The study was conducted in an agroforestry system that occupies an area of 2.0 ha and has oil palm as the main crop of economic value.

The system, called the Biodiverse Agroforestry System (AFS-BIO), was implemented in 2008 and consists of double lines of oil palm (spacing of 7.5 m between lines and 9.0 m between plants) alternated by lines of herbaceous, shrub and tree species. In addition to oil palm (*Elaeis guineensis* Jacq) the predominant species were *Acacia mangium* (acácia), *Euterpe oleracea* (açaí), *Carapa guineenses* (andiroba), *Theobroma cacao* (cacau), *Lecythi spisonis* (castanha), *Theobroma grandiflorum* (cupuaçu), *Adenanthera pavonina* (falso pau-brasil), *Gliricidia sepium* (gliricídia), *Inga edulis* (ingá), *Artocarpu sheterophyllus* (jaqueira), *Mangifera indica* (manga), *Spondias lutea* (taperebá), *Bixa orellana* (urucum). The fertilization is organic and consists of the application of empty bunches of the oil palm (that is, those remaining after the oil has been extracted in the industry) in the crowning area of the plant.

Four plots measuring 30 m x 30 m were delimited and, in each plot, we collected samples in the following zones: weeded circle oil palm (WED); harvest path (HAR), machine traffic location; leaf pile (PIL), stacking location of oil palm leaves and diversified strip (DIV). In each management zone in the plots, we collected two samples (duplicates) of soil with preserved structure in volumetric cylinders and in the form of monoliths measuring 10 cm x 10 cm x 10 cm in layers 0-5; 5-10; 10-20 and 20-30 cm of soil.

We determined the stability of aggregates through wet sieving (YODER, 1936), using a set of seven sieves with decreasing mesh opening, namely: 4.0 mm; 2.0 mm; 1.0 mm; 0.5 mm; 0.25 mm; 0.106 mm and 0.053 mm. After wet sifting, we transfer the samples of aggregates of each class of sieve diameter, by means of a light jet of deionized water, to aluminum containers and then we dry the samples in a forced air circulation oven at 105 ºC for a period of 24 h (EMBRAPA, 2017). After this period, we determine the dry mass of the samples retained in each sieve. We calculated the mean weighted diameter of the aggregates (MWD) using the equation below:

$$\mathrm{MWD} = \sum_{i=1}^{n} \mathrm{xi\ wi}$$

xi: medium diameter of each class of aggregates;

wi: proportion of each class of aggregates in relation to the total aggregates.

We determined the density soil (Ds) following the methodology of Embrapa (2017), in which the samples were dried in greenhouses with forced air circulation at 105 ºC for 48 h. We calculate the density soil according to the equation below:

$$D_s = \frac{m_s}{V}$$

D_s: soil density, in g cm^{-3};

m_s: mass of dry soil in an oven at 105 ºC until constant weight, in g;

V: cylinder volume, in cm^3.

We used one-way analysis of variance (Anova, $p \leq 0.05$) to test the effect of management zones on variables, separately by soil layer. To compare the averages, we applied the Tukey test ($p \leq 0.05$). We performed statistical analysis with the AgroEstat software (BARBOSA; MALDONADO JÚNIOR, 2015).

RESULTS AND DISCUSSIONS

The management zones of the weeded circle oil palm, leaf pile and diversified strip in the 0-20 cm layer of the soil showed a higher weighted average diameter of the aggregates statistically, compared to harvest path. In the 20-30 cm depth, the average diameter of the aggregates was greater in WED than in DIV (Table 1). The larger diameter of the aggregates that we found in these management zones (WED, PIL and DIV) in the 0-20 cm profile compared to harvest path may be related to the greater presence of roots and continuous supply of organic matter, in addition to the absence of the passage of machines in these management zones. The roots of the plants release exudates and organic compounds that act as cementing and bonding agents between mineral particles, playing a fundamental role in the formation of soil aggregates (TISDALE; OADES, 1982; XIAO et al., 2020).

The higher organic matter content influences the average diameter of the aggregates in a positive way, through the links between organic polymers and inorganic surfaces of soil particles (CASTRO FILHO et al., 2002; SALTON et al., 2008). On the other hand, to harvest path, the constant passage of agricultural machines and implements causes negative impacts on the soil surface, since it leads to the breaking of the aggregates of larger diameter to their conversion into smaller aggregates, causing soil compaction (COLOMBI et al., 2018; ZURAIDAH, 2019).

The soil density to harvest path was statistically higher than that of the leaf pile and diversified strip in the 0-10 cm depth and in the 10-20 cm depth, differed from the weeded circle oil palm and diversified strip (Table 1). The management of organic fertilization close to the oil palm and the continuous supply of mulch to leaf pile and diversified strip, tend to provide less soil density, while in the harvest path the passage of machines and less ground cover contribute to high values of soil density, above the ideal for sandy loam soils (1.4 g cm^{-3}), according Arshad et al. (1997). At 0-10 cm depth the bulk density values are close to the critical limit (1.75 g cm^{-3}), according to Arshad et al. (1997), which can hinder, for example, the growth of oil palm roots in this management zone. In fact, the use of machines for harvesting and other management operations can contribute to the deterioration of the physical conditions of the soil, which can restrict the growth and function of the oil palm roots (ZURAIDAH et al., 2010).

Thus, the management of organic fertilization and the continuous supply of litter on the soil favored greater physical quality of the soil, through greater aggregation and lower apparent density in agroforestry systems with oil palm. However, the traffic of machines for the management of the system deteriorates the physical conditions of the soil, causing compaction in the harvest path, which arouses attention, to weigh in management practices that mitigate the damage on the physical attributes of the soil.

Table 1. Mean weighted diameter of aggregates and soil density in a biodiverse agroforestry system (AFS-BIO) in the county of Tomé-Açu, eastern Amazon, Brazil.

System	Management zones			
	WED	**HAR**	**PIL**	**DIV**
	Mean weighted diameter of aggregates (mm)			
	Soil depth 0-5 cm			
AFS-BIO	4.78 ± 0.24 a	2.61 ± 0.35 b	5.78 ± 0.01 a	4.95 ± 0.33 a
	F= 25.45**		CV= 11.82	
	Soil depth 5-10 cm			
AFS-BIO	4.73 ± 0.14 a	2.61 ± 0.17 b	4.96 ± 0.23 a	5.02 ± 0.33 a
	F= 24.94**		CV= 10.65	
	Soil depth 10-20 cm			
AFS-BIO	4.06 ± 0.13 a	3.01 ± 0.30 b	4.08 ± 0.26 a	4.50 ± 0.11 a
	F= 8.69**		CV= 11.03	
	Soil depth 20-30 cm			
AFS-BIO	4.50 ± 0.12 a	3.06 ± 0.16 b	3.94 ± 0.33 ab	3.53 ± 0.16 b
	F= 8.49**		CV= 11.20	
	---------------- **Soil density (g cm^{-3})** -------------			
	Soil depth 0-5 cm			
AFS-BIO	1.53 ± 0.03 a	1.67 ± 0.02 ab	1.35 ± 0.03 b	1.35 ± 0.08 b
	F= 10.44**		CV= 6.44	
	Soil depth 5-10 cm			
AFS-BIO	1.58 ± 0.05 a	1.68 ± 0.03 ab	1.49 ± 0.04 b	1.46 ± 0.04 b
	F= 6.35**		CV= 5.16	
	Soil depth 10-20 cm			
AFS-BIO	1.48 ± 0.02 b	1.60 ± 0.02 a	1.52 ± 0.02 ab	1.46 ± 0.02 b
	F= 7.30**		CV= 3.13	
	Soil depth 20-30 cm			
AFS-BIO	1.52 ± 0.04 a	1.57 ± 0.01 a	1.54 ± 0.01 a	1.50 ± 0.02 a
	F= 1.17^{ns}		CV= 3.16	

**Significant at 1% probability of error; ns not significant; CV coefficient of variation; Same letters do not differ by Tukey test at 5% probability of error.

CONCLUSIONS

The organic management and the litter supply over the soil contributed to a better physical quality of the soil in the management areas without machine traffic. In the harvest path, due to the passage of machines, the physical quality of the soil is lower and the density of the soil has reached values close to the critical limit for soils with a sandy loam texture.

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