TEMPORAL VARIATION OF PENETRATION RESISTANCE IN AN AGROFORESTRY SYSTEM WITH OIL PALM

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ABSTRACT

Soil penetration resistance penetration is property important to characterize the state of soil compaction in cultivated systems. Thus, this work aimed to evaluate the impacts of management and moisture on soil penetration resistance in an agroforestry system with oil palm. The research was carried out at an experimental site, located in the county of Tomé-Açu, eastern Amazon, Brazil. The system is called the Biodiverse Agroforestry System (AFS-BIO), with oil palm as the species with the greatest economic value. We collect soil samples weeded circle oil palm (ACP); Harvest path (CAR); leaf pile (PIL) and diversified strip (DIV) in depths 0-5; 5-10; 10-20; 20-30 and 30-50 cm of soil for determine gravimetric moisture. The penetration resistance is determined by means of an impact penetrometer with a cone angle of 30°. Soil resistance in periods of lower moisture is higher than in periods of high soil moisture. There is an increase in resistance with the depth of the soil, which may possibly be influenced by the increase in bulk density. In the period of lower moisture the soil resistance reached critical values, mainly in the harvest path, due to the passage of machines in this management zone. Soil moisture and management are the main factors that directly influence soil penetration resistance.

Key words: Amazon; Management zones; Mechanical resistance

INTRODUCTION

Soil penetration resistance has been considered an important property to characterize the state of soil compaction and has also been used in the assessment of physical soil quality in agricultural and forestry systems (DEARMOND et al., 2020; POLANÍA-HINCAPIÉ et al., 2021). The management practices carried out in the production systems can influence the organic matter content, the bulk density and the water status of the soil, which will consequently affect the resistance to penetration (GABRIEL et al., 2021; VAZ et al., 2011).

In the last decades, the cultivation of oil palm has grown strongly in the countries of the African and American continents, driven mainly by the world demand for vegetable oil (HANSEN et al., 2015). One of the characteristics of the production system of this agricultural commodity is the spatial variation of the soil due to the (NELSON et al., 2015). The spatial variation of soil carbon found in the studies by Frazão et al. (2013) and Carvalho et al. (2014), resulting from management in monoculture and agroforestry systems with oil palm, can indirectly affect penetration resistance. In the area of machine traffic, especially in periods of lower soil moisture, the resistance of the soil to penetration can reach critical values, which can restrict the growth of oil palm roots (SATO et al., 2017).

The cultivation of oil palm in agroforestry systems can provide numerous environmental benefits, such as carbon storage similar to that of natural vegetation areas (CARVALHO et al., 2014). In these production systems, the impacts of moisture and management on the temporal variation of soil resistance to penetration have not yet been reported. The most recent studies on physical attributes were carried out in monoculture systems (FERREIRA et al., 2019; SATO et al., 2017; ZURAIDAH, 2019), but not in diversified systems with oil palm.

Therefore, the objective of this work was to evaluate the impacts of soil management and moisture on soil penetration resistance in 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 *Euterpe oleracea* Mart (açaí), *Carapa guineenses* Aubl (andiroba), *Oenocarpus mapora* H. Karsten (bacabi), *Theobroma cacao* Linn (cacau), *Bertholletia excelsa* (castanha), *Adenanthera pavonina* (falso pau-brasil), *Inga edulis* Mart (ingá), *Tabebuia sp* (ipê), *Hymenaea courbaril* L (jatobá), *Mangifera indica* L (manga), *Swietenia macrophylla* King (mogno), *Azadirachta indica* (nim), *Virola surinamensis* (ucuuba). 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). At each location in the plots, we collect deformed soil samples through the probe-type auger, in depths 0-5; 5-10; 10-20; 20-30 and 30-50 cm from the ground, to determine gravimetric moisture (EMBRAPA, 2017).

We determined the soil penetration resistance with an impact penetrometer (Stolf model) with an angle of the cone of 30°. The readings made in the field were recorded and later processed in an electronic spreadsheet (Excel VBA) developed by Stolf et al. (2014). The equation we used to transform the number of dm^{-1} impacts into mechanical resistance (MPa) was proposed by Stolf (1991) and restated by Stolf et al. (1998; 2005; 2014):

$$PR\ (\text{kgf cm}^{-2}) = 5.6 + 6.89 * N\ (\text{impacts dm}^{-1}),$$ $PR\ (\text{kgf cm}^{-2}) = 5.6 + 6.89 * N\ (\text{impacts dm}^{-1}),$

PR: soil penetration resistance, in MPa;

N: is 10 x number of impacts divided by penetration, in cm.

RESULTS AND DISCUSSIONS

Soil penetration resistance increased with the depth of the soil, especially in periods of lower soil moisture. In general, when the soil was drier, we observed a greater variation in resistance between the management zones. The trend we found is that in the period of lowest soil moisture, at the harvest path showed penetration resistance above the critical limit (2.0 MPa) in all layers of the soil, while in the weeded circle oil palm, leaf pile and diversified strip at resistance was lower than the critical limit in the most superficial layers and tended to increase, starting at 10 cm from the ground (Figure 1).

In the period of highest soil moisture, soil resistance to penetration varied little between management zones. Although the harvest path showed greater resistance, the values did not reach the critical limit in the most superficial layers of the soil, which are the most influenced by management, in these production systems. The management of organic fertilization and the contribution of mulch over the soil, from the pruning of the plants, contribute to decrease the resistance of the soil, especially in periods of lower soil moisture, in the weeded circle oil palm, leaf pile and diversified strip. However, the soil compaction in the harvest path, due to the traffic of machines in this management zone and less presence of mulch on the soil, presented greater resistance, mainly in the period of less precipitation and soil moisture.

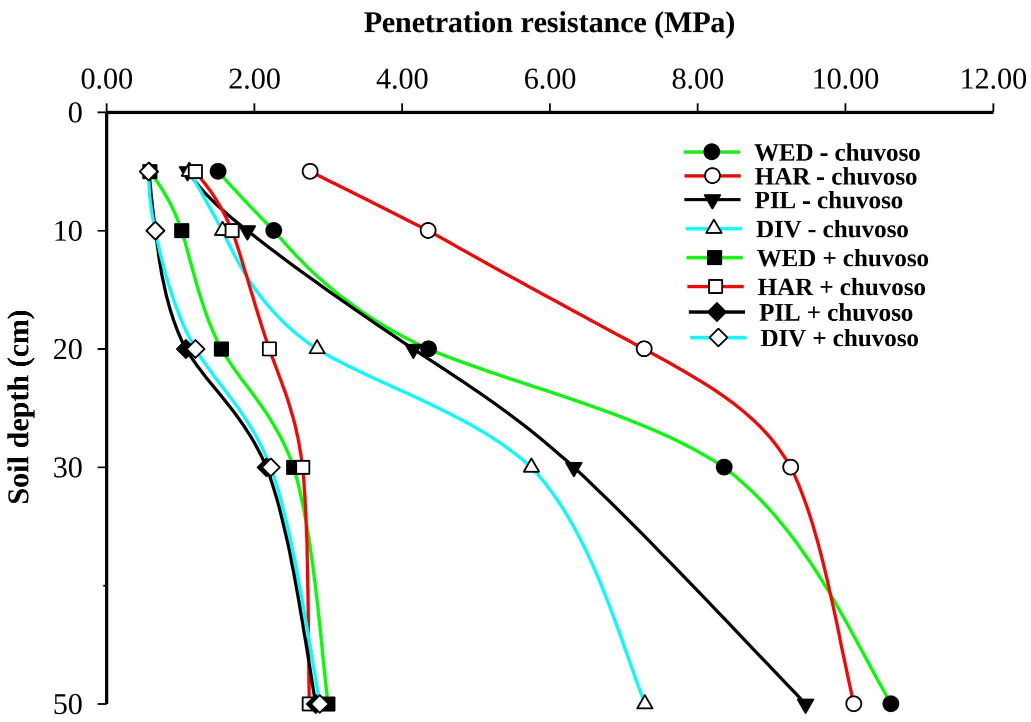

Figure 1. Variation of soil penetration resistance in a biodiverse agroforestry system (AFS-BIO) in the county of Tomé-Açu, eastern Amazon, Brazil.

The gravimetric moisture of the soil showed greater variation between the management zones in the less rainy period, compared to the wetter period. The harvest path was the area that had the lowest soil moisture up to the 30 cm depth, which was related to greater soil resistance to penetration in this management area. In the rainy season, there was less variation in moisture between the management areas studied (Figure 2).

Our results suggest that soil moisture was the main factor that influenced soil resistance to penetration, but other factors such as texture, soil density, organic matter content can be affected by the type of management used on the soil and, consequently, can also influence resistance (GABRIEL et al., 2021; SAYEDAHMED, 2015; VAZ et al., 2011). The type of soil cover that provides higher levels of organic matter can provide better water conditions and soil density, consequently positively impacting soil penetration resistance (GABRIEL et al., 2021; SAYEDAHMED, 2015). Future studies in our study area will assess the relationship of resistance to penetration with factors other than soil moisture.

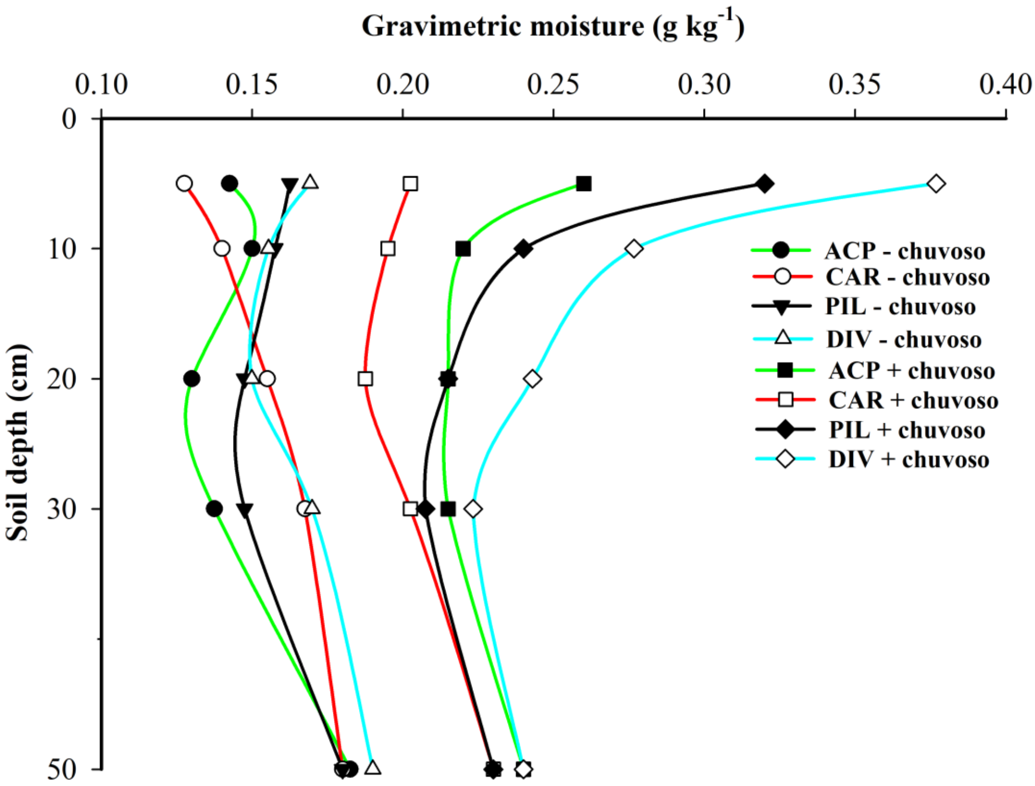

Figure 2. Variation of gravimetric moisture in a biodiverse agroforestry system (AFS-BIO) in the county of Tomé-Açu, eastern Amazon, Brazil.

CONCLUSIONS

The soil penetration resistance varies in time and space in the agroforestry system with oil palm. Soil moisture and management are the main factors that directly influence soil resistance.

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REFERENCES

CARVALHO, W. R.; VASCONCELOS, S. S.; KATO, O. R.; CAPELA, C. J. B.; CASTELLANI, D. C. Short-term changes in the soil carbon stocks of young oil palm-based agroforestry systems in the eastern Amazon. **Agroforestry Systems**, v. 88, n. 2, p. 357-368, 2014.

DEARMOND, D.; FERRAZ, J. B.; EMMERT, F.; LIMA, A. J. N.; HIGUCHI, N. An Assessment of Soil Compaction after Logging Operations in Central Amazonia. **Forest Science**, v. 66, n. 2, p. 230-241, 2020.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. **Manual de métodos de análise de solo**. 3.ed. Brasília, DF: Embrapa, 2017. 573 p.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. **Sistema Brasileiro de Classificação de Solos**. 5.ed. Brasília, DF: Embrapa, 2018. 356 p.

FERREIRA, R. L. C., SATO, M. K., RODRUGUES, S.; DE LIMA, H. V.; TEIXEIRA, O. M. M. Tráfego de máquinas agrícolas em cultivo de palma de óleo: implicações na qualidade física do solo. **Amazonian Journal of Agricultural and Environmental Sciences**, v. 62, 2019.

FRAZÃO, L. A.; PAUSTIAN, K.; PELLEGRINO CERRI, C. E.; CERRI, C. C. Soil carbon stocks and changes after oil palm introduction in the Brazilian Amazon. **Gcb Bioenergy**, v. 5, n. 4, p. 384-390, 2013.

GABRIEL, J. L.; GARCÍA-GONZÁLEZ, I.; QUEMADA, M.; MARTIN-LAMMERDING, D.; ALONSO-AYUSO, M.; HONTORIA, C. Cover crops reduce soil resistance to penetration by preserving soil surface water content. **Geoderma**, v. 386, p. 1-8, 2021.

HANSEN, S. B.; PADFIELD, R.; SYAYUTI, K.; EVERS, S.; ZAKARIAH, Z.; MASTURA, S. Trends in global palm oil sustainability research. **Journal of Cleaner Production**, v. 100, n.1, p. 140-149, 2015.

NELSON, P. N.; BANABAS, M.; GOODRICK, I.; WEBB, M. J.; HUTH, N. I.; O'GRADY, D. Soil sampling in oil palm plantations: a practical design that accounts for lateral variability at the tree scale. **Plant and Soil**, v. 394, n. 1, p. 421-429, 2015.

POLANÍA-HINCAPIÉ, K. L.; OLAYA-MONTES, A.; CHERUBIN, M. R.; HERRERA-VALENCIA, W.; ORTIZ-MOREA, F. A.; SILVA-OLAYA, A. M. Soil physical quality responses to silvopastoral implementation in Colombian Amazon. **Geoderma**, v. 386, p. 1-10, 2021.

SATO, M. K.; LIMA, H. V. D.; FERREIRA, R. L. D. C.; RODRIGUES, S.; SILVA, Á. P. D. Least limiting water range for oil palm production in Amazon region, Brazil. **Scientia Agricola**, v. 74, n. 2, p. 148-156, 2017.

SAYEDAHMED, A. Modeling and correlation of soil cone index for bulk density, moisture content and penetration depth levels in a sandy loam soil. **Journal of Soil Sciences and Agricultural Engineering**, v. 6, n. 2, p. 259-273, 2015.

STOLF, R.; CASSEL, D. K.; KING, L. D.; EICHARDT, K. Measuring mechanical impedance in clayey gravelly soils. **Revista Brasileira de Ciência do Solo**, v. 22, p. 189-196, 1998.

STOLF, R.; MURAKAMI, J. H.; BRUGNARO, C.; SILVA, L. G.; SILVA, L. C. F. D.; MARGARIDO, L. A. C. Penetrômetro de impacto Stolf - programa computacional de dados em EXCEL-VBA. **Revista Brasileira de Ciência do Solo**, v. 38, p. 774-782, 2014.

STOLF, R.; REICHARDT, K.; VAZ, C. P. M. Response to "Comments on 'Simultaneous measurement of soil penetration resistance and water content with a combined penetrometer - TDR moisture probe' and 'A dynamic cone penetrometer for measuring soil penetration resistance'". **Soil Science Society of America Journal**, v. 69, p. 927-929, 2005.

VAZ, C. M.; MANIERI, J. M.; DE MARIA, I. C.; TULLER, M. Modeling and correction of soil penetration resistance for varying soil water content. **Geoderma**, v. 166, n. 1, p. 92-101, 2011.

ZURAIDAH, Y. Influence of soil compaction on oil palm yield. **Journal of Oil Palm Research**, v. 31, n. 1, p. 67-72, 2019.