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INFLUENCE OF SOIL COVER ON PORE DISTRIBUTION IN A FERRALSOL EVALUATED BY 3D COMPUTERIZED MICROCT

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Abstract
In the search for new techniques aimed at complementing and adding new data on Ferralsols, high resolution computer microtomography (microCT) appears as a non-destructive and fast analytical technique. MicroCT has been outstanding in the international scenarios and it is more and more present in soil analyses. Analyzing a soil sample by microCT allows obtaining knowledge, in microscale, on shape, size, distribution, volume, area and pore connectivity and having a 3D visualization of the soil sample and its structure. The objective of this work is to use microCT to compare the porosity distribution and pore connectivity density between a soil without vegetation cover and a soil with grass cover, both Ferralsols. Four undisturbed samples of each soil were collected. The results show that the MicroCT technique is an efficient and non-destructive tool for the analysis and characterization of the pore structure of soils protected from and degraded by erosion, underlining clear differences between them, as expected.

Introduction

The pores of the soil are represented by cavities with different sizes and shapes, determined by the arrangement of solid particles which constitute a volumetric fraction of the soil filled with air, water and nutrients solution (Hillel, 1972). The soil porosity influences in aeration, water conduction and retention, resistance to penetration and branching of the roots in the soil and, consequently use of available water and nutrients (Tavares Filho, J. & Tessie, Stubff et al, 2014). Several techniques can be used to obtain soil porosity index. In the search for new techniques aimed at complementing and adding new data on Ferralsols, high resolution computer microtomography (microCT) appears as a non-destructive and fast analytical technique.

The microCT provides high resolution images with a set of volume data of an inspected sample that does not need to be modified and no preparation method has been submitted. Its physical principle is based on the attenuation of the X-rays when they interact with the object and are modulated according to the physical characteristics. To obtain microCT images, it is necessary to acquire many projections at constant angular steps and the reconstruction is performed with an appropriate algorithm based on the filtered overhead.

The objective of this work is to use microCT to compare the porosity distribution and pore connectivity density between a soil without vegetation cover and a soil with grass cover, both Ferralsols. Four undisturbed samples of each soil were collected.

Methodology

The work developed on a slope within the limits of the Stream of Thorn Microbasin, which has a total area of 9.14km^2 being located in the Farming Paiol, where agricultural activities related to the genetic improvement of cattle and dairy cattle are developed. The area is located in the municipality of Silva Jardim, State of Rio de Janeiro, and access is given by BR 101.

The undisturbed samples for the tests were collected on the half slope of a dissected hill within the limits established by erosion plots, totaling eight replicates packed in plastic film for transportation and handling without loss. The samples were distributed in the following way: four in soil with grass cover and four in soil without vegetation cover, using acrylic tubes measuring 50mm in height and 32mm in diameter.

The samples were scanned in a high energy system - Skyscan / Bruker, model1173. The system operates with voltage and current of 130 kV and 61 µA, respectively. A flat panel detector (2240 x 2240 pixels) was used to register the transmission of the X-ray beam. After acquisition, the image is captured and reconstructed using the FDK reconstruction algorithm, (Feldkamp; Davis; Kress, 1984).

In the present study, we chose to use a adaptive method segmentation. In this method for each voxel, the threshold is calculated as the mean of all pixel/voxel grayscales within a selected radius. In this way, the binary image is obtained, with the objects (soil matrix) in white and the background (pore) in black. Thus, it was possible to quantify the total porosity and density of connectivity. The schematic of this segmentation.

Results and discussion

To acquire the data, the values of the parameters were adjusted to acquire the information within a pattern that responded in the most accurate way, searching for the openings with the smallest possible size, in order to identify more clearly the class of Micropores. In this sense the soil pore diameters analyzed were classified according to Brewer (1964) that define micropores that have a diameter smaller than 0.03mm and macropores larger than this value.

Covered soil (CS) presented the following percentages of total porosity: 21.1; 24.6; 27.3 and 36.7%; As the soil without cover (SWC) had porosities of 13.6; 20.5; 21.8 and 30.8%. The pore densities in the covered soil were 46.7; 76.7; 155.4 and 508.63 mm3, while in the uncovered terrain were 19.9; 45.8; 76.7 and 511.3 mm3. The values of soil porosity presented higher values in the soil covered with grass in relation to the same pairs of soil samples without vegetation cover. This trend was also observed in the values of density of connections between the pores. (Table 1)

The values corresponding to macroporosity were 7.37; 13.78; 9.01 and 12.54% on CS soil and 7.66; 7.48; 13.18; 12.52% not only SWC. Both coverages obtained an average very close to this index, varying only 0.46%. Already the values of microporosity for the soil CS was 13.75; 10.91; 18.37 and 24.17%, in SWC soil the indices were in the houses of 5.94; 13.08; 8.71 and 18.36. In this cyst it is noticed that there is evidence for CS soil, showing an average 5% higher than SWC soil. This can be explained because the permanence of the vegetal cover increases organic matter in the soil, it keeps the root system active and assists in the stability of its aggregates generating an increase of the microporisdade according to Viana *et al* (2011).

In order to obtain a standard of comparison, the soil water retention curve test was carried out in soil samples from the same aforementioned environments (CS and SWC), which presents several practical, technical and scientific applications, such as: The determination of the soil field capacity, the permanent wilting point and the total availability of water in the soil, indispensable variables for an adequate irrigation management, soil water balance and macro and micro porosity (Table 2).

One of the ways to determine the water retention curve in the soil is to use the Richards pressure chamber, which simulates a determined tension in the soil sample and later, by weight difference (wet soil after being subjected to pressure - Soil dried in an oven at 105 ºC for 48 hours), the water content related to the applied voltage is determined. For all eight samples submitted to the assay an eight-strain sequence was applied on the following increasing scale: 0.01; 0.033; 0.06; 0.33; 1.00; 5.00 and 15.00 bar.

What is evident when carrying out a relationship with both methods is that the Retention Curve is larger than the Computed Microtomography because this method can identify a greater percentage of microporosity reaching the house of 23.17% more in the soil CS and 28.05% in soil SWC. This is due to the fact that the maximum resolution of the MCT reaches the equivalent of 0.03mm, however there are a series of pores with smaller sizes that are not identified by the tomographic sensors. Regarding macroporosity data, the Retention Curve showed an average of 12.11% for CS soil and 5.40% for SWC soil. In this same index for MCT, 10.21% for CC soils and 11.52 for SWC were presented. This demonstrates a greater capacity of the microtomography in the identification of pores larger than 0.03mm, mainly to environments that have already been worn in compacts for a period of five years.

Samples		Retention Curve			
		Total Porosity (%)	Macropores (%)	Micropores (%)	Soil density (g/cm³)
Soil with grass Cover	1	49.45	8.95	40.90	2.52
	2	52.86	15.16	42.10	2.63
	3	50.78	9.98	35.80	2.53
	4	53.66	14.36	41.10	2.59
Soil without Vegetation	5	46.15	5.25	40.50	2.59
	6	45.10	3.00	37.70	2.57
	7	47.03	11.23	40.80	2.53
	8	43.24	2.14	39.30	2.57

Table 1 - Distribution of porosity and connectivity density in different systens of use.

Samples		X-ray computed microtomography			
		Total Porosity (%)	Macropores (%)	Micropores (%)	Connectivity Density (mm^3)
Soil with grass Cover	1	30.88	12.52	18.36	511.13
	2	24.69	13.78	10.91	76.76
	3	27.38	9.01	18.37	155.42
	4	36.71	12.54	24.17	508.63
Soil without Vegetation	5	13.60	7.66	5.94	19.91
	6	20.56	7.48	13.08	45.84
	7	21.89	13.18	8.71	76.79
	8	21.12	7.37	13.75	46.03

Table 2 - Distribution of the values processed by Retention Curve.

Conclusions

The results show that the presence of the vegetal cover is a relevant factor in the increase of the porosity of the superficial layers of the soil, because the root system develops ducts that are connected with the progress of its development. In this sense, identified a concentration of 18.60 g/dm3 of organic carbon in the A horizon of this soil, which may aid in the stability of aggregates and condition the occurrence of pores. On the other hand, the lack of vegetation cover considerably reduces the pore indices of the superficial layers of the soil, which can be explained by the fact that the sealing process of the exposed soil occurs when the material disaggregated by erosion caused by the impact of the raindrops (Splash) obliterates the pores, corroborating with this hypothesis identified, for the same area, very high apparent density values for horizon A, at the house of 1.45 g/dm3. Thus, the MicroCT technique demonstrated an efficient and non-destructive tool for the analysis and characterization of the pore structure of soils protected from and degraded by erosion, underlining clear differences between them, as expected.

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