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The use of Tomography to Evaluate Soil Compaction in a Red Yellow Podzolic Area of the Brazilian Northeast

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Abstract

Petrolina / Juazeiro is an important fruit growing area. In this region some soils present compacted layers and there is no agreement whether this compaction is a natural process or if it is man induced. The presence of compacted layers, occurring down to a depth varying from 0.4 to 1.0 m, affects water distribution which occurs mostly in the horizontal direction. Thus long term irrigation can lead to soil saturation (ponding) causing poor root aeration. In this paper tomography was used to analyze soil density in a central pivot irrigated area and the results were compared to measurements made on a natural vegetation (caatinga) area, not submitted to human action. The area under central pivot were cultivated with corn and soy bean during 14 years.

1. Introduction

Deep dense soil layers is a characteristic of soils which present an increase in values of clay fraction along soil profile (clay illuviation), and this increase can take place very abruptly (Gameda et al., 1985; Oliveira et al., 1994). This formation of dense layers can be intensified by pedogenetic processes of wetting and drying because soil sections that experience fluctuations in groudwater rich in Fe^{2+} are particularly suited to accumulate precipitable iron hydroxides, due to the oxidation of Fe^{2+} into insoluble Fe^{3+}. Groundwater brings in Fe^{2+} during the rainy season. This Fe^{2+} is oxidized by the air entering the soil during the dry season, and it is almost irreversibly precipitated as Fe^{3+}. When this mechanism is repeated year after year, accumulation of iron oxides may lead to plinthite formation (Van Wambeke, 1992). In semi-arid regions the silica solubilization can also present a cementing action.

The employment of machinery in agriculture activities can cause soil compaction, which in other words can be expressed as soil structure alteration diminishing volume, size and shape of voids.

Both dense layer formation and compaction can directly interfere in soil water and solute dynamics (Libardi et al., 1982; Landina & Klevensk, 1984), as well as in root system distribution (Demattê, 1980; Alvarenga et al., 1996) and in soil aeration. As the dense layers and the compaction may occur in thin layers of soil, the conventional methods for determining soil density may not be able to evaluate it under this condition. X and gamma ray tomography (C.T.) has greatly contributed in such studies (Petrovic et al., 1982; Crestana et al., 1986; Vaz, 1989; Vaz et al., 1989; Cruvinel et al., 1990; Crestana et al., 1992; Oliveira et al., 1995; Vaz et al., 1996; Naime et al., 1997; Macedo et al., 1998; Macedo & Crestana, 1999).

In this paper C.T. scanning was used to evaluate soil density in two different areas in Petrolina – PE / Brazil: (1) area under central pivot irrigation – ACP - and (2) natural vegetation (caatinga) area - NVA.

2. Material and Methods

The samples were collected in two trenches, one in ACP and the other in NVA. They were collected down to a depth of 1 m, in intervals of 10cm. The soil is a Red Yellow Podzolic. Sample humidity was determined by measuring its wet weight and oven drying it at 110°C, during 36 hours. To convert the Tomographic Units (T.U.) into density, the following equation was applied:

$$\rho = \frac{T.U.}{K.(\mu_{ms} + \mu_{mw}.w)} \quad (1)$$

K is the C.T. scanner constant factor, w the weigh humidity, m_{ms} and m_{mw} the mass attenuation coefficient of soil and water respectively.

The mass attenuation coefficient was measured in disturbed samples, sieved and poured in acrylic recipients. It was measured according to the following equation:

$$I = I_O.e^{-x(\mu_{ms}.\rho)} \quad (2)$$

C.T. scanning was performed in the millimetric and micrometric scales. In the millimetric scale it was made in the vertical direction. This made it possible to analyze the density almost continuously, that is, in 2.0mm steps. In the micrometric scale it was made in the horizontal direction.

3. Results

The values of bulk density shown in Table 1 and Figure 1 were calculated using the gravimetric method. The volumes of the samples were determined on intact clods by coating their surfaces with a thin layer of paraffin and measuring the volumes of displaced water when the clods were lowered into a water filled beaker. The values showed statistical difference only in the layer from 20 to 30 cm. However, it can be noticed higher values of density in ACP in the depth from 0 to 40 cm. This can be explained by the machine usage in soil preparation, and fertilizers application, and harvesting, during 14 year of agricultural activities.

Table 1 - Density in Natural Area and in Area under Central Pivot, measured by gravimetry.

Depth (cm)	Density ($g.cm^{-3}$)	
	Nat. Veg.	Centr.Piv.
0-10	1.67	1.78
10-20	1.52	1.71
20-30	1.55	1.81
30-40	1.61	1.76
40-50	1.65	1.72
50-60	1.78	1.74
60-70	1.84	1.76
70-80	1.90	1.75
80-90	1.78	1.74
90-100	1.87	1.72

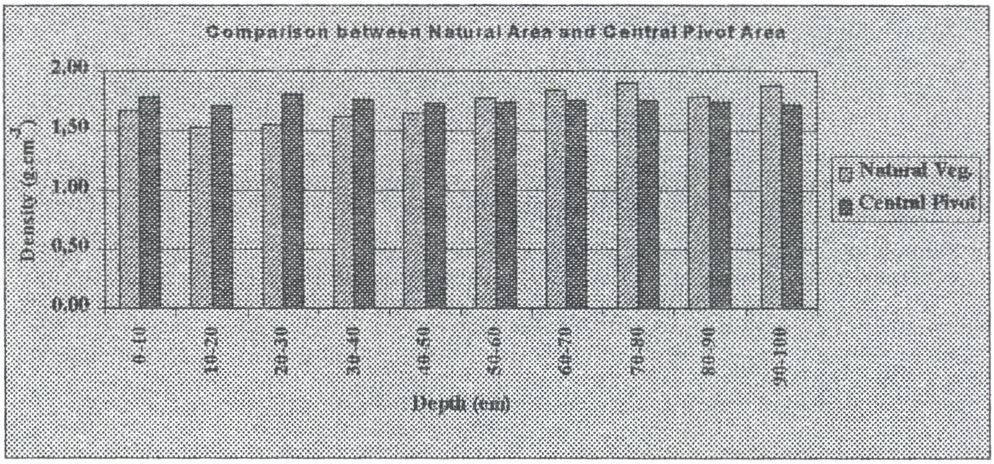

Figure 1 - Graph showing the comparison of density in the areas of Natural Vegetation and Central Pivot, measured by gravimetry.

In Table 2 and Figure 2 the densities were calculated from the C.T. images. They were averaged to construct this table and figure, but the planes of acquisition were vertical and, so, the information is available in the depth sense in steps equal to the 2.0mm resolution of C.T. scanning. This means an almost continuous investigation, instead of the conventional bulk information. A good agreement with the results presented above is noticed. The advantage of the C.T. method is that the semi-arid region soil is very compact and difficult to extract using volumetric rings and even the paraffin method is very limited because to get clods as small as the required dimension of beakers is not always possible.

Table 2 - Density in Natural Area and in Area under Central Pivot, measured by Computerized Tomography.

Depth (cm)	Density ($g.cm^{-3}$)	
	Nat.Veg.	Centr.Piv.
0-5	1.62	2.00
5-10	1.70	1.87
10-15	1.63	1.81
15-20	1.63	1.90
20-25	1.66	1.83
25-30	1.66	1.94
30-35	1.66	1.70
35-40	1.71	1.70
40-45	1.73	1.87
45-50	1.75	1.90
50-55	1.89	1.85
55-60	1.91	1.90
60-65	1.96	1.85
65-70	1.90	1.89
70-75	2.00	1.75
75-80	1.98	1.77
80-85	1.87	1.73
85-90	1.82	1.73
90-95	1.90	1.77
95-100	1.95	1.80

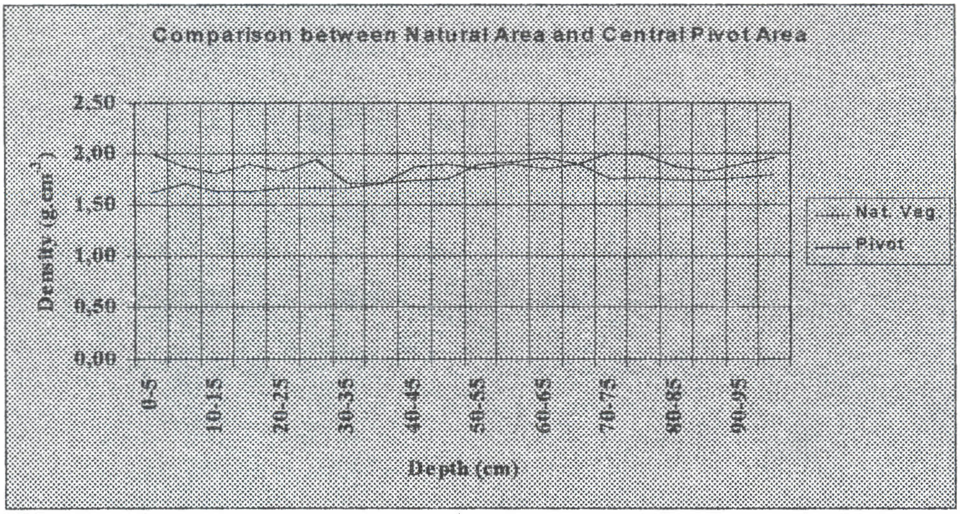

Figure 2 - Graph showing the comparison of density in the areas of Natural Vegetation and Central Pivot, measured by Computerized Tomography.

In Figure 3, C.T. images in the micrometric scale are shown. Macropore and minerals are seen. Because the number of macropores in NVA seems to be greater than in ACP, a qualitative evaluation tells that the ACP is more compact, but in this scale the area under evaluation is very small and this statement cannot be taken as conclusive. More sections should be examined. The actual micrometric scale C.T. scanner is a first generation equipment, leading to long periods of acquisition. A new version of this equipment, with fan beam and vertical movement is under development. This will allow to get more images in shorter acquisition times and it will also permit to examine several layers of the same sample. This way, a more representative evaluation will be possible.

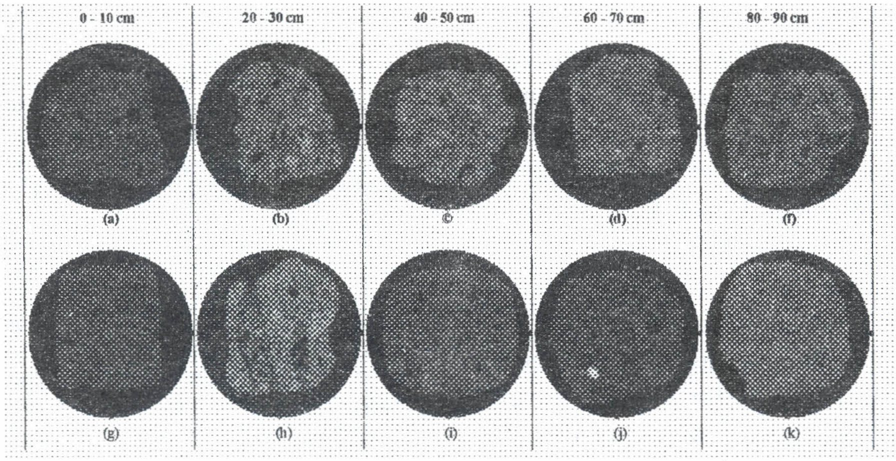

Figure 3 - C.T. scanning in the micrometric scale of samples in Natural Area (from a to f) and in Central Pivot Area (from g to k). Samples were collected at the center of each previous samples used in millimetric scale scanning at the depth indicated above.

4. Conclusions

- Down to depth 40-50 cm, density in Central Pivot Area is greater than in Natural Area due to compaction caused by machine traffic;
- Low values of density in the first layers is caused by the soil fragile structure near to surface;
- C.T. scanning makes it possible to analyze density along a vertical profile almost continuously.

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6. References

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