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SPATIO-TEMPORAL VARIABILITY OF SOIL PENETRATION RESISTANCE IN A FIELD CULTIVATED WITH SUGARCANE UNDER CONVENTIONAL TILLAGE SYSTEM IN NORTHEAST BRAZIL

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INTRODUCTION

Soil management, although intended to create favorable structural conditions for crop growth and development, without the prior assessment of potential and limitations, can represent a factor influencing the degradation of natural resources. The effects on soil degradation and its structural quality are generally evaluated by some physical soil attributes such as bulk density, total porosity, and soil penetration resistance (PR).

The PR is recognized as a physical parameter supporting the identification of areas with different stages of compaction and thus can be used to define appropriate management for soil remediation. Besides, this parameter depends on intrinsic soil factors (texture, structure, and mineralogy) and soil water content (θ); therefore, PR increases with bulk density and decreases with θ.

Thus, it is possible to establish the critical limit of PR (PR_{CL}) associated with the value of θ limiting the growth of plant roots. Despite PR_{CL} varies according to soil type and plant species, it is scientifically accepted that the critical value of 2.0 MPa limits the root growth.

OBJECTIVE

To evaluate the spatial and temporal variability of PR in a field cultivated with sugarcane, under conventional tillage system.

MATERIAL AND METHODS

The research was carried out in the Carpina Sugarcane Experimental Station (EECAC), Pernambuco, Brazil (Fig. 1). A grid of 70 x 70 m with intervals of 10 m (Fig. 2) was selected and soil samples were collected in each grid point at 0 - 0.30 m and 0.30 - 0.60 m depth. The first sampling was done 6 months after subsoiling (Time 6) and before harrowing and planting, the second sampling after 12 months of subsoiling (Time 12, six months after harrowing and planting), whereas the third sampling after 18 months of subsoiling (Time 18), before harvesting (Fig. 3). At each sampling time, *in situ* PR measurements were carried out with the Solo Track equipment (Fig. 4) and the simultaneous values of soil water content were determined and associated with the PR data (θ_{PR}).

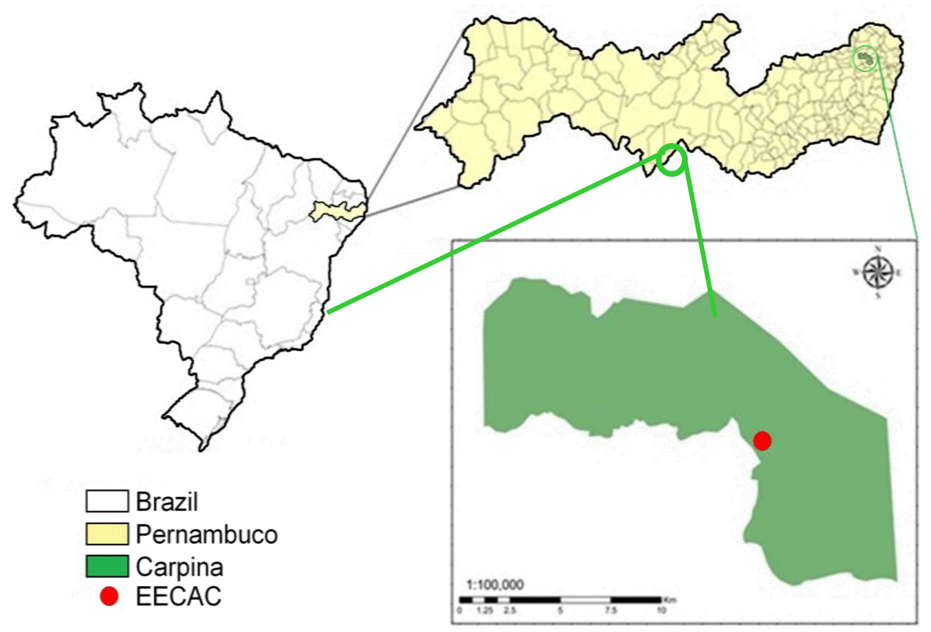

Figure 1. Geographical location of the experimental area

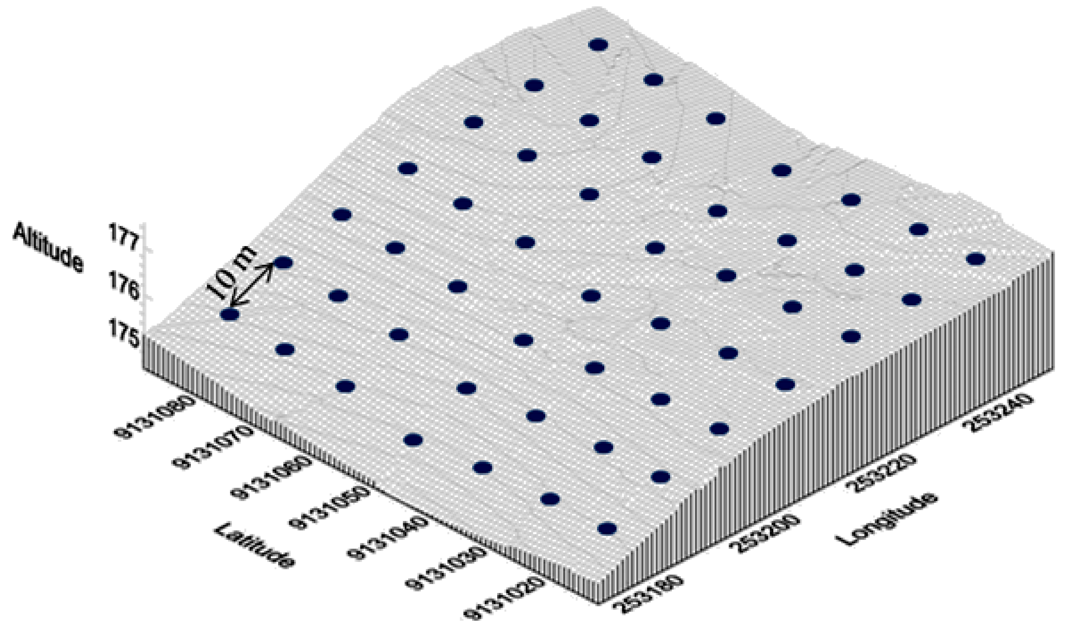

Figure 2. Distribution of sampling points in the experimental area

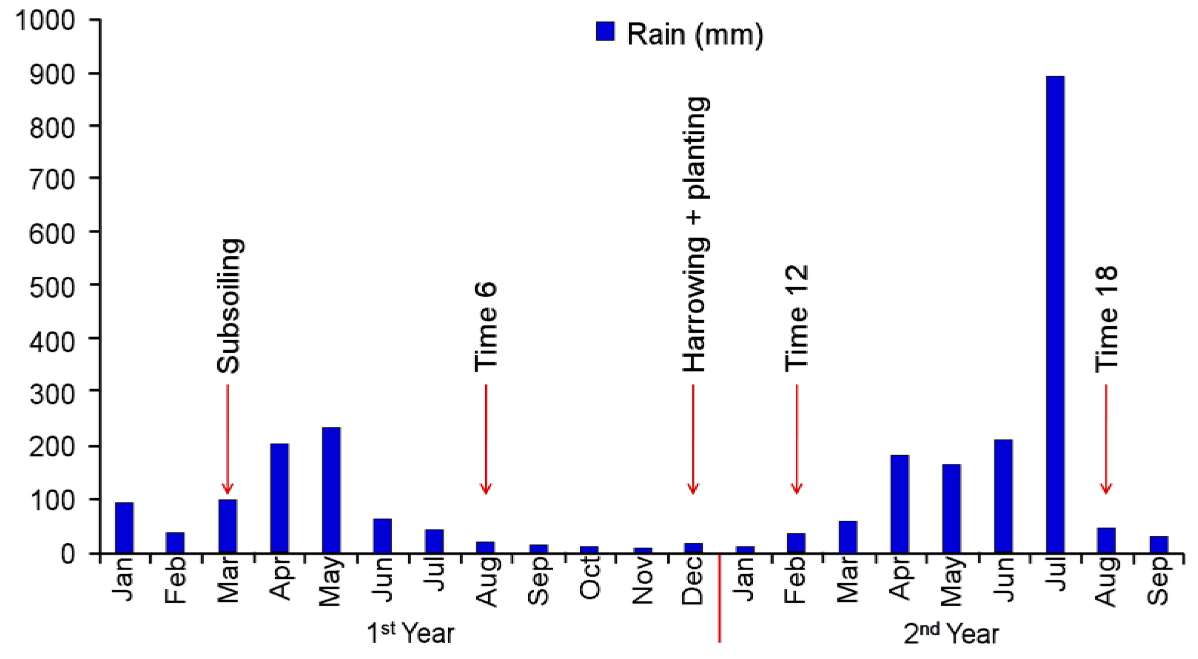

Figure 3. Rainfall events during the experiment, soil management practices and sampling times.

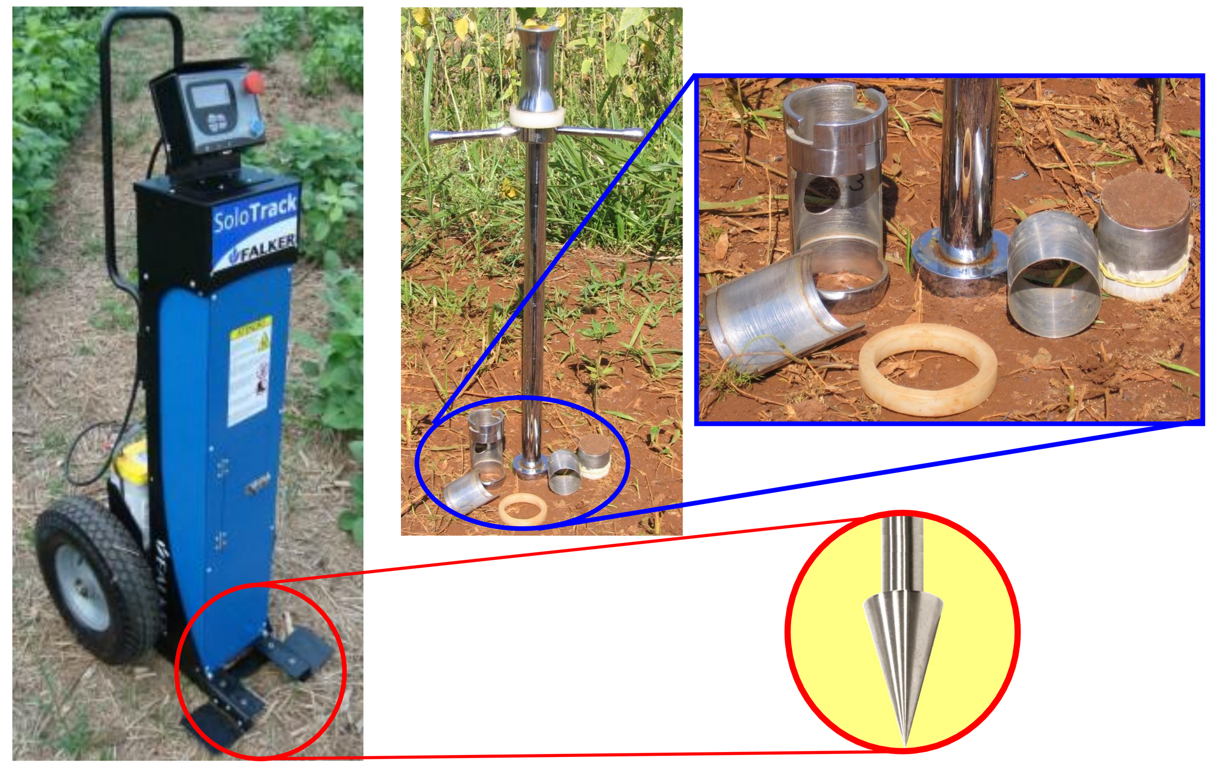

Figure 4. Equipment used for in situ PR testing and samplings
Source: https://www.falker.com.br/produto-solotrack-medidor-automatizado.php

RESULTS AND DISCUSSION

Table 1. Descriptive statistics and geostatistical parameters of θ_{PR} and PR referring to the spatio-temporal variability

Descriptive Statistics	θ_{PR} (kg kg^{-1})	PR (MPa)	θ_{PR} (kg kg^{-1})	PR (MPa)	θ_{PR} (kg kg^{-1})	PR (MPa)	θ_{PR} (kg kg^{-1})	PR (MPa)	θ_{PR} (kg kg^{-1})	PR (MPa)	θ_{PR} (kg kg^{-1})	PR (MPa)
	Time 6				Time 12				Time 18			
	0 – 0.30 m		0.30 – 0.60 m		0 – 0.30 m		0.30 – 0.60 m		0 – 0.30 m		0.30 – 0.60 m	
Minimum	0.0384	0.54	0.0759	0.90	0.0015	0.54	0.058	1.02	0.0206	0.34	0.0273	0.67
Maximum	0.0970	4.38	0.1326	4.34	0.1023	2.64	0.1655	4.71	0.0798	2.18	0.0797	2.94
Mean	0.060 A	2.42 A	0.106 A	2.32 A	0.068 A	1.34 B	0.090 B	1.93 B	0.045 B	1.04 C	0.054 C	1.56 C
Standard Deviation	0.0128	0.9614	0.0154	0.7486	0.0147	0.4627	0.0181	0.7626	0.0118	0.4892	0.01268	0.4096
CV (%)	21.03	39.60	14.44	32.23	21.68	34.36	19.95	39.41	26.03	46.87	23.23	26.25
Nugget Effect / Sill (%)	6.28	21.08	—	25.00	27.10	0,00	31.43	11.88	23.08	7.69	54.07	5.56
Spatial Dependence	Strong	Strong	—	Strong	Moderate	—	Moderate	Strong	Strong	Strong	Moderate	Strong
Model	Exponential	Exponential	Linear	Spherical	Spherical	Spherical	Exponential	Spherical	Spherical	Exponential	Exponential	Exponential
Range (m)	49.13	593.46	—	26.09	20.05	17.35	25.21	282.48	200.37	25.99	56.54	26.96
R^2	0.816	0.866	—	0.921	0.937	0.805	0.748	0.905	0.900	0.961	0.836	0.913

The average PR values determined after Time 6 are above those recommended for the root system growth, being higher than the critical limit, i.e., $PR_{CL} > 2$ MPa; however, the values determined after Time 18 were the lowest during the one-year cultivation and were probably influenced by the sugarcane root system. Thus, PR values showed that the subsoiling did not promote a positive effect on the soil physical quality, with PR values 2.42 – 2.32 MPa in Time 6, while in Time 18 the PR values reduced to 1.04 – 1.56 MPa, and therefore below the critical value.

The classification used for the degree of spatial dependence (SD) was SD ≤ 25% strong dependence; 25% < SD < 75%, moderate dependence; SD > 75%, weak dependence. Thus, θ_{PR} showed spatial dependence ranging from strong (6.28 to 23.08 %) to moderate (27.10 to 54.07 %); while PR presented a strong dependence (5.56 to 25.00 %). The semivariogram models that best fit to θ_{PR} and PR were spherical or exponential (and linear, in the case of the pure nugget effect). The pure nugget effect presented in the θ_{PR} for Time 6, 0.30 - 0.60 m depth, can be explained by the sampling distance, since the variation of this attribute in the area occurs on a smaller scale than that adopted in this research (10 m, Fig. 2); therefore a finer sampling grid, with lower distance between the collection points should have been adopted at Time 6.

The evaluation of the CV, as a measure of spatial variability, showed that the values for θ_{PR} and PR were of medium variability ($12 < CV_{\%} < 60$), with lower values for θ_{PR} (14.44 to 26.03%) compared to those associated with PR (26.25 to 46.87%).

The range results showed a different behavior for θ_{PR} and PR. It is noted that, in general, the range of θ_{PR} increases from Time 6 to 18, mainly on the surface where it changed from ≅ 49 m to ≅ 200 m. This result can be justified by the heavy rainfall event of about 1000 mm (Fig. 3), occurred in the area one month before sampling in Time 18, homogenizing the soil moisture, with a greater effect on the surface (≅ 200 m).

On the other hand in Time 6, the range values for PR reflected the subsoiling effects on the soil surface, with greater range (≅ 593 m) and consequently more similar compared to the deeper soil (0.30-0.60 m) where the range resulted of about 26 m. However, harrowing and planting, carried out two months before Time 12 (Fig. 3), changed the values of the surface range, reducing them to ≅ 17 m and increasing in the subsurface to ≅ 282 m. Thus, the growth of the root system sugarcane, from Time 12, reduced the soil resistance to penetration, promoting lower values of the subsurface range in Time 18 (27 m).

CONCLUSIONS

- Spatio-temporal variability of soil penetration resistance is greater than that associated with soil water content.
- Soil water content had a moderate degree of spatial dependence, indicating the need to increase the number of sampling points.
- Subsoiling was not adequate to increase the soil physical quality, being the main result associated to the action of sugarcane root system.
- The range values associated with PR are inversely related to the growth of sugarcane root system.

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