SPATIAL VARIABILITY OF SOIL PENETRATION RESISTANCE AND TEMPERATURE IN AGRESTE PERNAMBUCO

K. J. Jimenez[1]; P. B. M. Mendes[2]; A. A. A Montenegro[3]; M. M. Rolim[4]; D.H Souza[5]; L.R.F. Lima[6]

ABSTRACT: The analysis of physical properties, temperature, and soil penetration resistance are important to consider for management strategies in irrigated areas. The aim of this research was to evaluate the spatial dependence of the granulometric fractions, temperature and penetration resistance in the semi-arid region of the state of Pernambuco. A 7 x 7 m regular mesh that corresponds to 49 sample points was adopted. Soil samples were collected, the temperature was measured using the thermometer; and the penetration resistance was evaluated at depth of 0-20 cm, using the Instrumented impact cone penetrometer - Stolf. Classical statistical analysis and geostatistics were used to analyze the variables. The coefficient of variation was classified as moderate spatial dependence. Granulometric fractions obtained all studied variables were 42.81 and 73.68%, the available temperature, ranges were 50 and 78, respectively. The soil penetration resistance ranged from 570 to 1000 kPa, in 0-5, 5-10, 10-15 and 15-20 cm depths the average soil penetration resistance is 580-820, 590-810, 590-780 and 620-860 kPa, increasing gradually along the depth due to the distribution of the tension of the machinery in the first layer. The mean temperature observed was 40.41°C, which was above the culture requirements, while soil penetration resistance was approximately 0.8 kPa, a critical level for root growth. The results indicate the importance of the temperature and granulometric in the spatial distribution of soil penetration resistance, and its importance for the adequate management of these soils.

KEYWORDS: Compaction, geostatistics, density, humidity and granulometric.

VARIABILIDADE ESPACIAL DA RESISTENCIA A PENETRAÇÃO E TEMPERATURA DO SOLO NO AGRESTE PERNAMBUCO

[1] Doutoranda, UFRPE/DEAGRI/PGEA. Recife – Pernambuco, Brasil. E-mail: keilajeronimo@gmail.com.
[2] Mestrando, UFRPE/DEAGRI/PGEA. Recife – Pernambuco, Brasil. E-mail: pericles_miller@hotmail.com
[3] Acadêmico, UFRPE/DEAGRI/PGEA. Recife – Pernambuco, Brasil. E-mail: Abelardo.montenegro@yahoo.br
[4] Acadêmico, UFRPE/DEAGRI/PGEA. Recife – Pernambuco, Brasil. E-mail: mariorolim10@uol.com.br
[5] Doutorando, UFRPE/DEAGRI/PGEA. Recife – Pernambuco, Brasil. E-mail: diegosilva1992@hotmail.com
[6] Doutoranda, UFRPE/DEAGRI/PGEA. Recife – Pernambuco, Brasil. E-mail: laerciarocha@hotmail.com

RESUMO: A análise dos atributos físicos, da temperatura e da resistência à penetração de solos em áreas irrigadas é de extrema importância para elaboração e implantação de propostas de manejo. Com o objetivo de avaliar a dependência espacial das frações granulométricas, da temperatura e da resistência à penetração, foi desenvolvido um estudo em área aluvial irrigada no semiárido de Pernambuco, em que se adotou uma malha regular de 7 x 7 m, correspondendo a um total de 49 pontos amostrais. Para a coleta foram coletados torrões de solo; mediu-se a temperatura utilizando o termómetro; e avaliou-se a resistência à penetração do solo na profundidade de 0-20 cm, com uso do penetrômetro de impacto – Stolf. As variáveis foram submetidas à análise estatística clássica, seguida de análise geoestatística. A variabilidade dos dados foi classificada como moderada e alta dependência espacial para todas as variáveis estudadas, com coeficientes de variação de 42,81% e 73,68% para granulometria e temperatura, com alcances de 50 e 78 m, respectivamente. A resistência à penetração variam entre 570 e 1000 kPa, nas camadas 0-5, 5-10, 10-15 e 15-20 cm a média da resistência à penetração é 580-820, 590-810, 590-780 e 620-860 kPa, aumentando gradativamente ao longo da profundidade devido à distribuição da tensão da maquinaria na primeira camada. A temperatura média observada foi de 40,41˚C, fora da exigência de qualquer cultura e a resistência à penetração foi de aproximadamente 0,8 kPa, nível crítico para o crescimento das raízes. Os resultados ressaltam a importância da temperatura e granulometria na distribuição espacial resistência à penetração, bem como na relevância para o manejo racional do solo estudado.

PALAVRAS-CHAVE: Compactação, geoestatística, densidade, umidade e granulometria.

INTRODUCTION

Agreste, located in Northeastern Brazil is characterized by drought periods, presenting rainfall in winter, irregular showers and high temperatures throughout the year. Agricultural production is under rainfed conditions, in which most farmers in this sector implement manual farming. According to the census of agriculture, only 20% of the local farmers use tractors for agricultural work, in the Northeastern region. The use of machinery to prepare agricultural land under inadequate moisture conditions promotes the natural imbalance of the soil, modifying its chemical, physical and biological properties (Campos et al., 2015).

Adequate soil temperature for seed germination of most crops is between 20 - 30°C, where the ideal temperature range for rapid and uniform emergence is 25°C. Geostatistics is a tool based on statistical methods and concepts, considering the values of the variables related to their spatial disposition (Herrmann, 2012).

Understanding spatial distribution of soil moisture and temperature in relation to soil penetration resistance in areas where agricultural machines are submitted is essential for proper soil management. The aim of this study was to analyze the mechanical conditions of the soil of an orchard unit prepared with farm machinery, by evaluating the spatial dependence of soil penetration resistance and temperature in a Flossic Neosol soil type, located in the alluvial valley of the Ipanema River, in Pesqueira, Agreste Pernambucano.

MATERIAL AND METHODS

The experiment was conducted in an orchid unit using farm machinery at Fazenda Mimosa, Pesqueira-PE., located in the region of Agreste, Pernambuco, at coordinates 08°10' South latitude and 35°11' West longitude, 650 masl. According to the Köppen classification system, the climate of the region is BSsh climate type defined as hot semi-arid, steppe type, with an average rainfall of 607 mm, distributed irregularly throughout the year (Montenegro & Montenegro, 2006). The pedological classification characterizes the soil as a Flossic Neosol (Souza et al., 2011).

At 7 x 7 m regular mesh was used, corresponding to a total of 49 sample points. In each sample point, soil was collected, at 0-20 cm depth, the temperature was measured and the soil penetration resistance was evaluated using the Instrumented impact cone penetrometer - Stolf. The physical indexes were determined by density (Ds) and gravimetric moisture (w), by drying the material in the greenhouse. To evaluate the degree of compaction, a soil penetration resistance test was performed at 0-20 cm, counting the number of strokes in every five cm registered by the rod of the Instrumented impact cone penetrometer - Stolf.

From the depth data and the number of impacts, the potential energy of the soil penetration resistance equipment was calculated by Equation 1.

$$R = \frac{Mg + mg + \left(\frac{M}{M+m} * \frac{Mg * h}{x}\right)}{A} \tag{1}$$

In which:

R is soil penetration resistance measured in kgf / cm^2 or kPa.

M is the mass of the piston, Mg corresponds to 4 kgf, m is the mass of the equipment without the piston, mg corresponds to 3.2 kgf.

h is the dropping height of the piston (0.4 m); x is the soil penetration rod of the apparatus (cm / impact).
A is the area of the cone (1.29 cm^2).
g is the gravity acceleration.

Descriptive statistics were used to determine the mean, median, standard deviation, maximum and minimum values, coefficient of skewness, coefficient of kurtosis, and coefficient of variation. The dispersion and distribution of the variables were analyzed by Kolmogorov Smirnov (KS) normality test at a significance level of 5%, using the statistical software and spatial maps. According to the methodology proposed by Warrick & Nielsen (1980), the variability in the values of the coefficient of variation were classified as CV <12% (low); CV <12> 62% (interval mean values) and CV> 62% (high).

For the spatial dependence analysis, the methodology proposed by Vieira (2000) was followed using the semivariograms, calculated by Equation 2. For higher semivariance, MPa data were transformed to kPa.

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i-1}^{N(h)} \left[z(x_i) - z(x_i + h) \right]^2 \qquad (2)$$

Where:
γ(h) are the semivariances values and N(h) is the number of pairs at each distance h. Z(xi) and Z(xi + h) separated by the distance h.

The semivariograms were adjusted according to the mathematical, exponential, spherical and Gaussian models, based on the following variables: nugget effect (C0); Extent of spatial dependence (a); Sill (C0 + C1). The degree of spatial dependence (SDD) was evaluated according to Cambardella et al. (1994).

RESULTS AND DISCUSSION

The Kolgomorov Smirnov test of grain size indicated normality in data at a significance level of 5% for sand, clay, and silt. The sand particles obtained low coefficient of variation, while the clay and silt particles showed a mean variability of 42.81%.

The soil penetration resistance values in the box plot (Figure 1A) ranged from 570 to 1000 kPa and showed positive mean skewness. In 0-5, 5-10, 10-15 and 15-20 cm depths the average soil penetration resistance is 580-820, 590-810, 590-780 and 620-860 kPa, increasing gradually along the depth due to the distribution of the tension of the machinery in the first layer

(Figure 3A), because in the 15-20 cm layer there is a load concentration up to 860 kPa, justifying the analysis with the penetrometer up to 20 cm due to the high compaction of the studied soil.

Table 1 shows the spatial dependence in of 0-5, 5-10 10-15, and 15-20 cm depths with 70, 30, 20 and 0 m range, with exponential, spherical, spherical and exponential adjustments, respectively. In the isoline map, Figure 3A, represents the distribution of the soil penetration resistance in the study area, showing soil penetration resistance incidence in the lower extremities. Higher distribution and lower intensity in the initial depth was obtained compared to the consecutive depths. Based on the box plot (Figure 1B), the soil moisture content in most of the sample points obtained less than 4%, and low negative skewness, at 0-20 cm depth.

The isoline map (Figure 4) shows, the distribution of the moisture content in the study area, with an average of 2.4%, concentrated on the right side, this due to the gradient, as well as the soil temperature and compaction. A minimum temperature of 34°C, maximum of 48°C and an average of 40.41°C was registered. Considering that the temperature value for suitable seed germination is 25ºC, it is observed that the average temperatures were high, as a result of the climatic conditions and the mechanical conditions of the soil, due to high air temperatures and low rainfall in the Brazilian Northeast (Leivas, 2014) directly influencing soil temperature.

The coefficients of variation obtained were <10%, indicating that at the points at which the temperatures were sampled, the observed values were close to the average. The absorption of water and nutrients from the roots and the activity of microorganisms. However, the vital processes of cultivated plants will be affected. These temperatures presented moderate spatial dependence (73.68%). Adjusting to the Gaussian model with R^2 0.9564 (Figure 2E).

REFERENCES

CAMBARDELLA. C. A.; MOORMAN. J. M.; NOVAK. T. B.; KARLEN. D. L.; TURCO. R. F.& KONOPKA, A. E. Field-scale variability of soil properties in Central Iowa Soils. Soil Science Society of America Journal, v.58, p.1501-1511. 1994.

CAMPOS, M. C. C., MANTOVANELLI, B. C., SILVA, D. A. P., SANTOS, L. A. C., GOMES, R. P., SOARES, M. D. R., & FRANCISCON, U. Avaliação dos atributos do solo sob diferentes usos na região de Humaitá, Amazonas. Journal of Agricultural and Environmental Sciences, v. 58, n. 2, p. 122-130, 2015.

HERRMANN, J. C., BERNARDI, J. V. E., BASTOS, W. R., & LACERDA, L. D. Dispersão espacial e amostragem pontual: a geoestatística como ferramenta de análise do mercúrio em solos de Rondônia, Amazônia Ocidental. Geochimica Brasiliensis, v (23), n. (1), 2012.

LEIVAS, J. F, ANDRADE, R. G., DE CASTRO V. D., TORRESAN, F. E., & BOLFE, E. L. Drought monitoring in 2011/2012 for the Brazilian Northeast based on the satellite spot-vegetation and TRMM. Revista Engenharia na Agricultura, v. 22, n. 3, p. 211, 2014.

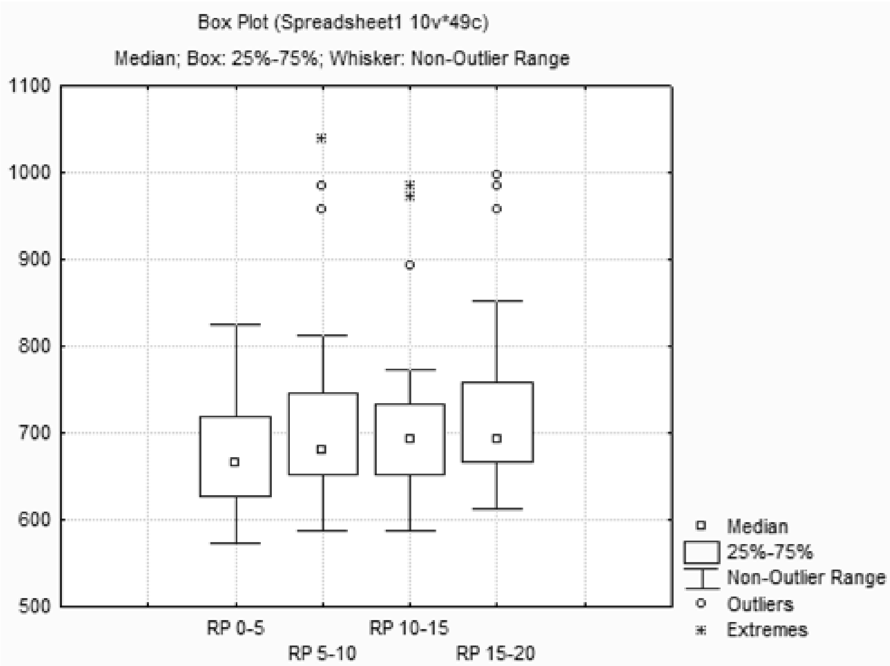
MONTENEGRO, A.A.A.; MONTENEGRO, S.M.G.L. Variabilidade espacial de classes de textura, salinidade e condutividade hidráulica de solos em planície aluvial. Revista Brasileira de Engenharia Agrícola e Ambiental, v.10, p.30–37, 2006.

SOUZA, E. R.; MONTENEGRO, A. A. A.; MONTENEGRO, S. M. G., MATOS, J. A. Temporal stability of soil moisture in irrigated carrot crops in Northeast Brazil. Agricultural Water Management, v.99, p.26-32, 2011.

VIEIRA. S.R.; HATFIELD. J.L.; NIELSEN. D.R.; BIGGAR. J.W. Geoestatitical theory and application to variability of some agronomical properties. Hilgardia, v. 51, n. 3, p. 1-75, 1983.

WARRICK, A. W.; NIELSEN, D. R. Spatial Variability Of Soil Physical Properties In The Field. Hillel, p.319-324, 1980.

A



B

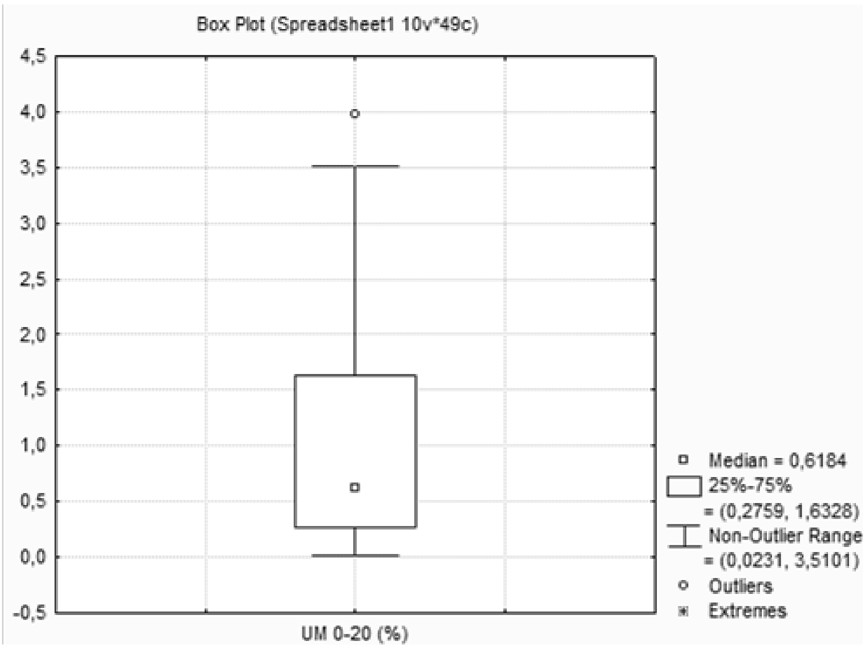


Figure 1. Box plot showing soil penetration resistance data (kPa) 0-5; 5-10; 10-15; and 15-20 cm, depths (A); natural gravimetric moisture (%) at 0-20 cm depth.

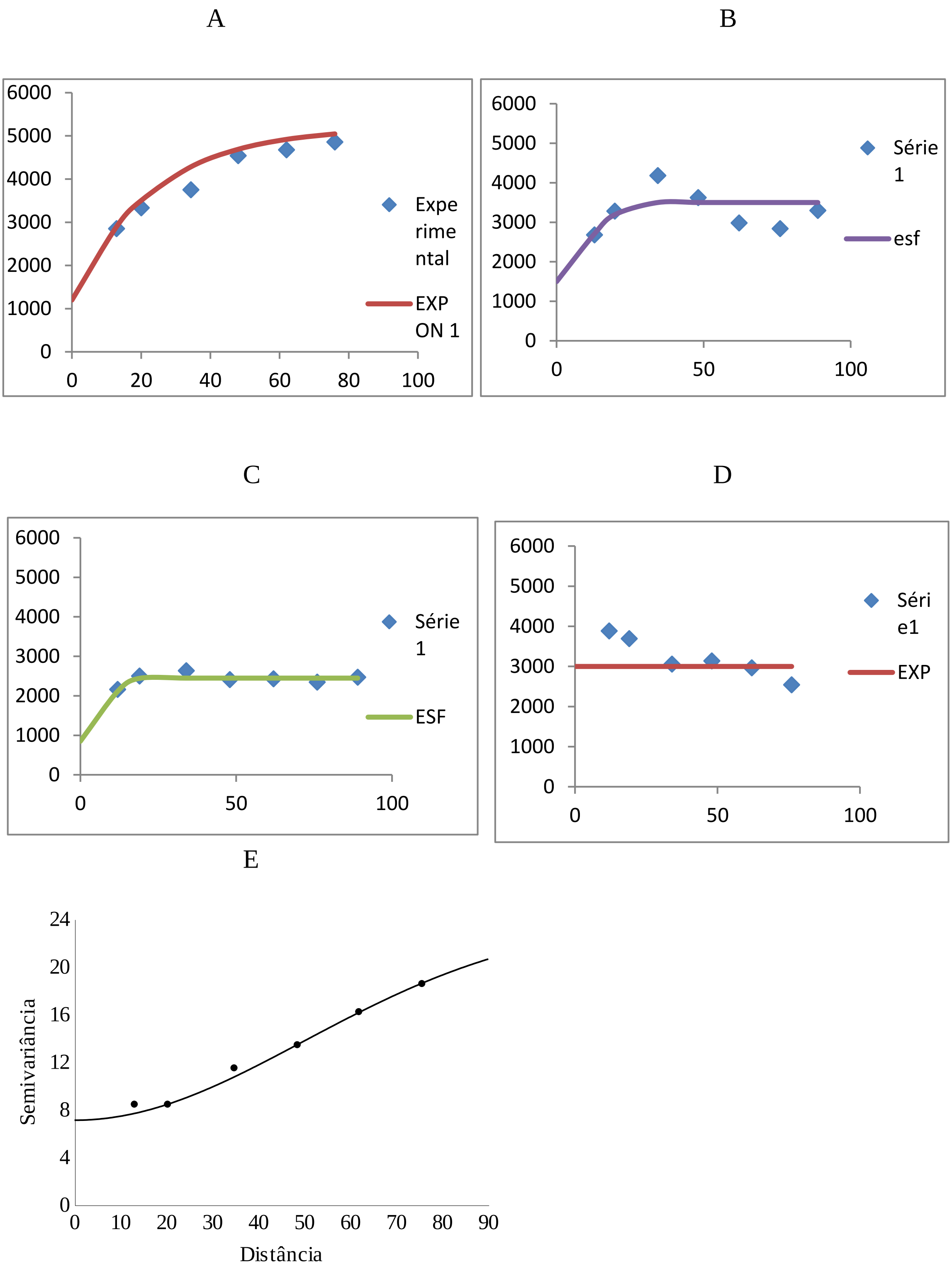


Figure 2. Semivariograms of the soil penetration resistance variables at 0-5 cm (A); 5-10 cm (B); 10-15 cm (C) e 15-20 cm (D) and semivariograms of temperature.

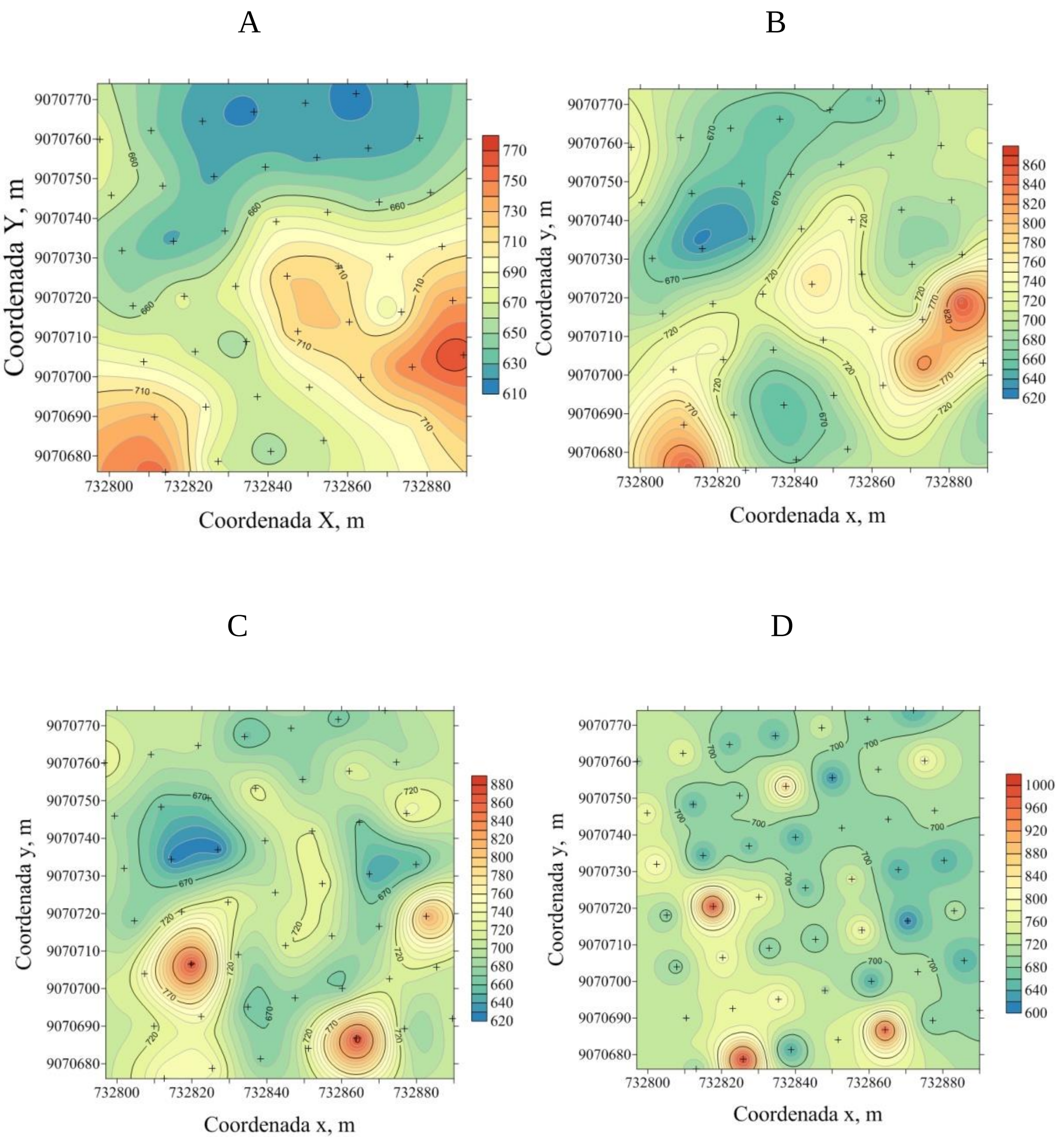


Figure 3. Thematic maps of soil penetration resistance, at 0-5 cm (A), 5-10 cm (B), 10-15 cm (C) and 15-20 cm (D).

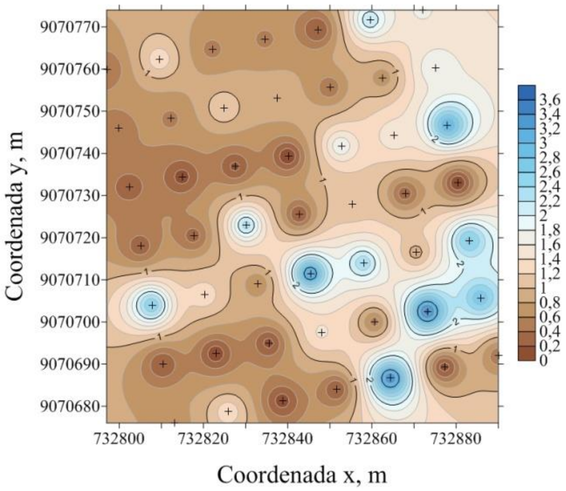


Figure 4. Thematic map of natural gravimetric moisture (%) at 0-20 cm.

Table 1. Semivariogram models, spatial dependence degree (SDD), mean reduced error (Mean) and standard deviation (SD).

	RP 0 a 5	**RP 5 a 10**	**RP 10 a 15**
C0(6)	1200	1500	850
C1(5)	4000	2000	1600
a(4)	70	30	20
Model	Exponential	Spherical	Spherical
SDD(3)	27,08	42,86	34,70
MEAN(1)	-0,025	-0,021	-0,06
DP(2)	1,014	1	1,027

(1) Mean: Mean. (2) DP: Standard Deflection. (3) :SDD: Spatial dependence degree. (4) a: Height. (5) C1: Porch. (6) C0: Effect nugget.

Table 2. Descriptive statistics for temperature values (° C) of 49 sample points.

MÉD	**M**(1)	**DP**(2)	**CV**(3)	**A**(4)	**C**(5)	**KS** $_{5\%}$	**KS** $_{1\%}$
40,41	39	3,74	9,26	0,6	-0,71	0,19	0,23

(1) M: Medium. (2) DP: Standard Deflection. (3) CV: Coefficient of variation. (4) A: Asymmetry. (5) C: Curtose. KSKolmogorov-Smirnov Normality Test (p < 0,05 e p < 0,01).