SPATIAL CONTINUITY OF ELECTRICAL CONDUCTIVITY, SOIL WATER CONTENT AND TEXTURE ON A CULTIVATED AREA WITH CANE SUGAR[1]

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ABSTRACT - Spatial variability of soil attributes affects crop development. Thus, information on its variability assists in soil and plant integrated management systems. The objective of this study was to assess the spatial variability of the soil apparent electrical conductivity (EC_a), electrical conductivity of the saturation extract (EC_{se}), water content in the soil (θ) and soil texture (clay, silt and sand) of a sugarcane crop area in the State of Pernambuco, Brazil. The study area had about 6.5 ha and its soil was classified as orthic Humiluvic Spodosol. Ninety soil samples were randomly collected and evaluated. The attributes assessed were soil apparent electrical conductivity (EC_a) measured by electromagnetic induction with vertical dipole (EC_a-V) in the soil layer 0.0.4 and horizontal dipole (EC_a-H) in the soil layer 0.0-1.5 m; and EC_{se}, θ and texture in the soil layers 0.0-0.2 m and 0.2-0.4 m. Spatial variability of the EC_a was affected by the area relief, and had no direct correlation with the electrical conductivity of the saturation extract (EC_{se}). The results showed overestimated mean frequency distribution, with means distant from the mode and median. The area relief affected the spatial variability maps of EC_a-V, EC_a-H, EC_{se} and θ, however, the correlation matrix did not show a well-defined cause-and-effect relationship. Spatial variability of texture attributes (clay, site and sand) was high, presenting pure nugget effect.

Keywords: Precision agriculture. Geostatistics. Chemical and physical soil attributes.

CONTINUIDADE ESPACIAL DA CONDUTIVIDADE ELÉTRICA, CONTEÚDO DE ÁGUA E TEXTURA EM UMA ÁREA CULTIVADA COM CANA-DE-AÇÚCAR

RESUMO - A variabilidade espacial dos atributos do solo, interferem sobre o desenvolvimento dos cultivos. Assim, o conhecimento dessa variabilidade permite o manejo integrado de solo e planta. Objetivou-se determinar a variabilidade espacial da condutividade elétrica aparente (CE_a), condutividade elétrica do extrato de saturação (CE_{es}), conteúdo de água (θ) e textura (argila, silte e areia) do solo em uma área cultivada com cana-de-açúcar, no Estado de Pernambuco. A área de estudo possui cerca de 6,5 ha e o solo da área é um Espodossolo Humilúvico órtico. As amostras de solo foram avaliadas em 90 pontos de amostragem distribuídos aleatoriamente. Foram amostrados os seguintes atributos: condutividade elétrica aparente (CE_a) medida por indução eletromagnética (dipolo vertical: CE_a-V e dipolo horizontal: CE_a-H) nas camadas de 0,0-0,4 m e 0,0-1,5 m de profundidade respectivamente. Os demais atributos foram medidos nas camadas de 0,0-0,2 m e 0,2-0,4 m de profundidade (CE_{es}, θ, argila, silte e areia). A variabilidade espacial da condutividade elétrica aparente do solo medida por indução eletromagnética (CE_a-V e CE_a-H) foi influenciada pelo relevo, não apresentando relação direta com a condutividade elétrica do extrato de saturação do solo (CE_{es}). Os atributos em estudo apresentaram distribuição de frequência com média superestimada, com valores de média se distanciando dos valores de moda e mediana. O relevo influenciou os mapas de variabilidade espacial da CE_a-V, CE_a-H, CE_{es} e θ, apesar da matriz de correlação não demonstrar relação de causa e efeito bem definida. Os atributos texturais (argila, site e areia) apresentaram elevada variabilidade espacial, apresentando efeito pepita puro (EPP).

Palavras-Chave: Agricultura de precisão. Geoestatística. Atributos químicos e físicos do solo.

INTRODUCTION

Precision agriculture requires determination and analysis of spatial and temporal variations of production factors, especially of the soil. These studies assist in determining specific management sites (SIQUEIRA; SILVA; DAFONTE, 2015; SIQUEIRA et al., 2016a), enabling variable rate input applications and determination of appropriate time of application, thus increasing crop yield (SILVA et al., 2013).

Thematic maps are among the main tools used to assess factors affecting crop development. Maps are used in precision agriculture to manage spatial and temporal variability of crop factors, guiding specific agricultural practices to improve efficiency of input application, reducing production costs, impacts on the environment (MOLIN; RABELO, 2011; GUO; MAAS; BRONSON, 2012; ALVES et al., 2013), and soil compaction caused by machinery traffic.

Several studies have sought to understand spatial variability of soil attributes, evaluating attributes that are easy to measure and direct correlated to other soil properties and crop yield. Thus, the apparent electrical conductivity (EC_a) measured by electromagnetic induction has been widely used due to its correlation with various attributes, such as organic matter, water and clay contents and soil salinity, density and porosity (FITZGERALD et al., 2006; AMEZKETA, 2007; BREVIK, 2012; SIQUEIRA; SILVA; DAFONTE, 2015; ATWELL; WUDDIVIRA; GOBIN, 2016; SIQUEIRA et al., 2016a), easy measurement (SHANER; FARAHANI; BUCHLEITER, 2008; KÜHN et al., 2009) and possibility of using large number of measures at low cost (ABDU; ROBINSON; JONES, 2007; SIQUEIRA; SILVA; DAFONTE, 2015; ATWELL; WUDDIVIRA; GOBIN, 2016).

Shaner, Farahani and Buchleiter (2008) also emphasized the importance of EC_a to determine sites for specific soil management, due to its correlation to different soil physical and chemical attributes that affect crop yield.

The determination of the EC_a measured by electromagnetic induction is related to different soil properties because its readings are the result of the interactions between soil porous spaces, which are filled with air or water, interactions between soil particles, and structure state (SIQUEIRA; SILVA; DAFONTE, 2015; SIQUEIRA et al., 2016a). Thus, information on the correlations of EC_a measured by electromagnetic induction to other soil properties in different types of soil and crops is important (SIQUEIRA; SILVA; DAFONTE, 2015; SIQUEIRA et al., 2016b).

Electromagnetic induction is an important alternative to evaluate EC_a, since it is a noninvasive technique that evaluate EC_a in the soil profile through multiple readings (ABDU; ROBINSON; JONES, 2007).

The objective of this study was to assess the spatial variability of the soil apparent electrical conductivity (EC_a), electrical conductivity of the saturation extract (EC_{se}), water content in the soil ($\theta_\%$) and soil texture (clay, silt and sand) of a sugarcane crop area in the State of Pernambuco, Brazil.

MATERIAL AND METHODS

The experiment was carried out in an area of about 6.5 ha of the Santa Teresa sugar and alcohol industry, in Goiana, Zona da Mata Norte, State of Pernambuco, Brazil (07°34'25"S, 34°55'39"W and average altitude of 8.5 m) (Figure 1).
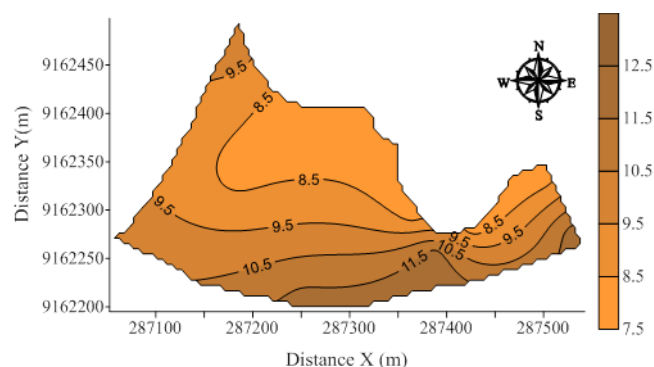

Figure 1. Topographic map of the study area.

The soil of the experimental area was classified as orthic Humiluvic Spodosol of sandy texture, according to the classification of EMBRAPA (2013). Textural classification of the soil (Table 1) was determined using the methodology recommended by EMBRAPA (2011).

**Table 1**. Textural classification of an orthic Humiluvic Spodosol.

Layer (m)	Texture (g kg^{-1})		
	Clay	Silt	Sand
0.0-0.2	253.20	33.91	712.89
0.2-0.4	253.38	26.87	719.76

The climate of the region is tropical humid type As', i.e., hot and humid, according to the classification of Köppen, with a rainy season from autumn to winter, annual average precipitation of 1,924 mm and annual average temperatures of 24 °C.

The study area has been used for rainfed sugarcane (*Saccharum officinarum* L.) crops, grown as single-crop, with straw burning before harvesting, since 1988. The crop area had been renewed in the 2010-2011 crops season; the soil was plowed, harrowed, grooved, limed, and fertilized and the

sugarcane variety RB867515 was planted.

Ninety sampling points were randomly chosen in the study area (Figure 2) and georeferenced with a GPS device with differential correction to subsequent data collection of the soil texture (clay, silt and sand), electrical conductivity of the saturation extract (EC$_{se}$) and water content. Samplings were carried out in January 21, 2014, with texture, EC$_{se}$ and water content determined in the soil layers of 0.0-0.2 and 0.2 -0.4 m.
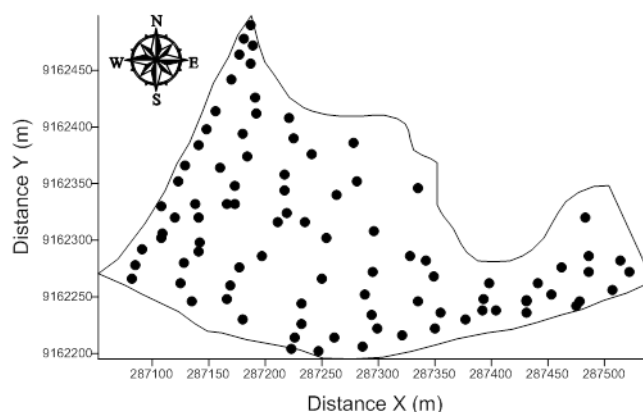
Figure 2. Location of the sampling points in the study area.

Field evaluations of soil apparent electrical conductivity (EC$_a$) (mS m^{-1}) was carried out using an electromagnetic induction device (EM38) (GEONICS, 1999), which measures the horizontal dipole (EC$_a$-H), with readings within the soil layer 0.0-0.4 m and the vertical dipole (EC$_a$-V), with readings within the layer 0.0-1.5 m, following the procedures described by Siqueira, Silva and Dafonte (2015) and Siqueira et al. (2016b).

Field evaluations of the volumetric water content in the soil ($\theta_{\%}$) in the soil layers 0.0-0.2 and 0.2-0.4 m was carried out using a transmission line oscillator (Hydrosense$^{®}$, Campbell Scientific Australia Pty. Ltd.), which has a probe that emits an electromagnetic signal in the soil and evaluates how many times the signal returns in a certain period of time (SIQUEIRA et al., 2015).

Laboratory evaluations of the soil texture (clay, silt and sand) (g kg^{-1}) and EC$_{se}$ (dS m^{-1}) were carried out in samples of the soil layers 0.0-0.2 and 0.2-0.4 m. The samples were air dried, disaggregated, sieved in a 2 mm mesh sieve. Soil texture (g kg^{-1}) was determined with a densimeter and EC$_{se}$ by the saturated paste extract method,

following the procedures described by EMBRAPA (2011).

The means of the attributes were subjected to the main statistical procedures (mean, median, standard deviation, coefficient of variation, skewness and kurtosis). The normality of the data was evaluated through coefficients of skewness and kurtosis and histograms of frequency distribution. The coefficient of variation (CV, %) was classified as low (<12%), intermediate (12% to 62%) and high (>62%) (WARRICK; NIELSEN, 1980). The linear correlation between the attributes was determined with significance level of 1% using the Shapiro-Wilk test, including the relief data of all sampling points to assess the effect of relief on the variables. Statistical analyzes were performed using software R 3.3.1 (R CORE TEAM, 2016).

Spatial dependence analysis was performed by adjusting of the experimental semivariogram, based on the assumption of stationarity of the intrinsic hypothesis (VIEIRA, 2000; SIQUEIRA et al., 2015). Spatial autocorrelation between neighboring sampling points was calculated by the

semivariance $\gamma(h)$, which is estimated by the Equation (1),

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(X_i) - Z(X_i + h)]^2$$

in which $N(h)$ is the number of experimental pairs of observations $Z(x^i)$ and $Z(x^i + h)$ separated by the distance h.

The semivariograms were developed according to VIEIRA (2000) in the software R. The spatial dependence index (SDI) was determined according to Cambardella et al. (1994), who classified dependences as strong (<25%), moderate (25 to 75%) and weak (>75%).

The software Surfer 11.0 was used to develop maps of spatial variability. Isoline maps were developed when the pure nugget effect was detected to compare the attributes, using the Surfer's default parameters, which is based on a linear interpolation model by kriging.

RESULTS AND DISCUSSION

According to the mean and median analysis (Table 2), the data of all variables tended to normality. However, the analysis of frequency distribution graphs (Figures 3 and 4) showed different distributions (symmetrical and asymmetrical). The coefficients of skewness and kurtosis were different than 0 and 3, thus, the data did not show normal distribution.

Table 2. Descriptive statistics of attributes of an orthic Humiluvic Spodosol of sandy texture.

	EC$_a$-V (mS m^{-1})	EC$_a$-H (mS m^{-1})	EC$_{se}$ (dS m^{-1})		$\theta_\%$	
Layer (m)	0.0-0.4	0.0-1.5	0.0-0.2	0.2-0.4	0.0-0.2	0.2-0.4
Mean	4.20	1.73	0.70	0.64	7.16	9.63
Median	4.00	0.50	0.68	0.65	6.50	8.90
Variance	8.94	5.95	0.03	0.01	17.20	29.67
SD	2.99	2.44	0.19	0.08	4.15	5.45
CV (%)	71.24	140.90	26.36	12.82	57.92	56.54
Skewness	0.79	1.53	0.53	-0.31	1.98	1.57
Kurtosis	-0.05	1.67	-0.45	-0.11	3.93	3.24
	Clay (g kg^{-1})		Silt (g kg^{-1})		Sand (g kg^{-1})	
Layer (m)	0.0-0.2	0.2-0.4	0.0-0.2	0.2-0.4	0.0-0.2	0.2-0.4
Mean	253.20	253.38	33.91	26.87	712.89	719.76
Median	256.00	256.00	27.20	20.00	716.80	724.00
Variance	786.85	447.77	1030.61	582.05	1399.26	989.82
SD	28.05	21.16	32.10	24.13	37.41	31.46
CV (%)	11.08	8.35	94.68	89.80	5.25	4.37
Skewness	-0.48	0.15	0.94	1.05	-0.24	-0.52
Kurtosis	0.54	0.42	-0.10	1.01	-0.20	0.33

EC$_a$-V = soil apparent electrical conductivity measured by electromagnetic induction with vertical dipole in the soil layer 0.0-0.4, EC$_a$-H = soil apparent electrical conductivity measured by electromagnetic induction with horizontal dipole in the soil layer 0.0-1.5 m, EC$_{se}$ = electrical conductivity of the saturation extract, SD = standard deviation; CV = coefficient of variation (%).
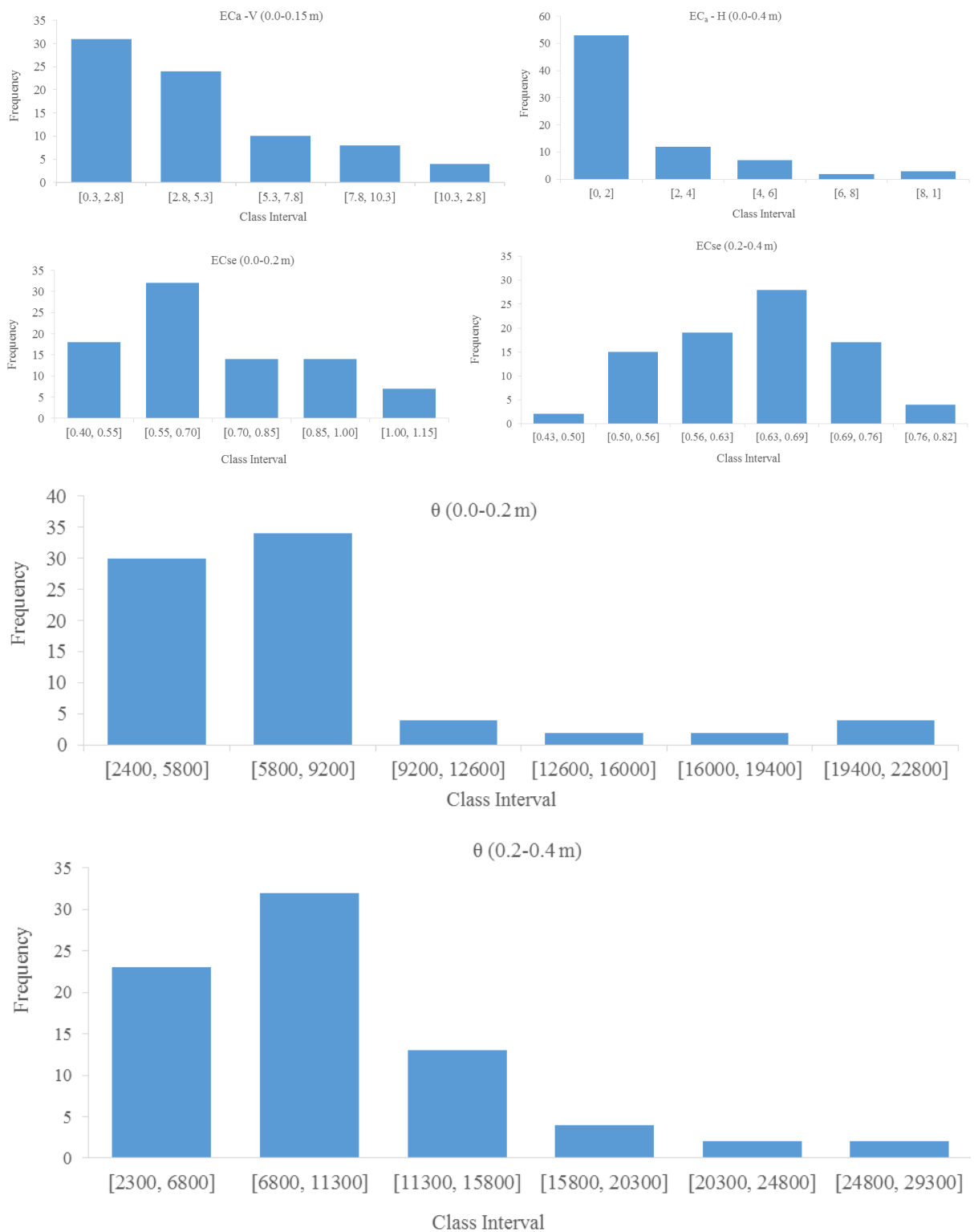
Figure 3. Histograms of frequency distribution of the soil attributes evaluated.
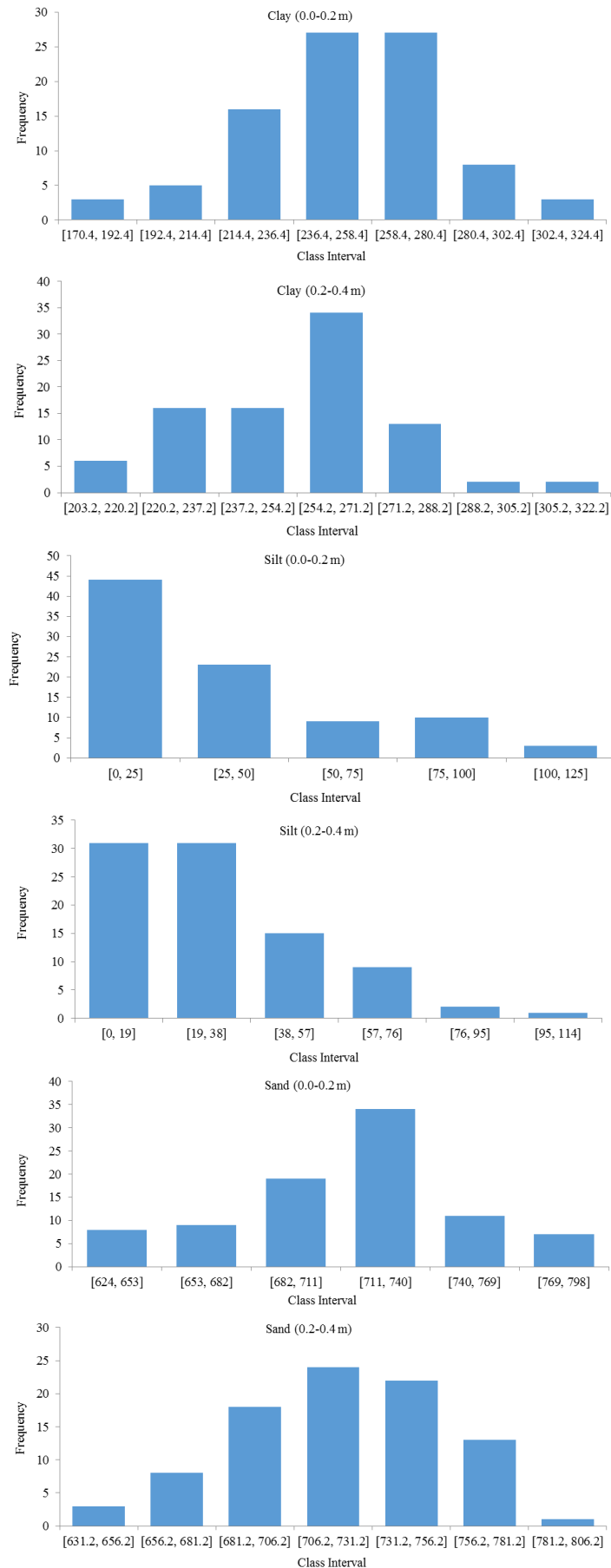
Figure 4. Histograms of frequency distribution of the soil attributes evaluated.

The means of EC_a-V and EC_a-H were different. According to Siqueira, Silva and Dafonte (2015) and Siqueira et al. (2016a), the largest differences in soil apparent electrical conductivity, measured by electromagnetic induction (EC_a-V and EC_a-H) are due to soil relief, water rate fluctuation, water content, texture and organic matter content. The water content in the soil and soil texture varied in both depths, explaining the greatest differences between EC_a-V and EC_a-H. Moreover, 80% of the EC_a-V readings were directly related to the EC_a-H readings, as also found by Geonics (1999) and Siqueira, Silva and Dafonte (2015). Therefore, despite the different means of EC_a-V and EC_a-H, these variables are correlated.

EC_a-V (mS m^{-1}), EC_a-H (dS m^{-1}) and EC_{se} (dS m^{-1}) means were different. However, despite representing the same soil attribute, they were evaluated through different methods and expressed in different scales. Their major differences were due to evaluation method, since the electromagnetic induction method is assessed in the field, considering the soil electric current flow as a three-dimensional body, encompassing a larger volume of soil (consisting of porous spaces, water and mineral particles), and EC_{se} is determined in laboratory, under controlled conditions, using disturbed soil samples, with readings that consider only the salts of the soil solution. (SIQUEIRA et al., 2014; SIQUEIRA; SILVA; DAFONTE, 2015).

The coefficient of variation (CV%) of clay and sand was classified as low (< 12%); water content in the soil ($\theta_\%$) and EC_{se} had intermediate CV (12% to 62%); and EC_a-V, EC_a-H and silt content had high CV (> 62%).

According to the frequency distribution histograms (Figure 3), most attributes had lognormal distribution, however, geostatistical analysis can be carried out despite the data normality (VIEIRA, 2000).

The frequency distribution graphs for EC_a-V and EC_a-H showed leptokurtic positively skewed distribution, i.e., there were many low EC_a-V and EC_a-H, thus, their mode and median were close and their means were overestimated. The EC_{se} of the soil layer 0.0-0.2 m also had leptokurtic positively skewed distribution, whereas the EC_{se} of the soil layer 0.2-0.4 m had normal frequency distribution, with slightly trend to a negatively skewed distribution. The histograms for EC_a-V, EC_a-H and EC_{se} was probably affected by the relief, as reported by Siqueira, Silva and Dafonte (2015), who found the relief affecting the water flow in the soil and consequently, the EC_a-V, EC_a-H and EC_{se}.

The water content in the soil ($\theta_\%$) had lognormal frequency distribution, also with overestimation of the mean and leptokurtic positively skewed distribution. This result was expected, since the water flow and distribution in the soil favor the formation of sites with high and low water content as a function of relief, as reported by Siqueira et al. (2015). The frequency distribution histograms for water content in the soil showed very elongated tails, confirming that the water content varied, showing areas of high and low water content along the landscape of the study area.

Only the data of silt, from the texture attribute, had lognormal frequency distribution in both soil layers. Data of clay and sand had normal distribution, with more homogeneous histograms and less elongated tails, resulting in more stable means.

According to the geostatistical analysis (Table 3), most of the texture attributes had pure nugget effect (PNE), denoting a small scale spatial variability, i.e., at distances smaller than that chosen by random sampling. Only the model for clay content of the soil layer 0.2-0.4 m fitted to the experimental semivariogram.

The spherical model was fitted to the semivariograms of EC_a-V, EC_a-H and θ (0.0-0.2); and the Gaussian model to EC_{se} in both layers. The spherical model fit to the semivariograms for most of the attributes, confirming reports of other authors, who describe this model as that that best fit to the attributes of the soil (CAMBARDELLA et al., 1994; VIEIRA, 2000; SIQUEIRA; SILVA; DAFONTE, 2015; SIQUEIRA et al., 2016a).

The highest range (a) (m) was found for the EC_{se} in the soil layer 0.2-0.4 m (199 m) and the lowest, for the EC_a-H in the soil layer 0.2-0.4 m (57 m).

According to the classification of Cambardella et al. (1994), the attributes evaluated had strong (< 25%,) and moderate (25 to 75%) spatial dependence index. Siqueira et al. (2015) evaluated the spatial variability of soil attributes with different scales and found high SDI (%) for water content in the soil (%) at different soil depths (0.0-0.2, 0.2-0. 4 and 0.4-0.6 m). Differences in spatial dependence index were due to the soil natural variation and relief of the study area.

Parameters of models fitted to the experimental semivariogram of EC_a-V and EC_a-H showed a similar spatial pattern, fitting a spherical model. The EC_{se} spatial pattern was different, especially by fitting a Gaussian mathematical model. This result was due to the scalar magnitude and because readings were performed in undisturbed (EC_a-V and EC_a-H) and disturbed (EC_{se}) soil samples.

According to the linear correlation matrix (Table 4), the relief was significantly correlated at 1% of probability (Shapiro-Wilk test) only to EC_a-V (| r | = 0,815) and to EC_a-H (r = 0.826).

Table 3. Parameters of models fitted to the experimental semivariogram of the attributes of an orthic Humiluvic Spodosol of sandy texture.

| | EC_a-V | EC_a-H | EC_{se} | | $\theta_{\%}$ | |
	0.0-0.4	0.0-1.5	0.0-0.2	0.2-0.4	0.0-0.2	0.2-0.4
C_0	0.32	2.70	0.02	0.0042	1.00	0.80
C_0+C_1	8.52	5.30	0.0343	0.0076	19.50	34.80
a (m)	65	57	121	199	65	120
SDI (%)	37	50	58	55	5	2
Model	Spherical	Spherical	Gaussian	Gaussian	Spherical	Exponential
r^2	0.627	0.235	0.896	0.999	0.465	0.849
	Clay		Silt		Sand	
	0.0-0.2	0.2-0.4	0.0-0.2	0.2-0.4	0.0-0.2	0.2-0.4
C_0	-	0.69	-	-	-	-
C_0+C_1	-	3.926	-	-	-	-
a (m)	-	70	-	-	-	-
SDI (%)	-	18	-	-	-	-
Model	PNE	Exponential	PNE	PNE	PNE	PNE
r^2	-	0.850	-	-	-	-

EC_a-V = soil apparent electrical conductivity measured by electromagnetic induction with vertical dipole in the soil layer 0.0-0.4, EC_a-H = soil apparent electrical conductivity measured by electromagnetic induction with horizontal dipole in the soil layer 0.0-1.5 m, EC_{se} = electrical conductivity of the saturation extract, $\theta_{\%}$ = water content in the soil; C_0 = nugget effect, C_0+C_1 = sill, a = range (m), SDI: spatial dependence index (%), r^2: coefficient of determination; PNE = pure nugget effect.

The correlations of relief to EC_{es} 0.0-0.2 ($|r| = 0.337$) and to EC_{se} 0.2-0.4 ($|r| = 0.051$) were low. This result was also due to the evaluation method used, with undisturbed (EC_a-V and EC_a-H) and disturbed (EC_{se}) soil samples.

Relief had no high linear correlation with the other attributes, since texture attributes are dependent on relief. Relief had some positive correlation only to silt ($|r| = 0.419$; 0.0-0.2) ($|r| = 0.564$; 0.2-0.4) and sand ($|r| = 0.559$; 0.0-0.2) ($|r| = 0.550$; 0.2-0.4).

Table 4. Linear correlation matrix for the attributes of an orthic Humiluvic Spodosol of sandy texture.

	Relief	ECa-V 0-1.5	ECa-H 0-0.4	ECse 0.0-0.2	ECse 0.2-0.4	θ 0.0-0.2	θ 0.2-0.4	Clay 0.0-0.2	Clay 0.2-0.4	Silt 0.0-0.2	Silt 0.2-0.4	Sand 0.0-0.2	Sand 0.2-0.4
Relief	1.000												
EC_a-V 0-1.5	0.815	1.000											
EC_a-H 0-0.4	0.826	0.940	1.000										
EC_{se} 0-0.2	0.337	0.530	0.638	1.000									
EC_{se} 0.2-0.4	0.051	0.350	0.543	0.564	1.000								
θ 0-0.2	0.215	0.412	0.162	0.076	0.308	1.000							
θ 0.2-0.4	0.374	0.531	0.464	0.338	0.249	0.497	1.000						
Clay 0-0.2	0.201	0.254	0.572	0.197	0.583	0.611	0.295	1.000					
Clay 0.2-0.4	0.185	0.284	0.486	0.394	0.686	0.527	0.231	0.510	1.000				
Silt 0-0.2	0.419	0.533	0.642	0.230	0.679	0.343	0.219	0.611	0.304	1.000			
Silt 0.2-0.4	0.564	0.640	0.599	0.582	0.717	0.290	0.430	0.477	0.300	0.377	1.000		
Sand 0-0.2	0.559	0.665	0.304	0.245	0.428	0.703	0.416	0.675	0.451	0.407	0.460	1.000	
Sand 0.2-0.4	0.550	0.907	0.227	0.397	0.444	0.493	0.570	0.953	0.913	0.739	0.198	0.678	1.000

*Significant at 1% probability by the Shapiro-Wilk test.

According to the spatial variability maps (Figures 5 and 6), the EC_a-V (Figure 5A) and EC_a-H (Figure 5B) had similar distribution of the contour lines, explaining their high correlation ($|r| = 0.940$). Moreover, the device used reads a same volume of soil, and vertical dipole readings (EC_a-V) are affected by the soil surface layer, which was evaluated by the horizontal dipole (EC_a-V) (CORWIN; LESCH, 2003, 2005; SIQUEIRA; SILVA; DAFONTE, 2015).

The spatial variability maps of EC_a-V, EC_a-H, EC_{se} and θ showed no similar patterns (Figure 5), confirming their low spatial correlation (Table 4). However, these maps followed a same trend pattern, as shown in the relief map (Figure 1). Therefore, the spatial distribution of the attributes (EC_a-V, EC_a-H, EC_{se} and θ) is affected by relief. According to Siqueira, Silva and Dafonte (2015) and Siqueira et al. (2015), soil declivity is the factor that most affect water distribution and consequently, the distribution and interaction of other soil attributes.

The maps of water content in the soil (θ) at 0.0-0.2 (Figure 5E) and 0.2-0.4 m (Figure 5F) showed the greatest similarity to the relief map (Figure 1) regarding the pattern of contour lines, however, with low correlation ($|r| = 0.215$; 0.0-0.2) ($|r| = 0.374$; 0.2-0.4).

Spatial variability maps of texture (clay, silt and sand) (Figure 6) in the soil layers 0.0-0.2 and 0.2-0.4 m (Figure 6) showed no spatial relationship with the maps of EC_a-V, EC_a-H, EC_{se} and θ (Figure 5), confirmed by the low values of linear correlation (Table 4).

The spatial distribution maps of soil texture (clay, silt and sand) showed great difference in contour lines, denoting high spatial variability. All texture attributes had pure nugget effect (PNE), except the clay at 0.2-0.4 m (Table 3). These maps were developed by linear interpolation to compare spatial patterns, even with PNE, since cartography is a classical science, and data with PNE processed by geostatistics are usually not properly analyzed. Thus, the PNE of texture attributes was due to the high variability of the data along the landscape, affected by different soil formation factors (SIQUEIRA; SILVA; DAFONTE, 2015; SIQUEIRA et al., 2015).
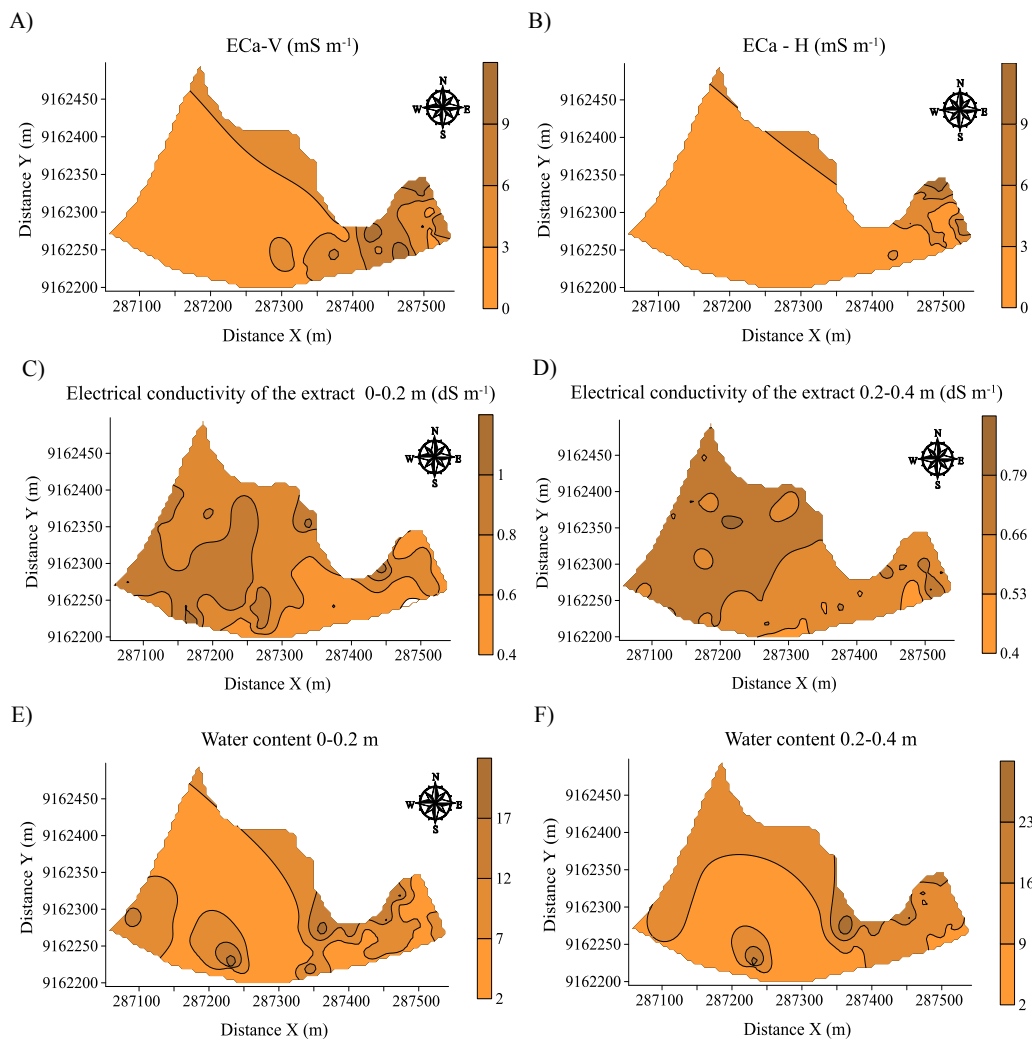

Figure 5. Isoline maps of EC_a-V (0.0-0.15 m), EC_a-H (0.0-0.4 m), EC_{se} (0.0-0.2 and 0.2-0.4 m) and θ (0.0-0.2 and 0.2-0.4 m) of an orthic Humiluvic Spodosol of sandy texture.
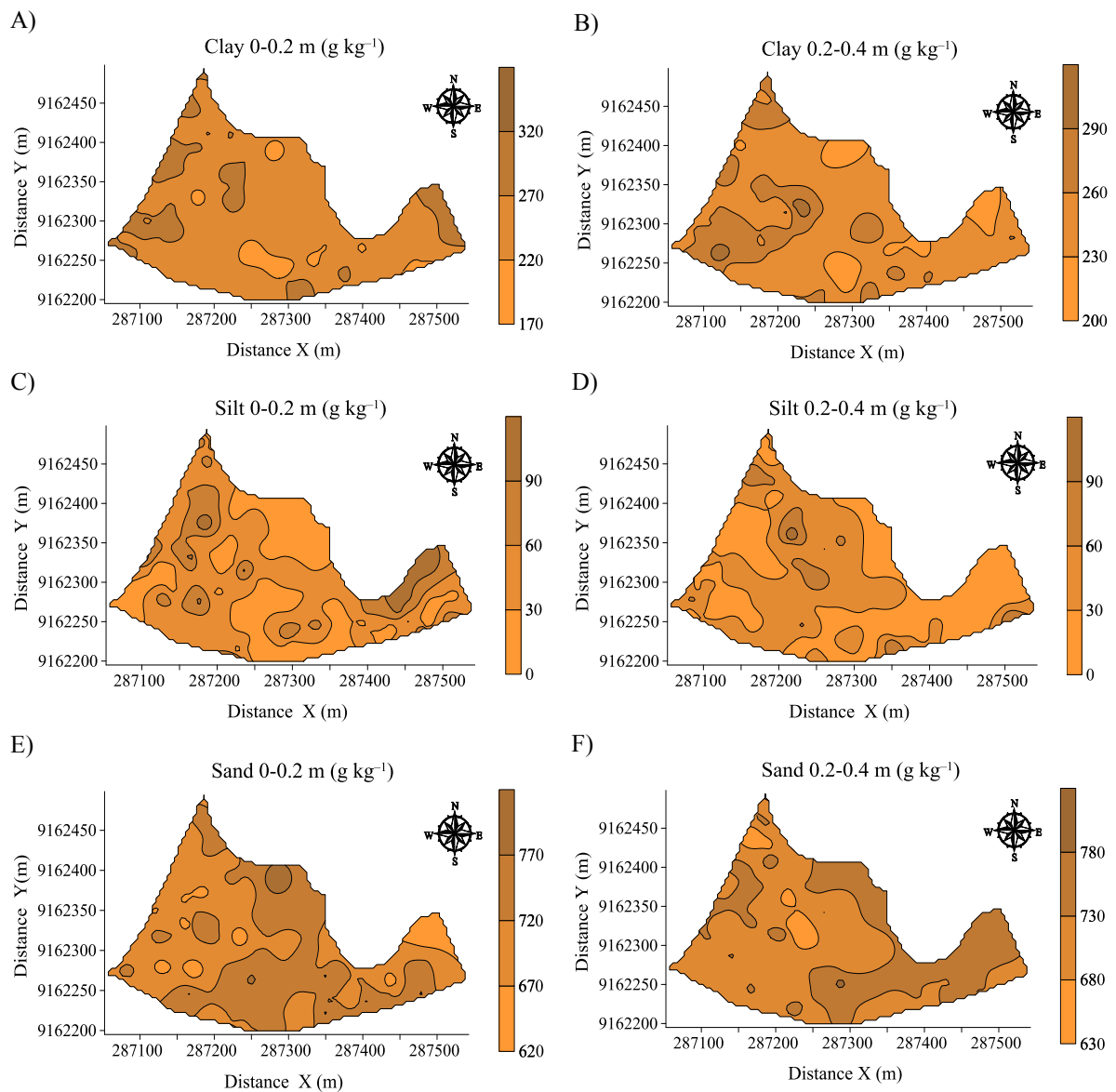
Figure 6. Isoline maps of soil texture (clay, silt and sand) in the soil layers 0.0-0.2 m and 0.2-0.4 m of an orthic Humiluvic Spodosol of sandy texture.

CONCLUSIONS

Spatial variability of the soil apparent electrical conductivity measured by electromagnetic induction (EC_a-V and EC_a-H) was affected by relief and had no direct correlation to the electrical conductivity of the soil saturation extract (EC_{se}).

The soil attributes evaluated had frequency of distribution with overestimated means, and means distant from the mode and median.

The area relief affected the spatial variability of EC_a-V, EC_a-H, EC_{se} and θ, however, the correlation matrix did not show a well-defined cause-and-effect relationship.

Spatial variability of soil texture attributes (clay, site and sand) was high, presenting pure nugget effect.

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