



SPATIAL VARIABILITY OF HUMIDITY AND TEXTURE IN A FLUVITIC NEOSSOL CROPPED WITH IRRIGATED BANANA

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ABSTRACT: Soil water dynamics usually presents spatial dependence in relation to the distribution of particle sizes. Precision agriculture is fundamental for the adequate use of irrigated areas with agricultural production because it allows controlled water applications from the management of spatial variability. The aim of this study was to evaluate spatial variability of the physical-hydraulic properties in an irrigated plot with banana production, located at the Experimental Basin of Rio Ipanema, municipality of Pesqueira, Pernambuco. Soil samples were collected from a 0 - 0.20 m layer and soil moisture was evaluated using a portable probe “Time Domain Reflectometry”, with a regular size 20 x 45 meters grid pattern, in 50 sampling points, 5 meters apart. The data were submitted to a descriptive statistical and geostatistical analysis. Data showed normal distribution using the Kolmogorov-Smirnov test. The semi-variogram model that best fit the analyzed variables was the exponential.

KEYWORDS: Spatial dependence, Soil water dynamics, Geostatistics.

VARIABILIDADE ESPACIAL DA UMIDADE E TEXTURA DE UM NEOSSOLO FLÚVICO CULTIVADO COM BANANA SOB IRRIGAÇÃO

RESUMO: A dinâmica de água no solo geralmente apresenta dependência espacial com a distribuição das frações granulométricas. A agricultura de precisão é fundamental para o manejo adequado de uma área irrigada com produção agrícola, pois permite aplicações controladas de água a partir do gerenciamento da variabilidade espacial. Objetivou-se com esse trabalho avaliar a variabilidade espacial dos atributos físico-hídricos, em um lote irrigado, com produção de bananeiras, na Bacia Experimental do Rio Ipanema, no município de Pesqueira em Pernambuco. A amostragem de solo foi realizada na camada de 0-0,20 m e a umidade do solo

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foi medida utilizando uma sonda portátil “Time Domain Reflectometry”, em uma malha regular de “grid” 20 x 45 m, em 50 pontos amostrais espaçados 5 m entre si. Os dados foram submetidos à análise de estatística descritiva e geoestatística. Os dados apresentaram distribuição de frequência normal pelo teste de Kolmogorov-Smirnov. O modelo de semivariograma que melhor se ajustou para as variáveis analisadas foi o exponencial.

PALAVRAS-CHAVE: Dependência espacial. Dinâmica de água no solo. Geoestatística.

INTRODUCTION

The monitoring of soil moisture content is not only essential for agriculture, but allows or controls the water applications based on hydraulic requirements of the soil (Buske et al., 2013).

The use and adequate soil management contribute to the improvement of water storage and infiltration capacity (Vieira et al., 2011). In this sense, precision agriculture acts as a tool that has great potential for improving adequate soil management, having as the main component the management of spatial and temporal variability of agricultural production (Silva, et al., 2014).

Hydrological processes such as infiltration and soil moisture redistribution in the soil are influenced by the physical-hydraulic properties (Silva et al., 2012). Soil moisture is affected by vegetation as well as by soil texture as described by Baroni et al. (2013). Different production areas can be revealed by using the spatial variability of irrigation areas, thus, maximizing the potential of land use (Castione et al., 2015).

Considering the importance of texture and soil moisture for agricultural productivity in the Brazilian semi-arid region, the aim of this study was to analyze the spatial variability of soil physical-hydraulic properties at 0 - 0.20 m depth, in an irrigated plot, located at the Experimental Basin of Rio Ipanema, municipality of Pesqueira, Pernambuco.

MATERIAL AND METHODS

The study was conducted in the municipality of Pesqueira-PE, at Fazenda Mimosa, in the alluvial valley of Rio Ipanema, wasteland region of Pernambuco, located at coordinates 08°10' South latitude and 35°11' west longitude, 650 masl. Based on the Köppen climate classification system, the region has a BSsh climate, defined as an extremely hot semi-arid climate. The

average annual rainfall is 607 mm (Montenegro & Montenegro, 2006). The predominant soil of the region is Flossic Neosol (Bastos, 2004).

To evaluate the variability of soil physical-hydraulic properties, a 20 x 45 m regular mesh grid was used, in 50 sample points, spaced 5 m apart, according to the graph shown in Figure 1.

The study was performed on October 27, 28 and 29, 2015. Soil samples were collected at 0-0.20 m depth, at 50 sampling points for texture analysis; also, three measurements were taken to evaluate the soil-water content using a portable time domain reflectometry (TDR) probe.

The Boyoucos hydrometer method was used to determine the particle sizes of sand, clay, and silt in the soil, based on the methodology proposed by Embrapa 2011.

Soil moisture monitoring was performed at three different irrigation moments: 12 hours after irrigation, 4 hours after irrigation and immediately after irrigation. The calibration of the TDR probe was carried out by adjusting and analyzing mathematical models to the soil moisture readings obtained by the probe, in relation to the soil gravimetric moisture values determined in the laboratory (Ávila et al., 2011).

In the banana cultivation areas, drip irrigation system was used, where mulch was applied as a cultural practice to cover the soil surface using banana leaves. Descriptive statistics, such as mean, median, standard deviation, coefficient of skewness, coefficient of kurtosis, and coefficient of variation were used to analyze the data. To identify discrete values (outliers) and data dispersion, “boxplot” graphs were constructed using statistic software. The hypothesis for normality was evaluated using the Kolmogorv-Smirnov test, at a significance level of 5%, using Excel spreadsheet (SOUZA et al., 2008).

The variability of the evaluated characteristics was estimated using the values of the coefficient of variation, which according to the classification by Warrick & Nielsen (1998), shows low variability if $CV < 15\%$; is moderate when found between 15-50%, and has a high variability when $CV > 50\%$.

In the study area, the spatial variability was analyzed using geostatistics by means of semivariogram adjustments described by Vieira (2000). The spatial autocorrelation between the neighboring points was calculated using semivariance $\gamma(h)$, where “h” is the distance that separates the points based on the stationarity hypothesis.

The experimental semivariogram models were obtained in which: the linear, gaussian, spherical and exponential models were tested, where the mathematical model and their

adjustment parameters were estimated (nugget effect, C_0 ; sill, $C_0 + C_1$; range, a) from the theoretical semivariogram models.

The model that best fits the data set was the one that presented the mean and standard deviation values closer to zero and 1, respectively, based on the geostatistical technique of the cross-validation using Jack-Knifing, described by Montenegro & Montenegro (2006). According to Cambardella et al. (1994), the degree of spatial dependence (DSD) was evaluated, based on the percentage ratio of the nugget effect (C_0) in relation to the ($C_0 + C_1$) levels as follows: (a) strong dependence when (DSD) $<25\%$; (b) moderate dependence when (DSD) is between 25 and 75% and (c) weak dependence when (DSD) is $>75\%$.

To visualize the spatial distribution of the soil texture and moisture content, the kriging method was used to construct the isoline map.

RESULTS AND DISCUSSION

The linear mathematical model was applied to calibrate the TDR probe used in this study, since it presented the best statistical adjustment among the tested models, with a coefficient of determination of 0.98. Ávila et al. (2011), using the TDR probe evaluated the spatial and temporal pattern of soil moisture in a Hydrographic Basin in the State of Minas Gerais and found that the coefficient of determination for calibrating an instrument is 0.85, thus, classifying the calibration as good and acceptable.

The values obtained from the descriptive statistics for soil moisture are presented in Table 1. Data analysis showed that the values of the coefficient of skewness and kurtosis were close to zero, which explains the fact that the data presented normal distribution obtained by the Kolmogorov-Smirnov normality test at a significance level of 5%. According to the classification by Warrick and Nielsen (1998) the values of the coefficients of variation for soil moisture obtained at the three considered irrigation moments presented medium variability, this is explained because the median and mean values did not present high variations when the measurements were carried out.

Rodrigues et al. (2015) evaluated the spatial moisture variability of a similar irrigated plot to this study, adopting an 8 x 4 m regular spaced mesh, in 104 sample points, and found similar results.

In the granulometric analysis, the Kolmogorov Smirnov test indicated normality in the data for sand, clay, and silt at a significance level of 5%. The sand particles presented a low coefficient of variation, while the clay and silt particles presented average variability. In a recent

study, Andrade et al. (2014) evaluated the spatial variability of the textural classes of Flossic Neosol soil, at 0 - 0.20 m layer; they obtained similar results, where the greater variability for the silt particles should be associated with its greater mobility in the soil profile of an alluvial valley.

After analyzing the variables U1 (12 hours after irrigation), U2 (4 hours after irrigation) and U3 (immediately after irrigation), in “box plot” graph (Figure 2.), the moisture levels at each irrigation moment for U1 and U2 presented low negative skewness. For U3, the highest data dispersion was observed for the values below the lower quartile, although negative skewness also occurred.

The texture variables of sand, silt, and clay contents showed skewness. Meanwhile, for the sand and clay values, a greater data dispersion is observed for the values below the lower quartile (negative skewness).

Existing spatial dependence was observed from the experimental semi-variograms, with the exponential model being the one that best fits the moisture measurements in the three irrigation moments and the analyzed texture particles, these results were based on the cross-validation technique (means value closer to zero and standard deviation closer to 1). The adjusted model parameters are shown in Table 2. Experimental semivariance and adjusted models (Figure 3).

The moisture values presented by U1, U2 and U3 ranged from 12 m, 9.5 m, and 9.0 m, respectively, for the exponential model, this allows a greater spatial dependence of soil moisture over time. Therefore, drip irrigation influences the space-time dependence of soil moisture. For texture data, the semivariogram model that best adjusted was the exponential, presenting in the study area a greater continuity in the distribution of the variables in the most superficial layer of the soil.

Santos et al. (2011) evaluated the spatial-temporal variability of soil moisture, using the TDR probe, in the Representative Basin of Alto do Ipanema, in the municipality of Pesqueira - PE, observing that the exponential model produced the best adjustment. Rodrigues et al. (2015) evaluated the spatial variability of soil moisture and granulometric particles in the semi-arid region of the municipality of Pesqueira, in the same irrigated plot with banana plantation, also verified that the exponential model was better adjusted for moisture and texture data.

Sand, clay and silt particles, ranged from 6m, 12m, and 12 m, respectively. Larger continued spaces were observed for clay and silt particles, allowing a better precision in non-sampled locations. The sand and clay particles presented high spatial dependence, although silt

presented moderate spatial dependence, these observations are based on the classification proposed by Cambardella et al. (1994), where low values of the nugget effect represent a high spatial dependence on the evaluated variables.

The management of the irrigated plot associated with the geomorphological processes in the alluvial valley causes deposition and accumulation of materials from other places, due to the topographic conditions of the area, and which explains the moderate spatial dependence of silt (Montenegro & Montenegro, 2006). Andrade et al. (2014), evaluated the variability of granulometric particles in Flossic Neosol soil, at Fazenda Nossa Senhora of Rosário, in the municipality of Pesqueira-PE, and found range values for sand, clay and silt of 15 m, 9 m, and 20 m, respectively.

The distribution of the water content in the study area is represented by isoline maps for the U1, U2 and U3 irrigation moments (Figure 4 - A, B and C), respectively, at 0 - 0.20 m layer. In the U3 map, a higher water content variation was obtained in the 0 - 0.20 m layer of the soil profile in the entire area, despite obtaining in the same map, higher water content concentration in the extremes when compared with U1 and U2 moisture maps, in relation to the water movement from the central part to the extremes.

Rodrigues et al. (2015), observed the same behavior of water dynamics, evaluating the spatial variability of soil moisture in the same area of the study. In the U1 and U3 isoline maps, in the central region, a higher concentration of water content in the soil was observed, which was possibly influenced by the minimization of soil water evaporation due to the shadowing caused by the hose located in the center of the area. In the U2 isoline map, a predominance of lower moisture values in almost every area was noticed, because the reading was performed outside the moisture bulb.

The isoline maps allow the adequate management of water distribution through the irrigation system, from the identification of regions with low moisture content, as justified by Souza et al. (2008). Higher moisture values were observed in the areas located at the extreme of the plot, showing the unevenness of the drip irrigation system in the study area, indicating possible temporal dependence.

The isoline maps for the granulometric particles (Figure 4. D, E and F) showed homogeneous behavior for clay and silt on the left side of the area. The highest sand content is concentrated in the lower soil moisture regions. Leão et al. (2010), in São Paulo, found similar results on a slope of an alluvial valley.

Santos et al. (2012) evaluated an alluvial valley in the semi-arid region of Pernambuco and found a medium variability for the textural particles: sand, silt, and clay, associating this

result to the transport and sedimentation processes, providing greater homogenization of sand and clay particles.

CONCLUSIONS

All physical-hydraulic properties followed a normal distribution frequency. Soil moisture at the three measuring moments and the clay and silt granulometric particles showed mean variation, while sand presented a low coefficient of variation. The spatial dependence of soil moisture and texture were best represented by the exponential model.

The moisture content at the different measuring moments for sand and clay granulometric particles presented high spatial dependence, while silt presented moderate spatial dependence. In the isoline maps after irrigation, greater water content was observed at the extremes of the study area, with an increase in the variability and spatial dependence of soil moisture with irrigation.

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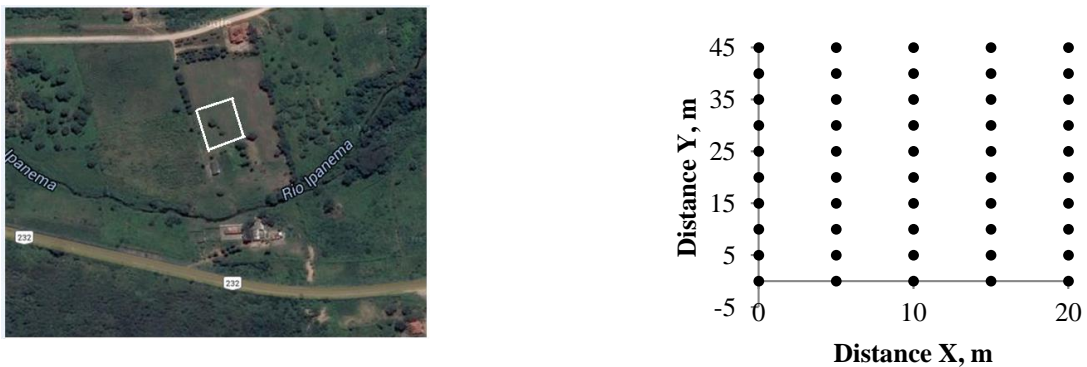


Figure 1. Location of the sample points in the experimental area for the physical-hydraulic properties.

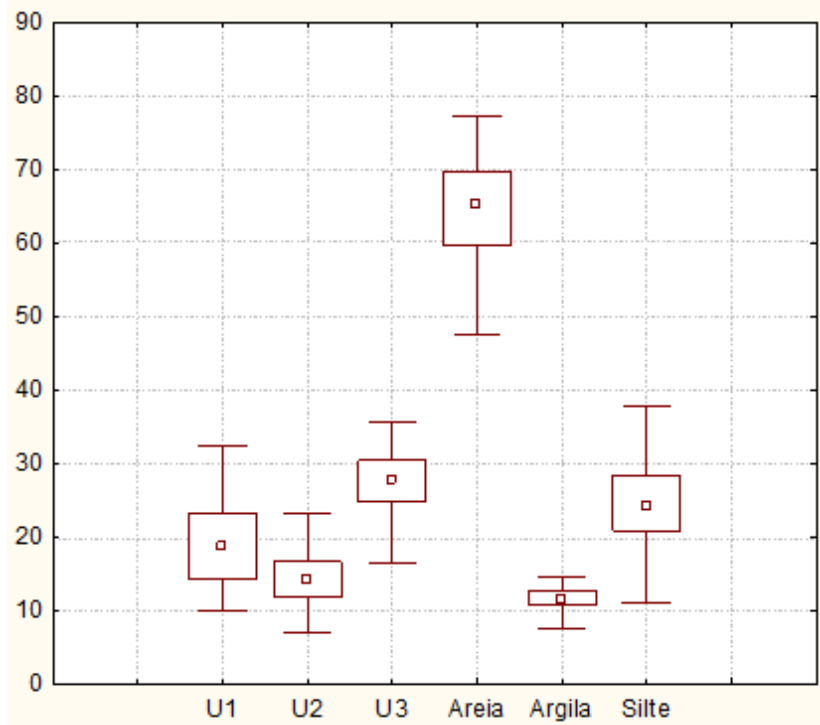
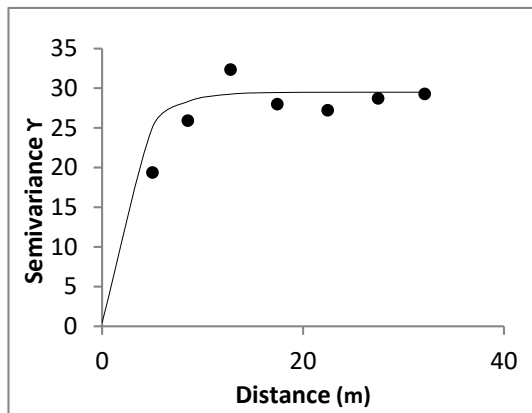
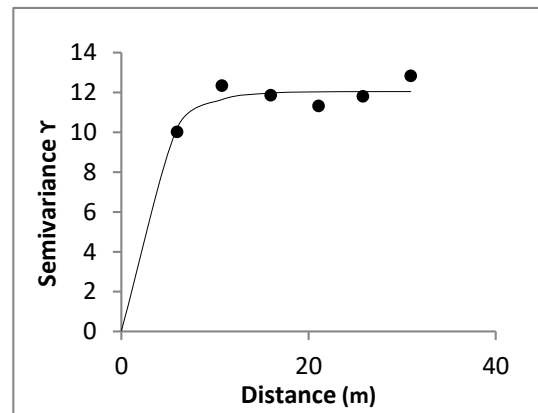


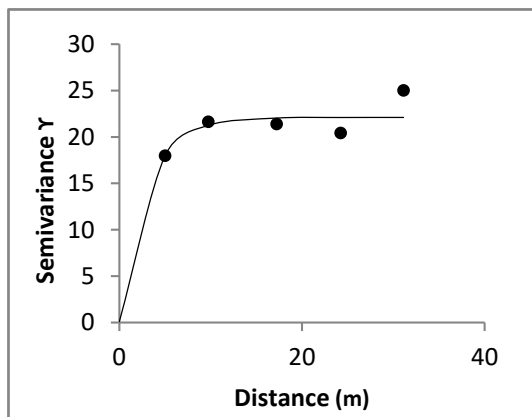
Figure 2. "Box-Plot" graph for the variables U1, U2, U3, Sand, Clay and Silt



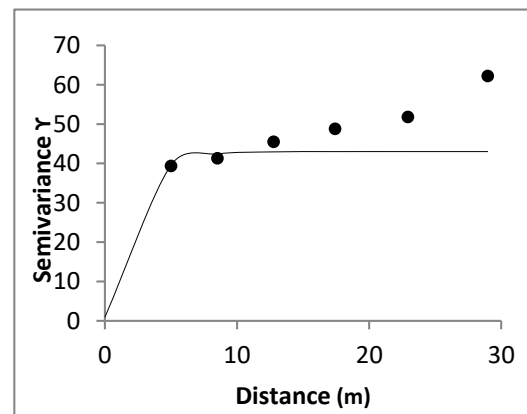
(A)



(B)



(C)



(D)

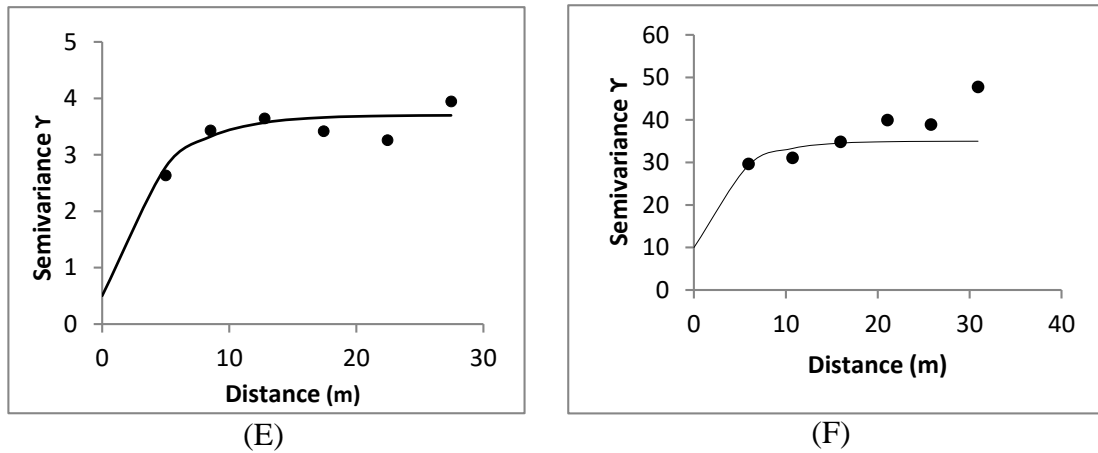


Figure 3. Adjusted semi-variograms for the moisture variables (%), in the irrigation moment U1 (A); irrigation moment U2 (B); irrigation moment U3 (C); and soil texture: sand content (g.kg^{-1}) (D); clay content (g.kg^{-1}) (E); silt content (g.kg^{-1}) (F), at 0 - 0.20 m depth.

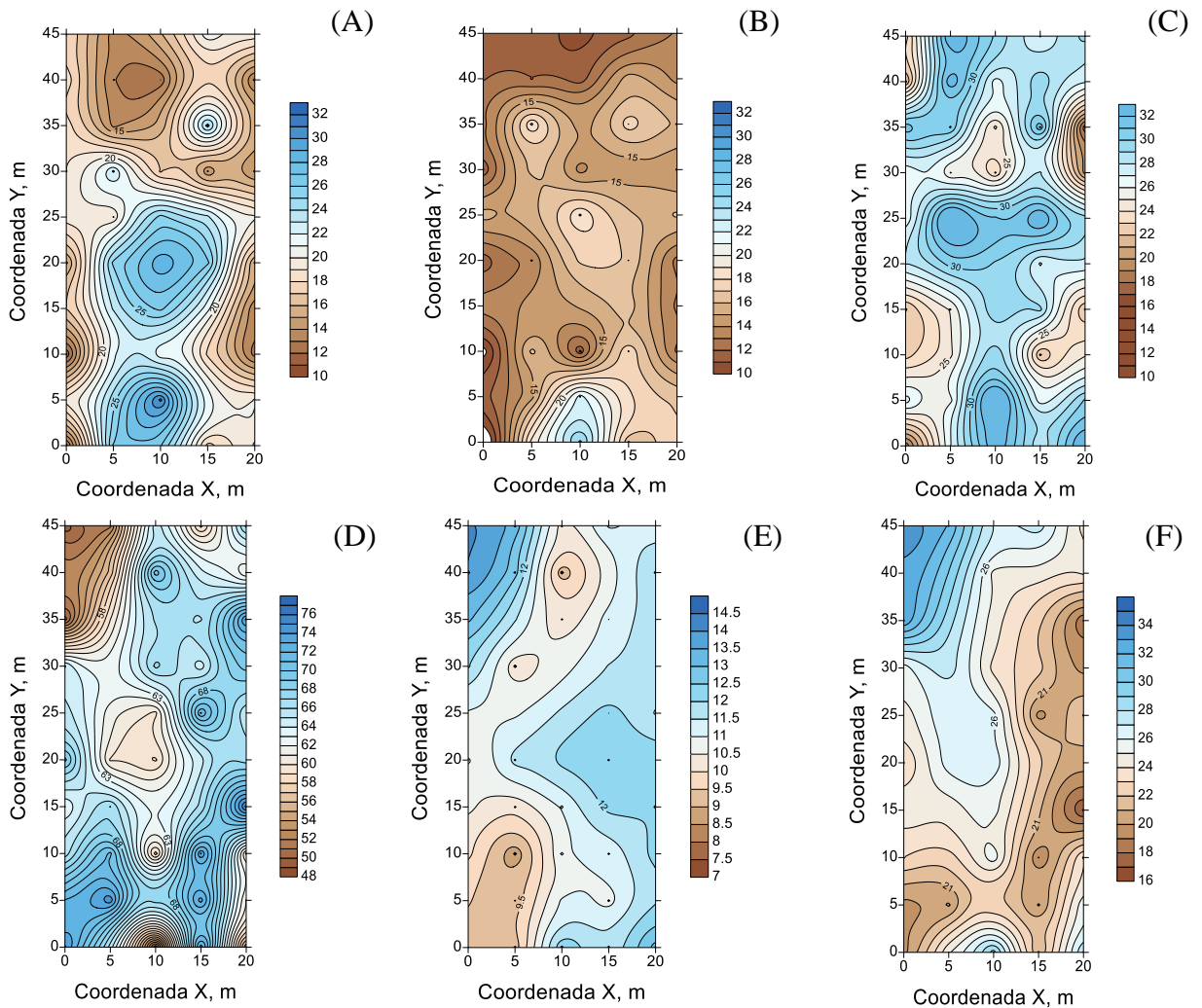


Figure 4. Isoline maps representing the moisture variables (%) in the irrigation moment U1 (a); irrigation moment U2 (b); irrigation moment U3 (c); and soil granulometric particles: sand content (g.kg^{-1}) (e); clay content (g.kg^{-1}) (f); silt content (g.kg^{-1}) (g), 0-0.20 m depth.

Table 1. Descriptive statistics obtained from the three measurements for the moisture variables and soil particle size.

Descriptive statistics	U1(%)	U2(%)	U3(%)	Sand(%)	Clay(%)	Silt(%)
1° Quartile	14.4	24.8	11.95	59.6	10.68	20.92
Median	18.9	14.3	27.9	65.3	11.68	24.12
Mean	19.17	14.71	27.42	64.26	11.33	24.42
3° Quartile	23.3	30.4	16.95	28.32	12.68	28.32
Coefficient of skewness	0.28	0.72	-0.34	-0.42	-0.31	0.08
Coefficient of kurtosis	-0.59	1.31	-0.35	-0.26	0.01	-0.24
Standard deviation	5.32	3.62	4.65	7.42	1.96	6.25
Variance	28.33	13.1	21.59	55.05	3.86	39.07
Coefficient of variation (%)	27.76	24.6	16.94	11.54	17.34	25.6
N° of sample elements	50	50	50	50	50	50

U1 – first soil moisture measurement (%); U2 – second soil moisture measurement (%); U3 – Third soil moisture measurement (%).

Table 2. Adjustment parameters and validation of semi-variograms for the three soil moisture measurements.

Semi-variogram Adjustment Parameters						
	U1(%)	U2(%)	U3(%)	Sand(%)	Clay(%)	Silt(%)
Nugget effect (C_0)	0.50	0.04	0.09	1.00	0.50	10.0
Sill ($C_0 + C_1$)	28.0	12.0	22.0	42.0	3.20	25.0
Range	12.0	9.50	9.00	6.00	12.0	12.0
Degree of dependence [$C_0 / (C_0 + C_1) \times 100$]	1.78	0.38	0.45	2.40	15.6	40.0
Model	Exp.	Exp.	Exp.	Exp.	Exp.	Exp.
Semi-variogram Validation Parameters						
Mean	0.035	0.057	0.029	-0.031	-0.010	-0.013
Standard deviation	0.962	1.013	1.072	1.042	0.983	1.061

U1 – first soil moisture measurement (%); U2 - second soil moisture measurement (%); U3 - third soil moisture measurement (%); Exp. - exponential