Geostatistical assessment of the spatial variability of soil texture in the coffee plantation

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Abstract

The aim of this study was to evaluate the variability of soil texture in coffee plantation by geostatistics, using simple kriging as linear interpolator to analyze the prediction errors. The research was conducted in Cafua Farm where 67 sample points were collected in an area of 6.5 ha. Spherical model variograms were adjusted by the methods of ordinary least squares (OLS), weighted least squares (WLS), maximum likelihood (ML) and restricted maximum likelihood (REML) for the data of clay, sand and silt. The best method of assessment was performed using the Akaike information criterion, where the REML method showed better performance for all attributes. The simple kriging was done for the data and for the standard deviation of the data. It was observed by kriging that the highest percentage of clay and silt were located in the northern area, while the highest percentage of sand concentrate in the south. Analyzing the standard deviation, data higher variation was found in clay, especially in places with sample deficiency. The range of spatial dependence of clay, sand and silt were 143.7m, 245.2m and 141.2m, respectively. The minor variations of the standard deviation are associated with the sampling points.

Keywords: simple kriging, Akaike information criterion, spherical model, prediction errors.

1. Introduction

The cultivation of coffee has great historical, economic and social importance in Brazil. In the coffee growing, the knowledge of soil physical properties, especially those related to the distribution of soil texture directly influence the flow and movement of surface water in the soil, being of fundamental importance for crop management.

Soil texture refers to the relative proportion in the determined mass of soil, relate to the particles or fractions of sand, silt and clay. It is the ownership for soil physics that suffers less change over time, however, is very important in irrigation management because it directly influences the rate of water infiltration, aeration, the ability to retain water, nutrition, as well as adhesion to soil particles (Araújo *et al*., 2003). On the other hand, in search of sustainable agriculture, knowledge of the spatial variability of soil physical attributes helps in the management of one culture by enabling the use of agricultural inputs differently, because the soil chemical variables are closely related to the class textural, (Mulla and Mcbratney, 2002) thus contributing to the maximization of production.

Technological advances in agriculture have shown the importance of measuring the spatial and temporal properties that affect crop yields, for optimal use of resources and minimization of costs. In this sense some authors reported the importance of knowledge of the textural variability of soil (Carvalho *et al*., 1998; Gonçalves, *et al*., 2001; Mello *et al*., 2006; Campos *et al*., 2007; Heil and Schmidhalter, 2011). The Precision Farming presents a set of techniques that can assist farmers in identifying strategies to be adopted to increase efficiency in the management of agriculture (Silva *et al*., 2008) since it is responsible for correlating the causes and effects with time series data and their spatial distribution (Carvalho *et al*., 2002).

Thus, geostatistics is presented as a technique used to study the spatial variability of variables. This technique is based on the theory of regionalized variables and allows the quantitative description of spatial correlation by means of the experimental variogram after adjust mathematical models and make the process of kriging interpolation, for the unbiased estimate and minimum variance of values for non-sampled locations from neighboring values (Gonçalves *et al*, 2001).

The objective of this study was to evaluate the variability of soil texture in the coffee plantation by geostatistics, using simple kriging as linear interpolator to analyze the prediction errors.

2. Metodology

The experiment was conducted on the Cafua Farm, located in the municipality of Ijaci, south of Minas Gerais, in an area of 6.5 ha of coffee plantation (Coffea arabica L.) of Mundo Novo cultivar, with ten years of age, spacing of 4m between rows and 1m between plants. The area lies between the geographical coordinates 21° 10 '11" S and 44° 58' 37" W, with an average altitude of 934m and slope of 0.84% in the north-south and 12% in the east-west, where transects were marked with 25mx25m and 50mx50m distances, totaling of 67 sampling points (Figure 1).

The georeferencing of points was performed with GPS TRIMBLE 4600 LS ® and Leica Total Station TC600 ®, based on quotas for correction of known coordinates on the campus of Federal University of Lavras. Soil samples were collected at a depth of 0.0-0.2 m in each of georeferenced points on 04/02/04 respecting the spacing of the sampling grid. The textural analysis of the soil has been made using the densimeter method. The sampling results for soil texture in the coffee crop were analyzed using descriptive statistics and geostatistics, with construction and adjustment of the experimental variograms and kriging, using the R software version 2.11.1 (Diggle and Ribeiro Junior, 2007).

The adjust the models to the experimental variogram were evaluated using the Ordinary Least Squares (OLS), Weighted Least Squares (WLS), Maximum Likelihood (ML) and Restricted Maximum Likelihood (REML) in order to choose the best fit method.

According Mello *et al.* (2005), the OLS and WLS methods are used to get the values of model parameters that minimize the sum of the squared of difference between observed and estimated data.

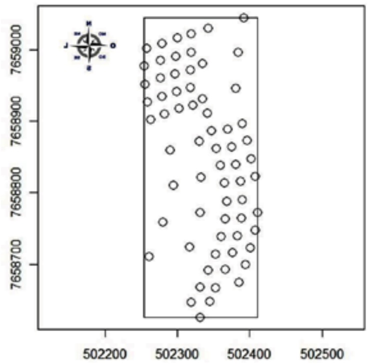

Figure 1: Representation of sampling points in the experimental area.

The performance evaluation and choose the best model was performed using the Akaike Information Criterion (AIC). As shown by Xavier (2000), the AIC is based on decision theory and can be defined as shown in Equation (1):

$$AIC = -2l + 2p \quad (1)$$

in which: l is the likelihood function ln (log likelihood) and p is the number of model parameters considered. According to this criterion the best model is one that has the lowest AIC value.

With the parameters defined in the variogram was performed simple kriging interpolation to data and to the standard deviation of the data.

3. Results

The results concerning the descriptive statistics for the soil texture data are presented in Table 1. Analyzing the descriptive statistical data of soil texture was observed that the soil is classified as clayey (57.1%). The low values of kurtosis could characterize normality the data. The average and median values were similar, but there was considerable difference between maximum and minimum values for both sand and for clay and silt. This variation can be explained by the altitude of the place where the highest altitudes are located in the northern study area. Relative to CV was observed that all elements tested showed low CV values. According to Warrick and Nielsen (1980) coefficients of variation for sand, clay and silt are of average variability.

The results of the geostatistical analysis are shown in Table 2. By Akaike information criterion, it was possible to choose the best combination of model adjustment, and that the spherical model adjusted to REML resulted in lower AIC value and therefore was used to map the spatial distribution of sand, clay and silt.

Table 1: Descriptive statistics of soil texture data.

Estatistic	Sand	Silt	Clay
Points number	67,0	67,0	67,0
Mean	31,6	11,3	57,1
Median	35,0	10,0	56,0
Minimum	11,0	4,0	42,0
Maximum	49,0	19,0	75,0
Kurtosis	-1,2	-0,8	-1,1
Standart derivation	12,0	3,7	9,3
CV	37,9	33,0	16,3
Variance	143,5	13,9	86,5

Table 2: Parameters and methods of variogram fitted to the data texture**.**

Elements	Method	Effect Nugget	Sill	Range	AIC
Clay	OLS	0,0	58,0	111,7	399,5
	WLS	0,0	57,8	109,5	399,5
	ML	0,0	60,1	143,1	404,0
	REML	0,0	62,0	143,7	396,0
Sand	OLS	0,0	254,8	328,5	408,2
	WLS	0,0	295,1	411,0	405,6
	ML	0,0	78,9	240,7	388,8
	REML	0,0	81,6	245,2	379,8
Silt	OLS	0,0	25,5	359,0	338,1
	WLS	0,4	30,5	471,2	332,8
	ML	2,1	11,1	139,5	319,8
	REML	1,9	11,8	141,2	313,6

Through the kriging maps showed higher percentage of clay and silt in the northern area (Figure 2A and 4A), while the highest percentage of sand concentrates in the south (Figure 3B). Analyzing the kriging standard deviation of the data, the greatest change was found in the data clay, especially in places with sample deficiency. The spatial dependence of clay, sand and silt were 143.7m, 245.2 m and 141.2 m respectively. The minor variations of the standard deviation are associated with the sampling points. The best fit method was REML. As Mello *et al.* (2005) stated, where the data is normal, the REML method of adjustment will result in a best set of parameters for a given data set.

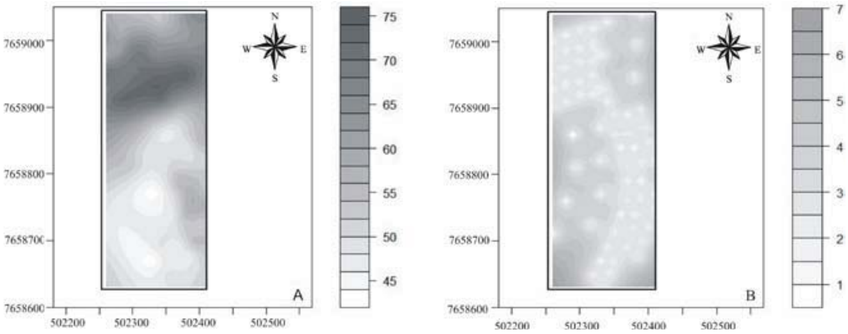

Figure 3: Kriging maps of the clay data (A) and standard derivation (B).

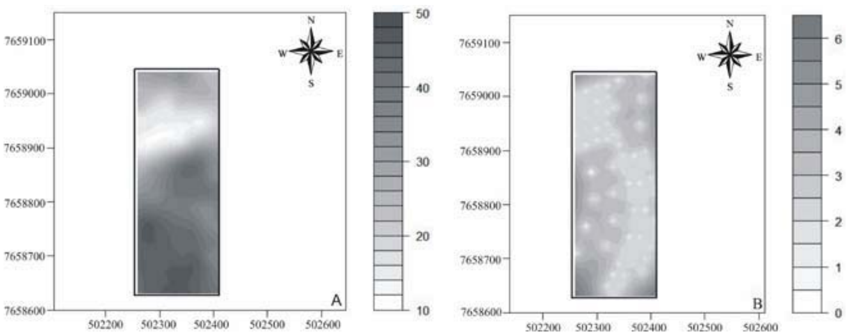

Figure 4: Kriging maps of the sand data (A) and standard derivation (B).

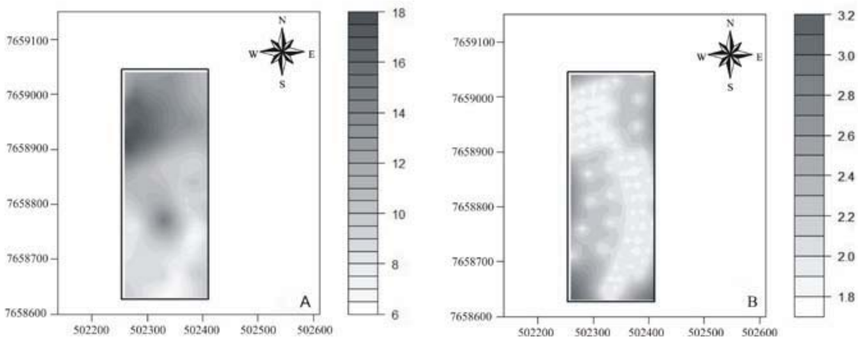

Figure 2: Kriging maps of the silt data (A) and standard derivation (B).

Analyzing the factors that are influenced by soil textural class as cation exchange capacity, porosity and water retention, it is necessary to know the spatial distribution of soil texture for the performance of different fertilization procedures, especially in relation to phosphate fertilization.

4. Conclusion

According to AIC, the best fit model was the REML for all elements evaluated.

The prediction errors are associated with places not sampled, and the clay had the highest error.

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