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Spatial Variability of the Morphological Attributes Soil Color and Texture of an Experimental Area in Santarem, Para, Brazil

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Abstract – **The study of the spatial variability and its characteristics provides the necessary information in the determination of quantitative and qualitative data. Thus, this work aimed to characterize the spatial variability of color and texture morphological attributes of the soil. The study was conducted in 84 hectares of an area. The points were geo referenced with a global positioning system receiver (GPS), where starting from a mesh in transects of 100 x 100m linear distance, the soil collections got started. A total of 97 points were identified, with soil sampling in the layers 0,0 – 0,2m, 0,4 – 0,6m and 0,8 – 1,0m, totaling 291 soil samples. Subsequently, the morphological analyzes of the color and texture attributes were performed in the field. Descriptive statistics were used to evaluate the parameters of central tendency and dispersion of the data, so that afterwards the characterization of the attributes spatial variability studied could occur. The Inverse of Weighted Distance was used to interpolate the data and make the isoline maps. The predominant texture of the area ranged from clayey to very clayey and color with nuances 2,5Y and 10YR. All variables analyzed showed spatial dependence, varying from weak to moderate degree. The data obtained will aid in the decision making for the soil profiles opening, for the purpose of a more detailed soil survey.**

Keywords – **Hue, Isoline Maps, Physical Attributes, Soil Survey.**

I. Introduction

Soil is a very heterogeneous system, complex, open and in constant transformation, result of the interaction of factors and processes of formation, divided into classes according to the similarity of their chemical, physical and biological attributes. The spatial characterization of these attributes is fundamental for proper soil management. Among these, physical (morphological) attributes such as soil color and texture are highlighted, preferentially diagnosed in the field as an initial step in soil surveys.

The soil texture is identified as one of the most important physical characteristics of the soil, since it influences most physical-chemical attributes, since its association with the organic matter content and the mineralogical composition of the clays are determinants of soil behavior. Besides the texture, the color is another attribute that deserves to be highlighted, considered as one of the main predicates for the classification of soils, indicating the richness in organic matter, as well as the mineralogical nature of the iron oxides present in the soil, presenting in this way its diagnostic value in the characterization and differentiation of several soils. However, the evaluation of soil texture in the field is a point analysis in the landscape, without considering the spatial variability of this attribute [1]-[2].

In this context, the characterization of the spatial variability of the soil attributes is fundamental, since such information provides the minimization of sampling errors, aiding in the decision making for the use of appropriate management systems besides interfering in the design of research design, thus presenting importance for the survey and classification of soils. It is also worth noting that knowledge and characterization of spatial variability provides a more accurate interpretation of the interrelations between soil attributes and their management, thus understanding that soil and crop management are determining factors in the variability of such attributes, as a result of the influence of each action performed. It should also be pointed out that the lack of this knowledge leads to several planning errors, especially in agricultural areas, regarding inadequate use of correctives and fertilizers, for example [3]-[4]-[5].

In this sense, the best technique for the spatial characterization of soil attributes is geo statistics. It emerges in the field of soil science as a real possibility as regards the studies of its attributes, through its correlations, thus allowing a better understanding of the spatial variability functioning through the interpretation of the results obtained. Geo statistical functions are thus assigned based on studies by other authors treating it as a tool used to describe and model spatial patterns (semivariograms) to predict values in non-sampled locations to obtain the uncertainty associated with an estimated value in non-sampled locations and to optimize sampling meshes [3]-[6].

Thus, it is observed that the use of geo statistics and maps from deterministic and statistical methods contribute to the identification of areas that need to be managed in a differentiated way, serving as an important tool in decision-making. It also is reported that geo statistical techniques are shown to be useful instruments in the study of textured attributes in soils of different origins [7]-[8].

Taking into account the importance of soil morphology in relation to the use of appropriate management techniques as well as soil survey and classification, the objective of the work is the spatial characterization of morphological attributes: color and texture, with the aid of geo statistical analysis in an experimental unit, with the purpose of subsidizing the soil survey in said area.

II. Material and Methods

A. *Study Area*

The study was carried out in a portion of the Experimental Academic Unit of the Federal University of Western Para, located in Santarem city, in Para state - Brazil, west region of the state (latitude 0775043 UTM and longitude 9703837 UTM). The study region is located in an area commonly known as Santareno Upland, near the Boa Esperança District, at km 37 of Santarem/Curue-Una Highway (PA 370).

B. *Characterization of the Area*

The predominant climate in the region is hot and humid. It presents annual temperatures with averages from 25° to 26 °C, maximum from 30 ° to 31 °C and minimum of 21 ° to 23 °C, with oscillating rainfall precipitation around 2,000 mm, with irregular distribution during the months. Thus, demonstrating the occurrence of two rainy periods in the region, with the most intense covering the period from December to June, since it concentrates in more than 70% of the annual precipitation. Regarding the climatic Koppen classification, Santarem is in the climatic type Am [9]-[10].

As for vegetation, the region is composed of four well-differentiated forest formations: subperenifolia equatorial forest and subperenifolia equatorial, cerrado (vegetation), solid ground, hygrophilous equatorial forest of floodplain and equatorial fields of floodplains, in areas subject to flooding. It is also worth noting that the soils raised in the Santarem city on a scale of 1: 100,000 were located mainly in regions known as Belterrense Upland and Moju River Basin, predominantly classified as Yellow Latosols, having a medium to very clayey texture; Yellowish Argisols, with medium clayey textures, and Gleissolos [9].

C. *Sample Collection*

The points were distributed in regular meshes, distant from 100 to 100 m, making a set of 97 points in transects of linear distance, totaling 291 samples considering the three depths, in an area of 84 ha. These pre-defined collection sites were georeferenced in UTM flat coordinates, located by the Global Positioning System (GPS) receiving equipment, thus, facilitating the prospecting process, since the coordinates of all sites of the points to be visited were provided. Therefore, the sampling stage was carried out by means of Dutch-language trades, obtaining simple soil samples in the depths of 0,0 - 0,2 m, 0,4 - 0,6 m and 0,8 - 1,0 m.

D. *Attributes Assessed*

The morphological attributes texture and color were determined in the field, the texture and color were identified through pre-established methods, and for the color attribute, its evaluation occurred from the analysis of its three components (hue, value and chrome). We opted for the analysis of only wet samples, since most of the criteria in which color is decisive in the classification of a soil, or a certain diagnostic horizon refers to the slightly moistened sample [11]-[12].

Because they were qualitative data, the values of color and texture were transformed into ordinal data, for later statistical analysis. Based on studies carried out in the same direction, the transformation of the hue component to ordinal data was applied, aiming at the later application of statistical methods. Thus, based on the color variation of the sample set, the shades were modified with a view to their arrangement in the Munsell color chart, establishing the following order: 5R (1), 7RR (2), 10R (3), 2.5YR (4), 5YR (5), 7,5YR (6), 10YR (7), 2,5Y (8), 5Y (9), 10Y-5GY (10), GLEY1, GLEY2 (12) and WHITE (13). Then, after changing the values, they were unified, according to the following arrangement of the color components: hue, value and chrome. That is, a wet sample that obtained the 5YR 5/6 notation was now represented by 5.56. Such transformation was established aiming at the best suitability for data manipulation [12]-[13]-[14]-[15].

As for the attribute texture, it also changed to quantitative values, obtaining the following data for the textured groups: sandy texture (1), clay texture (2), very clay texture (3), texture medium 4) and silty texture (5) [11].

E. *Data Analysis*

The variability of the soil morphological attributes was evaluated by the exploratory analysis of the data, calculating the minimum, mean, maximum, standard deviation, standard error, variance, coefficients of variation, asymmetry and kurtosis. The coefficient of variation (CV) classification was evaluated, in which the CV is shown low when the values are < 12%, average when the CV is set from 12 to 24% and high when the value is > 24% [16].

The spatial dependence of the attributes was analyzed through semivariograms generated in the GS + software, as well as the descriptive statistics. Thus, for the geo statistical analysis, the existence of a spatial dependence structure was then verified by semivariograms, estimated according to equation 1:

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

Where y * (h) is the estimated semi variance; N (h) represents the number of pairs of measured values Z (), Z (+ h) separated by a vector (h). In this context, for the study in question, the Z values were the morphological attributes of the soil analyzed, while the values of e + h were defined according to the positions of the samples in the field [17].

From the adjustment of the theoretical mathematical model to the calculated values of y * (h), the parameters of the theoretical model for semivariograms, called nugget (C0) contribution (C1), range (C0+C1) and reach (a) are estimated. The criteria for choosing the best mathematical model adjusted to the experimental semivariograms were the highest values of R^2 (determination coefficient), lower values of the sum of the squares of the residuals (SQR) and the degree of spatial dependence (C0/ (C0+C1)). The spatial dependence was classified, where spatial dependence is considered weak when the ratio is higher than 75%; moderate when the ratio is greater than 25%; and less than or equal to 75%; and strong when the ratio is or less than or equal to 25%. In relation to the kurtosis coefficient, the same was classified according to its three distributions, where the distribution is considered to be platicurtic or characterized by a flattened curve when the < 0; mesocurtic or medium kurtosis, when a = 0 and leptokurtic or of shar-

-per kurtosis, when a > 0 [18].

Since no spatial dependence structure was found for the morphological attributes in said sample mesh, the isoline maps were produced using the IDW non-geo statistical interpolation method, or Inverse of the Weighted Distance. Which is an interpolation technique in which the interpolated estimates are made based on the weighted values of their neighbors only by the distance to the interpolation site, described by equation 2:

$$z = \frac{\sum_{i-1}^{n} \frac{1}{di} zi}{\sum_{i-1}^{n} \frac{1}{di}} \quad (2)$$

Where z = estimated values; zi = known values; di = distances between known and estimated values (zi and z); and n = number of samples.

III. Results and Discussion

Soil texture at the three depths obtained values of CV classified as medium (12 to 24%), while the color attribute presented low indices (< 12%) for the same depths (Table I). In this context, the authors emphasize that the coefficient of variation can be used to compare and evaluate the variables, and it can be observed that variables with a low CV, as in the case of the color attribute, indicate a small variation of the data in relation to the average.

In this way, it can be seen from the values of the aforementioned coefficients. In relation to the texture attribute, the results obtained presented the closest indices of zero in the three depths, with values of asymmetry between -0.10 to 0,27 and for kurtosis all the results obtained were negative at depths (-1.93, -1.99 and -2.00), being classified as platicurtic. On the other hand, the color results showed discrepant indices, distanced from the ideal value of zero, with quantifications for asymmetry between 1.82 and 3.74 and for the coefficient of kurtosis between 8.80 and 17.64, characteristics of leptokurtic distributions.

Table 1. Basic statistics and normality parameters of texture and color values determined at the three depths.

Attributes	Statistical Parameters[1]									
	N	Average	Mean	Maximum	Standard Deviation	Standard Error (%)	CV (%)	Asymmetry	Kurtosis	Variance
0,0 – 0,2 m										
Texture	97	2,00	2,433	3,00	0,498	5,05	20,46	0,27	-1,93	0,24807
Color	97	7,31	7,911	11,80	0,664	6,74	8,39	3,74	17,64	0,44106
0,4 – 0,6 m										
Texture	97	2,00	2,485	3,00	0,502	5,09	20,20	0,06	-2,00	0,25236
Color	97	7,41	8,143	11,50	0,587	5,96	7,20	1,82	8,80	0,34430
0,8 – 1,0 m										
Texture	97	2,00	2,526	3,00	0,502	5,09	19,87	-0,10	-1,99	0,25193
Color	97	4,71	7,891	11,81	0,775	7,86	9,82	2,16	13,70	0,60081

[1]N, number of observations (samples); CV, coefficient of variation.

[19] and [20] reinforce that a coefficient of asymmetry of the data between the values of 0 and 0.5 does not indicate the necessity of transformation, a coefficient between 0.5 and 1,0 the transformation in square root is the most recommendable and that a coefficient greater than 1,0 logarithmic transformation of the data is required. In this aspect, the color attribute is the logarithmic transformation of the data for the three depths studied. Thus, based on this information, the presence of a strong asymmetry, that is, a common departure from normality is then verified.

The classifications according to the degree of spatial dependence (GDE) were obtained, in which the texture attribute showed that between the layers of 0,0 and 0,6 m presented weak GDE, whereas in the layer of 0,8 - 1,0 m. This relation was considered moderate. However, for the color attribute variation occurred, since the depth of 0,4 – 0,6 m presented a moderate degree of dependence, in contrast to the more superficial and subsurface layers, which obtained a weak GDE [18]. Thus, in relation to the DGE, it is necessary to emphasize that the lower this relation, the smaller the value relative to the nugget effect (C0) and consequently the better the spatial arrangement.

In relation to the texture attribute, it was observed a greater range in depth 0,8 - 1,0 m (182 m), indicating greater spatial continuity, in contrast to the depth of 0,0 - 0,2 m, which presented 36 m spatial dependence. Regarding color, the largest range was recorded in the depth of 0,4 - 0,6 m (131 m) while the lowest spatial dependence was found in the depth of 0,0 - 0,2 m (43 m). The range represents the limit distance at which a regionalized variable has spatial continuity, which is spatial dependence. [21] In their study on chemical attributes variability in an Underbrush under pasture concluded that the greater range indicates greater spatial continuity in the area, contributing to a more reliable estimation of this attribute. In this context, variables sampled at distances greater than range values present random distribution, thus being independent of each other [19]-[22].

Table 2. Geostatistical parameters of the texture and color values determined at the three depths.

Attribute	Model	EP (C0)	Landing (C0+C1)	Reach (a)	R²	IDE (C0/(C0+C1))	GDE	SQR
				0,0 – 0,2 m				
Texture	Exponential	0,0257	0,2474	36	0,047	0,103	Weak	3,437
Color	Exponential	0,00002	0,01014	43	0,024	0,001	Weak	2,594
				0,4 – 0,6 m				
Texture	Exponential	0,0286	0,2532	42	0,072	0,112	Weak	2,950
Color	Exponential	0,2144	0,4298	131	0,827	0,491	Moderate	8,983
				0,8 – 1,0 m				
Texture	Exponential	0,1938	0,3886	182	0,827	0,498	Moderate	2,720
Color	Exponential	0,00003	0,00956	46	0,020	0,003	Weak	9,150

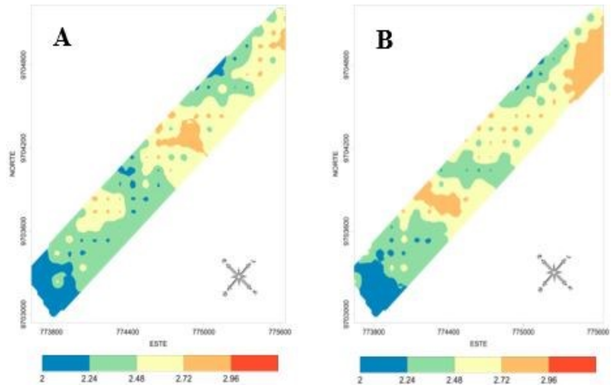
[1] EP, nugget effect; R^2, coefficient of determination; SDI, spatial dependency index; SQR, sum of squares of residues; GDE, degree of spatial dependence.

For each attribute, the model that best fit was the exponential, since it presented better parameters, according to Table 2, which brings the semivariograms generated after adjustment. According to [23] it is a model considered transitive, because it has a threshold, that is, from a certain value of the distance between the samples there is no more spatial dependence. In this context, it is confirmed that the exponential model, along with the spherical, are the most common attributes of soil and plant [3]-[18]-[24]-[25].

This premise resembles the results obtained by [26], who studied the variability of soil texture in irrigated area by central pivot found in the exponential model a better fit to their data. [27] Evaluating the spatial variability of soil physical attributes also found in the exponential model a better fit. [28] And [27] point out that the fact that the exponential model models all semivariograms indicates that the threshold is reached asymptotically, unlike the spherical model, in which the stabilization is reached in the range value.

Table 2 shows that only the color variables in the depths 0,0 - 0,2 m and 0,4 - 0,6 m did not show pure nugget effect, this parameter presented indices far from the zero value considered ideal. According to [18] the nugget effect constitutes an important measure of the semivariograms and indicates the unexplained variability, which may be due to undetected measurement errors and micro variations, considering the sampling distance used.

The predominance of the clayey texture at depths of 0,0 - 0,2 m (A) and 0,4 - 0,6 m (B) is observed through the maps of isovalues A, B and C, whereas the predominance of the clayey texture was found in the layers of 0,8 - 1,0 m (C).



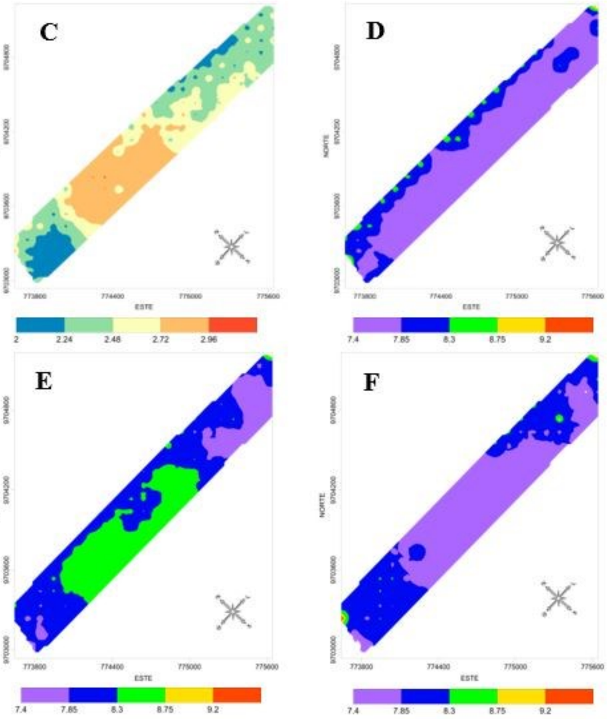


Fig. 1. Isolates maps, by the Inverse method of the weighted distance, for the variables: texture at depths of 0,0 - 0,2 m (A), 0,4 - 0,6 m (B) and 0,8 - 1,0 m (C), and color in the depths of 0,0 - 0,2 m (D), 0,4 - 0,6 m (E) and 0,8 - 1,0 m (F).

In relation to the color attribute, it is observed that in the depth 0,0 - 0,2 m (D) there was the predominance of the hue 10YR, followed by the hue 2.5Y and a small portion of GLEY 1. For depth 0,4 - 0,6 m (E) it is noted that both shades 2,5Y and 10YR were uniformly arranged in the study mesh, followed by a small plot of GLEY 1 coloration. At the depth of 0,8 - 1,0 m (F), it emerges from the spots the predominance of the 10YR hue in relation to the 2.5Y and GLEY 1 shade. In addition, it is emphasized that this more subsurface depth of the soil also presented shades not found in the more superficial depths, being 2,5YR, 7,5YR and 5Y.

According to the information obtained in the isoline map, the decision making to open profiles in the soil should be assisted.

IV. Conclusion

The soil texture ranged from clayey to very clayey, and the predominant color was shades 2,5Y and 10YR for all depths. From the analyzed samples, all had some spatial dependence at different depths, varying between weak and moderate degrees, for both texture attributes and weak for color attributes, at different depths. The data obtained in the study will serve as a support to the UAE/UFOPA soil survey, helping in the decision making regarding the opening of soil profiles.

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