Variographic Analysis of the Soil Characteristics and its Application in the Irrigation Projects in a Small Rural Area in the Paraíba state, Northeast Brazil.

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ABSTRACT

This study deals with the analysis of the physical-hydrological properties of alluvial soil in rural area in the state of Paraíba, northeast Brazil, for the purpose of water management for irrigation. The sampling was undertaken along a line of 3000 meters in the direction of the drainage and in two sample grids of 40 x 40 meters intercalated along the line. A total of 63 samples from linear sampling and 25 samples each from the grid were collected for this work. The variables obtained were real and apparent density, soil humidity and moisture content, porosity, and percentages of sand, silt and clay.

Spatial variability of these variables were analyzed through variographic analysis and range of influence of the soil properties were determined. The variables tend to be multimodal in nature with small skewness and kurtosis. Spatial correlation and spatial variance is well defined in the linear sampling pattern than in the grid sampling due to differences in number of samples and the total area considered. The variables show the presence of reasonably good variographic structures. Coefficient of variation tend to be relatively high for soil humidity, sand, silt and clay than for other variables. The linear sample pattern shows a mixture of more than one variographic structure in the experimental variogram due to variations in the sediment type coming from erosion causing variation in the soil characteristics. The grid sampling showed the presence of isotropy in the variation of these variables.
It is concluded that the variables analyzed show a good spatial correlation and that the range of influence may help plan better the irrigation network and other treatment given to the soil of the study area.

**INTRODUCTION**

The spatial variability of soil properties is widely studied since beginning of the century to understand the behavior of the soil for agricultural purposes. Understanding of the spatial variability of physical-hydrological parameters of the soil is important for irrigation and subdivision of the land for differential treatment. The nature of the soil physical parameters is necessary for elaboration of rational projects of irrigation, considering the facility with which the water can move in the soil and its availability for the plants. Aeration and porosity are also important for better planning and dimensioning of irrigation and drainage of agricultural land. For this reason the parameters such as total and real density, field capacity, point of permanent withering, porosity, soil humidity and water availability for plant, are normally determined in the laboratory.

It is known that the spatial variability of soil is important in pedological mapping and land use (Berg and Klamt 1997; Burrough 1986; Becket 1971; Becket and Webster 1971). In a detailed analysis of the existing literature Webster (1985) showed that a large number of methods have been developed to evaluate the spatial variability of the soil properties. The most important method mentioned include analysis of variance through sampling by groups which can show the distribution of the variance along an increasing spatial scale and computing semivariance of the georeferenced samples in a line or grid or slightly irregular sampling.

The objectives of this study is to study the spatial variability of these physical-hydrological parameters in an alluvial type soil situated in the Riacho São Pedro hydrographic basin in the Paus Broncos rural area near Campina Grande, Paraiba, Northeast Brazil (Figure 1) and attempt to find solutions for the management of the irrigation water in the study area. The precipitation rate in this region is less and irregular resulting in prolonged dry seasons and for this reason this study will try to contribute towards better management of the limited water supply available in the region for irrigation and other uses.
METHODOLOGY

The study was realized in a small rural area known in the region as "Paus Branco" localized in an São Pedro Creek hydrographic micro-basin near Campina Grande, Paraíba in Northeast Brazil. The climate in this region is arid with high solar radiation, low relative humidity, low pluviometry and with occasional torrential rains. As a result the erosion rate is very high and soil horizons tend to be very thin.

The experiment was realized in two stages: In the first stage the sampling of the alluvial soil was carried out along a line parallel to the creek bed extending to 3.15 km, where the average soil thickness is about 60 cm (Figure 1). Here the soil properties variation is analyzed in one specific direction. In the second stage sampling was made in two small grids of 20x20 m located along the linear sampling trend with a distance of 1 km apart between the

Figure 1. Study area and the alluvial soil showing line of sampling.
In this paper detailed analysis of the samples obtained along a line is shown. The sample were collected at 50 m interval resulting in a total of 63 samples. All the samples were obtained along three horizons at depths of 0 to 20 cm, 20 to 40 cm and 40 to 60 cm from the surface. The samples obtained from three horizons samples were mixed and homogenized and a part of this homogenized material was used for analysis. In the laboratory the following properties were determined: total and real density, field capacity, point of permanent withering, porosity, soil humidity and water availability for plant, utilizing the standard procedures detailed in Bouyoucos (1951), Embrapa (1979), Black (1965).

**ELABORATION OF VARIOGRAMS**

In this project a total of seven variables were determined and were analyzed for spatial variability. However in this paper spatial variability and structural analysis of the variables field capacity, point of permanent withering, and water availability for the plant are discussed in detail due to the fact they are of considerable importance to the irrigation projects in the study area. The field capacity of soil is its capacity to store water after the soil is being saturated and drained by irrigation or by rain water; point of permanent withering of plants is the minimum moisture content of the soil to avoid permanent withering of the plant; the variable water availability is the percentage of soil moisture whose limits are defined by values of field capacity and point of permanent withering.

Variogram elaboration and other calculations were carried out using the GEO-EAS software developed by Englund & Sparks (1988). The basic statistical parameters were calculated with histogram for defining nature of the population followed by modeling of the variograms. The variogram modeling was unidirectional due to sampling carried out one along a line longitudinal to the valley.

**Variable Field Capacity**

The field capacity of the soil vary considerably with a minimum of 2.8% and a maximum of 27.5% with the mean being around 15.17% and a variance of 46.30% (Table 1). The distribution tend to be multimodal with a wide variation which is reflected in the coefficient of variation of 44.84% (Figure 2). The coefficient of variation tend to be with in the limits observed by Warrick & Nilsen (1980) and Coelho Filho (1998).
The variograms were computed using different step sizes or distance between the samples pairs to select a model which shows a reasonably good structure. The direction along which the variogram elaboration was done followed the longitudinal line parallel to the valley. After several attempts the variogram of the variable field capacity showing a acceptable structure and spatial correlation was obtained in the direction of $0^\circ$, window of $90^\circ$ and step size of 158.29 m (Figure 3). It could be noted from the variogram that there is an apparent mixture of structure as indicated by the stepwise nature of the curve. A theoretical spherical variogram curve was adjusted using the following parameters: $C_0 = 39.4$, $C = 31.07$ and range of influence = 1500 m.

Table 1. Statistical distribution and parameters of the variables.

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>Field Capacity (%)</th>
<th>Permanent Withering Point (%)</th>
<th>Water Availability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>15.17</td>
<td>9.05</td>
<td>6.11</td>
</tr>
<tr>
<td>Median</td>
<td>15.94</td>
<td>9.07</td>
<td>6.57</td>
</tr>
<tr>
<td>Variance</td>
<td>46.30</td>
<td>16.44</td>
<td>8.50</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>6.80</td>
<td>4.05</td>
<td>2.91</td>
</tr>
<tr>
<td>Coefficient of Variation (%)</td>
<td>44.84</td>
<td>44.76</td>
<td>44.67</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.102</td>
<td>0.099</td>
<td>-0.206</td>
</tr>
<tr>
<td>Curtosis</td>
<td>1.95</td>
<td>2.12</td>
<td>1.77</td>
</tr>
<tr>
<td>Minimum</td>
<td>2.86</td>
<td>1.73</td>
<td>1.13</td>
</tr>
<tr>
<td>Maximum</td>
<td>27.50</td>
<td>17.08</td>
<td>11.08</td>
</tr>
</tbody>
</table>
Figure 2. Frequency distribution of the (a) Field Capacity, (b) Permanent Withering Point, and (c) Water Availability.
The variable point of permanent withering indicate the point at which plants tend to dry out and do not recover due to lack of minimum amount of moisture in the soil. The sixty samples analyzed show a wide variation with a minimum of 1.73% and a maximum of 17.08% in the soil, with the average value laying around 9.06 and a variance of 16.44 (Table 1). The histogram of the distribution tend to be multimodal (Figure 2). The coefficient of variation is 44.76% similar to the filed capacity and tend to be with in the limits observed in other studies.

The variogram modeling followed the procedures applied for filed capacity. A variogram showing a structure and spatial correlation was obtained for direction $0^0$, window $90^0$, and step size of 158.29 m (Figure 3). The variogram pattern is similar to the filed capacity but show a better spatial correlation is well defined. Also show stepwise pattern.
demonstrating a mixture of more than one model. The theoretical model was adjusted using the following parameters: \( Co = 14.0, C = 7.0 \) and range of influence = 667 m.

**Variable Water Availability**

The variable water availability in soil is the percentage of humidity retained in the soil to maintain thriving and growth of the plants. Its content in soil of the study area vary widely with a minimum of 1.13% and a maximum of 11.08% (Table 1). The average of the water availability in the soil is 6.11% and a variance of 8.50. The distribution of the values tend to be bimodal with the coefficient of variation falling in the range of 47.67% (Figure 2).

Figure 3 shows the variogram with pattern similar to the others meaning a stepwise growth of the curve reflecting most probably a mixture of various models. The theoretical model adjusted has the following parameters: \( Co = 6.77, C = 4.64 \) and range of influence = 360 m.

**DISCUSSION AND CONCLUSIONS**

The three variables field capacity, point of permanent withering, and water availability for the plant analyzed in this study are indirectly interrelated and their spatial variation showed the existence of correlation and variographic structure for each variable. The longitudinal sampling of the soil along a valley permitted variogram modeling in a specific predetermined direction which showed a mixing of more than one model in the variographic structure. This soil in the study area is apparently not homogeneous due to admixing, transport and variations in drainage network resulted in heterogeneity of the soil, which resulted in the presence of more than one variographic structure. In addition the soil cultivation in different parts resulted in modifying its texture and other properties along its extension thus imposing interruptions in spatial continuity as seen in variograms in Figure 3. A high component of random variance \((C_0)\) is very characteristic of these variables, which is caused by the high heterogeneous nature of the soil. The range of influence of the samples for these variables which varies from 1500m for field capacity, 667 m for point of withering to 360 m for water availability, which demonstrates heterogeneity of this alluvial soil. At the same time the range of influence can be utilized to subdivide the soil stretch in sub-areas for differential irrigational and soil treatment projects.
REFERENCES


