Analysis of spatial variability of pH, P and K in red latosol cultivated in direct planting system

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Abstract

The concern about the environmental quality, together with new technologies, like the Geographic Information Systems – GIS has been helping many sectors, including agriculture. The digital mapping that is being done from the harvesting of field work, with machines equipped with mass sensors and GPS receptors, allows geographic identification of proper places for great productivity. To this technique it is given the name of precision agriculture. With this, it is possible to analyze the specific factors of each site, allowing the maximization of its productive potential. The increase in productivity in cultivated field works only happens with the knowledge of the attributes of the soil and its characterization in specific areas within the cultivated glebe. In direct planting system, the superficial application through casting limestone and traditional fertilizers done in the sowing line, provide vertical and horizontal variability of some attributes of the soil, fact that may cause great variation of nutrient contents with low mobility of the soil, even in samples collected a few centimeters from each other. Through the panorama depicted above, the aim of this research is to evaluate the variability of phosphorus and potassium contents, and pH of the soil from samples collected from 0 to 10 cm and 10 to 20 cm depth. The study was carried out in a glebe which has been cultivated for twelve years with direct planting system that is part of a land in the countryside of Lagoa Vermelha, Rio Grande do Sul State, Brazil. The exact geographic locations of the sampling points and the geostatistical treatment allowed the definition of spatial variability and the nutrient dispersion around the analyzed area. The preparation of variograms in order to quantify the reach of each sample together with the kriging technique made the drawing of thematic maps from the analyzed attributes possible. Results have shown that in the study area there is a necessity of pH correction of the soil in specific places and the geostatistical analysis proved the impossibility of phosphorus and potassium application in variable quantities.

Keywords: analysis, spatial variability, geostatistics

1 Introduction

Agriculture, which has been traditionally targeted at the expansion of the rural frontier, is going through a transitional period, especially in the Southern States of Brazil. Furthermore, agribusiness itself, which has become more globalized and extremely competitive, makes it necessary to take a different position from the one generally taken. One
is forced, due to elevated costs and investments, to optimize production factors, minimizing the causes which might be a risk to the stability of the property.

The rural producer, who formerly aimed at profit through production, now must search for productivity and product quality, as defined in terms of purity, sanity and nutritional value. Legislation has also been gradually inhibiting production at the expense of degradation of soil and water.

According to Cunha (1996), the most important aspect in precision agriculture is the analysis of the spatial variability of productive factors. In this context, its principles have been developed aiming at the recommendation of the use of fertilizers, based on temporal and spatial variability among soil units, in the specific case of the use of fertilizers, the solution which has been pointed out for precision agriculture has been localized application, according to existing levels of soil fertility and the productivity indexes of cultures. In order to be feasible, the variability of the soil within a farming unit must be quantified. This quantification makes use of geostatistic techniques; its spatial location needs georeferencing through high-resolution GPS.

Traditional agriculture treats wide land surfaces as uniform, and bases the fertilization of cultures on mean parameters, obtained through soil analysis from sampling and subsampling, without the parameters capable of allowing for a homogenization of localized attributes.

Most equipments used for sampling are inadequate for the direct planting system, because either the surface layer is lost, the volume of sampled soil is too small or because a great number of subsamples is needed.

According to Wiethölter (2002), because the soil is not turned over in the direct planting system, soil sampling must be done more carefully. It is crucial to ensure the uppermost centimeters of soil are included in the sampling. Thus, the screw auger and the dutch auger are inadequate, because they generally make it difficult to sample the upper layer. When fertilization is done through casting, sampling may be done using a spade or a gauging auger. In planted fields which have been fertilized on the sowing line, it is important to sample the soil between each sowing line, using a spade, collecting the soil at 3 to 5 cm of depth. This sampling may be substituted by soil collection using a gauging auger, making a crosscut line through the sowing line, collecting one point at the center and 1 on each side for cereals grown in winter, collecting one point at the center and 3 on each side for soy, or one at the center and 6 on each side for corn (Nicolodi et al., 2002). If there is reason for wanting to ignore the amount of fertilizer used in the previous fertilization, the sampling may also be done exclusively on the spaces between sowing lines.

The sample may be collected from the layer from 0 to 10 cm depth, especially in planted fields with P and K levels below sufficiency. For soils with higher levels, sampling from the layer from 0 to 10 cm depth, or 0 to 20 cm, may be used, because the results do not affect the fertilization recommendation.

In georeferencing of sampling points, it is necessary to work with instruments allowing for high precision, so that the geostatistic study and the thematic mapping may represent with optimal exactitude the conditions and special characteristics of the point and the region which have been sampled within the planted area, facilitating, as well, agronomical practices.
Petersen et al. (1996) in Fragomeni (2002), sustain that, when it comes to soils, variation and heterogeneity are rather the rule, not the exception, and the intensity with which the soil must be sampled depends on the magnitude of this variation. These authors point out that systematic soil sampling has been preferred, and that new methods have been proposed in order to assess sampling errors. However, in spite of that, few studies have been carried out in order to improve sampling procedures.

The representation of soil variability must be done through land maps, or the soil attributes deemed important to plants, and intensive sampling using a square grid is the commonest method.

Geostatistics deals with problems related to regionalized variables, which present an apparent continuity in space, and are represented by ordinary numeric functions, which take a definite value at each point and, mathematically, describe a natural phenomenon. The attributed geographic continuity can be measured through the tendency of the variable toward very similar values at neighboring points, which grow different as the points become more distant.

Two tools are considered fundamental for geostatistical methods in the study of the behavior of regionalized variables: the semivariogram and kriging.

The semivariogram shows the degree of spatial dependence among samples throughout a specific support, and its obtention is crucial, because it determines the zone of influence around a sample, the anisotropies, when the semivariograms become different for different directions of sampling lines, and the continuity, which determines the value of the nugget effect, through which the degree of precision or error of the sampled parameters may be evaluated. The kriging techniques complete the spatial analysis, providing, through interpolation, the estimates for places not sampled.

This is the context within which SIGs (Geographic Information Systems) and GPS (Global Positioning Systems), which are geostatistical techniques associated with other technologies, make it possible to collect many different data, which may be then georeferenced, analyzed, spatialized, visualized through thematic maps and interpreted in order to correct localized problems.

Among the many themes which have to be approached in precision agriculture, spatial variability of soil attributes plays an extremely important role for the localized handling of production factors.

The objective of this study is to verify, using the method recommended for the sampling of soil with a gauging auger, and applying geostatistical techniques and SIG, the zones of influence of soil samples, using a grid of approximately 80 m, and the possibility of determining spatial structures of P and K dispersion, pH\text{water} in red latosol, cultivated in direct planting system. Based on this information, it was tried to verify the possibility of using these results to recommend the correction of soils for acidity at specific places and spatial structures which allow the visualization of the possibility of recommendation of P and K fertilization in variable doses for the sampled area.

2 Characteristics of the Studied Area
The area is located on the countryside of the municipality of Lagoa Vermelha, in the region named Superior Highlands, in Rio Grande do Sul State – Brazil, registered on the Sheet Clemente Argolo SH.22-V-B-III-1, MI – 2920/1, on a 1:50.000 scale, from the Diretoria de
Serviço Geográfico do Exército (DSG – Brazilian Army Geographic Services Head Department). Referential coordinates UTM SAD-69-IBGE, N 6,899.240 m and E 456.596 m, as it can be seen in Figure 1.

The total area being used for agriculture covers a 850 ha land, using the direct planting system. From this surface a 160.11 ha glebe was selected and, within it, a 49.08 ha section, where the sampling grid was installed.

![Figure 1 Location of the study area.](image1)

The ground plane is wave-shaped, with a moderately accentuated declivity at some points, as it can be seen in Figure 2.

![Figure 2 Numeric model of the terrain with the sampling points.](image2)
3 Classification and Use of the Soil

According to the Brazilian System of Soil Classification, the analyzed glebe belongs to the following classification: red latosol, aluminoferric, argilous to very argilous texture, wave-shaped ground plane, and basalt substrata.

The owner of the land has adopted the direct planting system for 12 years. The glebe which is the object of this study has been used for annual cultures: winter crops with wheat for grain production, rotated with black oat for plant coverage of the soil and organic fertilization; in summer, with soy for grain production, rotated with corn and more recently popcorn.

Acidity corrections of the soil are done once every three years, with the application of limestone by casting over the non-incorporated surface. Maintenance fertilization of the crops is done on the sowing line.

4 Materials and Method

Georeferencing of the sampling points has been done through planimetric inspection of the total glebe, using a Geodesic GPS receptor and determining UTM coordinates referenced to the Ellipsoid SAD-69. On the glebe a section was selected, which had more favorable characteristics, and a grid was established, with 30 points on a 80 m x 80 m grid, which were memorized on a GPS Etrex nbr.132 receptor, brand Garmin, used for the localizing on the field.

After the samples were collected, all points which were collected within the glebe were tied up, using a GPS receptor, model GTR1, brand Sight GPS, composed by 12 parallel channels for the reception of the L-1 carrier and the C/A code, post-processing software, model EZSurv able to receive C/A code and L-1 carrier, using the post-processed differential method.

When collecting soil samples, the method proposed by Nicolodi et al. (2002) and Wiethölther (2002) was used; sampling was carried out on the stubble of the soy crop, at a 0 to 10 cm and 10 to 20 cm depth, using a gauging auger with seven subsamples (one from the sowing line and six from the spaces between the lines, three on each side). In order to obtain a comparative effect, two subsamplings were immediately collected ahead of the collected points, from the middle of the spaces between sowing lines, at the same depth.

The subsamples were then mixed using the traditional system, with a plastic bucket. For each collected point, four samples were collected, with a total of 120, which were then individually labeled and sent to the laboratory, where the pH in water was determined, as well as the P and K levels through the Mehlich-I method. Many different software applications were used throughout the research.

5 Results and Discussion

The analyses of the soil samples have demonstrated that the collecting method which was used is efficient for the correction of the variability in the microregion of the subsamplings, presenting coherent results when compared to each other by sampling point, as it can be seen in Figures 3 and 4.
The statistics of the values of pH in water shows a great similarity of behavior of this variable for the four situations by sampling point. The values of the coefficients of variation were low, between 4.5 and 6.0%, which proves the homogeneity of the behavior of pH in water, showing that it is not a variable subject to the influence of depth, in the studied soil layer.

In all cases, the variograms were adjusted to the spherical model and the nugget effect was virtually nonexistent. With the good adjustment which was obtained, it is possible to assume a reach of 120 m on all levels.

The variographic analysis of the pH attribute and the variograms are presented on Table 1.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Depth (cm)</th>
<th>Nugget Effect</th>
<th>Reach (m)</th>
<th>Over the threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line and space between lines with seven subsamples</td>
<td>00 - 10</td>
<td>0.00</td>
<td>129</td>
<td>0.057</td>
</tr>
<tr>
<td></td>
<td>10 - 20</td>
<td>0.00</td>
<td>121</td>
<td>0.102</td>
</tr>
<tr>
<td>Space between lines with two subsamples</td>
<td>00 - 10</td>
<td>0.00</td>
<td>120</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>10 - 20</td>
<td>0.01</td>
<td>118</td>
<td>0.098</td>
</tr>
</tbody>
</table>
In the statistical study of variable P, a 40.5% coefficient of variation was observed for the most homogeneous one (for samples collected with seven subsamples on the line and on the spaces between the lines at 0 to 10 cm depth). The most heterogeneous one had a 56.5% coefficient of variation (for samples collected with seven subsamples on the line and on the spaces between the lines at a 10 to 20 cm depth). On the four levels of samples studied for P, it is clear that the samples collected with two subsamples on the spaces between the lines at a 10 to 20 cm depth and, for samples collected with seven subsamples on the line and the spaces between the lines at a 0 to 10 cm depth, contained more than one modal value. Among the various studied levels, some hypotheses were tested, and significant differences were not observed, considering a level of trustability of 95%. A hypothesis test was used through the application of the values of t from student, also for P, with no significant response differences according to the chosen level. The only differences observed occurred in the behavior of histograms, with the appearance of more modal values. Among the studied variables, P was the most heterogeneous in behavior.

Similarly to what happened to the variables P and K, the geostatistical study showed weak adjustments to the theoretical spherical model. In P, the weakness of the adjustments is due to its greater variability, with pure nugget effect occurring on the four studied levels. For the variable K, it was especially conspicuous on the levels of the samples collected with two subsamples on the spaces between the lines at a 0 to 10 cm depth and, in the samples collected at the same depth with seven subsamples on the line and on the spaces between the lines, a reach of around 120 m, but with high nugget effect levels (over 35% over the threshold). On the other levels, pure nugget effect occurred.

The variographic analysis of the K attribute and the possible variograms can be seen on Table 2.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Depth (cm)</th>
<th>Nugget Effect</th>
<th>Reach (m)</th>
<th>Over the threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line and space between lines with seven subsamples</td>
<td>0 - 10</td>
<td>950</td>
<td>114</td>
<td>1750</td>
</tr>
<tr>
<td>Space between lines with two subsamples</td>
<td>0 - 10</td>
<td>1800</td>
<td>130</td>
<td>716</td>
</tr>
</tbody>
</table>

That may be due to mobility differences of these nutrients in the soil. K has low mobility, but it is greater than that of P. With fertilization on the line, a greater dispersion of K might be occurring toward layer closer to the fertilization point, which justifies the better vertical and horizontal dispersion of this element up to a depth of 10 cm. The result thus obtained for these nutrients confirms data cited in the related literature, demonstrating the need to reduce the sampling grid, as well as the need for further studies in order to determine with greater precision the reach of the samples and its spatial structure of soil dispersion.

The spatial distribution of the analyzed attributes, visualized in thematic map, has been carried out through kriging, using as an interpolator the reverse of the distance.
The isoline maps for soil pH_{water} allow an estimate of the points whose measurement presented satisfactory accuracy levels, taking into account the results obtained in the variograms and in Figure 5.

The isoline maps for the attribute P, as shown in Figure 6, allow an estimate of the points which were not measured, but without any accuracy warranted, since it is not possible to do variograms for the sampling grid which was carried out.

![Isoline cartogram of the pH indexes at a 0 to 10 cm depth, from the samples with seven subsamples on the line and on the spaces between the lines.](image1)

Figure 5 Isoline cartogram of the pH indexes at a 0 to 10 cm depth, from the samples with seven subsamples on the line and on the spaces between the lines.

![Isoline cartogram of the indexes of P at a 0 to 10 cm depth, from the samples with seven subsamples on the line and on the spaces between the lines.](image2)

Figure 6 Isoline cartogram of the indexes of P at a 0 to 10 cm depth, from the samples with seven subsamples on the line and on the spaces between the lines.

Otherwise, the results do not allow us to visualize the possibility of a safe recommendation of K in varied doses, since the obtained results were too fragile. It is also impossible to recommend P doses, due to the impossibility of building dispersion structures based on variograms with a definite reach, for the grid which was drawn.
With the results obtained, it is possible to recommend soil corrections with limestone at specific places within the glebe that was sampled, and the places where pH H₂O levels were inferior to 5.5 (which is the factor to decide to recommend the application of limestone in cultivated areas in direct planting system) could be perfectly delimited. Future studies may be carried out to also analyze pH SMP levels, which will enable one to recommend the doses to be applied according to the distribution of isolines in the thematic map. The application of limestone in varied doses, according to regional needs, will contribute to the homogenization of soil pH, with advantages in the handling of nutrients, aiming at greater productivity.

Maybe the solution lies in the reduction of the sampling grid, as well as the need for further studies in order to determine with greater precision the reach of samples and the spatial structure of their dispersion in the soil.

7 Conclusions
The method that was used to collect samples from the soil, with a gauging auger, was efficient to correct the microregionalized distortions. For P and K, the method enabled the homogenization needed to represent the levels of these elements at each collecting point.

With the grid that was used, it was possible to determine the spatial structure of the dispersion of pH₅₀₀ in the soil, demonstrating that this attribute has normal dispersion, possibly linked to the practice of liming, which has traditionally been done by casting at homogeneous doses and levels. This attribute has presented great homogeneity and coherence for all sampled levels, making it possible to assume a reach of approximately 120 m (118 to 129 m) per sampling, with the possibility of enlarging the sampling grid.

At a low accuracy level, it was possible to demonstrate the spatial structure of pH₅₀₀ on soil for samples up to 10 cm deep, with a similar reach of 120 m (114 and 130 m). The grid did not allow us to establish the reach of samples done for K at a 10 to 20 cm depth, and, for P, at all depths. K has low mobility, however greater than P, with fertilization on the line what might be occurring is a greater dispersion of this nutrient to soil layers closer to the fertilization point, justifying better vertical and horizontal dispersion of this element up to a depth of 10 cm.

It is possible to recommend the correction of the soil with limestone at specific places of the glebe, and the places with pH H₂O levels inferior to 5.5 can be perfectly delimited. For future studies, we suggest the analysis of pH SMP, which might enable us to recommend the doses to be applied according to the distribution of the isolines in the thematic map. The application of limestone at varied doses, according to regionalized necessities, will contribute for the homogenization of soil pH, with advantages in the handling of nutrients, aiming at greater productivity.

New studies must be carried out aiming at establishing the reach of P and K samples for cultivated field works under the direct planting system with fertilization on the sowing line, and the consequent recommendation of those nutrients, in variable quantities in the practice of precision agriculture.

References

