Characterization of spatial variability of the need of limestone for the application at a varied rate in an agricultural trade area

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Abstract:
Outside the ideal range of pH, the cultures are limited in terms of the availability of nutrients, so the setting of the limestone is linked directly to the production yield, in which the application is usually performed based on an average value of the Need for Limestone (NL). The work aims to build the map of NL, using the tools of Precision Agriculture (PA) and by the conventional methodology, then performing a comparison between the methods of application of NL used, giving the benefits of the varied rate application. 59 samples were collected through a sampling grid, within the experimental area of 82.67 ha. With the use of Geostatistics it was possible to determine the spatial variability of NL in the study area, with a moderate degree of spatial dependence between the sampled points, it was possible to build a thematic map of NL. By comparing the amount of lime to be applied according to the thematic map with the conventional method of application from the average of the NL, the amount of lime applied in varied rate decreased in the order of 73%, boasting with it, greater environmental benefits to the soil and also financial savings in the amount of correction.

Keywords: geostatistics; soil acidity; precision agriculture

Introduction

The soil acidity promotes changes in the chemical characteristics of the soil, as increase of the concentration of elements which are toxic for the plants, also limiting the adsorption and availability of nutrients in the soil, affecting negatively the harvest and making it difficult the use, by plants, of the nutritive elements that exist in the soil. The consequences are the injuries caused by low productive yield of the cultures. Therefore, the correction of the soil acidity, trough liming, is fundamental to a productive agricultural activity.

The need of liming for its turn is determined trough the chemical analysis of the soil, the first and more critic step of the analysis is the soil sampling. The methodology of soil sampling which has been used and spread over the years predicts the division of the property in uniform areas of until 10 hectares, for the sampling. Each one of these areas should be uniform in color, topography, texture and necessity of fertilization and liming. The samples should be taken, walking at random zigzaging in the area, to form the composed sample. The number of simple samples should not be inferior to 10 points per homogeneous plot, considering that the ideal is of approximately 20 points. It should not be collected samples close to houses, sheds, ponds, gullies, pathway for pedestrian, anthill etc., avoiding the introduction of error in the sampling (BORGES and ACCIOLY, 2007).

Studies conducted prove that there is special variability of the soil attributes even in very small areas. GOTWAY et al. (1996) found that several cases in which the space of distribution is quite complec, it is necessary a denser sampling grid for the production of maps with accurate prescription. Nowadays the technologies associated to the Precision Agriculture (PA) enable a more detailed study of the soil, determining the variables existent in areas considered uniform before, trough sensors, computers and receivers of signal of the Global Navigation Satellite System – GNSS (MURAKAMI 2006).

In the cycle of the PA, the modeling of the

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special variability of the information is performed trough geostatistic techniques, which are based on the "Regionalized variable theory" which appears as a technique that considers the spatial distribution of the measures (collected data), which enables to define the range of spatial or temporal dependence of stochastic processes (GIACOMIN et al., 2009).

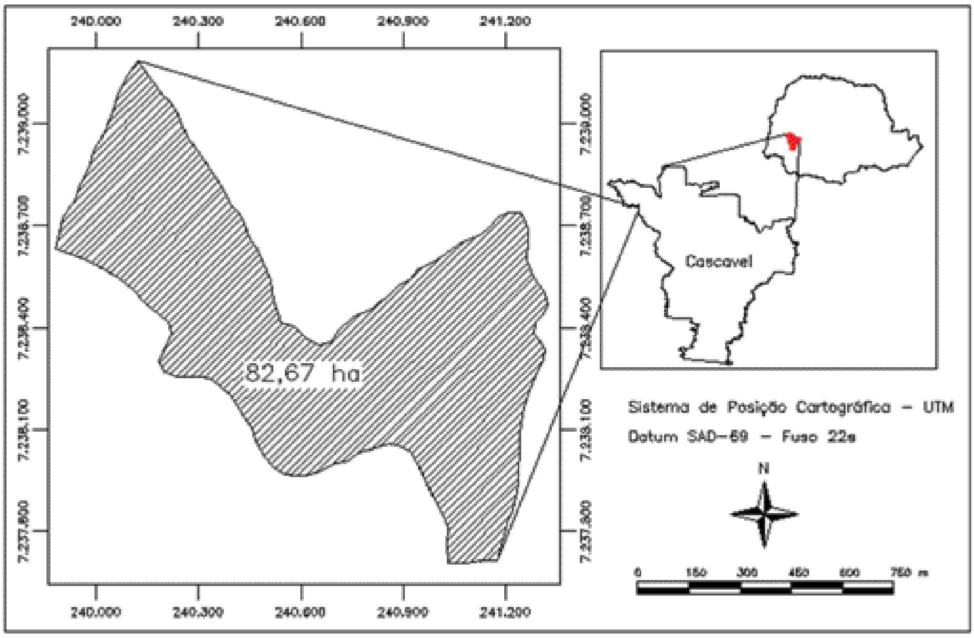
These technologies of PA and geostatistics enable the management and amplification of the knowledge of the cultivated areas with evaluation and treatment of the spatial variability until the present, however without alternative of determination in commercial areas, as exampled it can be named the works of SOUZA et al. (1999); MERCANTE et al. (2003); JOHANN et al. (2010).

The adoption of the concept of PA defined by MANZATTO et al. (1999) as application of input in the correct place, in the appropriated moment, with the quantity of input needed to the agricultural production, in areas increasingly smaller and more homogeneous, as much as the technology and the costs involved allowed. With the implementation of the cycle of the PA, it is aimed at using the application of the corrective, increasing the production in regions which have higher NL and reduce thus cost with the reduction of the volume of corrective in areas with lower necessity.

In this context, the construction of the map of NL, using the Precision Agriculture – PA tools, and trough the conventional methodology, had as objective to compare the results of each method, determining the benefits of the application to the varied rate.

Material and methods

The data to the execution of this work come from an ongoing research developed by the Grupo de Estatística Aplicada (Group of Applied Statistic) – GGEA with support of the Laboratórios de Estatística Aplicada (Laboratory of Applied Statistics)-LEA/CCET/UNIOESTE and Topografia e Geoprocessamento (Topography and Geoprocessing) – GeoLab/CCET/UNIOESTE. The studied agricultural year was the summer crop 2008/2009 (November 2008 to March 2009), the research was developed in commercial agricultural area, in which the soil was classified as Latossolo



Source: the author

Figure 1. Research area with 82.67 ha.

Vermelho Distróferrico[1], according to EMBRAPA (1999).

The studied agricultural area (Figure 1) has 82.64 ha of extension and it is located in the municipality of Cascavel – PR, its UTM coordinates are 262.900.00 meters and 7.138.300.00 meters, in the zone 22S for the Datum SAD 69.

First, in the data collection, it was conducted the planimetry and the georreferencing of the area with use of a GPS receiver apparatus of the brand Trimble, model GeoExplorer3, with accuracy of 1 to 5 meter with C/A code according to the producer (GeoExplorer 3 Operation Guide). In the sampling design among the georeferenced points, it is adopted an irregular mesh with distances of 50, 75 and 140 meters, as a way to characterize better the existing spatial variability, thus it was defined a total of 59 sampling points in the entire area. With aid of an electric screw auger, it was collected five sub-samples of soil in the depth of 0.00 – 0.20 meters for each one of the 59 sampling points, which after being homogenized originated a compound sample to the chemical analysis of the soil.

The chemical analysis of the soil for their turn was conducted in the laboratório de química de solo (soil chemistry laboratory) of the Cooperativa Central de Pesquisa Agrícola (Center Cooperative of Agricultural Research) – COODETEC. From the method of elevation of the base saturation, it was calculated the NL to the calcitric limestone with RPTN (Relative Power of Total Neutralization) of 80% trough the method of base saturation (Equations 1,2, 3, 4 and 5). The base saturation is variable for each state or region, according to EMBRAPA SOJA (1993) and the recommendation to the state of Paraná is 70%.

$$NC = \frac{[(V_2 - V_1) \cdot T \cdot f]}{100} \quad (1)$$

$$V_1 = 100 \cdot \left(\frac{S}{T}\right) \cdot V \quad (2)$$

$$S = Ca^{2+} + Mg^{2+} + K^{+} \quad (3)$$

$$T = S + (H + Al^{3+}) \quad (4)$$

$$f = \frac{100}{PRNT} \quad (5)$$

1 Brazilian Soil Classification

In which:

NL = Necessity of Limestone (t ha^{-1})

V_2 = Value of the exchangeable base saturation which is desired (%);

V1 = Value of the exchangeable base saturation of the soil (%); S = Sum of bases ($cmol_c$ dm^{-3});

E = Cation Exchange Capacity, (cmolc dm^{-3}); f = Factor of correction of the RPTN of the limestone;

Ca = Calcium ($cmol_c$ dm^{-3});

Mg = Magnesium ($cmol_c$ dm^{-3});

K = Potassium ($cmol_c$ dm^{-3});

H = Hydrogen ($cmol_c$ dm^{-3});

Al = Aluminum ($cmol_c$ dm^{-3}).

The NL data were initially calculated with aid of spreadsheets in order to perform the descriptive statistics. In order to estimate the soil attributes in the areas among the sampled point it was used Geostatistics, with the analysis and modeling made in the softwares *Geo R* and *Surfer 9.0*.

Before the analyses of special dependence using geostatistics, it was verified the normality, asymmetry, kustosis, mean, pattern deviation and coefficient of variation.

Inside geostatistics, it was used the estimator of the moments described by the equation 6 (PANNATIER 1996):

$$\gamma(h) = (\tfrac{1}{2}\,(N(h)) \cdot \sum N(h)[z(si + h) - z(si)] \quad (6)$$

In which:

z(si) = Value of the variable in the point si;

z(si + h) = Value of the variable in the point si + h

N(h) = Number of parts separated at a distance h.

As the real variogram of the NL data is unknown, it was needed a theoretical semivariogram of reference which would adjust better to the experimental variogram, so that by the theoretical model it can be done interferences over the real variogram. With aid of the geostatitiscs module *Geo R*, RIBEIRO JR. and DIGGLE (2001), it was determined the semivariograms of the spherical, exponential and gaussian models to the method of ordinary least squares (OLS), weighted least squares (WLS1), maximum likelihood (ML) and restricted maximum likelihood (RML).

In the confection of the thematic maps which express the special variability of the NL it was used the interpolation by ordinary kriging, by which it was obtained the prediction of values in places that were not sampled in the studied area. The maps were reclassified in subareas, with the values of the Quartis it was created a thematic map of NL, reporting the different characteristics inside the agricultural area analyzed.

Results and discussion

Table 1 presents the database analysis of the values calculated for NL. It can be verified that the mean value of NL was 2501.80 kg ha^{-1} for calcitric limestone with RPTN of 80%

Trough the test of Anderson Darling it was verified that the data have normal distribution, with p-value of 0.54. In relation to the coefficient of variation (CV) of 55.53%, data are classified as heterogeneous according to GOMES (2000). The standard deviation (S) of 1389.28 also indicated that the data have high dispersion, which can be proved with the maximum and minimum values found (Table 1).

Table 2 presents the parameters of the modeling of the spatial variability effected to the data of NL and obtained trough variographic study.

The model of the semivarigram of better adjustment was the *Spherical*, with ratio of spatial dependence of 206.9 meters. Analyzing the relative nugget effect (E), which was of 27.8%, it can be observed that the samples presented a moderated degree of spatial dependence, since the value is between 0.25 ≤ and ≤ 0,75 classified as moderate by CAMBARDELLA et al., (1994).

The temathic map of NL presented in Figure 2 was obtained trough the interpolation by kriging trough the software *Surfer 9.0*, using the parameters of the spatial analysis, nugget effect (C0), contribution (Cl) and reach, obtained trough the model adjusted to the variogram (Table 2).

By the thematic map, it was determined the areas of the spatial distribution of the NL for each class created by the Quartis values, i.e., for the classes seen in the subtitle.

These results can be visualized in the Table 3, which also contains the calculations of the NL and the total quantity (ton) to be applied in each one of the areas described in the thematic map.

As a form to compare the use of the technique of PA with the conventional methodology to soil acidity correction trough NL, it was executed the calculations of the Table 4. In it, it is presented the average NL of the entire area, obtained trough the average value of NL of the systematic samples aiming to simulate the total amount of limestone to be applied according to this methodology of recommendation.

When comparing the needed amount of calcitic limestone to correct the soil acidity in the total area, it can be verified that the correction of the acidity, trough the conventional method, needed 206.76 ton against only 55.16 ton (Table 3) presented trough the method of application at a variable rate of the PA. This represented a significant reduction in the amount of corrective to be applied, approximately 73.32% or 151.6 ton.

The advantageous results found, concerning

Table 1. Database analysis of NL.

Variable	N°	Mean	Median	Q1	Q3	Min	Max	S	CV (%)
NC	59	2501.80	2610.00	1382.00	3443.00	0.00	6819.00	1389.28	55.53

Note: N° - number of samples; Q1 – Quartile 1; Q3 – Quartile 3; Min – minimum; Max – maximum; S – standard deviation; CV – coefficient of variation.

Table 2. Spatial analysis of NL.

Variable	Model	C0	C1	E= C0/(C0+ C1)	reach (m)
C	Spherical	454435.52	1630467.24	27.80%	260.9

Note: C0: nugget effect, C1: contribution and E: relative nugget effect (%).

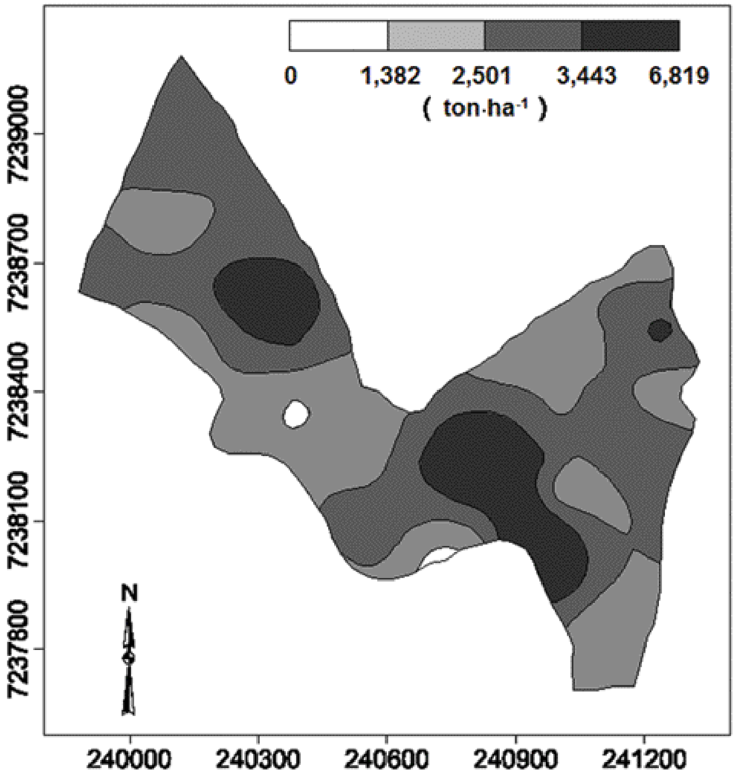


Figure 2. Map of the spatial distribution of NL (t ha^{-1}).

Table 3. Area and amount of limestone to be applied according to thematic map of NL.

Region	NlL(t ha^{-1})	Area (ha)	Amount of limestone (t)
1°Q	0 – 1.38	0.71	0.49
2°Q	1.38 – 2.50	29.97	16.77
3°Q	2.50 – 3.44	39.80	18.83
4°Q	3.44 – 6.62	12.01	19.07
Σ =		82.67	55.16

Note: 1°Q – first quartile; 2ºQ – second quartile; 3ºQ – third quartile; 4ºQ – fourth quartile.

Table 4. Amount of limestone for the conventional methodology.

Region	NL (t ha^{-1})	Area (ha)	Amount of limestone (ton)
Average	2.501	82.67	206.76

the reduction of the amount of calcitic limestone to be applied in the area with the application with variable rate inside the PA, support the results found by GIACOMIN et al. (2009), however, these authors found a reduction of only 6.9% in the amount of calcitic limestone, with the application with variable rate in relation to the conventional methodology.

Conclusions

The construction of the map of NL using the tools of Precision Agriculture – PA and trough the conventional methodology, performing later a comparison between the methods of application of NL used, showed that the applications at a variable rate use less corrective than the uniform conventional applications.

The results indicate that less than half of the calcitic limestone was really necessary to this research area, determining thus the benefits of the application in varied rate, when compared to the uniform treatment.

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