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SPATIAL VARIABILITY OF SOIL CHEMICAL ATTRIBUTES SUBMITTED TO DIFFERENT TYPES OF AGRICULTURAL USE IN THE CERRADO-AMAZON ECOTONE

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ABSTRACT:

The knowledge of the spatial variability of the soil's chemical attributes increases the accuracy of fertility management. In this sense, the objective of this study was to characterize the spatial variability of chemical attributes in a Cambisol Haplastic Ta Eutrophic under different use types. The study was carried out in the municipality of Combinado - TO. To carry out the study, 40 soil samples were collected at a depth of 0-20 cm, in a grid with three meshes to represent better the conventional pasture 40x40m mesh, irrigated pasture 20 x 20 m, and livestock integration area 22 x 22 m. The chemical attributes of the soil were evaluated: pH, phosphorus, potassium, calcium, magnesium, exchangeable aluminum, potential acidity, cation exchange capacity at pH 7.0, saturation by aluminum, saturation by bases, and organic matter. It was observed that chemical properties are influenced by land use. Except potassium and saturation by base and aluminum, the other variables showed spatial dependence. They indicated that the number of samples was sufficient to map the study area, except phosphorus and organic matter, which indicates the need for a shorter distance between the sampling points to be detected, using geostatistics techniques. The chemical attributes were sensitive to the type of exploration and possibly to the process of soil formation. Thus, using geostatistics and the elaboration of isoline maps by kriging allowed the definition of soil fertility management zones.

Key Words: Soil fertility. Geostatistics. Kriging. Pasture.

VARIABILIDADE ESPACIAL DOS ATRIBUTOS QUÍMICOS DO SOLO SOB DIFERENTES USOS AGRÍCOLAS NO ECÓTONO CERRADO-AMAZÔNIA

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RESUMO:

O conhecimento da variabilidade espacial dos atributos químicos do solo permite aumentar a precisão do manejo da fertilidade. Nesse sentido, objetivou-se caracterizar a variabilidade espacial de atributos químicos em Cambissolo Háplico Ta Eutrófico sob diferentes tipos de uso. O trabalho foi realizado no município de Combinado – TO. Para a realização do estudo, foram coletadas 40 amostras de solo na profundidade de 0-20 cm em "grid", com três malhas para melhor representar os sistemas de produção: a primeira malha de 40 x 40m em pastagem convencional, a segunda malha de 20 x 20 m em pastagem irrigada e a terceira malha de 22 x 22 m em área de integração lavoura pecuária. Foram avaliados os atributos químicos do solo: pH, fósforo, potássio, cálcio, magnésio, alumínio trocável, acidez potencial, capacidade de trocas de cátions a $pH_{7,0}$, saturação por alumínio, saturação por bases e matéria orgânica. Foi observado que as propriedades químicas são influenciadas pelo uso do solo. Com exceção do potássio e saturação por base e alumínio, as demais variáveis apresentaram dependência espacial, indicando que o número de amostra foi suficiente para mapear a área de estudo, exceto fósforo e matéria orgânica. Estes últimos apontaram para a necessidade de distância menor entre os pontos de amostragem, pois a detecção destes exigem o uso de técnicas específicas de geoestatística. Os atributos químicos se mostraram sensíveis ao tipo de exploração e, possivelmente, ao processo de formação do solo. Assim, com o uso da geoestatística e a elaboração de mapas de isolinhas por krigagem, foi possível demonstrar com precisão as zonas de manejo da fertilidade do solo.

Palavras-chave: Fertilidade do solo, geoestatística, krigagem, pastagem.

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INTRODUCTION

The Brazilian cerrado, presents favorable conditions for the exploration of livestock activity in pasture systems. Data released by the Department of Agriculture, Livestock and Supply of the State of Tocantins (SEAGRO/TO), estimated in 2015 that the breeding of beef cattle was the main economic activity in the pasture area cultivated in the state with 7.5 million hectares, (Jardim, 2015).

In line with that, the most practical and economical way to raise cattle is pasture. However, the results obtained by livestock farmers in this exploration model are modest, considering the potential that this activity can offer when well managed (Vitor et al., 2009).

The low productivity of forages is due to the advanced stage of degradation of most pasture areas of the Brazilian territory and the low natural fertility in highly weathered environments.

The degradation of pasture areas occurs due to inadequate management of factors that affect pasture quality. The lack of conservation practices that prevent erosion, the lack of care with chemical, physical and biological properties are among some of these factors. In addition to that there is the excessive grazing of animals. Thus, when poorly managed, the pastures become unproductive and quickly submerged by spontaneous natural regeneration (Almeida and May, 2016).

In general, soils can be naturally productive due to factors such as geological nature and formation conditions or they can become productive due to the adoption of management practices. However, to apply proper management, it is necessary to know the characteristics and properties of the soil. This is possible from surveying its chemical, physical and biological properties (Silva and Chaves, 2001).

Naturally, soils are heterogeneous environments in terms of chemical and physical attributes, thus requiring thorough survey and technology toassist in decision-making processes. In this sense, geostatistics has been successfully applied in studies that seek to understand the spatial distribution of soil attributes. The information in the mappings is highly relevant for those who aim at sustainable production because it allows strategic planning of specific management of the worked areas (Weirich Neto et al., 2006). This tool also allows quantifying the magnitude and degree of spatial dependence of the variables studied, through accurate and accurate interpolation, adjusted to the collected data (Aquino et al., 2014).It is known that chemical properties present in the soil, except for pH, demonstrate high variability, superior when compared to physical attributes (Bottega et al., 2013). Thus, the use of random sampling (which considers the means to represent a given attribute) is insufficient to represent the entire soil class and may induce interpretative errors by limiting information. Also, several studies show that soil chemical attributes indicate spatial dependence, with significant variation within the same area, justifying the use of geostatistics precepts to understand and plan efficient management (Silveira Junior et al., 2014).

In this perspective, this study evaluates the spatial distribution of soil chemical attributes in three different systems of exploration and pasture management, intensified (irrigated), extensive (conventional), and crop-livestock integration.

MATERIAL AND METHODS

The study was carried out at Aroeira Farm, in the city of Combinado in Tocantins (12°47'46" S and 46°30'45" W), and 396 m above sea level, located in the Cerrado biome (Figure 1)., According to Koppen classification (1948), the climate of the regionis Aw (hot and humid). The average annual temperature is 26,2 °C and 1,529 mm of annual precipitation. The soil used in the experiment was the Cambisol Haplastic Ta Eutrophic.

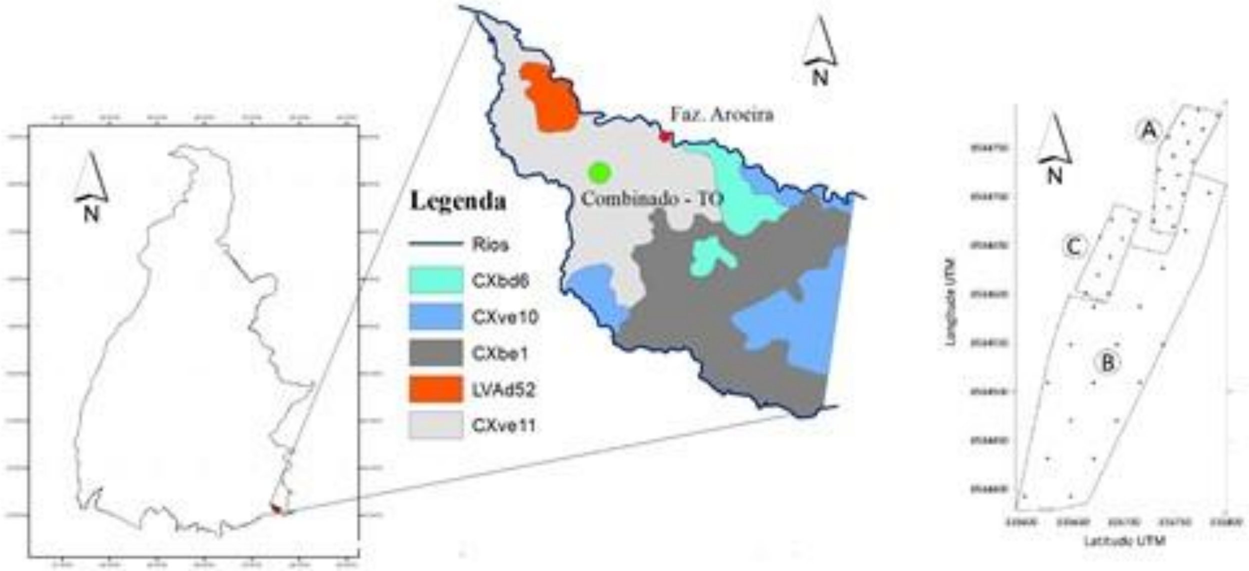

Figure 1. Soil classification and search location. Rivers = Palmas River and Peixe River, CXbd6 = Dystrophic Tb Háplico Cambisolo, CXve10 = Uroctous Háplico Ta Eutrophic, CXbe1 = Eutrophic Tb Háplico Cambisolo, LVAd52, CXve11 = Cambisol Haplastic Ta Eutrophic. A = Irrigated pasture, B = Conventional pasture, C = Crop-livestock integration area.

The study area consisted of three uses and management of soil cover:

1. Intensive dairy production systems in irrigated pastures

2. Extensive grazing systems with beef cattle and replacement animals

3. The conventional pasture subarea associated with the production of sorghum [Sorghum bicolor (L.) Moench].

The pasture subarea irrigated by sprinkler with Mombaça grass (*Megathyrsus maximus* Jacq.) comprises 0.45 ha and six years of implantation. The management of the subarea consisted of dredging and fertilization with nitrogen. Nitrogen fertilization was divided throughout the year, with an annual application of 1181 $kg.ha^{-1}$ of N in the form of urea. It is noteworthy that dairy cattle remained for one day with a capacity of 24,44 $animais.ha^{-1}$ and rest period of 28 days in the grazing subareas.

The conventional pasture subarea with Mombaça has 2.67 ha and twenty years of implantation. The utilization of the subarea alternated between beef cattle and sorghum cultivation for silage production. It is important to emphasize that at the end of the rainy season, the subarea was reformed without fertilization for the implementation of conventional pasture with Mombaça. Therefore, continuous grazing with beef cattle and spare animals, with a stocking of 0,5 $animal.ha^{-1}$.

The Mombaça pasture subarea associated with sorghum production has 0.3 ha and eight years of implantation. The nutritional management of the subarea consisted of lime and application of 150 kg of NPK (5-25-15) at the beginning of each forage sorghum production cycle.

The total area was 3.41 ha, distributed in an irregular sampling mesh composed of 40 pointsobtained through the Global Positioning System (GPS - Garmin Etrex DATUM WGS 84, Zone 23). It is important to emphasize that, the study used three meshes to better represent the production systems, 40x40m mesh in the conventional pasture, 20 x 20 m in the irrigated pasture, and 22 x 22 m in the crop-livestock integration area. Soil collection and laboratory analyses occurred from June to July 2018.

The soil samples were collected in the 0-20 cm depth layers using a Dutch auger at georeferenced points, totaling 40 simple samples. The following soil chemical attributes were studied: pH $CaCl_2$ ($CaCl_2$ 0,01 M 2,5: 1 soil); phosphorus (P) and potassium (K) by atomic emission (0,05 mol L^{-1} HCl +0,0125 mol L^{-1} H_2SO_4; Mehlich I); calcium (Ca), magnesium (Mg) and aluminum (Al) by atomic emission (KCl 1 M); potential acidity (H+Al) per potentiometer (calcium acetate at pH 7); organic matter (M.O) by colorimetry ($Na_2Cr_2O_7.2H_2O$ + H_2SO_4), allowing the calculation of Cation Exchange Capacity (CTC), sum of bases (SB), base saturation (V%) and aluminum saturation (m%), according to methods described in Embrapa (2011).

The chemical attributes of this soil under different forms of exploration and management are represented in Table 1.

Based on the collected data, descriptive statistics were performed composed of measures of position (mean, median, and mode), dispersion (minimum, maximum, and standard deviation) and distribution (coefficients of variation, skewness, and kurtosis). The normality hypothesis was verified by the Kolmogorov-Smirnov test (KS) at the level of 5% probability with the aid of the statistical program BioEstat 5.0.

The limits of the coefficient of variation (CV%) were used to measure variability according to Warrick and Nielsen (1980) in: weak CV <12%, moderate CV between 12% and 62% and strong CV> 62%. The coefficient of asymmetry (CA) was used as a characteristic of precision. The normalized distribution function, in: AC = 0 is asymmetric distribution, AC>0 is a skewed distribution to the right, and AC <0 is a skewed distribution to the left. The kurtosis coefficient (KC) was used according to the criteria of Alves et al. (2014) in: CK = 0 is a flattened distribution, CK <0 is a platicurtic distribution and CK> 0 is a leptokurtic distribution.

Table 1. Average soil chemical characteristics of Aroeira Farm in the studied areas 0-20cm depth layer, Combinado - TO, (2018).

Production System	pH	P	K	Ca	Mg	Al	H+Al	$CTC_{7,0}$	m	V	O.M	Clay
	$CaCl_2$	mg. dm^3			$cmol_c.dm^3$					%		
I. P	5,35	3,74	0,16	8,68	2,10	0,00	2,00	12,94	0,00	84,53	2,70	30
P. C	5,15	2,67	0,11	7,45	2,14	0,01	3,02	12,73	0,24	75,24	3,17	20
C. L	5,63	4,30	0,29	9,15	2,01	0,00	1,95	13,40	0,00	85,38	3,73	23

P = Irrigated Pastures; P.C = Pasture Conventional; C. L = Crop-Livestock; pH = Hydrogen Potential; M.O = Organic Matter; P= Phosphorus; K = Potassium; Ca = Calcium; Mg = Magnesium; Al = Aluminium; H+Al = Hydrogen plus Aluminum; $CTC_{7,0}$ = Cation exchange capability to pH 7,0; m = Aluminium Saturation; V = Base Saturation; Soil Clay.

According to the intrinsic hypothesis, the spatial variability of soil chemical attributes was determined by the construction of their respective semivariogram. The semi variogrammes were adjusted to the theoretical mathematical models: spherical, exponential, linear and Gaussian, to define the values of the nugget effect (C0), reach and level (C + C0).

The spatial relationship patterns were estimated by semivariance, and autocorrelation as a function of distance γ (h) (Matheron, 1963), with the aid of GS + software (Robertson, 1998), as a function of equation (1).

$$\gamma(h) = \frac{1}{2N(h)} Z(Xi)Z$$

Where,

γ (h) = experimental semivariance made from the obtained values; h = distance between sampling points; N (h) = number of pairs of values obtained Z (xi); Z (xi + h), separated by a distance h; Z = any parameters studied; Xi and Xi + h = positions of the sample point (Vieira et al., 1983).

In order to choose our theoretical model for classification of the Degree of Spatial Dependence (GDE) (SPD) wedetermined C and C + C0as a relationship between structural variance (C) and plateau). the GDE into: weak spatial dependence (GDE <0, 25), moderate spatial dependence (0.25 ≤ GDE <0.75) and strong spatial dependence (GDE ≥ 0.75) (Robertson 1998), as a function of the equation (2).

$$\text{SPD}=\frac{C}{\text{C+C}_0}$$

Where,

SPD = degree of spatial dependence; C = structural variance; and C + C0 = landing.

The selection of the adjusted model of the semi variogrammes was performed according to the lowest sum of the square of the residues (SQR), in the highest SPD and higher coefficient of determination (R^2). In addition, the analysis of the presence of isotropic was calculated in four directions in semi variogrammes with amplitude at 45º (0, 45, 90 and 135º). We chose to analyze the 90º isotropic semi variogrammes, we did not find any anisotropy.

We performed data and map analysis using the researched area as a whole, without splitting it into pickets. For orientation and distinction of the types of soil use, we displayed the division on the map. The interpolation of the values was performed by the kriging method, to construct isoline maps, using surfer v. 13.0 software (GOLDEN SOFTWARE, 2015).

The descriptive analysis of data revealed the non-normality of the variables pH, Ca^{2+}, Mg^{2+}, M.O, $CTC_{7,0}$, SB, V and m%, for the values of soil chemical attributes; however, the attributes, K^{+}, Al^{+3}, P, e H+Al presented normal distribution (table 2).

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RESULTS AND DISCUSSION

Table 2. Measurements of spatial analysis of soil chemical attributes, in different agricultural uses, at a depth of 0-20 cm.

Variable	Min	Max	M	Md	Apl	S	CV (%)	As	K	K-S
pH ($CaCl_2$)	4,80	5,80	5,32	5,30	1,00	0,25	4,80	0,19	-0,61	Ns
P ($mg.dm^{-3}$)	1,50	9,00	3,40	2,80	7,50	1,67	49,30	1,75	2,78	<0,05
K^{+} ($mg.dm^{-3}$)	32,00	284,00	65,25	50,00	252,00	44,70	68,71	3,42	14,57	<0,01
Ca^{2+} ($cmol_c.dm^{-3}$)	4,30	9,90	8,25	8,90	5,60	1,62	19,58	-1,31	0,87	Ns
Mg^{2+} ($cmol_c.dm^{-3}$)	1,30	3,60	2,10	2,00	2,30	0,41	19,78	1,20	3,52	Ns
Al^{3+} ($cmol_c.dm^{-3}$)	0,00	0,10	0,00	0,00	0,10	0,02	441,44	4,29	17,28	<0,01
H+Al ($cmol_c.dm^{-3}$)	1,50	3,80	2,42	2,20	2,30	0,62	25,78	0,37	-1,13	<0,05
SB ($cmol_c.dm^{-}3$)	5,98	13,08	10,50	11,20	7,10	1,88	17,87	-1,16	0,74	Ns
$CTC_{7,0}$ ($cmol_c.dm^{-3}$)	9,08	16,10	12,94	13,24	7,02	1,83	14,14	-0,65	-0,09	Ns
V (%)	66,00	89,00	80,75	82,5	23,00	6,12	7,58	-0,90	0,20	Ns
m (%)	0,00	2,00	0,13	0,00	2,00	0,46	370,72	3,74	13,17	Ns
M.O ($dag.kg^{-1}$)	2,20	4,60	3,10	2,85	2,40	0,70	22,42	0,73	-0,59	Ns

Mín = Minimum value, Max = Maximum value, M = Mean, Md = Median, Apl = Amplitude, S = standard deviation, CV = coefficient of variation, As = Asymmetry coefficient, K = Kurtosis, K-S = Kolmogorov-Smirnov test, NS = No Significant to 5% of probability.

The absence of normality of some soil chemical attributes is probably due to the influence of management practices used in the soil in the different farms of pasture areas. As well as soil pedological factors, making some soil chemical characteristics with specific zones influenced by the practices performed in each crop.

According to Silveira Junior et al. (2014), the spatiality of soil chemical attributes in the north of Tocantins, evidenced the non-normality of the data studied. This is due to the management adopted in the different agricultural uses and pedological factors, which influences the chemical characteristics of the soil. However, the normality of data distribution is not a requirement for the use of geostatistics, although it is convenient that the asymmetry values are not too far from zero, to characterize caudal elongation (Corá and Beraldo, 2006; Kruger et al., 2016).

The attributes pH, P, K^{+}, Mg^{2+}, Al^{+3}, H+Al, m%, and M.O showed a positive asymmetry coefficient (Table 1), while other soil chemical attributes, such as Ca^{2+}, $CTC_{7,0}$, V%, and SB, presented negative asymmetric distribution. The Kurtosis coefficients were correlated with the K-S normality test, with the highest values of Kurtosis for the variables that presented a significant effect for normality, typical leptokurtic behavior, according to the classification of Alves et al. (2014). Descriptive data analyses of the soil chemical properties' parameter showed no discrepant values influencing the dispersion measurements. Results show that the observed data present reliable values representing the spatial variability of the soil chemical attributes in the central trend measurements. The proximity relationship between the mean and the median in all classes is observed, thus eliminating the possibility of atypical data that would cause interference in the central measures.

The difference between the types of land use is evident when analyzing together both the values of the coefficients of asymmetry and kurtosis (values distant from zero characterize distributions as non-normal) for the variables under study. This is explained by the expressive variation around the mean that they promote. Kriging presents better results when data normality is observed. In general, the observed values are abnormal, a factor due to the excessive variation of the studied area, relating to the effects of the different land uses and managements adopted (Silveira Junior et al., 2014).

By analyzing together, the values of amplitude, coefficient of variation (CV) and normality test This difference in land use is evident when analyzing together the values of amplitude, coefficient of variation (CV) and normality test according to the average coefficient of variation. In this manner, classifying high (CV > 62%) for the variables K^{+}, Al^{+3} e m%, mean (12% to 60%) for P, Ca^{2+}, Mg^{2+}, H+Al, SB e $CTC_{7,0}$, and low CV (<12%) for pH and V. The lower the coefficient of variation, the more homogeneous the distribution and the lower the degree of dispersion of the data around the mean

The spherical model was the one that best fitted the semivariogrammes of soil chemical attributes except for M.O and P that presented better adjustments to the exponential model, while Mg^{2+} e H+Al^{+3} were the variables best adjusted to the Gaussian model (Table 3). Potassium and SB were the only ones classified by the linear model (Table 3). For Bottega et al., (2013), this indicates that the semivariance value is equal to the level for any distance. The absence of spatial dependence is called a pure nugget effect. It means that there is a homogeneity of the attribute studied, discarding the need for map making.

The range value of an attribute is the maximum distance between one point and another. According to Machado et al. (2007) all points within a circle with this radius have values remarkably close to the point of where it is possible to estimate values between them The study observed the lowest range value for the attributes M.O and P (Table 2), and the highest K^+, Mg^{2+}, H+Al, SB and m%. This can also be divided into three groups: Close range, for values less than 50 m (M.O and P); Mean range between 50 and 100 m (pH, Ca^{2+}, Al^{+3}, CTC e V%),;and long range greater than 100 m (K^+, Mg^{+2}, H+Al, SB e m%) (see Table 2).

This high spatial variability for the attributes P and M.O may reflect oscillating values with low spatial dependence, resulting in difficulty to determine the number of sampled points that were insufficient to capture the actual variability of the elements in the soil. In general, , the sampled points are insufficient, which can be noted by the low coefficient of determination.

The result of all this is the generation of low-precision maps for these attributes. Results similar to those found for the attributes K^+ e Mg^{+2} are corroborated by Silva Neto et al (2011) in studies in the *Cerrado* domain. These studies occurred in different uses and occupations;natural vegetation converted into pasture or under other management modalities (Silveira Junior et al., 2014). Therefore, the differences observed between the variables studied to show the importance of the parameter in strategic planning, especially in cases where the randomness of the data is assumed (Guimarães et al., 2016).

Spatial dependence analysis (GDE) allowed classifying the variables pH, P, Ca2+, Al+3, CTC, V% and M.O as strong (>0.75), Mg2+ as moderate (0.25 ≤ GDE ≤ 0.75), and K+ and SB as low (<0.25). It is important to highlight that the higher the GDE value, the more the semi variograms explains data's variance since the sampling mesh used was adequate and managed to capture spatial dependence (Guimarães et al., 2016).

The spatial distribution values of soil chemical attributes obtained with kriging interpolation models (Table 3) are (?) essential tools for strategic planning and management actions. It is pertinent to emphasize that the values of the variables, aluminum saturation and Al+3, were close to zero in the vast majority, not justifying the map-making.

When analyzing the pH of the area as a whole, it is possible to observe an average value of 5.32 (Table 2)-according to Prezotti and Guarçoni (2013) classification, this is considered average acidity. However, the minimum and maximum variations oscillate from 4.8 to 5.8, between the mean and weak classifications, with the minimum value found in the conventional pasture system (Figure 2) and the maximum value in the Livestock Crop Integration area (Figure 2). The pH range is considered high with a degree of spatial dependence (DG) classified as strong, revealing variation between the different uses (Table 3, figure 2).

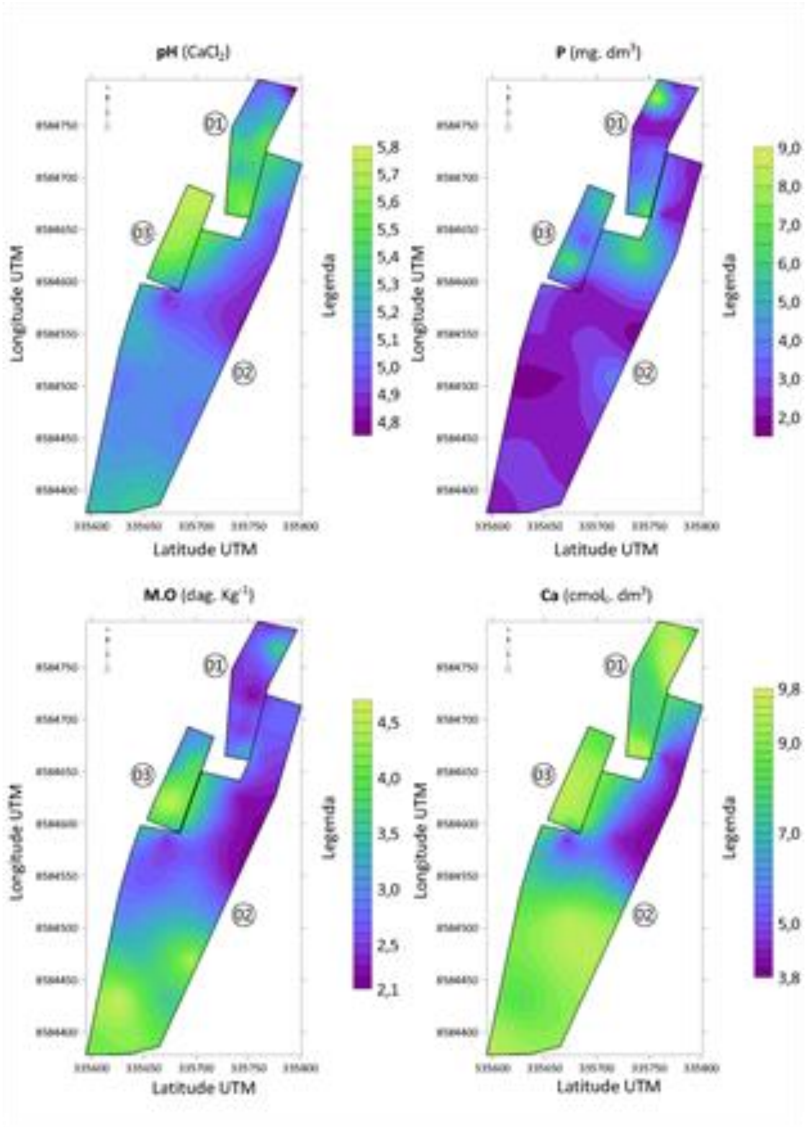

Figure 2. Spatial distribution of chemical attributes at the depth of 0-20 cm in an area of Cambisolo. pH: Hydrogen potential; P: phosphorus; M.O: organic matter; Ca^{+2}: calcium. 01 = Irrigated pasture; 2 = Conventional pasture; 3 = Livestock farming integration

Results showed the lowest pH value in the conventional pasture area. This was followed by higher H+Al values (Figure 3). Thus, showing fidelity of the samples obtained, which can be justified by the historical absence of the practice of the cathe, leading to the acidity condition, differently from the other systems evaluated. Therefore, the results obtained show the anthropic influence on the spatial distribution of pH in the soil as a function of the residual effect of soil correction management used in the different systems explored. Also, it is related to the process of soil formation and addition of organic substances as a function of use (Silveira Junior et al., 2014). The variables exchangeable aluminum (Al^{+3}) and H+Al (potential acidity) presented low range value (Table 2), showing that parts of the land present some homogeneity in the spatial distribution inherent to the studied areas. Exchangeable acidity (Al^{+3}) has an inverse relationship with soil pH.

Table 3. Measurements of spatial analysis of soil chemical attributes, in different agricultural uses, at a depth of 0-20 cm.

Chemical attributes	Mode	Nugget effect (Co)	Landing (Co+C)	Ao	SPD	Classification	r^2
pH em $CaCl_2$	Spherical	0,00	0,58	74,6	1,00	Strong	0,09
P ($mg.dm^{-3}$)	Exponential	0,32	2,83	33,0	0,89	Strong	0,00
K^+ ($cmol_c dm^{-3}$)	Linear	1.574,40	1.574,40	452,9	0,00	Low	0,70
Ca^{+2} ($cmol_c dm^{-3}$)	Spherical	0,00	2,05	53,7	1,00	Strong	0,01
Mg^{+2} ($cmol_c dm^{-3}$)	Gaussian	0,12	0,20	364,7	0,57	Moderate	0,47
H + Al ($cmol_c dm^{-3}$)	Gaussian	0,17	1,86	683,64	0,91	Strong	0,88
SB ($cmol_c dm^{-3}$)	Linear	4,18	4,18	216,41	0,00	Low	0,00
$CTC_{7,0}$($cmolc.dm^{-3}$)	Spherical	0,01	3,19	85,2	1,00	Strong	0,12
V (%)	Spherical	0,10	35,44	73,8	1,00	Strong	0,16
MO (%)	Exponential	0,30	2,83	33,0	0,9	Strong	0,01

Ca = Calcium, Mg = Magnesium, K = Potassium, P = Phosphorus, Al = Aluminium, Co = Nugget effect, Co + C = Landing, Ao = Reach, [Co/(Co+c)]x100 = Contribution of the nugget effect (%), SPD= Degree of Spatial Dependence, r2 = coefficient of determination.

The present study generated an isoline map for the phosphorus element, revealing spatial variability of P at different levels of intensification of pasture production systems, differing from that reported by Silveira Junior et al., 2014. The authors reported a lack of adjustment of the semivariogram to P due to the randomness of the distribution of this nutrient, and it was not possible to perform kriging. Also, the p range was classified as strong, revealing variation between uses (Figure 2). The P distribution presented mean values of 3.40 $mg.dm^{-3}$ classified as low (Sousa and Lobato, 2004), with point values ranging from 1,5 to 9,0 $mg.dm^{-3}$, showing that the land presents low availability for this element. The area with conventional pasture presented minimum values; While the maximum values were verified in the irrigated pasture. The study demonstrated that the intensification of animal production to pasture leads to a small increase in the availability of P in the soil. As it is a system of lower productivity, the conventional system of pasture exploitation receives little contribution of organic phosphorus, due to lower biomass production, justifying lower levels. In addition, it is worth mentioning that much of the P in the soils of *Cerrado* is in the non-labile form. This is mainly due to the covalent type bonds formed in the internal sphere complex, making it unavailable to plants. According to Silva et al. (2010), the soil capacity factor is reduced due to the high bonding energy, reflecting low levels of the element in solution, which are usually insufficient to meet the needs of the plants.

The percentage of soil organic matter (M.O) was higher in the Livestock Crop Integration area, while the lowest percentage was observed in the irrigated pasture area (Figure 2). The accumulation of organic matter in Crop and Livestock Integration can be explained by the fact that in this place it provides higher biomass production from the litter of the crop in successive cultivation cycles.

The incorporation of trees in pastures in the Amazon region brings several benefits related to more significant deposition of biomass by trees, promoting increased organic matter, and consequently improving soil fertility, through nutrient cycling, which results in the reduction of the inputs (Xavier et al., 2003).

A certain irregularity was observed in the distribution of soil M.O in the conventional pasture área. The management adopted in a system close to extractivism, as well as uniformity of chemical attributes in the irrigated area was expected by intensification management with higher grazing pressure. This fact reveals problems probably related to stocking rate, grazing pressure, and grazing efficiency, accelerating the degradation of organic residues, and reducing root growth due to the depletion of plant reserves (Silveira Junior et al., 2014).

The Ca^{2+} contents in the soil presented on average 8,25 cmolc.dm^{-3} (Table 2), classified as high (Sousa and Lobato, 2004). The minimum and maximum values range from 4.3 to 9.9 cmolc.dm^{-3}, with the lowest values found in the system run in conventional pasture and the maximum in irrigated pasture. As the Ca:Mg ratio increases in the soil, there is a decrease in Mg^{+2} availability, due to the greater preference of Ca^{2+} for attraction in exchange complexes, due to the smaller hydration radius. Thus, the excess of Ca^{2+} in relation to Mg^{2+} in the soil solution can impair the absorption of this (Medeiros et al. 2008). Ok

The average soil content of 2.1 cmol$_c$.dm^{-3} (Table 2) was observed when verifying the Mg^{2+} contents. - and classified as high. With values ranging from 1,3 to 3,6 cmol$_c$.dm^{-3}, the lowest values verified in the conventional grazing management system and the maximum values in the irrigated pasture. The K^+/Mg^{+2} ratio found in the study area (Sousa and Lobato, 2004).

Although the Variable K^+ presented linear effect and consequent pure nugget effect, revealing error greater than spatial dependence, due to uniformity between the different uses, the mean potassium content in the study area was 65,25 mg.dm^{-3} , which was classified as adequate (Sousa and Lobato, 2004). With values ranging from 32 to 284 mg.dm^{-3}, presenting the lowest value in the conventional pasture area and the maximum value found in crop and livestock integration. This behavior is due to the introduction of soil in the cultivation system, modifying the soil export pattern by the root system because they are deeper roots that acquire nutrients in greater depth and deposit on the surface in the decomposition process. Ok

Sousa e Lobato (2004) points out that besides the availability range, potassium sufficiency is evaluated through the percentage of saturation of this nutrient in soil CTC Exchangeable potassium is still the best rate of availability for plants. However, it is recommended not to exceed the limit of 3% of CTC by potassium, if the preference is to use the percentage of CTC saturation of the soil with potassium for soils originating in the *Cerrado*. Otherwise, the potential for this nutrient loss by leaching is significant, particularly in quartz sands (Raij, 1991). Potassium, calcium, and magnesium found naturally in tropical soils result from the dissolution of primary minerals and soil formation processes, resulting from the weathering of the source material (Benites et al., 2010). Initial availability is the result of mineralogical composition that causes losses by leaching and/or erosion or by exploration by plants after assimilation. The high levels of potassium, calcium and magnesium are possibly linked to soil formation, originated in basaltic rocks. Soils of this hue have a large mineralogical reserve of these elements, in addition to the fraction of expandable clay minerals with high cation exchange capacity. as shown in the results of the analyses. It allows the adsorption of cations in the exchange complex, reducing the phenomenon of leaching, which is problematic for highly sandy soils, reduced organic matter and low-activity clay.

The monoamonic phosphate fertilizer (MAP) with 48% P_2O_5 was used as a recommendation for phosphorus correction of the soil considering an utilization efficiency of 20% (Figure 4B). Falcão and Silva (2014) estimate that only 5 to 25% of soluble phosphorus added to the soil is used by crops, .The remainder is fixed through specific covalent adsorption mechanisms, making it unavailable for the plant (Novais and Smyth, 1999).

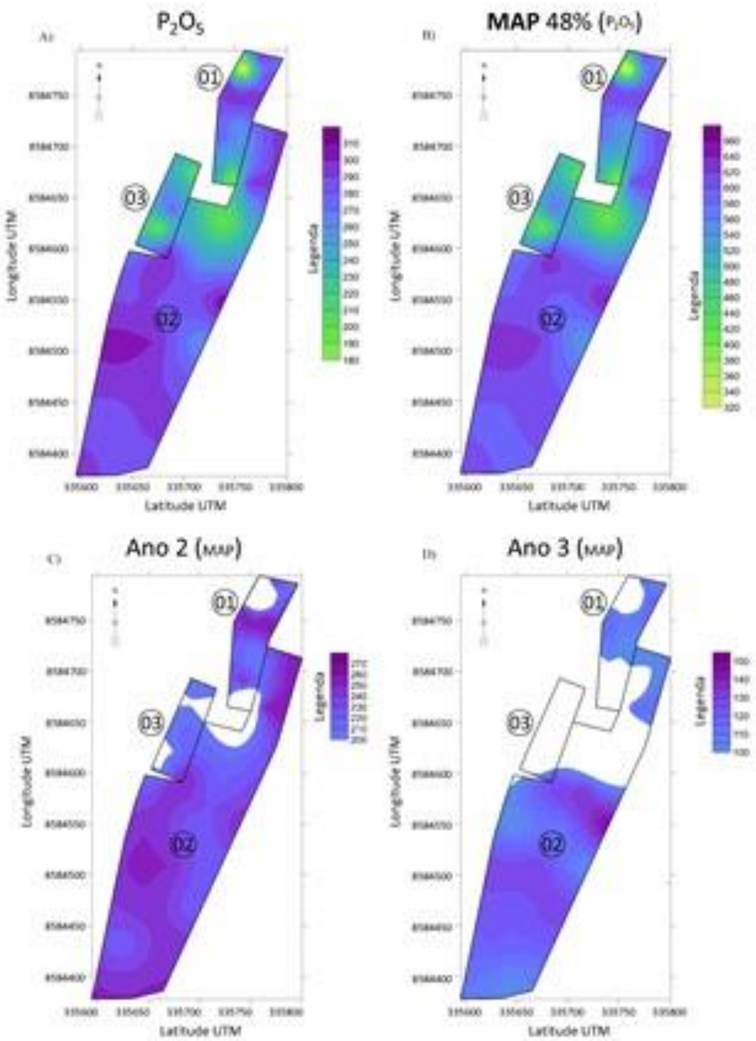

Figure 4. (A) Need for P2O5 to increase adequate levels of phosphorus availability. (B) Need for MAP to raise adequate levels of phosphorus availability. (C) MAP recommendation for Year 02. (D) MAP recommendation for Year 03. Aroeira Farm, Combined - TO, (2018).

In the first cycle, the addition of 300 kg ha-1 of MAP was recommended in the total area. In contrast, the second and third cycle recommendations are presented in figures 4C and 4D, respectively. The plotting in P fertilization aimed to dilute the costs with the total correction of availability levels since, in most of the sampled conditions, the soil presented low availability of the element. Gradual corrective fertilization can be practiced when there is no capital to correct phosphorus in only one operation, a common situation in poor or clayey soils to very clayey (Sousa et al., 2004).

Due to the existence of spatial variability in phosphorus attributes and with the aid of geostatistical tools, it was possible to generate management maps that meet the specific needs for nutrient correction. The surface maps allow the appropriate management for the micro-regions, indicating priority areas of management and that need more attention. In this case, the phosphorus correction plan is based on increasing the nutrient availability at the sampled or estimated points. This is done to homogenize the total availability. This variable rate application strategy can allow greater savings and better planning in the acquisition of inputs, better control and distribution of fertilizers, with the ultimate objective of higher productivity. Kriging maps are tools that allow accurate localization with areas of low phosphorus availability, which would be impossible with average data, as observed by Freddi et al., (2006), for grain yield.

CONCLUSION

The variability analysis of soil chemical attributes revealed different patterns for the different attributes in the Cambisol Haplastic Ta Eutrophic, which allowed identifying a distinction between management methods and their interference in soil fertility, especially for the phosphorus element.

The application of Geostatistics proved to be efficient in representing and understanding the spatial variability of the chemical attributes studied, enabling the elaboration of a fertility management plan.

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