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Diagnosis of soil fertility for possible use in precision agriculture

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Abstract:*The present work aims to make the diagnosis of soil fertility for possible use in precision agriculture, in a central pivot production area, in the municipality of Sandolândia, in the south of the state of Tocantins.In the property and soil sampling in grid of 2.0 ha with georeferenced points accounting for 44 composite samples, with the purpose of generating thematic maps for fertilizer and corrective application at varied rate.Soil samples were collected in the years 2017 and 2019, at a depth of 0 to 20 cm, collecting 5 simple samples to generate a complete sample. The samples for each year were sent to the soil laboratory to measure the contents of phosphorus, sulfur, calcium, magnesium, potassium, hydrogen plus aluminum and hydrogenic potential.Starting from the mean of each soil attribute, in a comparison with the year 2017, the year 2019 suffered a significant decrease. It is noted that the values of the means and medians have a proximity, making the normal distribution evidenced. The area under study has great potential for use in precision agriculture, in which it will be possible to perform geostatistical techniques and map processing forming management zones for the application of inputs at varied rate.*

Keywords:*geostatistics, mineral nutrition, spatial variability, temporal variability*.

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I. INTRODUCTION

The modernization of agriculture can be defined as the search for improvement of production, through the adoption of modern techniques aimed at greater productivity of land and labor. At the same time, there is a greater need in the demand for food and products from agriculture, in which it is necessary to optimize agricultural production for sustainability and food security (Molin et al., 2015).

Precision agriculture (PA) can be defined as the use of agricultural practices based on information technologies for the treatment of spatial variability. And it can be understood as a cycle that begins in data collection, analysis and interpretation of this information, generation of recommendations, application in the field and evaluation of results (Gebbers andAdamchuk, 2010). The first productivity map derived from a GPS-coupled yield monitor was produced in Germany in 1990 from a canola culture (Schnug et al., 1991). Since then, precision agriculture has become accessible to producers, with the emergence of various equipment and technologies.

U.S. grain and cotton producers dominated the technologies and expanded activities with AP. According to Griffin and Lowenberg-DeBoer (2005), in the early 2000s, about 90 percent of the world's productivity monitors were in operation in the U.S. In about 28% of the planted corn area and 22% of the soybean planted area, the yield was monitored with these equipments (Winstead et al., 2010). The main factors for the adoption of PA technologies in the USA were the increase in the efficiency of production systems, with the optimization of costs through the application of fertilizers at the variable rate (Godwin et al., 2003; Doerge, 2005) and maximizing income (Kitchen, 2008).

The set of geoprocessing, or geotechnologies that include technologies for collecting, processing, analyzing and providing information with geographic reference, has great potential for management of agricultural and livestock production (Batistella et al., 2011; Filippini Alba, 2014). The modeling via geographic information system (GIS) enables the fusion of these layers of information, expanding the capacity of interpretation of the data and assisting in decision making for the management of the production system (Filippini Alba, 2014).

In the past, the high price and lack of technical knowledge have made precision agriculture restricted only to large farmers. But in recent years, with research developed and the technologies that form the basis of precision agriculture, which are GPS and GIS, today are fully accessible to the small and medium producer. And this is tied to both price and technical issues, since the training is simple, cheap and often provided free of charge by the same company that sells the equipment (Jacto, 2020).

The chemical analysis of the earth is one of the most used resources in Brazil to evaluate soil fertility. By means of chemical extractors, it is sought to determine the degree of sufficiency or deficiency of the elements in the soil, besides quantifying adverse conditions that may impair plant development (Raij, 1983). Inamasu and Bernardi (2014) confirm that the vast majority (93%) producers who adopt the PA uses this tool.

With this in mind, it is necessary to pre-monitor soil attributes to make inferences regarding soil nutritional status and the use of geostatistical techniques and application at a varied rate.

In view of the above, the present work aims to make the diagnosis of soil fertility for possible use in precision agriculture, in a central pivot production area, in the municipality of Sandolândia, in the south of the state of Tocantinsin the years 2017 and 2019.

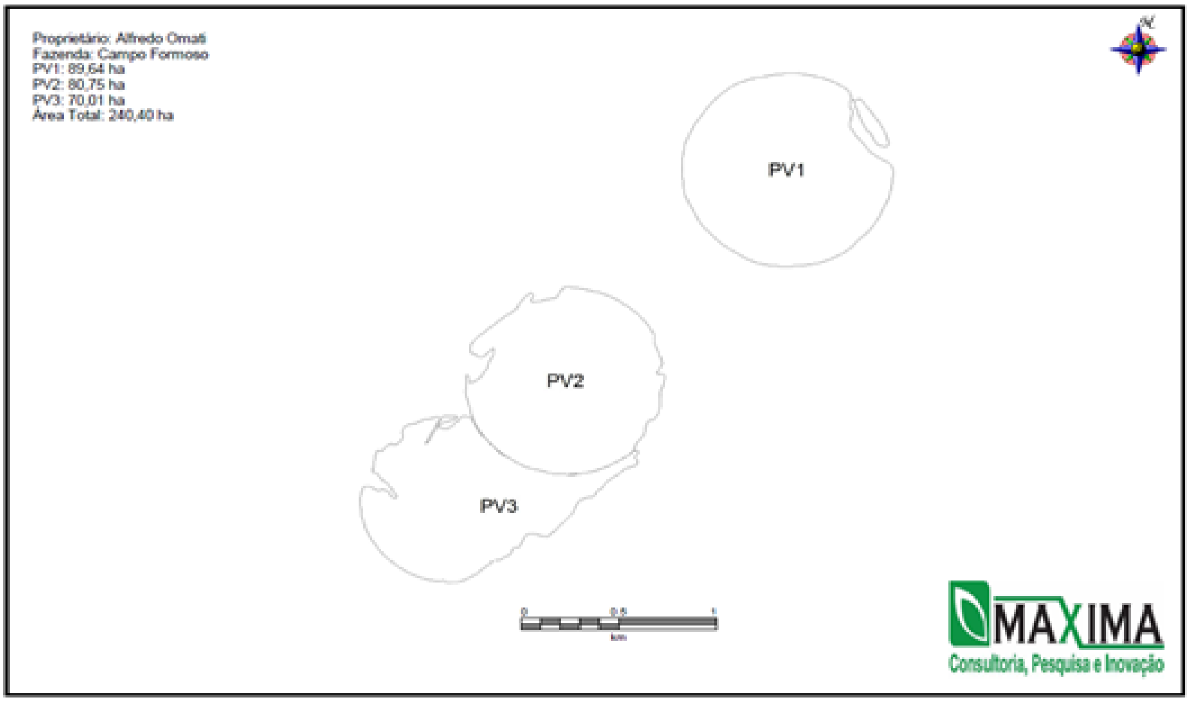
II. EXPERIMENTAL PROCEDURE

The present work was carried out from Julyto November 2017 and 2019, at Campo Formoso Farm, located in the municipality of Sandolândia - TO, coordinates 12°33'26.49"S and 49°51'43.24"O, to the left of highway TO 181 under consulting and partnership of the company MáximaConsultancy, Research and Innovation. It has a current cultivation area of 240.40 hectares of soybean production, and this area is irrigated with three pivots. The soil management adopted is the no-tillage system, the mean annual rainfall is 1,641 mm, with an altitude of 248 meters.

In the property and soil sampling in grid of 2.0 ha with georeferenced points accounting for 44 composite samples, with the purpose of generating thematic maps for fertilizer and corrective application at varied rate. For the development of the present study, pivot 1 (PV1) (Figure 1) data were used in which the area was measured and georeferenced points were collected with GPS.

According to Pires (2017), measurements made with these applications, when activities do not require high precision, can serve as a basis for planning the collection of georeferenced data for the realization of rural environmental records, preparation of thematic maps, division of areas, among other possibilities.

Figure1. Production area of campo formoso farm, municipality of Sandolândia - TO.



Source: Máxima Consultancy, Research and Innovation(2019).

Each year, soil samples were collected at a depth of 0 to 20 cm, collecting 5 simple samples to generate a complete sample, with the aid of a Stihl Bt 45 model motor with a drill coupled to a base that is in the ground

(Figure 2), with a circle where the drill is placed. With the drilling movement of the soil, in the removal of the implement the loose soil accompanies the movement of the drill and is collected in the collection base.

Figure2. Engine for collection, drill drill and soil sample collection base.

The samples were packed in plastic bags, identified and sent to the soil laboratory to measure the contents of phosphorus (P), sulfur (S), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), hydrogen plus aluminum (H^{+}+Al^{3+}), hydrogenic potential (pH), sum of bases (SB), total cation exchange capacity [CTC(T)]the pH 7.0, and base saturation (V%).The data obtained were submitted to descriptive statistical analysis and the Surfer 8 program (Golden Software, 2002) was used.

III. RESULTS AND DISCUSSIONS

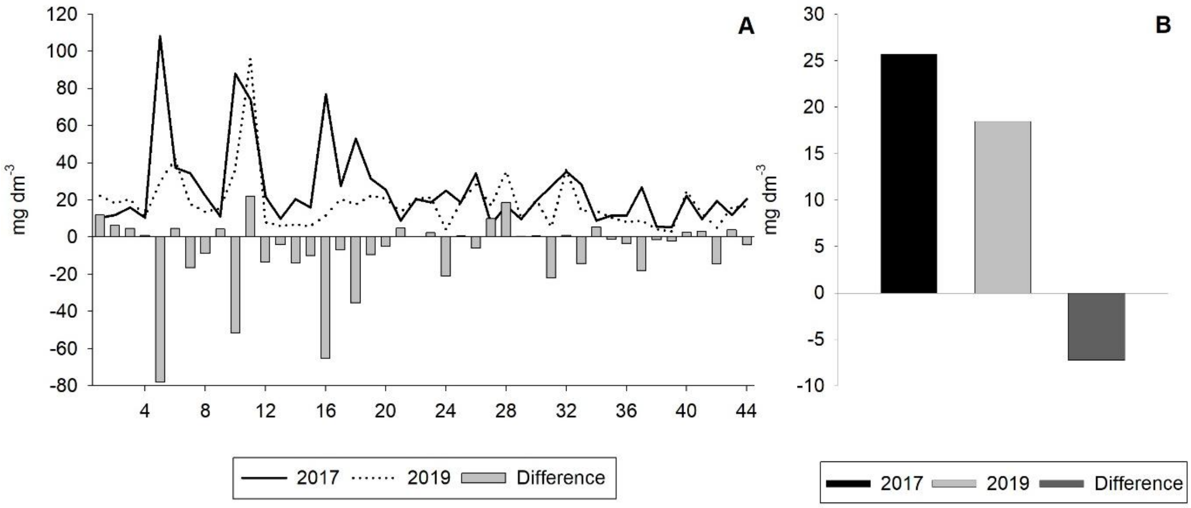
3.1. Phosphorus

Analyzing figure 3-A, for the phosphorus nutrient, more than 50% of the sampled points decreased the levels when compared to 2017 and 2019. The decrease was approximately 7.2 mg dm^{-3}, considering the mean of all the points sampled in the two years of sampling, as shown in Figure 3-B.

For adequate nutrition of soybean crop in braziliancerrado soils, it is necessary to use high fertilizer doses, due to the predominance of highly weathered soils, characterized by low nutrient availability to plants. In these soils, phosphorus deficiency is intense due to adsorption and the formation of precipitates with iron and aluminum (Bedin et al., 2003). Thus, phosphorus is the nutrient that most limits productivity in most of these soils and there is a need for frequent fertilization. According to Prado (2008), the main role of phosphorus in plant physiology is to provide energy for biosynthetic reactions and plant metabolism.

Acccording to the levels of phosphorus in 2019, it is necessary to carry out corrective and maintenance fertilization. To increase the levels to the point of maximum economic efficiency of the crops and replace the amount of extracted nutrients and losses (SociedadeBrasileira de Ciência do Solo, 2004).

Figure3. Difference between phosphorus contents at each sampling point (A) and mean values (B)



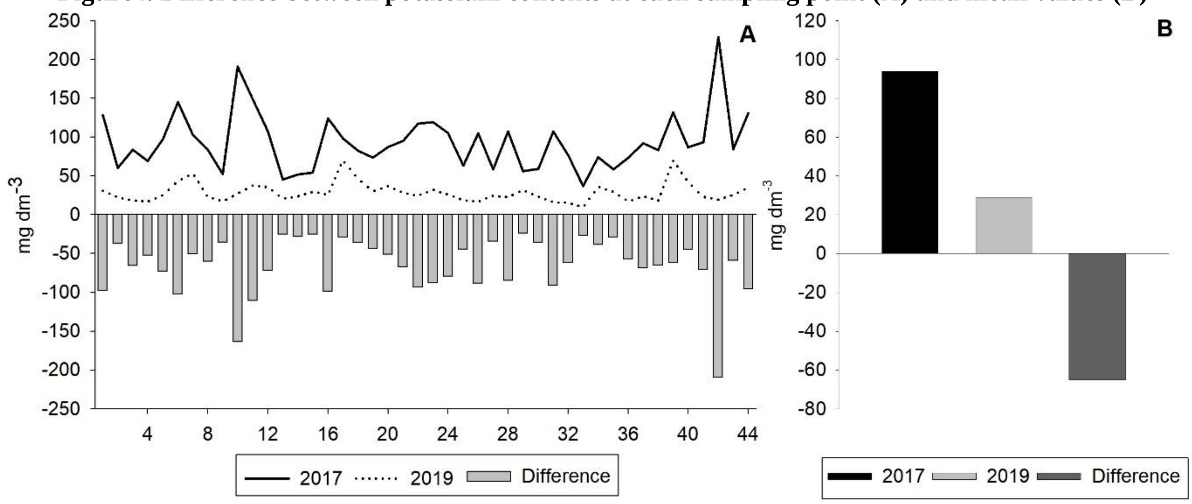
3.2. Potassium

Analyzing figure 4-B for the potassium nutrient, the decrease was approximately 65.27 mg dm^{-3}, considering the mean of all the points sampled in the two sampling years.K^+content in 2017 was considered good and in 2019 was low or not sufficient (Ribeiro et al., 1999).

Soil potassium, in turn, is formed by solution K, exchangeable K, non-tradable K (fixed) and structural K, and K supply to plants comes from the solution and soil colloid exchange sites, which are in balance with non-tradable K and mineral structural K (Sparks anf Huang, 1985). According to Marschner (1995), potassium is the second mineral nutrient required in greater quantity by plant species, after N, and has high mobility in the plant, in any concentration, whether within the cell, in plant tissue, in xylem or in phloem.

Acccording to the potassium content in 2019, it is necessary to carry out corrective and maintenance fertilization. To raise the levels to the critical threshold, and replace the lossesand the amount extracted by the culture (SociedadeBrasileira de Ciência do Solo, 2004).

Figure4. Difference between potassium contents at each sampling point (A) and mean values (B)



3.3. Calcium/MagnesiumRatio

In the Figure 5-A we have the calcium/magnesium ratio, in the two years of sampling, it is noted that the values of the relationship increased significantly when compared to the year 2019 with the year 2017. Taking as a parameter the means of all points sampled in each year, we have anmean increase of 1.1 $cmol_c$ dm^{-3} from the year 2017 to the year 2019.

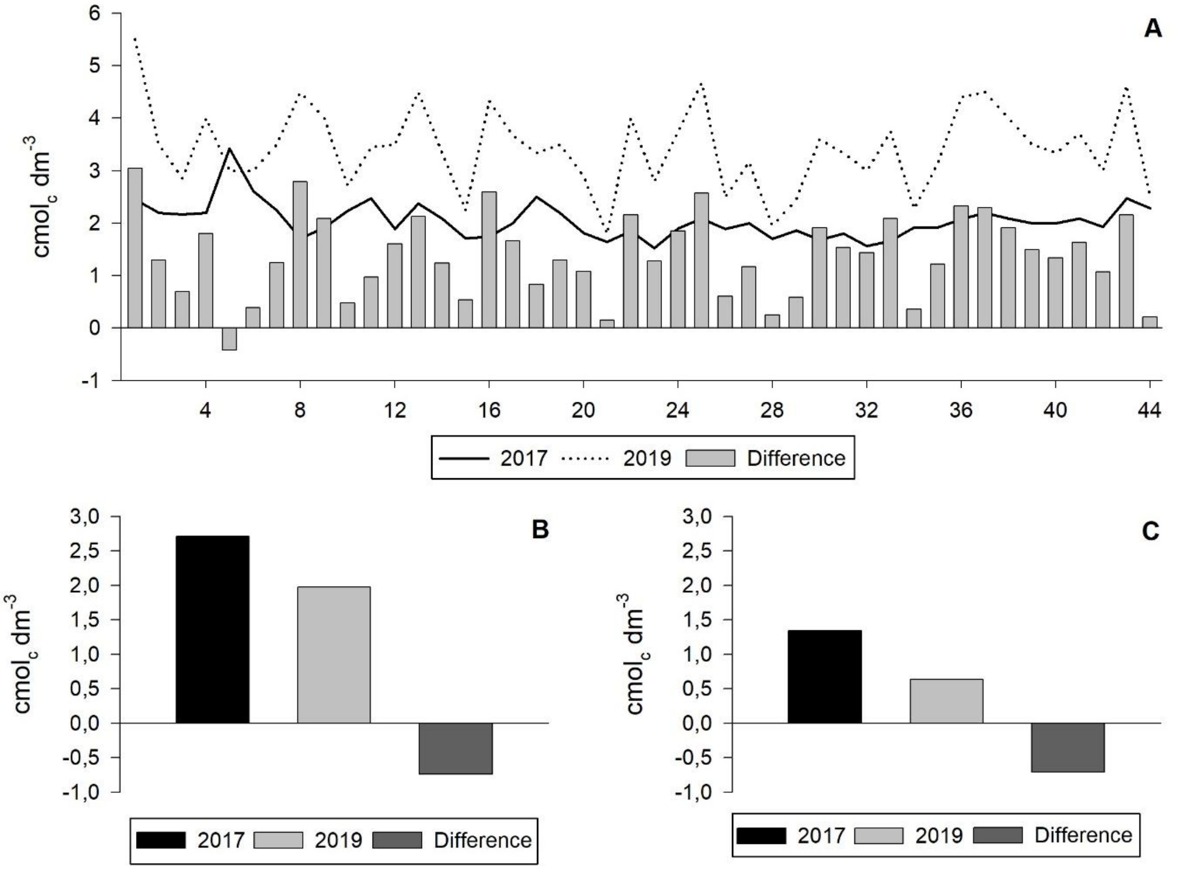
According to Figures 5-B and 5-C, there is a reduction in the mean of calcium and magnesium contents of the sampled points. The decline presented in Ca^{2+} is 0.74$cmol_c$ dm^{-3}. Since the mean values go from 2.71 (2017) to 1.98 $cmol_c$ dm^{-3}(2019) approximately. In relation to Mg^{2+}, the decline was 0.71, from 1.34 (2017) to 0.63

$cmol_c dm^{-3}$(2019). According to Malavolta and Kliemann (1985), there is an interrelation between the nutrients mentioned.

Comform Ribeiro et al. (1999), in relation to the means presented in 2017, the levels of Ca^{2+} and Mg^{2+} were considered good or sufficient. Already in 2019, this classification fell to medium.

The interrelation between calcium and magnesium nutrients in plant nutrition is related to their close chemical properties, such as ionic radius, valence, degree of hydration and mobility, causing competition for adsorption sites in the soil, and absorption by roots. As a consequence, the presence of one can impair the processes of adsorption and absorption of the other, a fact that occurs for the ions $Ca^{2+}$and Mg^{2+} (Orlando Filho et al., 1996). Excess calcium in relation to magnesium in the soil solution may impair the absorption of the soil, as well as excess magnesium also impairs calcium absorption (Malavoltaand Kliemann, 1985).

Figure5. Difference between calcium/magnesium ratio at each sampling point (A), mean of calcium (B) and mean of magnesium (C)



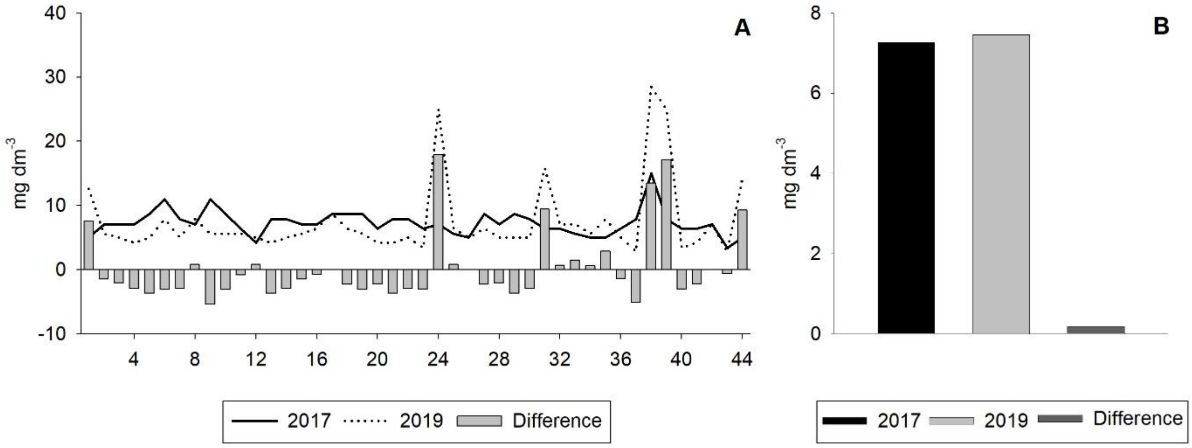
3.4. Sulphur

Based on Figure 6-A, the reduction of sulfur levels per sampled point is noted, in some points, such as P24, P31, P38, P39 and P44, sulfur levels increased, however, the explanation would be that the sampling coincided with an agricultural gypsum stain, so the values extrapolated the mean of the points.

According to Figure 6-B, when compared to 2017 and 2019, we have a small increase in sulfur content in the mean sampled points. Considering the cultural treatments made on the property, the application of agricultural gypsum was performed, so even the extraction of the nutrient by the crops cultivated in this period of time was not enough to lower the mean of the same.

The maintenance of adequate levels of organic matter ensures the gradual supply of S to plants through mineralization. However, land use inadequately, resulting in decreases in organic matter content, associated with the use of surface correctives and concentrated fertilizers with absence of S, and exports of this element by harvests reduce the availability of S. In this context, the probability of response of agricultural crops to sulfated fertilization increases, in addition to making areas deficient in S (Jordan andEnsminger, 1958; Elkins &Ensminger, 1971).

Figure6. Difference between sulfur contents at each sampling point (A) and mean values (B)



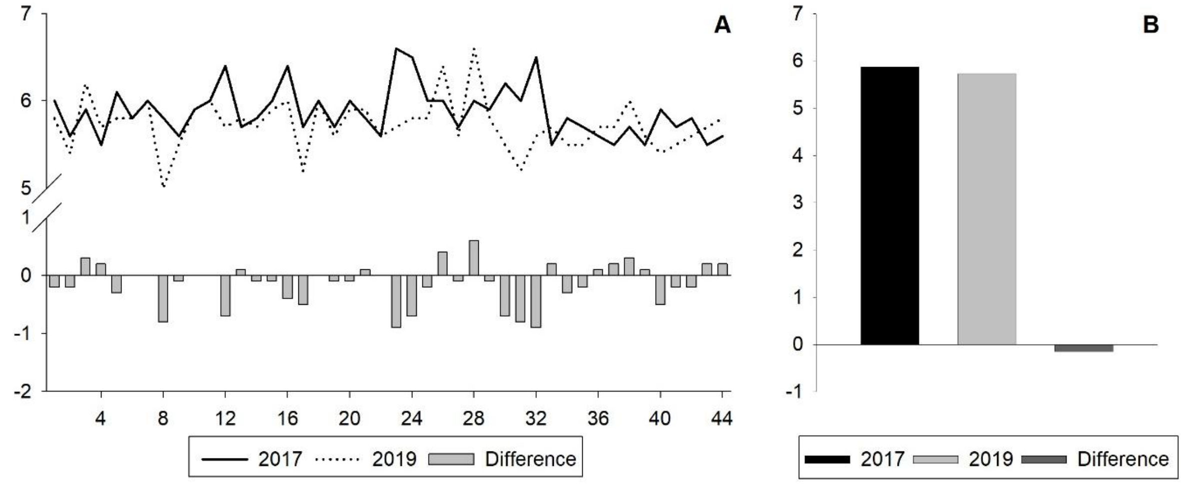
3.5. HydrogenicPotential

Analyzing Figure 7-A, the behavior of pH values had little variation, because when we analyzed Figure 7-B, we noticed that this variation, when compared to 2019 and 2017, was only 0.15 in the mean pH value of the sampled points.

Acidification of cultivated soil is an ongoing process. The frequent mobilization of the soil, the large nuber of annual crops (three or more), the use of irrigation and the application of large quantities of fertilizers, are factors that contribute to accelerate this acidification process (SociedadeBrasileira de Ciênciado Solo, 2004).

Acidic soils present problems for agriculture because plants do not develop well in these acidity conditions. The availability of nutrients is very small for plants, consequently crop productivity is very low.

Figure7. Difference between hydrogenic potential values at each sampling point (A) and mean values (B)



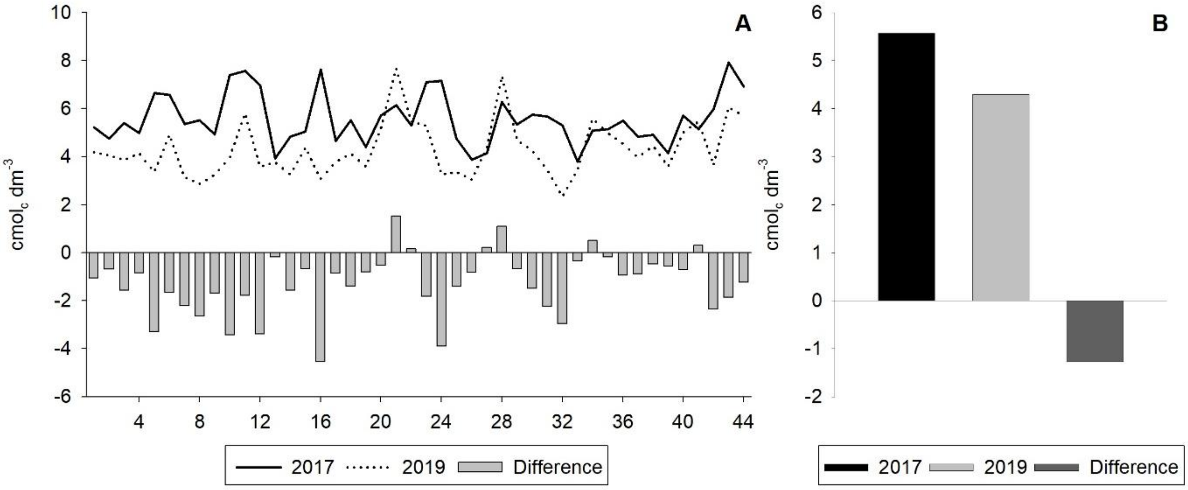
3.6. Total Cation Exchange Capability

The mean reduction of CTC(T) of the sampled points, when compared to the two years of sampling, was approximately 1.3 $cmol_c$ dm^{-3}. The mean of 2017 (5,57 $cmol_c$ dm^{-3}) was classified as medium, and with this decrease, in 2019 (4,30 $cmol_c$ dm^{-3}) was for low (Ribeiro et al., 1999).

The cation contents Ca^{2+}, Mg^{2+} and K^{+} analyzed previously, severely reduced in their contents, when compared to the year 2017 with 2019, this consequently interferes in the cation exchange capacity, which is the result of the sum of these, which form the sum of bases, with H^{+} and Al^{3+}. It is therefore concluded that if the cation contents decreased, as a result the CTC(T) will also decrease, this behavior is observed.

In tropical soils, 70% to 80% of total CTC(T)is related to negative MOS charges (Luz et al., 2005). Therefore, the increase of MOS and the cycling of nutrients are fundamental, both in the retention and in the reduction of nutrient leaching, also increasing the cation exchange capacity of the soils.

Figure8. Difference between total cation exchange capacity valuesat each sampling point (A) and mean values (B)

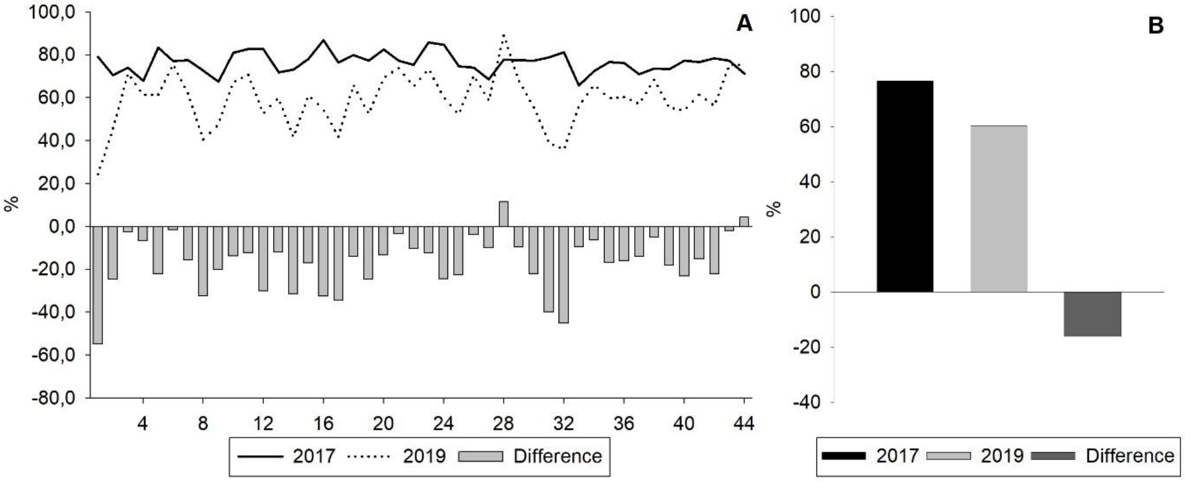


3.7. Base Saturation

There was a decrease in base saturation when compared to 2017 and 2019. The mean decrease in the sampled points was 16,18% in 2019, when compared to 2017 (Figura 9). According to Ribeiro et al. (1999), both in 2017 (76,51%) and in 2019 (60,32%) the means were considered good.

Base saturation is the ratio between the sum of the bases (Ca^{2+}, Mg^{2+} and K^{+}) and the total CTC (Ca^{2+}, Mg^{2+}, K^{+}, H^{+} and Al^{3+}), expressed as a percentage. It is also known that there is a positive correlation between pH and V% (Catani and Gallo, 1955; Raij et al., 1968), relationship is so close, that talking about increasing base saturation means increasing soil pH (Raij, 1983).

Figure9. Difference between base saturation valuesat each sampling point (A) and mean values (B)



3.8. Descriptive statistics

Starting from the mean of each soil attribute (Table 1), in a comparison with the year 2017, the year 2019 suffered a significant decrease.

It is noted that the values of the means and medians have a proximity, making the normal distribution evidenced, this fact was confirmed in the Kolmogorov-Smirnov test (KS) at 5% (Carneiro et al., 2016). The coefficients of variation (CV), asymmetry (Cs) and kurtosis (CK) were used to evaluate whether the characteristics analyzed followed a normal distribution. Only K^{+} presented a variation that does not fit the coefficients mentioned above. According to NegreirosNeto et al. (2014),since the coefficients should be null, but results with a variation of +2 or -2 are acceptable.

It is also observed that the P obtained the highest CV in relation to the other characteristics, meaning that there is a constant variation in the P contents in the soil, regardless of the years evaluated, being sensible the use of the application of inputs in varied rate for greater homogenization of these contents in total area.

Table1. Descriptive statistics of the chemical attributes of the Red Latosol, Campo Formoso Farm, located in the municipality of Sandolândia - TO.

Attributes	Mean	Median	Minimum	Maximum	Amplitude	Coefficient			KS
						CV	Cs	Ck	
2017									
pH $CaCl_2$	5,88	5,80	5,50	6,60	1,10	4,86	0,86	0,34	0,17
CTC(T)	5,57	5,35	3,79	7,92	4,13	19,18	0,51	-0,41	0,14
V%	76,51	77,18	65,6	86,87	21,17	6,40	-0,03	-0,17	0,10
SB	4,29	4,14	2,49	6,62	4,13	24,15	0,58	-0,35	0,12
$H^{+}+Al^{3+}$	1,27	1,30	1,00	2,00	1,00	16,81	1,18	2,24	0,15
P	25,72	20,00	5,30	108,00	102,70	86,57	2,21	4,94	0,23
K^{+}	93,95	87,10	37,00	229,00	192,00	40,04	1,40	3,16	0,13
S	7,27	7,10	3,40	15,00	11,60	27,11	1,36	4,66	0,17
Ca^{2+}	2,71	2,60	1,50	4,20	2,70	25,34	0,71	-0,10	0,17
Mg^{2+}	1,34	1,30	0,80	2,30	1,50	26,60	0,92	0,68	0,14
2019									
pH $CaCl_2$	5,73	5,70	5,00	6,60	1,60	5,07	0,35	1,78	0,13
CTC(T)	4,30	4,09	2,34	7,67	5,33	26,473	1,03	1,20	0,11
V%	60,32	60,77	35,90	89,13	53,23	18,624	-0,13	0,15	0,08
SB	2,68	2,55	0,84	6,56	5,72	43,086	1,28	2,26	0,16
$H^{+}+Al^{3+}$	1,62	1,60	0,80	2,30	1,50	20,587	-0,12	0,08	0,11
P	18,47	16,25	3,00	96,00	93,00	82,405	3,27	15,24	0,22
K^{+}	28,68	25,25	10,00	70,10	60,10	44,585	1,70	3,50	0,15
S	7,46	5,60	2,80	28,50	25,70	77,283	2,60	6,37	0,31
Ca^{2+}	1,98	1,85	0,60	4,30	3,70	39,885	0,89	0,82	0,14
Mg^{2+}	0,63	0,50	0,20	2,20	2,00	63,807	2,31	6,62	0,19

CTC(T): total cation exchange capacity; V%: base saturation; SB: sum of bases; $H^{+}+Al^{3+}$,: potential acidity; P: phosphorus in mg dm^{-3}; K^{+}: potassium in mg dm^{-3}; S: sulfur in mg dm^{-3}; Ca^{2+}: calcium in $cmol_c$ dm^{-3}; Mg^{2+}: magnesium in $cmol_c$ dm^{-3}; CV: coefficient of variation (%); Cs: asymmetry coefficient; Ck: short coefficient; KS: Kolmogorov-Smirvov normality test.

IV. CONCLUSION

The area under study has great potential for use in precision agriculture, in which it will be possible to perform geostatistical techniques and map processing forming management zones for the application of inputs at varied rate.

Conflict of interest

There is no conflict to disclose.

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