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SOIL ORGANIC MATTER FRACTIONS AND MULTIVARIATE ANALYSIS IN THE DEFINITION OF PASTURE MANAGEMENT ZONES

Eudocio R. O. da Silva[1], Marcos G. Pereira[1*], Murilo M. de Barros[1], Luise M. M. dos Santos[1], João H. G. Gomes[1]

[1*]Corresponding author. Federal Rural University of Rio de Janeiro (UFRRJ)/Seropédica - RJ, Brazil.
E-mail: mgervasiopereira01@gmail.com | ORCID ID: https://orcid.org/0000-0002-1402-3612

KEYWORDS

geoestatistic, humic substances, k-means clustering, precision agriculture, Tifton 85.

ABSTRACT

The use of Precision Agriculture tools and soil attributes has contributed to local agricultural management in the identification of different productive potentials and quality of pastures. The present study aimed to use Precision Agriculture tools to investigate the spatial variability of soil organic matter fractions and soil chemical and physical attributes and to delineate management zones in pasture soils cultivated under tropical conditions. The study was conducted on a hay production farm located in Seropédica, Brazil. Fifty points were collected on a irregular grid and soil samples were taken at depths of 0-0.20 and 0.20-0.40 m and crop productivity was evaluated. Chemical and physical soil organic matter fractionation was performed to obtain data on fulvic acid, humic and humin fractions, mineral-associated and particulate organic carbon, and light organic matter. Geostatistics and multivariate analysis (principal component analysis and k-means clustering) were performed to define the management zones. The results obtained contributed to the division of the pasture area into two regions that can be managed in different ways aiming to increase soil organic matter in a localized manner with the possibility of reducing the use of inputs and directed management that respects the productive potential of the pasture on the farm.

INTRODUCTION

The advancement of technologies and pasture management are essential to the livestock sector. Pastures are a source of livelihood for more than 800 million people worldwide (Quiroz et al., 2021) and in Brazil they play a high economic role in beef production (Serafim et al., 2021). Globally, grassland soils store more stable carbon (C) than other terrestrial ecosystems, playing a key role in climate change mitigation (Escribano et al., 2020; Raiesi, 2021).

Despite the importance of their conservation and socioeconomic value, Brazilian soils are occupied by large areas of pastures in some degree of degradation, about 130.3 million hectares compared to the 190 million hectares of pastures in Brazil (Oliveira et al., 2019). In the Southeast region of Brazil, this was due to the intense exploitation of these soils in the coffee and sugarcane cycles in the 18th and 19th centuries (Devide et al., 2014), in which most of them are naturally acidic, with low fertility and low soil organic matter (SOM) content.

In tropical regions, pastures for animal production system use mechanized biomass harvest associated with the absence or low levels of fertilization. However, certain forages require high soil nutrient demand, requiring proper management to avoid degradation and loss of plant stand in these soils (Borges et al., 2019).

The SOM is one of the main indicators of soil quality and conditions higher agricultural productivity (Đurđević et al., 2019). Cultivation on pasture soils affects the labile and stable fractions of MOS and can decrease the physical protection of MOS in soil aggregates. These MOS fractions

[1] Federal Rural University of Rio de Janeiro (UFRRJ)/Seropédica - RJ, Brazil.

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contribute to increased cation exchange capacity (CEC), soil nutrient and water retention, and reduced soil penetration resistance (Raiesi, 2021). These aspects demonstrate the importance of MOS in pasture quality, since soil chemical and physical properties are conditioning factors for pasture biomass and its nutritional quality (Moral et al., 2019).

In the context of Precision Agriculture (PA) there are several studies that use total organic C information to assess the spatial variability of SOM, an attribute used as an indicator of changes in responses to soil management. However, the use of this quantitative information alone proves to be limited for management and cultivation practices, requiring other more specific soil size/density fractions that are used as sensitive indicators of changes in soil C reservoirs (Borges et al., 2019).

In pasture areas, the use of PA has contributed to the frontier of precision livestock knowledge (Aquilani et al., 2022) with pasture management and conscious use of agricultural inputs (Moral et al., 2019). The proper management of pasture areas enables the optimization of localized application of inputs and offers subsidies for the recovery of soil fertility and its conservation, demonstrating the potential in the recovery of degraded pastures. However, the evolution and adoption of PA practices in pasture areas for grass cultivation and hay production is lower compared to other crops, such as grains. And knowledge is even less regarding the use of SOM fractions in this context, such as the use of chemical fractions (humic substances) and physical fractions of SOM.

The investigation of the spatial variability of soil attributes and the definition of management zones (MZ) are PA approaches that have been used to indicate site-specific management on the farm. The definition of MZ in crops using multivariate statistical analysis is a growing approach in the literature, in which unsupervised learning clustering algorithms such as Principal Component Analysis (PCA), Fuzzy C-Kmeans and K-Means can be applied (Schemberger et al., 2017; Ohana-Levi et al., 2020; Moharana et al., 2020; Denora et al., 2022).

Few studies have investigated the spatial variability of SOM fractions as indicators of site quality (Silva et al., 2017; Costa et al., 2018) and defined pasture management zones using these soil attributes for farm specific management. This work contributes to the development of studies in the area as a function of incorporating PA techniques associating them with quality SOM contents in grassland areas, providing an approach with potential for localized management in the area using soil attributes that are strongly affected by land use change. Therefore, it was hypothesized that soil attributes along with SOM fractions can be used to determine management zones in a pasture area. From the above, the present study aimed to use PA tools to investigate the spatial variability of SOM fractions and soil chemical and physical attributes and delineate management zones in cultivated grassland soils under tropical conditions.

MATERIAL AND METHODS

Study area

The study was conducted at Feno Rio Farm (22° 47' 27.68" S and 43° 40' 49.24" W), located at the Seropédica, Rio de Janeiro, southeastern Brazil. The climate of the region is tropical humid (Aw, according to Köppen's classification), with average annual temperature of 24 °C and average precipitation of 1260 mm. The experimental area is 3.91 ha, with mean altitude of 26 m, flat relief and soil classified as *Argissolo Vermelho-Amarelo distrófico típico* (Ultisol). It was observed that the experimental area is located at a low point of the landscape, consisting of an allochthonous soil, formed by sediments from higher points. In addition, it has a Tifton 85 grass (*Cynodon* spp.) cultivation system for hay production with crop cycles throughout the year, with correction of the acidity of soils of this region through the conventional only one rate application of liming according to Freire et al. (2013).

Fifty points were collected in an irregular grid and random sampling to capture the local variability, georeferenced using Total Leica Station, TPS300 Basic Series. In each sampling point, disturbed soil samples were collected at depths of 0-0.20 and 0.20-0.40 m (Figure 1).

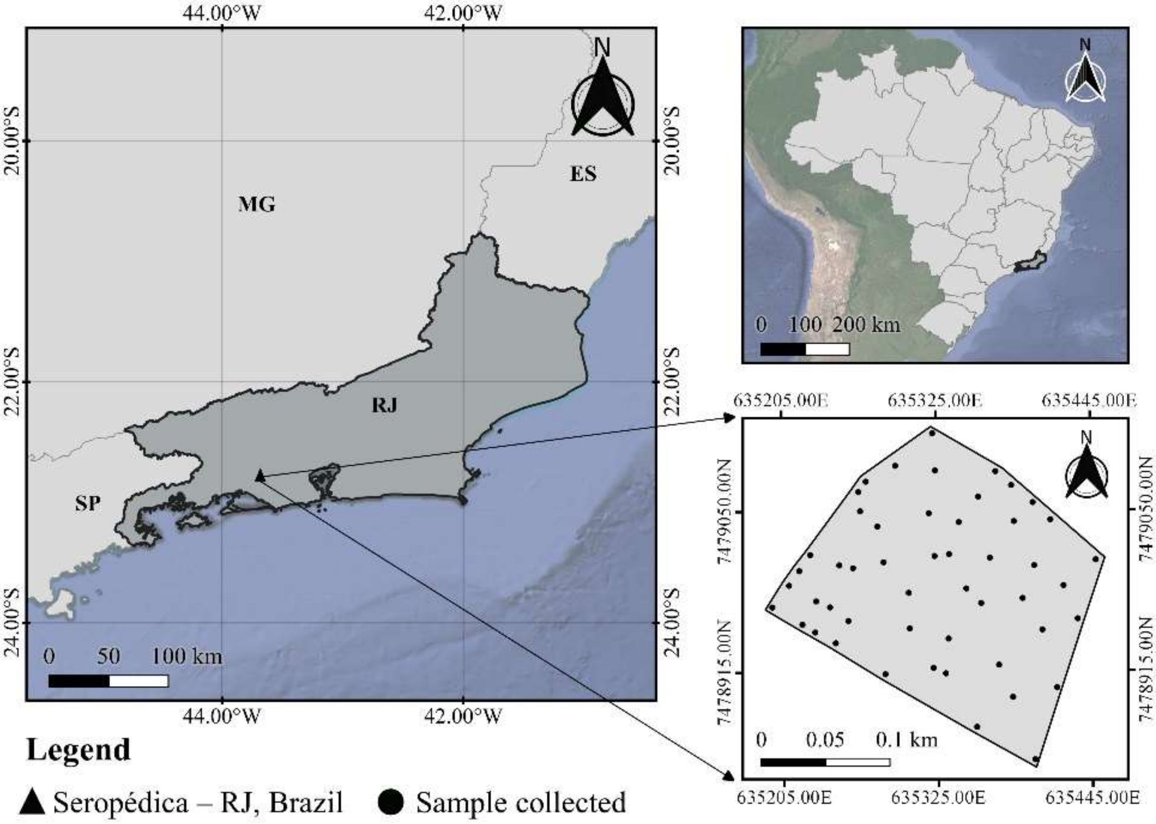

FIGURE 1. Experimental area located in the municipality of Seropédica-RJ and spatial distribution of georeferenced points in the Tifton 85 cultivation area.

Analysis of attributes and database construction

The samples were air dried, pounded to break up clods and passed through a 2.00-mm-mesh sieve to obtain the air-dried fine earth (ADFE). Data on pH, using soil in water (1:2.5), Ca, Mg, Al, Na, K, P, H + Al, sum of exchangeable bases (SB), total cation exchange capacity (T value) ($cmol_c$ dm^{-3}), base saturation (V%), total organic carbon (TOC), total clay, total sand and silt (g kg^{-1}) contents according to Teixeira et al. (2017); organic matter (OM) (Yeomans & Bremner, 1988); carbon contents in the fulvic acid fraction (C-FA), humic acid fraction (C-HA) and humin fraction (C-HUM) (g kg^{-1}) from the chemical fractionation of SOM (Benites et al., 2003).

The particulate organic carbon (POC) and mineral-associated organic carbon (MAOC) (g kg^{-1}) was obtained by the granulometric fractionation of SOM (Yeomans & Bremner, 1988; Cambardella & Elliott, 1992), and the light organic matter (LOM) according to Anderson & Ingram (1989), with subsequent determination of C and N values contained in LOM mass (g kg^{-1}) by the dry combustion method in an auto analyzer of C and N at 900 ºC (CHN-600 Carlo Erba EA-1110, Italy).

The fresh mass (FM) of Tifton 85 was obtained using a 0.35 m² rectangular metallic frame around the sampling points, where the grass was cut in the delimited area and placed in a sealed plastic bag for transport to the laboratory. Immediately after collection and transport, carried out in an only period of the day, the samples were placed in previously tared and identified paper bags, weighing them in sequence to determine the FM, being used to evaluate the yield (Santos & Castilho, 2018).

Descriptive statistics and geostatistics

Using the software programs R Studio 3.5.1 (R Development Core Team, 2022) an exploratory and descriptive analysis of the data was performed. The hypothesis of data normality was tested using the Shapiro-Wilk test at 5% significance level ($p<0.05$). In order to verify the correlations between the variables under study, Pearson's linear correlation was performed at 5% significance level ($p<0.05$). In R Studio 3.5.1 software using geoR, sp and gstat packages, the data were subjected to geostatistical analysis to obtain the variographic parameters: nugget effect, sill and range. The fit of the semivariogram models was determined according to the methods of Ordinary Least Squares (OLS) and Maximum Likelihood (ML), in which the spherical, exponential and Gaussian models were tested.

Cross-validation of the data was performed for the generated semivariogram models, and the fitted model was determined according to the mean reduced error ($\overline{RE}$), standard deviation of mean reduced error (S_{RE}) and value of Akaike Information Criterion (AIC). Ordinary kriging was performed and the spatial variability maps of the variables that showed the variographic parameters (nugget effect, sill and range) were obtained.

The semivariogram parameters obtained from fresh mass (FM) were used in the generation of the probability map. This map was calculated from the weights obtained by means of ordinary kriging (Yamamoto, 2010). Thus, the FM data were transformed into probability indicators, in which if the variable under study showed values above a certain pre-established cutoff value, there would be a higher probability of occurrence at a given point (direction at 100%

probability); if it showed values below the cutoff value, there would be lower probability of occurrence (direction at 0% probability).

The cutoff point was defined according to the mean FM value of the entire area, obtained in the amount of 4,505.8 kg ha^{-1}. Therefore, the cutoff value equal to 4,505.8 kg ha^{-1} was adopted for the FM variable, making it possible to represent the probability of the regions with higher and lower yields of Tifton 85.

Ordinary cokriging (CK) was performed in variables that did not show good variographic adjustments using covariates for their modeling and spatialization (Dasgupta et al., 2022). The data set used were isotopic (coincident sampling points), and a significant correlation was verified between the attributes from Pearson's linear correlation at 5% significance level ($p<0.05$). The models were fitted according to the OLS method, and cross-validation of the data was performed. ArcGis 10.5 software was used to generate the spatial variability maps.

Multivariate analysis and delineate of management zones (MZ)

The management zones were delineated from the soil attributes in the 0-0.20 m layer, because of the greater presence of Tifton 85 roots and the higher TOC content in this soil layer, estimated at average values of 21.93 g kg^{-1}. The soil attributes that had significant linear correlation with fresh mass (FM) were selected to generate the management zones.

The selected variables were subjected to multivariate analysis. Principal component analysis (PCA) was applied from the covariance matrix, obtaining the contribution of each component, the scores and weights of the variables. Among the components with the highest contribution, the variables of highest weights (coefficients) and that influenced the delineation of the MZ were verified (Ohana-Levi et al., 2020).

Then, these variables were subjected to non-hierarchical cluster analysis by the k-means method. The ideal value of parameter k was obtained by the Elbow method, obtaining the ideal number of clusters for the data set. In this way, the number of clusters formed was the number of management zones formed (Ohana-Levi et al., 2020). The heterogeneity of the results between the management zones was evaluated using t-test at 5% significance level ($p<0.05$). R Studio 3.5.1 software using factoextra and ggplot2 packages was used to perform multivariate analyses. The maps of management zones were produced using ArcGis 10.5 software.

RESULTS AND DISCUSSION

Spatial variability of soil and crop attributes

The mean values of C of light organic matter (C-LOM) (305.40 and 323.10 g kg^{-1}, in 0-0.20 and 0.20-0.40 m, respectively) suggest greater losses of labile fractions in the surface layer, which may be due to the greater intensity of environmental and agricultural impacts directly on the surface layer of the soil. The greater presence of C-LOM in the 0.20-0.40 m layer can be explained by the presence of plant residues in the subsurface, resulting from the rhizodeposition and renewal of the Tifton 85 root system.

For the C/N ratio of LOM, mean values of 25.66 and 28.59 were observed for the layers 0-0.20 and 0.20-0.40 m, respectively, indicating higher quality of grass residues in the subsurface layer and lower decomposition of these residues, with lower concentrations of N.

The LOM represents the youngest, most recent and biologically active organic material and its substrate is used as an energy source for microbial growth and for the release of nutrients through biomass cycling. In crop-livestock integration system, no-till system and native vegetation in Cerrado in tropical climate C-MOL and C/N ratio of MOL values of 19.76 and 278.10 g kg^{-1}, 17.32 and 307.25 g kg^{-1}, 24.13 and 324.60 g kg^{-1}, respectively were verified (Loss et al., 2012). Therefore, the MOL values of the study area indicated substrate supply in values close to other agricultural systems in tropical regions.

Regarding the geostatistical aspect, Table 1 presents the values of the parameters obtained in the study of the semivariogram of each variable.

TABLE 1. Parameters of the variographic models, cross-validation and associated prediction errors obtained for the attributes.

Variable	Fitting method	Model	Range (m)	$\overline{RE}$	S_{RE}	AIC
			0-0.20 m			
SB	PNE	-	-	-	-	-
T value	ML	Sph	32.8	-0.0014	1.0564	216.11
V%	ML	Sph	30.6	-0.0088	1.0614	399.69
Total clay	OLS	Exp	31.3	-0.0024	1.0364	-
Total sand	OLS	Exp	29.1	0.0065	1.0461	-
Silt	ML	Exp	10.2	0.0230	1.0759	490.93
OM	OLS	Sph	49.2	0.0028	1.2114	-
C-FA	OLS	Gau	156.9	0.0118	1.0491	-
C-HA	ML	Sph	46.8	0.0002	1.0442	146.19
C-HUM	ML	Gau	7.8	0.0083	1.0339	239.43
POC	ML	Sph	19.1	0.0182	1.0787	182.74
MAOC	OLS	Gau	21.5	-0.0134	1.1727	-
N-LOM	PNE	-	-	-	-	-
C-LOM	PNE	-	-	-	-	-
			0.20-0.40 m			
SB	PNE	-	-	-	-	-
T value	ML	Gau	12.3	0.0089	1.0629	226.95
V%	PNE	-	-	-	-	-
Total clay	OLS-CK	Exp	30.0	0,0200	1.5411	-
Total sand	OLS-CK	Exp	30.0	0.0500	1.4870	-
Silt	OLS	Gau	22.4	0.0084	1.1359	-
OM	ML	Gau	13.6	-0.0113	1.0737	329.29
C-FA	OLS-CK	Sph	50.0	0.0751	1.3230	-
C-HA	OLS-CK	Gau	30.0	0.0625	1.2105	-
C-HUM	OLS-CK	Sph	50.0	0.0101	1.1021	-
POC	OLS	Sph	21.4	0.0052	1.0677	-
MAOC	ML	Gau	14.8	-0.0142	1.0761	271.96
N-LOM	PNE	-	-	-	-	-
C-LOM	PNE	-	-	-	-	-
FM	OLS	Exp	23.3	-0.0008	1.1340	-

Model: Sph - spherical, Exp – exponential, Gau – Gaussian; $\overline{RE}$: Mean reduced error; S_{RE}: standard deviation of mean reduced error; AIC: Akaike Information Criterion; PNE: Pure nugget effect; ML: Maximum Likelihood; OLS: Ordinary Least Squares; OLS-CK: Ordinary cokriging with model fitted by the Ordinary Least Squares method. Variables used in the cross-semivariogram: total clay of the 0.20-0.40 m layer (primary variable) and total clay of the 0-0.20 m layer (secondary variable), total sand of the 0.20-0.40 m layer (primary variable) and total sand of the 0-0.20 m layer (secondary variable), C-FA (primary variable) and OM (secondary variable) of the 0.20-0.40 m layer, C-HA (primary variable) and OM (secondary variable) of the 0.20-0.40 m layer, C-HUM (primary variable) and MAOC (secondary variable) of the 0.20-0.40 m layer.

The spherical model was the most frequent among the fitting models, followed by the Gaussian and exponential models. Greater fits of the semivariograms for spherical models in attributes of soil organic matter (SOM) were observed by Leite et al. (2015) and Gontijo et al. (2016). For the attributes SB, N-LOM and C-LOM of the 0-0.20 m layer and SB, V%, N-LOM and C-LOM of the 0.20-0.40 m layer, PNE was verified.

For the 0-0.20 m layer, the highest values of range were obtained by the variables C-FA (156.9 m) and OM (49.2 m) and the lowest values were observed for C-HUM (7.8 m) and silt (10.2 m). At 0.20-0.40 m depth, the highest ranges were verified for C-FA and C-HUM, both with 50 m. The lowest values of range were obtained for T value (12.3 m) and OM (13.6 m), indicating the maximum distance at which the variables have spatial dependence.

Leite et al. (2015) in their study found that the range values of the soil humic fractions showed different continuities in the spatial distribution in surface and subsurface of degraded pasture in recovery, highlighting the largest ranges of C-FA (40.8 m) and C-HA (57.0 m) compared to C-HUM (39.6 m) in the 0.10-0.20 m layer, a pattern similar to the results observed in the 0-0.20 m depth in this study. Figure 2 illustrates the spatial distribution of soil and crop attributes in the 0-0.20 m layer.

The lowest values of V% were identified in the ranges of the central, north and west regions (Figure 2B). This pattern suggests the need to correct the acidity of these soils using agricultural inputs to make them potentially more productive and suitable for the cultivation of the grass of the genus *Cynodon*. The soils of the region under study are located in the morphoclimatic domain known as "Mares de Morros" and are originated from acidic rocks, especially gneiss and granite, or sediments produced from the weathering of these rocks (Costa et al., 2018).

Figure 2D showed that the northern region had the lowest C-FA contents, indicating that the labile fractions were more easily removed from the soil in this region, disfavoring the steady state, promoting the reduction of this fraction and modifying the relationship in the distribution of humic substances. The highest contents of C-HA (Figure 2E) were verified in the central, northeast and east regions and the C-HUM fraction (Figure 2F) in the central and southern regions of the Tifton 85 area.

This pattern makes it possible to infer that these are the regions with the highest stable fractions of SOM, being the accumulation of these fractions favored by the position of the pasture area in the landscape, due to the slower decomposition in these regions. These characteristics, together with the highest rates of C-FA in the same regions, promote soils in good conditions for cultivation, which is also demonstrated with the higher probability of being more productive.

These results corroborate with studies on MOS fractions in tropical climates, Silva et al. (2017) found that spatialization of C-FA, C-HA and C-HUM under agroforestry system (AFS) in the topsoil layer (0-0.10 m) allowed quantifying higher C-FA, C-HA and C-HUM contents in landscape positions that favored slower MOS decomposition (at the lowest altitude of the AFS).

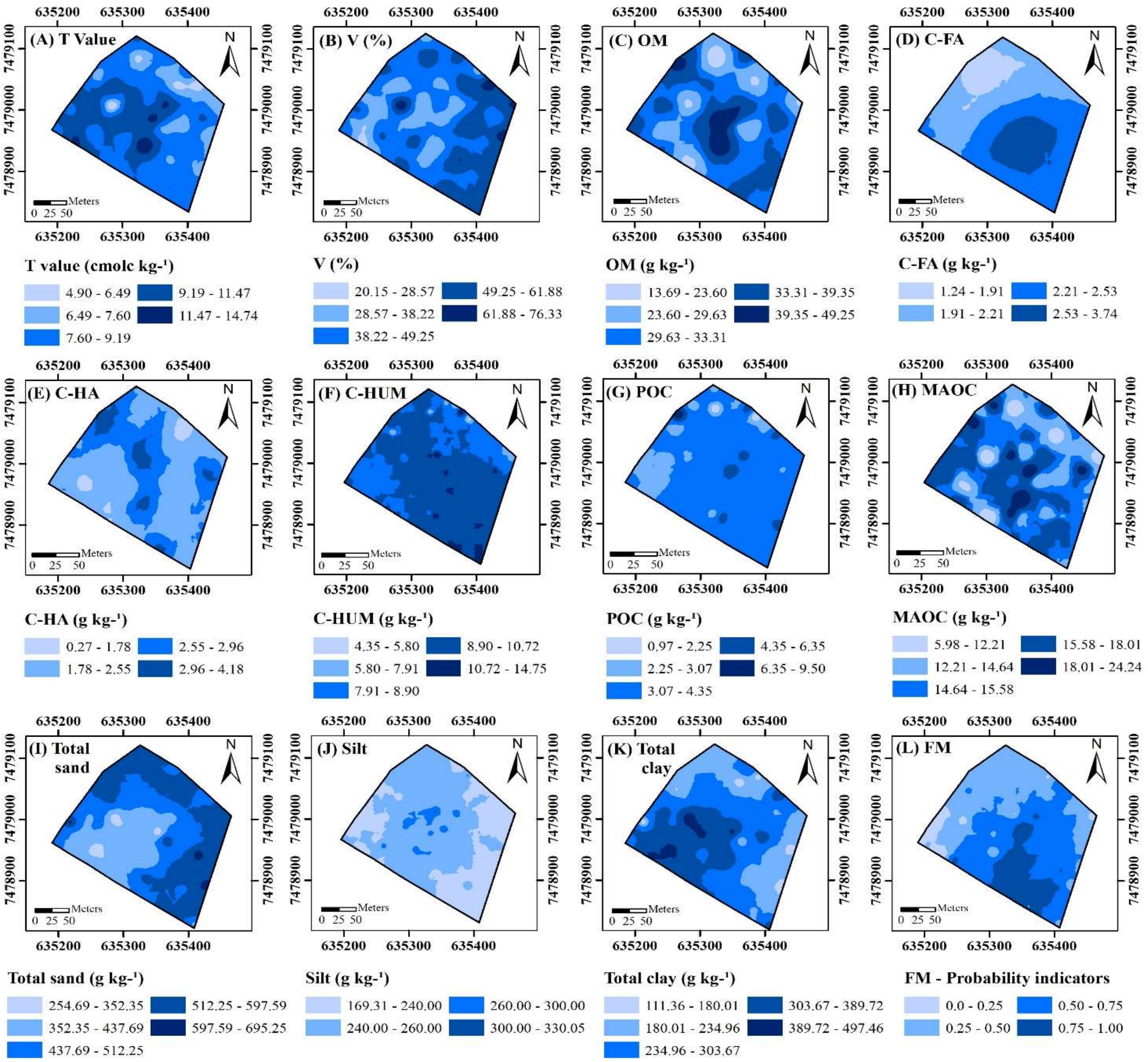

FIGURE 2. Spatial variability maps generated from ordinary kriging of the variables in the 0-0.20 m layer in the Tifton 85 cultivation area.

T value: total cation exchange capacity; V%: base saturation; OM: organic matter; C-FA: carbon contents in the fulvic acid fraction; C-HA: carbon contents in the humic acid fraction; C-HUM: carbon contents in the humin fraction; POC: particulate organic carbon; MAOC: mineral-associated organic carbon; FM: fresh mass.

The spatial distribution of OM, C-FA, C-HA, C-HUM, MAOC and POC (Figures 2C to 2H) suggests that the highest contents of SOM are distributed in regions of high probability of occurrence of higher yields. This pattern is confirmed by verifying a correlation that is positive and significant at 5% of FM with the attributes OM, C-FA and MAOC.

The regions with higher contents of MAOC are related to the highest probabilities of high yield (greater amounts of plant residues) and to the higher contents of C-HA, seen in the spatialization of these attributes in Figure 2H. There were higher contents of MAOC compared to POC, which occurs because MAOC has a slower decomposition cycle, being more recalcitrant in the environment and having greater interaction with the mineral fraction of the soil.

Figure 2L presents the distribution of probabilistic uncertainty of occurrence of the FM variable, indicating the regions of lower and higher yield. The probabilities of finding values greater than the reference value established for yield (>4,505.8 kg ha^{-1}) were in the central, south and southwest regions of the map, with probabilities of occurrence from 50 to 100%. The lowest probabilities of occurrence of high yield are found particularly in the western region of the map, with values from 0 to 25%. These values may be related to high contents of T value and low values of V% in this region, indicating areas of higher potential acidity. Figure 3 presents the spatial distribution of soil attributes in the 0.20-0.40 m layer.

At the two depths evaluated, there was a predominance of higher contents of C-HUM in comparison to C-FA and C-HA, a pattern also observed by Leite et al. (2015) for *Argissolos* (Ultisol). Costa et al. (2018) evaluated the SOM fractions in the "Mares de Morros" region, in Rio de Janeiro, Brazil, and noted that in addition to the predominance of higher contents of C-HUM, there were high contents of this fraction in pasture areas with grasses. This pattern may be related to the resistance to biodegradation favored by the formation of stable clay-humic complexes, leaving most of the organic matter insoluble, as well as greater presence of C-HUM related to tropical climate (Silva et al., 2017).

The positive correlation of FM values with total clay indicated the favoring of this attribute in plant growth at both soil depths, possibly due to the better conditions for nutrient adsorption and water retention. The probabilities of occurrence of higher yields are located especially in the areas of medium texture. This pattern suggests that the particle-size fractions in these regions are found in sufficient contents to promote adequate moisture retention in the soil surface layer. As indicated by Pinheiro et al. (2018), mapping and the estimation of soil texture values in PA are important, because soil texture is directly related to yield.

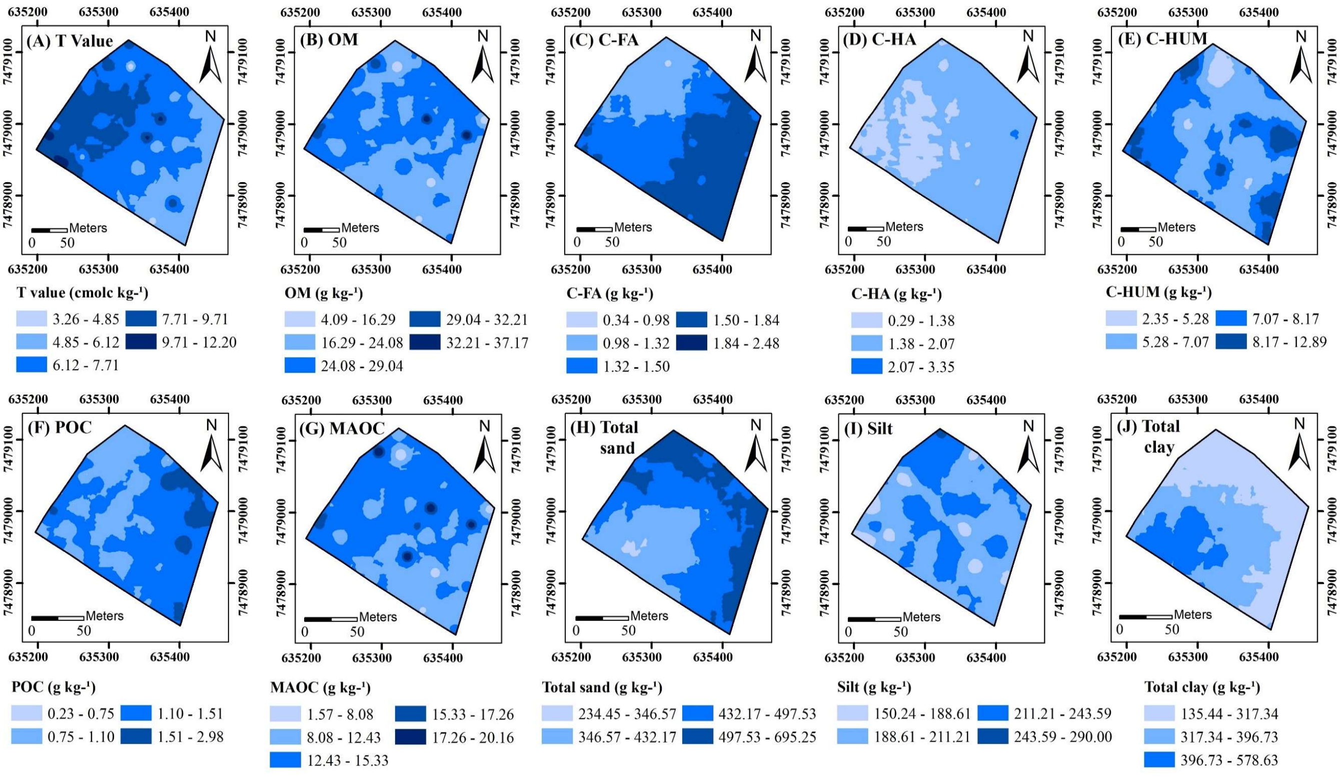

FIGURE 3. Spatial variability maps generated from ordinary kriging and cokriging of the variables in the 0.20-0.40 m layer in the Tifton 85 cultivation area.

T value: total cation exchange capacity; V%: base saturation; OM: organic matter; C-FA: carbon contents in the fulvic acid fraction; C-HA: carbon contents in the humic acid fraction; C-HUM: carbon contents in the humin fraction; POC: particulate organic carbon; MAOC: mineral-associated organic carbon.

Management zones (MZ)

The variables selected to delineate the MZ were FM, total clay, total sand, OM, C-FA and MAOC. It was verified that the principal components 1 and 2 (PC1 and PC2) were the ones with the greatest contributions, showing 77.20% of the total cumulative explained variation, and it was found that the attributes OM, MAOC and C-FA had the highest coefficients in PC1 while total clay and total sand had the highest coefficients in PC2, indicating that these were the soil attributes that most contributed to the zoning of the region under study in relation to yield.

The indication of the creation of two management zones (clustering with k=2) presented itself as the ideal by the Elbow method, in view of the better site-specific management, logistics and ease of the farmer in managing these areas (Figure 4).

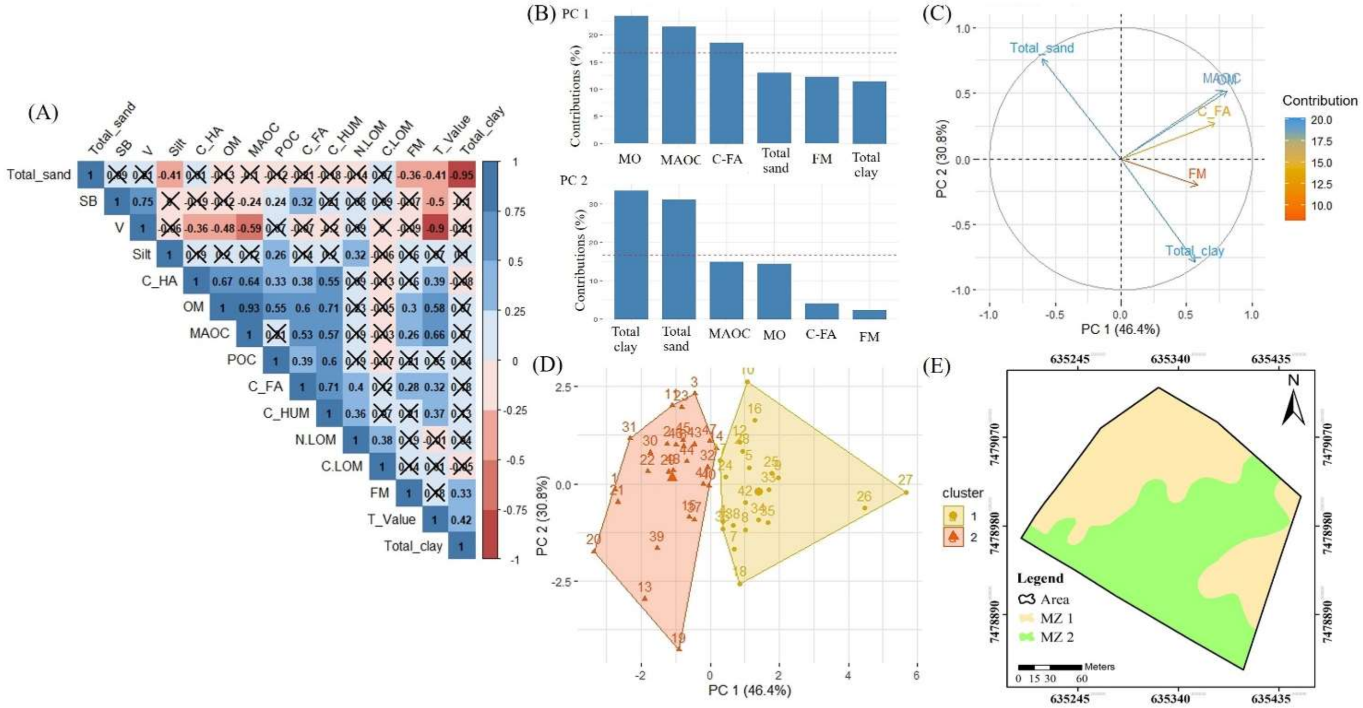

FIGURE 4. Pearson's linear correlation at 5% significance level (p<0.05) in the 0-0.20 m layer (A), Principal Component Analysis (B and C), clustering of the data by k-means (D) and management zones generated in the Tifton 85 area (E).

SB: sum of exchangeable bases; T value: total cation exchange capacity; V%: base saturation; OM: organic matter; C-FA: carbon contents in the fulvic acid fraction; C-HA: carbon contents in the humic acid fraction; C-HUM: carbon contents in the humin fraction; POC: particulate organic carbon; MAOC: mineral-associated organic carbon; N-LOM: N value contained in LOM mass; C-LOM: C value contained in LOM mass; FM: fresh mass.; PC: Principal Component; MZ: Management Zone. Values crossed with X were not significant, i.e., presented no significant correlation at 5% significance.

Moharana et al. (2020) studied different clustering approaches for MZ delineation and when performing principal component analysis found that the first four PCs explained 66% of the total accumulated variance, with organic carbon having a significant influence on PC3 and PC4. Denora et al. (2022) agronomically validated two MZs identified by the k-means algorithm, with MO significantly different between the generated MZs.

Table 2 shows the mean values of soil attributes and the t-test at 5% significance level (p<0.05), in which the mean of each variable between the management zones created was compared.

TABLE 2. Mean values of the attributes within each MZ created and t-test (p<0.05).

MZ	FM	T	Total clay	Total sand	OM	C-FA	C-HUM	MAOC	N-LOM
	kg ha-¹	cmol$_c$ kg^{-1}	-------------------------------g kg^{-1}					--	
1	3255.5^A	8.1^A	227.2^A	536.9^B	29.2^A	1.9^A	7.9^A	13.8^A	11.2^A
2	6113.5^B	9.8^B	339.9^B	409.3^A	36.3^B	2.6^B	10.6^B	17.1^B	12.9^B

Means followed by equal uppercase letters do not differ from each other in the column at 5% probability level by t-test (p<0.05).

The FM values between management zones 1 (MZ1) and 2 (MZ2) were significantly different by t-test at 5% significance level. Regions with the lowest probability of having above-average yield, being regions of lower yield, were verified in MZ1, while regions with the highest probability of having high yield were verified in MZ2. The regions with the greatest presence of organic fractions of the soil were those with highest probability of being more productive. This is evident when observing that higher contents of OM, C-FA, C-HUM, MAOC and N-LOM were verified in MZ2, when compared with MZ1, with significantly different mean values by t-test (p<0.05).

The mean values of soil organic fractions of the Tifton 85 area (Table 2) indicate that in MZ1 there is a higher rate of decomposition of SOM, indicating higher rates of degradation to management and cultivation practices (Raiesi, 2021) when compared to MZ2. The higher average contents of MAOC in MZ2 indicate higher recalcitrance and greater associations between organic molecules and the mineral fraction of the soil, which makes organic residues more resistant to microbial attack and, in turn, protect SOM against decomposition (Pinheiro Junior et al., 2022).

The site-specific management will aim to provide nutrients for the soil and stability from the SOM humification process. In MZ1 there was a greater need for OM with a certain degree of soil stability and that provides nutrients for the soil. For this, the most appropriate structure of OM should be the one with aromatic condensation, generating a certain degree of structural stability associated with carboxylic and hydroxyl groups that promote the generation of charges in the soil solution (Aguiar et al., 2022).

Higher contents of humified organic matter were verified in MZ2, showing greater stability than MZ1, in addition to higher contents of labile organic fractions. This suggests that the higher agricultural yield of MZ2 was favored by the humic substances, since these are intrinsically associated with the mineral fraction of the soil, favoring processes such as the increase of soil CEC and the decrease of the adsorption of phosphate anions by 1:1 clays and iron (Fe) and aluminum (Al) oxides (Iorio et al., 2022).

The greater accumulation of C in MZ1 can be carried out by the OM humification process until more stable structures are achieved. As in MZ2, higher contents of organic fractions of SOM were observed, with more labile and stable OM than in MZ1, the addition of labile OM will be lower in this region. The higher mean value of N-LOM in MZ2 may be due to the deposition of material with higher nitrogen (N) concentrations from the decomposition of Tifton 85, since the regions with highest probabilities of having greater amounts of plant biomass are observed in this MZ (Raiesi, 2021). In view of this, practices that increase C contents in the soil should be adopted such as organic localized fertilization, use of forage grasses, pasture reform or other existing approaches. The economic and operational feasibility of operating in the outlined MZs should be evaluated, since pasture management should offer profitability to the farmer.

The approach followed in this study demonstrates the importance of obtaining spatial information on soil organic matter fractions and combining them with multivariate methods for specific pasture management. In addition to understanding the conservation of C in these soils, the generation of management zones in the pasture can direct fertilizer applications, with the possibility of reducing the use of inputs and directed management that respects the productive potential of pastures on the farm.

CONCLUSIONS

As conclusions, the use of precision farming tools in pasture production enables the indication of localized management using as a source of data the chemical, physical and the fractions of soil organic matter attributes. The evaluation of the spatial variability of this attributes through geostatistics and multivariate analysis allowed the definition of management zones for pasture and the verification that there was heterogeneity of soil nutrients in the management zones formed. The results obtained contributed to the partitioning of the Tifton 85 area into two areas that can be managed in different ways aiming at increasing OM in the soil in a localized manner.

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