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FORESTRY SCIENCE

Spatial variability of the nutritional status and the leaf chlorophyll index of from rubber tree

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Abstract: The development of crops is related to their nutritional status and the leaf chlorophyll apparent index. The objective of this study was to use fuzzy classification to determine the degree of membership (fuzzy index - FI) of macronutrientes and leaf micronutrients classified as low, adequate and high, quantify the chlorophyll index and to determine the spatial variability of these attributes for the rubber tree (*Hevea brasiliensis*) (Fx 3864) at the initial stage of development, aiming at the definition of management zones. Sampling grid regulates at 6x7 m spacing was built to determine the attributes: chlorophyll *a* and *b*, macro and leaf micronutrients, totaling 100 sample points. The fuzzy classification and geostatistical was used to map the nutritional status of the rubber tree. In the fuzzy analysis the macronutrient map shows the degree of membership 0.50<FI<0.75, in more than 75% of the area, indicating high nutritional status. The limiting factor was the concentration of P in the lowest percentage of points (58%) in the appropriate class. Micronutrients have 0.25<FI<0.50, for more than 75% of the area, therefore, average nutritional status. Leaf Cu presented 48% of the data in low sufficiency. Therefore, it is recommended to analyze macronutrients and leaf micronutrients separately to define management zones for foliar fertilization. Chlorophyll *a*, *b* and *a*/*b* leaf index do not correlate with macronutrients and fuzzyficated micronutrients. The leaf indices of chlorophyll *a* and *b* have a very high correlation (r = 0.89)

key words: fuzzy classification, geostatistics, leaf nutrients, precision silviculture.

INTRODUCTION

The rubber tree [*Hevea brasiliensis*] is a dicotyledonous, it has male and female flowers in the same individual. The perennial tree from which the latex is removed for the manufacture of natural rubber and adapts well to climatic conditions and soil throughout the territory of Brazil. According to Rosado et al. (2007) for being undemanding in soil fertility, it is a good option to be cultivated in degraded areas and with its development favoring plant cover, minimizing the loss of soil and nutrients in the erosive process.

The precision silviculture favor the collection and analysis of geospatial data enabling interventions located in the forest with adequate accuracy and precision (Medauar et al. 2018). Thus, the study of the spatial distribution of the dendrometric variables of the rubber plants and their relationship with the other attributes of the soil becomes essential to understand their productive behavior (Vetorazzi & Ferraz 2000).

The spatial and temporal variability of dendrometric variables of the rubber tree in the initial phase of development, in order to estimate values in non-sampled areas in the area, showed that the variables under study presented spatial continuity and correlated with potassium (K) and soil phosphorus (P) concentrations in the 0 - 0.20 m depth layer (Lima et al. 2018a).

The concentration levels of macronutrients and micronutrients in soil and leaves for agricultural crops are defined in values that follow the classical (Boolean) logic, that is, the results found in the laboratory analysis belong or do not belong to certain classes, which are linguistic variables such as: low, medium and high. For this question, according to Farias et al. (2010), fuzzy classification a mathematical tool is used known as fuzzy set which theory treats inaccurate or vague information defining them in degrees of membership, as opposed to classical logic.

According to Lima et al. (2018b) used fuzzy classification together with the analysis of the spatial variability of soil chemical attributes, for the rubber tree, constructing a map of the degree of membership (FI) soil fertility in two depths, defining differentiated zones for the production fertilization. According to Godoy et al. (2008) leaf nitrogen (N) correlated with chlorophyll index for coffee.

In this context, the objective of this research was to determine the spatial variability of the leaf chlorophyll index (LCI) and also of the degree of membership (FI) of the macronutrients and leaf micronutrients using fuzzy classification for the definition of management zones for rubber tree, in the initial state of development.

MATERIALS AND METHODS

The study was carried out in a commercial area of rubber tree (clone Fx 3864) for the purpose of latex production, in a clayey Latosol, according to the Brazilian Soil Classification System (Santos et al. 2013). The area has 1,68 ha, located in coordinate UTM (longitude 357594.870 m; latitude 793163.215 m) and 65 m above sea level in the county of Nova Venécia, Espírito Santo, Brazil (Figure 1) (Lima et al. 2018b). The region

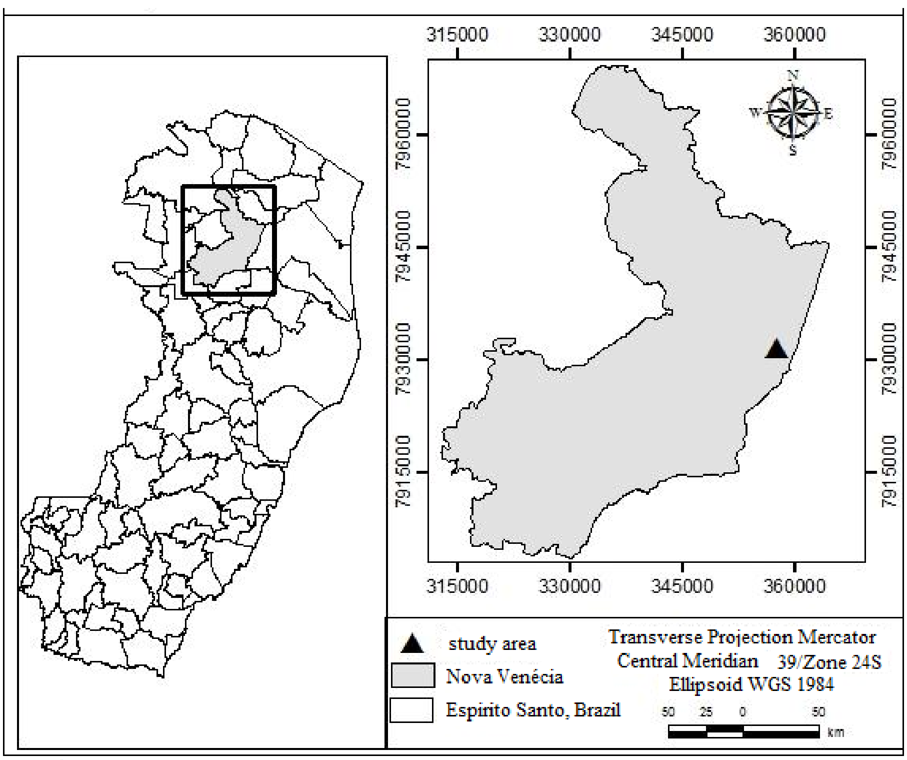

Figure 1. Location of the study area in Nova Venécia-ES, Brazil.

is classified as hot tropical Am, according to Köppen, with high temperatures in the months of November to March (Alvares et al. 2013). The average annual precipitation is between 1400 and 2200 mm, according to Silva et al. (2011), and the temperature ranging from 24 to 26^{0}C. The average values of the particle size fractions of the Oxisol are: total sand = 411.2, silt = 123.4 and clay = 469.3 g kg^{-1}.

The mechanized preparation of the area consisted of cutting and also of subsoiling with subsoiler of three stems coupled in the hydraulic system of the tractor. Then, the groove was accomplished defining the lines for manual transplanting of the seedlings, in pits of 0.30 x 0.15 m (depth x diameter) in the spacing of 3 m in the row and 7 m in the row between January 2013, totalizing 476 plants ha^{-1}. Before and after placing the seedlings in the pits was applied 5 L of water with hydrogel. On the following days, 5.0 L water were applied, and shading of the seedlings with coconut leaves was done to minimize the solar incidence.

Ammonium sulphate (0.010 kg) was applied to the soil around the pits after 10 days, 30 days and 60 days of transplanting the seedlings. In NPK fertilization, the formulation 20-00-20 (0.050 kg) was used at intervals of every 30 days until the completion of one year with the application of 5 L water cova^{-1}. After one year of transplanting, 0.10 kg of the 20-00-20 formulation was applied to the soil every 60 days.

In the study area, a sampling grid was constructed, totalizing 100 points, in the spacing of 6 x 7 m, and the samples of the attributes under study were collected in the month of December/2016, each sampling point consisting of a rubber tree before completing four years of implementation.

The mean values of the chemical attributes that characterize the average soil fertility in the 0 - 0.20 m depth layer for samples collected at 0.50 m from the trees in the line are:

P = 9.4 mgdm^{-3}; K = 88.2 mgdm^{-3}; Ca = 2.0 cmol$_c$dm^{-3}; Mg = 0.6 cmol$_c$dm^{-3}; BS = 2.7 cmol$_c$dm^{-3}; CEC (pH$_7$) = 9.2 cmol$_c$dm^{-3} and V = 29.8 %. All the chemical attributes of the soil are at the maximum value for the respective intervals, with the exception of P in the two layers, since they show values of < 20 mg dm-3, the minimum value for the interval (Lima et al. 2018b).

For the analysis of the nutritional status, leaves were collected from the base of the last ripe shoot of the crown, without petioles, in branches exposed to the sun, being fixed a quadrant of the plant for collection, since the planting is less than four years (Traini et al. 1983). Six leaves per tree were collected in the morning, and the leaf chlorophyll apparent index a and b were determined by the Falker chlorophyll index (LCI) (Clorofilog - CFL 1030). The collected leaves were sent to the laboratory to determine macronutrients and micronutrients.

The results were submitted to an exploratory analysis to verify the presence of discrepant values (outliers) and their influence on position and dispersion measurements, using the box-plot. The Pearson correlation analysis ($p \leq 0.05$) between the macronutrients and micronutrients fuzzyfied with the results of leaf chlorophyll (*a* and *b*) was performed to see the relationship with the nutritional status of the rubber tree.

The fuzzy classification was used to classify, for each attribute (Input), at each sample point, the values determined in the leaf analysis, according to the intervals of the appropriate level for macronutrients and micronutrients concentrations (Table I), according to the procedure adopted by Bönisch et al. (2004) and Lima et al. (2018b). The intervals were defined considering the lower limit and the upper limit of the appropriate level presented by Cantarutti

Table I. Criteria for classification of the degrees of membership (FI) of the leaf chemical attributes of the rubber tree: macronutrients: phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and micronutrients: B (boron), Zn (zinc), Mn (manganese), Fe (iron) and copper (Cu).

Attributes Levels				
Attributes	**Units**	**Low (< p)**	**Appropriate (p ≤ z ≤ q)**	**High (z > q)**
P	g kg^{-1}	< 1.6	1.6 - 2.5	> 2.5
K	g kg^{-1}	< 10.0	10.0 - 17.0	> 17.0
Ca	g kg^{-1}	< 4.0	4.0 - 10.0	> 10.0
Mg	g kg^{-1}	< 1.7	1.7 - 4.0	> 4.0
S	g kg^{-1}	< 1.4	1.4 - 2.6	> 5.0
B	mg kg^{-1}	< 20.0	20.0 - 70.0	> 70.0
Zn	mg kg^{-1}	< 20.0	20.0 - 50.0	> 50.0
Mn	mg kg^{-1}	<15.0	15.0 - 200.0	>200.0
Fe	mg kg^{-1}	<50.0	50.0 - 200.0	>200.0
Cu	mg kg^{-1}	<20.0	20.0 - 50.0	>50.0

z: observed value of attribute; p: lower limit f the appropriate level and q: higher limit of the appropriate level.

& Neves (2007), Raij et al. (1996) and Garcia et al. (1999).

This classification was carried out to transform all point values of macronutrients and micronutrients on the same scale to perform the algebra operation between maps of different attributes in the definition of management zones based on the nutritional status of the rubber tree.

The associated function chosen in the continuous data classification was the linear one, used by Bönisch et al. (2004), Silva & Lima (2009) and Lima et al. (2018b) in the study of soil fertility, according to equations 1, 2 and 3 for data set with increasing values:

$$MF_A(Z) = 0 \qquad se\ z < p \tag{1}$$

$$MF_A(Z) = \frac{z-p}{q-p} \qquad se\ p \leq z \leq q \tag{2}$$

$$MF_A(Z) = 1 \qquad se\ z > q \tag{3}$$

where: *MFA* is the degree of membership (fuzzy index) (FI) with which an element z belongs to the fuzzy sets (FS); p is the lower limit and q the upper limit of the FS level belonging to a set A.

To verify the existence and quantify the spatial degree of dependence of leaf chlorophyll *a*, *b* and *a*/*b* fuzzy index of attributes, the data were submitted to geostatistical analysis, from the adjustment of theoretical functions to the experimental semivariograms models, based on the assumption of stationarity of the intrinsic hypothesis and according to equation 4 (Isaaks & Srivastava 1989).

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[z(x_i) - z(x_i + h) \right]^2 \tag{4}$$

where: N (h) is the number of pairs of values $[Z(x_i), Z(x_i + h)]$ separated by a vector h, and x_i is a spatial position of the variable Z.

The experimental semivariograms was adjusted to theoretical models (spherical, exponential and gaussian), whose parameters are known: nugget effect (C_0), which indicates the discontinuity at the origin: sill (C_0 + C), where the semivariance stabilizes, which is close to the data variance and the range (a) indicates the distance from which the sample data are independent. The spatial analysis was processed in the VESPER 1.6 software (Minasny et al. 2002).

The choice of model was based on the minimization of the sum of squares of the residues and the coefficient of multiple determination (R^2) of the adjustment of the theoretical models to the experimental semivariograms. The ordinary least squares (OLS) method was used which consists of obtaining the values of the parameters of a model that minimizes the sum of the square of the difference between the observed and estimated values (Mello et al. 2005). Then, the correlation between the observed values and those estimated by the cross-validation, also, was done in the definition of the models (Ferreira et al. 2013, Oliveira et al. 2015).

The degree of spatial dependence (DSD) was calculated in accordance with Cambardella et al. (1994) by means of the relation $[C_0/(C+C_0)] \times 100$. According to these authors, DSD values of up to 25 %, from 25-75 % and above 75 % denote strong, moderate and weak spatial dependences, respectively.

Once the existence of spatial dependence for the attributes under study and after application of the fuzzy classification was proven, the respective thematic maps were constructed by the ordinary kriging method by QGIS software version 1.7 (Sherman et al. 2011). Kriging is the geostatistical interpolation method to estimate values of variables distributed in space from adjacent values, based on the semivariogram (Landim 1998).

The combined effect of leaf attributes was measured using algebra functions for FS maps with QGIS software. It was considered the same contribution (weight) for each leaf attribute (macronutrients and micronutrients), that is, the attributes contribute equally to the nutritional status of the rubber tree. Thus, in the fuzzy output operation, the maps were the individual nutritional status and then the average map (AM) for the macronutrients (AM Macro) and for the micronutrients (AM Micro) representing the management zones by the different classes (Lima et al. 2018b, Silva & Lima 2009, Souza et al. 2009).

For the conditions of the nutritional status (NS) of the rubber tree, the input linguistic variables used were: very low (VL), low (L), medium (M), high (H) and very high (VH). In order to evaluate the output (defuzzyfication), the following inference rules were used to define the nutritional status (Table II).

RESULTS AND DISCUSSION

In the box-plot (Figure 2) were observed unilateral outliers on the left for chlorophyll *a* and the macronutrient K presented an one-sided outliers on the right. The micronutrients, Zn, Mn, Fe and Cu, presented unilateral outliers to the right, seven, one, seven and two, respectively. These points were removed, according to Lisbôa et al. (2016), and the descriptive analysis of the data was performed.

Table II. Rules of inference to the rubber tree nutritional status.

IF 0.75<FI<1.00 AND percentage of area (PA) > 75% THEN nutritional status (NS) = VH
IF 0.50<FI<0.75 AND percentage of area (PA) > 75% THEN nutritional status (NS) = H
IF 0.25<FI<0.50 AND percentage of area (PA) > 75% THEN nutritional status (NS) = M
IF 0.00<FI<0.25 AND percentage of area (PA) > 75% THEN nutritional status (NS) = VL
IF 0.75<FI<1.00 AND percentage of area (PA) < 25% THEN nutritional status (NS) = L
IF 0.50<FI<0.75 AND percentage of area (PA) < 50% THEN nutritional status (NS) = M
FI: fuzzy index; PA: percentage of area; NS: nutritional status; VH: very high; H: high; M: medium; L: low; VL: very low.

The attributes chlorophyll *b*, P, K, Ca, B, Zn, Mn, Fe and Cu show positive asymmetry. This fact indicates an average greater than the median and with a concentration of values below the mean of the data. The positive kurtosis, leptocurtica, were: K and S, indicating concentration of values around the central value (Table III).

The average chlorophyll index *a* and *b* values were 37.6 and 12.4 LCI, respectively. Thus, a greater influence of chlorophyll *a* for total chlorophyll content is evidenced. According to Naves et al. (1993) the concentration of chlorophyll *b* tends to be higher in plants that develop under shading environments, decreasing the relation a/b. The chlorophyll *a/b* ratio was 3.11: 1, at 47 months, close to that found by Conforto et al. (2015) with a ratio of 3.17:1, for the rubber tree after 24 months after transplanting. Streit et al. (2005) comment that the proportion of chlorophyll *a/b* in the leaf tissue, in general, is approximately 3.00: 1.

In the Pearson correlation analysis ($p \leq 0.05$) the chlorophyll *a* versus *b* presents a very high correlation (r = 0.89), chlorophyll *a* versus *a/b* with average correlation (r = - 0.69) and chlorophyll *b* versus *a/b* very high correlation (r = - 0.92). Thiesen et al. (2017) studied chlorophyll in leaf *Aloysia Triphylla*, using the Clorofilog - CFL 1030, obtaining very high correlation the chlorophyll *a* versus *b* (r = 0.86), chlorophyll *a* versus *a/b* average correlation (r = -0.59) and chlorophyll *b* versus *a/b* high correlation (r = -0.81). According to Conforto et al. (2011) under shading conditions there is an increase in specific leaf area, with sufficient thickness for good distribution of chloroplasts and high content of photosynthetic pigments (mainly chlorophyll *b* and carotenoids).

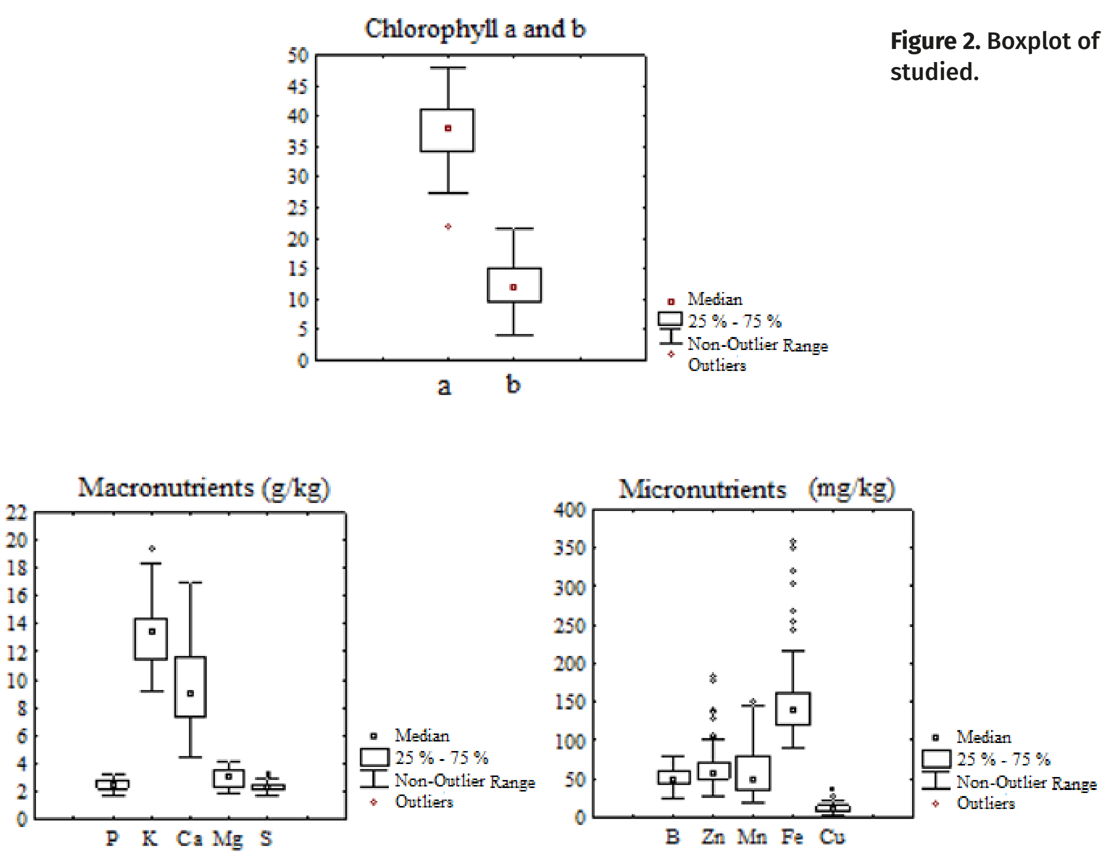

Figure 2. Boxplot of attributes studied.

In the present research, the height of the trees at the sampling points was not measured, but it was observed that in the rubber tree this dendrometric variable presents variability and, with this, it is possible that there is shading in the smaller plants causing chlorosis, that in a certain way interferes with the values of leaf chlorophyll indexes (LCI). Chlorophyll a is the pigment used in photochemistry, while chlorophyll *b* is part of the accessory pigments that aid in the absorption of light and is greater than chlorophyll *a* in the shaded leaf (Neves et al. 2005, Streit et al. 2005).

It should be emphasized that the values of chlorophylls do not present correlation with the defuzzyficated leaf nutrients and with the original data. However, Neves et al. (2005) using SPAD, found correlation of chlorophylls *a* and *b* with macronutrients (N and S) and not found with micronutrients (Fe and Mn) for herbaceous cotton.

The leaf chemical attributes were classified according to the level of sufficiency, according to Table I. Considering the percentages of the sampling points that are within the appropriate level, the following order for the macronutrients: Mg (96%) > S (91%) > K (87%) > Ca (61%) > P (58%) and the micronutrients: Fe (100%) = Mn (100%) > B (89%) > Cu (52%) > Zn (28%).

With a representative percentage value above the sufficiency level, Zn with 72% of the sample points and below is the Cu element with 48%. In this analysis, it is verified that the micronutrients are more limiting in the study of the nutritional status of the rubber tree. Mendes et al. (2012) determined average Cu values below the appropriate level and claim that low Cu

Table III. Descriptive analysis of the attributes: Chlorophyll *a*, *b* and *a/b* (LCI), macronutrients and micronutrients leaf of the rubber tree.

Attributes	n	A	Md	Min	Max	S	ks	kc	CV(%)
Chlorophyll									
a	99	37.6	38.0	27.4	48.1	4.5	-0.18	-0.65	11.9
b	100	12.4	12.1	4.2	21.6	3.6	0.23	-0.65	29.2
a/b	100	3.2	3.2	2.0	4.8	0.6	0.18	-0.58	18.1
Macronutrients									
P	100	2.5	2.4	1.7	3.2	0.4	0.10	-0.85	14.5
K	99	13.3	13.4	9.2	19.4	2.2	0.33	0.02	16.5
Ca	100	9.4	9.0	4.4	16.9	2.9	0.48	-0.47	30.3
Mg	100	3.0	3.0	1.8	4.1	0.6	-0.08	-1.04	21.6
S	91	2.2	2.2	1.7	3.1	0.3	0.88	0.93	12.7
Micronutrients									
B	100	51.4	49.4	23.6	78.1	13.1	0.21	-0.43	25.4
Zn	88	56.7	55.7	27.2	85.2	12.9	0.28	-0.04	22.7
Mn	99	58.6	50.0	20.0	145.0	31.0	0.93	-0.01	52.8
Fe	90	137.6	135.0	90.0	195.0	23.2	0.29	-0.32	16.9
Cu	98	11.3	11.6	3.3	22.4	4.6	0.23	-0.59	40.8

n: number of observations; A; average; Md; median; Min: minimum value; Max: maximum value; S: standard deviation; ks: asymmetry coefficient; kc: kurtosis coefficient; CV: coefficient of variation.

levels are related to high Mn values. Carmo et al. (2002) studied the nutritional status at the time of dry rubber production and found a positive correlation with K and Cu and negative correlation with leaf Ca.

The results of the spatial analysis of leaf nutrients are presented in Table IV, with the standardized semivariograms by the variance of each nutrient aiming to standardize the semivariance scale.

The standardized semivariograms for the attributes related to chlorophylls (Figure 3) and leaf nutrients are in Figures 4 and 5, with adjustments to spherical and exponential models, which according to Seidel & Oliveira (2013) are the most used in soil attributes. The correlation between the values observed and those estimated by cross-validation showed a significant correlation. According to Castro Junior et al. (2017) adjusted exponential model to leaf chlorophyll index (LCI) data for conilon coffee grown on different faces of sun exposure. The leaf chlorophyll index (LCI) of the rubber tree adjusted to the spherical model and with close ranges indicating the same spatial pattern, which confirms the linear correlation values found.

The macronutrients of rubber tree leaf adjusted to the spherical model, for K, and the exponential for P, Ca, Mg and S (Figure 4). The Ca and Mg showed the same distribution pattern, exponential model and range of 13.0 m.

The micronutrients of rubber tree leaf such as B, Mn, Fe and Cu adjusted to the spherical model with ranges of 11.0 to 15.0 m (Figure 5). This behavior of the nutrients indicates pattern in

Table IV. Models and parameters of the standardized semivariograms for leaf chlorophyll index (LCI), macronutrients (g kg^{-1}) and micronutrients (mg kg^{-1}) of leaf defuzzyficated.

Attributes	Model	C_0	C_0+C	a (m) (m)	DSD (%) (%)	R^2 (%) (%)
Chlorophyll						
a	SPH	0.28	1.00	15.0	28.0	88.0
b	SPH	0.17	0.98	13.0	17.3	90.0
a/b	SPH	0.25	0.98	15.0	25.5	90.0
Macronutrients						
P	EXP	0.22	1.04	17.0	21.0	82.0
K	SPH	0.21	1.00	10.0	20.0	71.0
Ca	EXP	0.21	1.00	13.0	21.0	77.0
Mg	EXP	0.31	0.98	13.0	33.0	78.0
S	EXP	0.23	1.00	15.0	35.0	79.0
Micronutrients						
B	SPH	0,18	1,05	11,0	27,0	70,0
Zn	EXP	0,38	1,00	25,0	37,0	72,0
Mn	SPH	0,22	1,00	15,0	21,0	75,0
Fe	SPH	0,17	1,00	13,0	17,0	89,0
Cu	SPH	0,27	1,00	13,0	25,0	72,0

SPH: spherical model; EXP: exponential model; C_0: nugget effect; C_0+C: still; a: range; DSD: degree of spatial dependence and R^2.

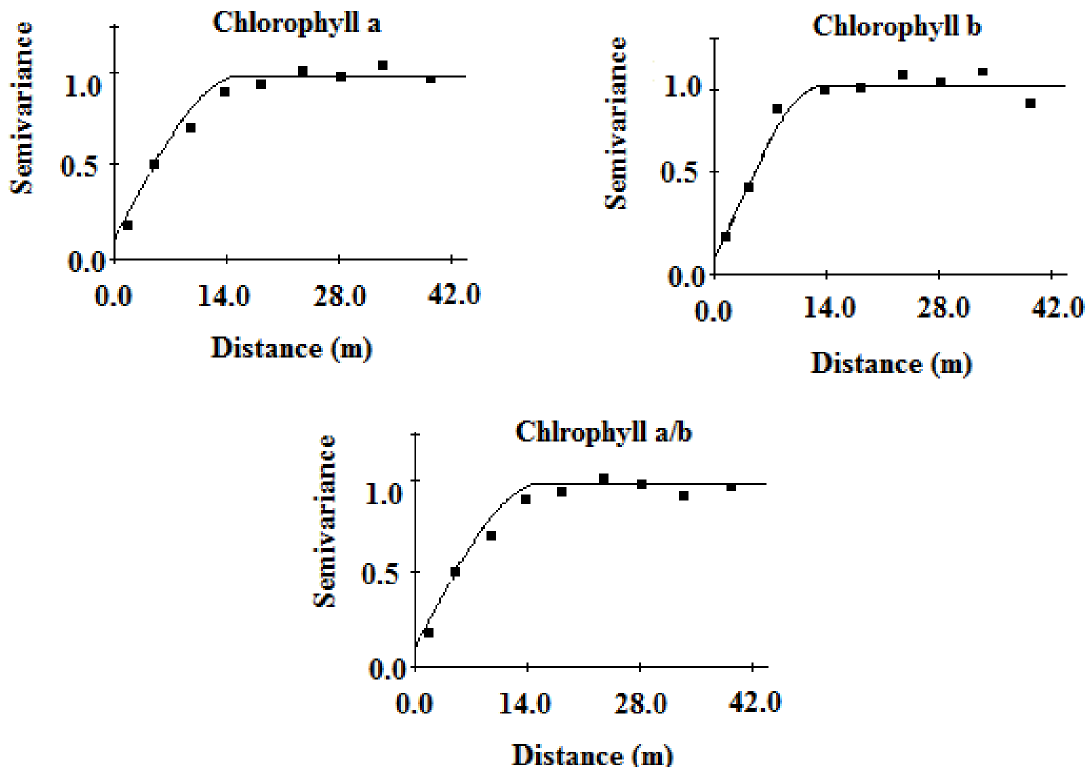

Figure 3. Standardized theoretical semivariograms for leaf chlorophyll index (LCI).

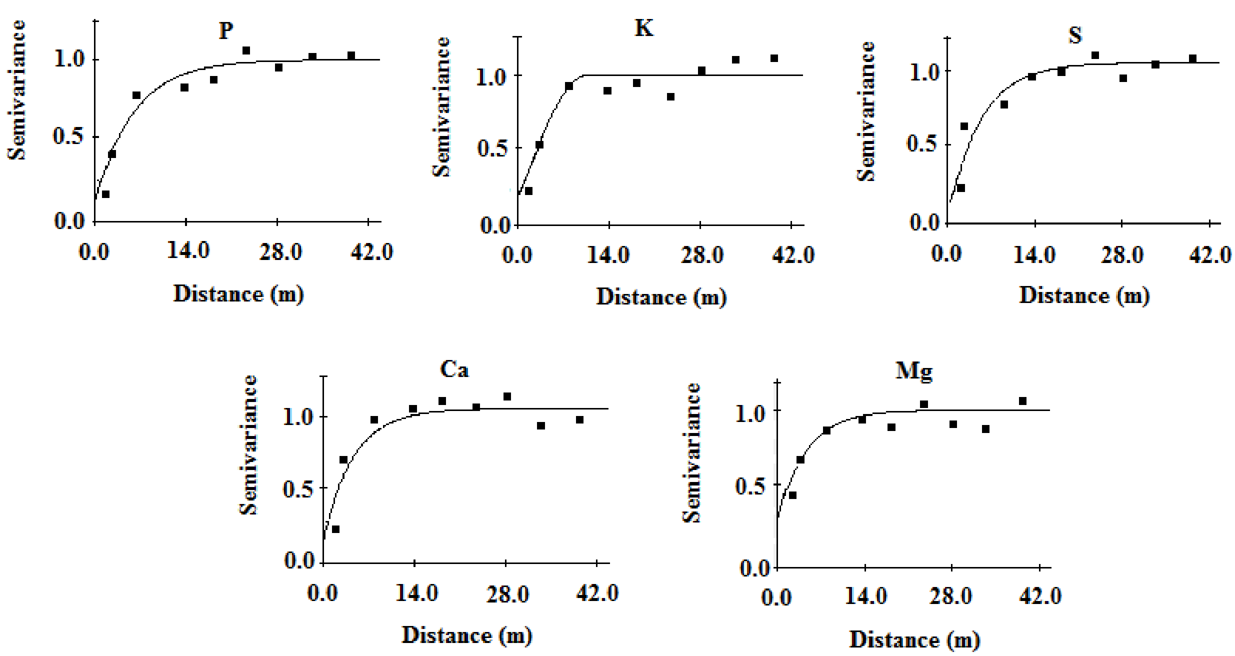

Figure 4. Standardized theoretical semivariograms for leaf macronutrients (P, K, S, Ca and Mg).

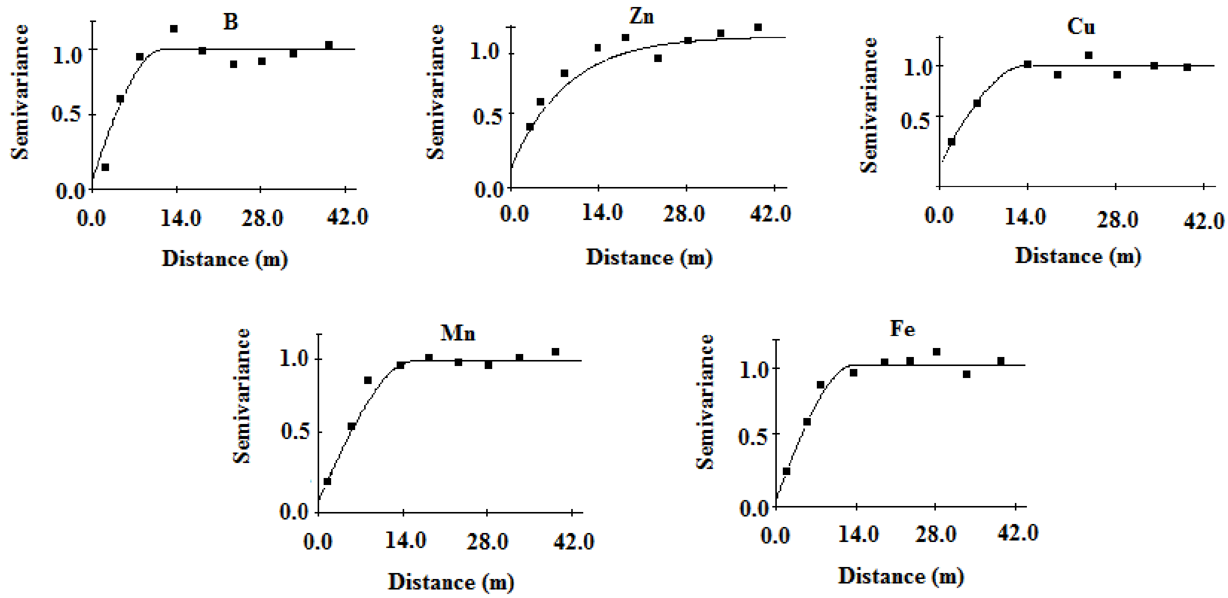

Figure 5. Standardized theoretical semivariograms for leaf micronutrients (B, Zn, Cu, Mn and Fe).

the spatial distribution of the nutritional status of the rubber tree. The nutrient Zn with 72% of the points below the appropriate range has a greater range (25.0), therefore greater spatial continuity adjusted to the exponential model.

The range value defines the maximum distance to which the value of an attribute has a spatial dependence relation with the value of the attribute at the next point. The greater range indicates greater spatial continuity, therefore, less spatial variability. According to Lima et al. (2013) ensure that determinations carried out with a greater number of neighbors within the reach range allow interpolations to be made for smaller spacings than the sampled ones and with greater accuracy in estimation for values at non-sampled sites.

The Degree of Spatial Dependence (DSD) was strong for all attributes, except for chlorophyll *a*, chlorophyll *a*/*b*, Mg, S, B, Zn and Cu with moderate DSD. The strong DSD indicates contribution of the spatial variance in the total data variance and the lowest component of randomness.

In Figure 6 are the maps of the leaf chlorophyll index (LCI) of the rubber tree (Fx 3864) and it is verified that in regions of the class of high values for the index a corresponds with the region where the index b is also high. The map of the relation a/b shows regions where it is high is correlated with regions where b is low. Note that the mean values for these variables are in the larger area color classes.

The results of chlorophyll *a* and *b* in the field are influenced by the stage of development of the plants, exposure of the leaf to the sun, form of leaf sampling, among others. Conforto et al. (2014) determined the LCI with the Clorofilog Falker in young plants and rubber tree adducts, with leaf of sun and shade, finding averages of 28 and 10, respectively.

In Figure 7, the AM Macro map shows a large part of the area between 0.50<FI<0.75 with a percentage of the area (PA) greater than 75%, then the nutritional status is high (H), indicating that the macronutrient concentration are not compromising the smooth development of the rubber tree. The AM Micro map shows an area greater than 75% with fuzzy index between 0.25 <FI <0.50, therefore, being medium nutritional status (M). This fact corroborates the percentage

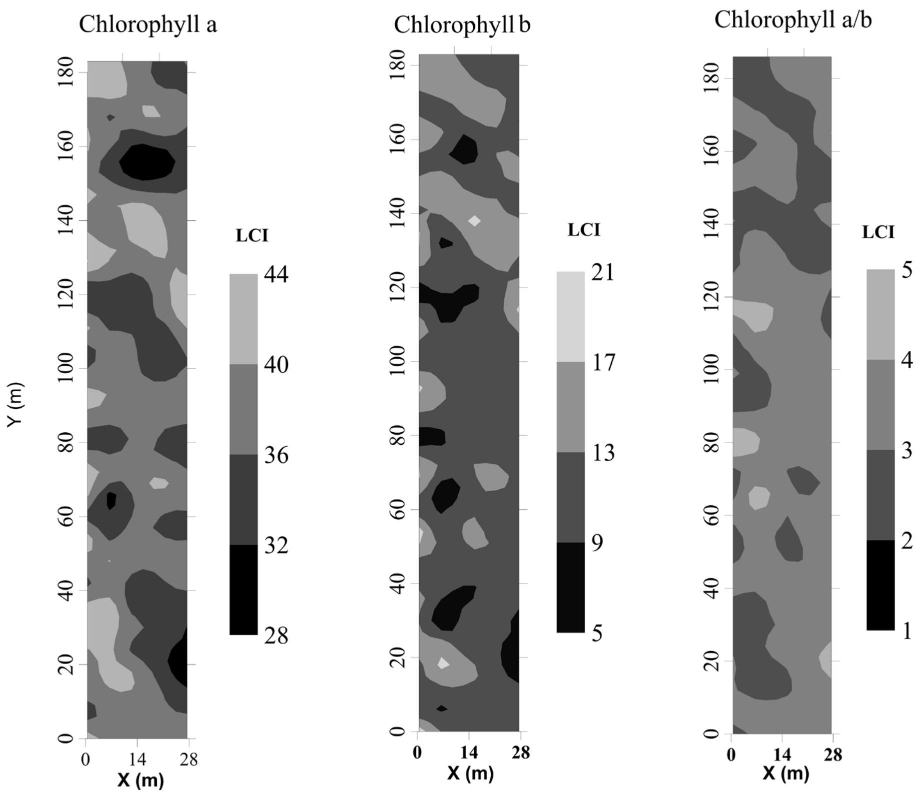

Figure 6. **Maps of the spatial distribution of leaf chlorophyll index (LCI): *a*, *b* and *a/b*.**

distribution of the ranges of sufficiency, being greatly influenced by the nutrients Zn and Cu that present the lowest percentage of the sampling points in the adequate nutritional range.

The fuzzy classification with the geostatistical analysis made it possible to construct zoning maps of the spatial distribution of the nutritional status of the rubber tree, showing distinct zones occupying different percentages of area (PA) in the rubber tree.

Considering the results found in the management zones defined in AM Macro (macronutrients) and AM Micro (micronutrients) (Figure 7) it is recommended to evaluate the nutritional status of the rubber tree, in the initial stage of development, based on the respective maps. Sine it is possible to more precision identify the nutritional needs of the rubber tree.

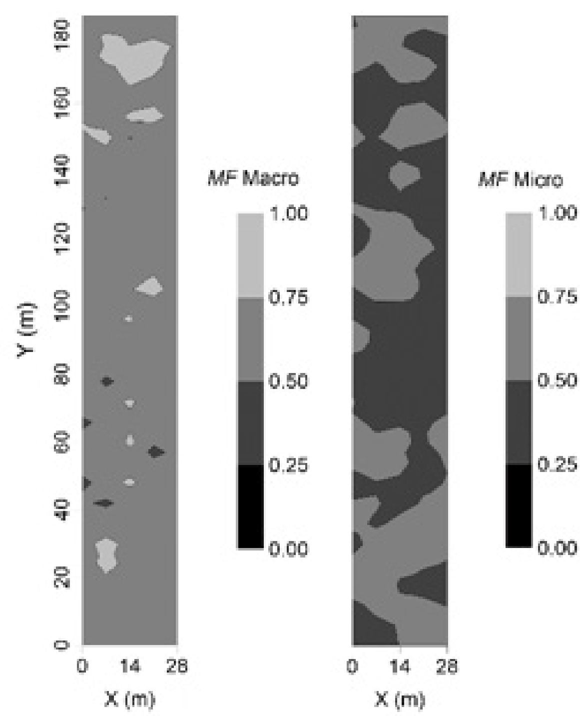

Figure 7. **Maps of the spatial distribution of the fuzzy index (FI), after fuzzy classification, for macronutrients (AM Macro) and leaf micronutrients (AM Micro).**

CONCLUSIONS

The leaf chlorophyll index (LCI) *a*, *b* and *a/b* of the rubber tree shows the same pattern of spatial distribution, adjustments to the same model and equal ranges. However, these attributes do not present a linear correlation with leaf nutrients at the initial stage of development.

The fuzzy classification associated with geostatistical analysis defined management zones with high nutritional status in more than 75% of the plants in the area with a fuzzy index (FI) between 0.5 and 0.75, for macronutrients, and FI between 0.25 and 0.50, for micronutrients, in more than 75% of the area with average nutritional status.

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