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Attributes of Neosols associated with agricultural uses in the Semi-arid Region of Rio Grande do Norte, Brazil

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The integrated study of soil properties allows the establishment of appropriate management practices in the Brazilian Semi-arid region. This study aimed at evaluating the physical and chemical attributes in Neosols under different agricultural uses in different landscape positions. The evaluations were carried out in five areas in the city of Martins, RN: Consortium of corn/bean/cassava (CON), monoculture of corn (MM) and banana (BN) all in Lithic Neosol; monoculture of sugarcane (SC) and elephant grass (EG) in Fluvic Neosol and native forest area (NF). For chemical and physical analysis, samples were collected from layers of 0.00-0.10, 0.10-0.20 and 0.20-0.30 m. Data were analyzed using multivariate analysis. The main results of the principal components analysis, CP1, CP2, CP3 and CP4, explained 87.16% of data variance: CP1 represented by pH and exchangeable cations (Ca^{2+}, Mg^{2+}), base saturation (SB), and the contrast represented by the potential acidity (H+Al) and aluminum (Al^{3+}). In CP2 electrical conductivity (EC), sodium (Na^{+}), aluminum (Al^{3+}) and acidity by aluminum (m) were responsible for the differentiation of uses, highlighting the importance of maintaining crop residues as responsible for the reduction of exchangeable Al^{3+} content and the increase in pH and release of exchangeable bases. It is concluded that agricultural systems that favored the maintenance of the total organic carbon were the grass-Elephant grass (EG), followed by the consortium of corn, beans and cassava (CON). The attributes (pH, Ca^{2+} and Mg^{2+}), sum of bases (t, V, EG, Na^{+} and PST) were indicators of separation of environments, and the most sensitive ($Al^{3+}$and H+Al). The chemical attributes in agricultural uses of banana monoculture (BN), consortium of corn, beans and cassava (CON), monocultures of Elephant grass (EG) and native forest (NF) had stood, reflecting higher weights in module, following the order of importance of the components: CP1>CP2>CP3>CP4.

Key words: Landscape, consortium, multivariate, soil management.

INTRODUCTION

Among the different factors that influence the spatial variability of soil attributes, the position of terrain in the landscape (slope and form) stands out for being a characteristic that controls the routes preferred by water

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flow and its dynamics in the soil (Souza, 2006). Thus, the location of soils in the landscape, different systems of agricultural use and soil management are considered to be the main tools for changing its composition and structural arrangements. Alterations resulting from inappropriate use of natural resources are normally compared to areas with less human interference and that are thus used as a reference. This includes the removal of original vegetation and the planting of crops, together with intensive soil preparation practices, which cause break ups in soil-plant-atmosphere stability (Bargali et al., 1992, 1993a, b; Bargali, 1996; Joshi et al., 1997).

Analyzing systems of agricultural use in the semi-arid region of Brazil, Marinho et al. (2016), found that the soil under agro-ecological areas (AGA) was less damaging to recalcitrant soil organic material fractions, with it being of a similar condition to that of native scrub (NSA), and obtaining higher levels of C-Hum humin carbon and C-FV fulvic acid carbon, unlike systems with intensive soil preparation. It was found that plant diversity in the systems is positively reflected in the maintenance and/or improvement of soil productive capacity, and consequently connected to root growth and the permanence of residual vegetation on the surface (Padalia et al., 2015; Parihaar et al., 2015).

The landscape position where the study was developed has the natural characteristics of rugged terrain with sloped areas, alongside agriculture that does not consider the neighboring sloped areas. This agriculture is conventional, with intensive soil preparation, and involving monoculture, extensive livestock rearing, burning, clearing and uncontrolled vegetation extraction, without observing the local characteristics, and thus making the location more susceptible to the processes of degradation (Nunes, 2015).

Studies evaluating soil attributes in the Potiguar region of Rio Grande do Norte, Brazil, are rare, considering that their quantification in different agricultural uses in an integrated way is necessary for establishing appropriate agricultural practices, given that these are inter-related.

In light of this, the aim of the study was to evaluate the physical and chemical attributes in neosols under different agricultural uses, in different landscape positions, using univariate and multivariate statistics as tools.

MATERIALS AND METHODS

This study was developed in the area on the perimeter of the Bela Vista Ranch, located in a small, flat bottom valley, approximately 200 m wide, more than 500 m long, and from 20 to 30 m deep, resulting from the widening of a ravine carved in sandstone down to the underlying crystalline base, in the municipality of Martins, in the state of Rio Grande do Norte, in the semi-arid region of Brazil. It is located in the Serrana do Oeste Potiguar mesoregion, between the geographical coordinates 6°05´16´´S and 37°54´40´´O and at an altitude of 705 m.

According to the Köppen climatic classification, the climate is of the forest type associated with *caatinga* scrubland. The Martins mountain range is an area of residual uplands of approximately two thousand hectares consisting of sandstone broken down by Borborema system erosion, and located between the high and Midwest of the State of Rio Grande do Norte (Jacomine, 1971).

The study was carried out in six areas, 5 of them agricultural, with particular characteristics regarding the agricultural uses, and 1 area of preserved scrub (reference), with their respective soil classes, which are: area 1 – joint corn, bean, and cassava (JNT), Litolic Neosol; 2 – sugarcane monoculture (SUG), Fluvic Neosol; 3 – banana monoculture (BN), Litolic Noesol; 4 – elephant grass monoculture (EG), Fluvic Neosol; 5 corn monoculture (CM), Litolic Neosol, and 6 – native scrub, as a reference (NS), Litoric Neosol.

To carry out the laboratorial analyses, samples of soil with deformed structures were collected, consisting of five samples, originating from 15 subsamples, from each of the aforementioned areas, taking 1 ha as a reference, from the 0.00-0.10, 0.10-0.20 and 0.20-0.30 m layers. They were removed with the help of a Dutch type auger, conditioned in duly identified plastic bags, and taken to the Soil, Water, and Plant Analysis Laboratory of the Semi-Arid Rural Federal University – *UFERSA*. Subsequently, they were air dried, buffered, and passed through 2 mm sieves to obtain air-dried fine earth (ADFE). These were submitted for chemical and physical soil analyses.

The physical and chemical analyses were carried out at the Soil Physics and Plant Fertility and Nutrition laboratories, respectively, both at the Soil, Water and Plant Analyses Laboratory complex of the Department for Environmental and Technical Sciences of the Semi-Arid Rural Federal University (SWPAL/DETS/*UFERSA*).

For the chemical attributes of the soil, the following analyses were carried out: hydrogenionic potential (pH) in water; electrical conductivity (EC) in water; exchangeable calcium (Ca^{2+}) and exchangeable magnesium (Mg^{2+}) levels, using a potassium chloride extractor; potential acidity (H+Al), using calcium acetate; and phosphorus (P^{+}), sodium (Na^{+}), and potassium (K^{+}) analysis, using a Mehlich -1 extractor. Consequently, the cation exchange capacity (CEC), sum of bases (SB), and base saturation (V) were calculated and analyzed in accordance with Donagema et al. (2011). The results for the chemical attributes were interpreted in accordance with recommendation tables for the use of correctives and fertilizers in Minas Gerais (Ribeiro et al., 1999).

For the physical soil attributes, the following analyses were carried out: granulometry via the pipette method using chemical dispersion (sodium hexametaphosphate) and distilled water in 20 g of air-dried fine earth (EDFE), with slow mechanical shaking in a Wagner 50 rpm shaker for 16 h (Donagema et al., 2011). The sand (2 to 0.05 mm) was quantified via sieving, the clay (< 0.002 mm) via sedimentation, and the silt (0.05 to 0.002 mm) via the difference between the sand and clay fractions. The particle density (Pd) analysis was carried out via the volumetric balloon method, using fine earth dried in an oven (ODFE) at 105°C and ethyl alcohol (Donagema et al., 2011).

The statistical methods for analyzing the difference between the variables were arranged into two groups: one which obtains information on the variables in an isolated way - univariate statistics (eg. anova and t test) - and the other using multivariate analysis techniques as the main tool, especially principle components analysis (STATISTICA, 2004), to distinguish between the areas studied in function of environment potentialities or restrictions.

RESULTS AND DISCUSSION

Table 1 presents the results using criteria to determine the sufficient quantity of principle components for the analysis, in which those components that explain at least 80% of total variability in the data are considered. The

Table 1. Autovectors of chemical and physical attributes of the analyzed soils, with the principle components and correlation matrix Eigen values, explanation percentages and accumulated explanation of the total variance.

Variables	**Components**			
	PC1	**PC 2**	**PC 3**	**PC 4**
pH	0.87	0.28	-0.05	-0.25
EC	-0.17	0.71	0.49	0.33
OM	0.37	0.41	0.71	0.08
Ca	0.93	-0.17	-0.15	-0.05
Mg	0.78	-0.29	-0.05	0.29
P	0.70	0.18	0.02	0.39
K	0.52	0.16	-0.51	0.13
Na	0.28	-0.33	0.82	0.10
Al	-0.82	0.37	-0.18	0.20
(H+Al)	-0.71	0.16	-0.33	0.55
SB	0.96	-0.21	-0.10	0.09
E	0.95	-0.15	-0.13	0.14
CEC	0.38	-0.05	-0.51	0.74
V	0.92	-0.24	0.07	-0.25
SEP	0.10	-0.37	0.85	0.22
Sand	0.37	0.87	-0.19	-0.16
Silt	-0.49	-0.77	0.08	-0.04
Clay	-0.08	-0.77	0.30	0.41
Agreg.	0.13	0.81	0.37	0.09
Est. Agreg.	0.19	0.90	0.25	0.11
Eigenvalue	7.68	4.89	3.19	1.68
Variability (%)	38.38	24.44	15.94	8.40
Accumulated (%)	38.38	62.82	78.76	87.16

Eignen values, an explanation of the variances associated with the principle components (PCs) generated, and an explanation of the accumulated variances, are included. With this, the main results for the principle components PC1, PC2, PC3 and PC4, were obtained, in which 87.16% of the variation in data were explained using an appropriate cut-off point for each component, and considering only the variables in bold (black) in Table 1.

It is observed in Table 1 that PC1 represents the pH, exchangeable cations (Ca^{2+}, Mg^{2+}), and base saturation (BS), while the contrast is represented by potential acidity (H+Al) and aluminum (Al^{3+}). In PC2, electrical conductivity (EC), sodium (Na^{+}), aluminum (Al^{3+}), and aluminum acidity (m) were responsible for the differences between the agricultural uses. This shows the importance of maintaining vegetable residues, as they are responsible for reducing exchangeable Al^{3+} levels, (Meurer, 2006), as well as increasing pH and liberating exchangeable bases (Table 1). Thus, the first component contrasts (pH; Ca^{2+}; Mg^{2+}; SB; e; V) - (Al; H+Al), and the second component contrasts between (EC; Na^{+}; SEP) – (K; CTC), and finally, principle component 3 is the sum of P and CEC.

This is in accordance with the vector projection diagram for the chemical and physical attributes, in function of the systems of agricultural use and the components found. For ease of interpretation, a Biplot-2D is used, in order to determine the relationships between the averages for the agricultural uses and native scrub (NS), as a reference, and the layers studied, presenting their own characteristics since they are grouped in different quadrants of the graph (Figure 1 A, B, C and D). This means that elephant grass (EG) monoculture agricultural use, present in the first quadrant (top right) of Figure 1, presented an eigenvalue for principle components 1 and 2, that is, high values for pH, Ca^{2+}, Mg^{2+}, SB, e, V, EC, Na^{+} and SEP, and low values for Al, H+Al and K, which can be explained by the location of the areas in the landscape (colluvial), with deposition of sediments originating for the sloped parts and from the material of origin.

Similar results were found by Marinho et al. (2016), who in studying Cambisols in the 0.05 – 0.10 m layer of a colluvial area, found high P, Ca^{2+}, and CEC values. By analyzing the same attributes, it was observed that the two principle components (Factors 1 and 2) explained 52.85% of the total variation in the attributes and the greatest correlation coefficients presented for chemical attributes were for P and K^{+}.

In contrast, the elephant grass (EG) monoculture area and the native scrub (NS) area present in the third

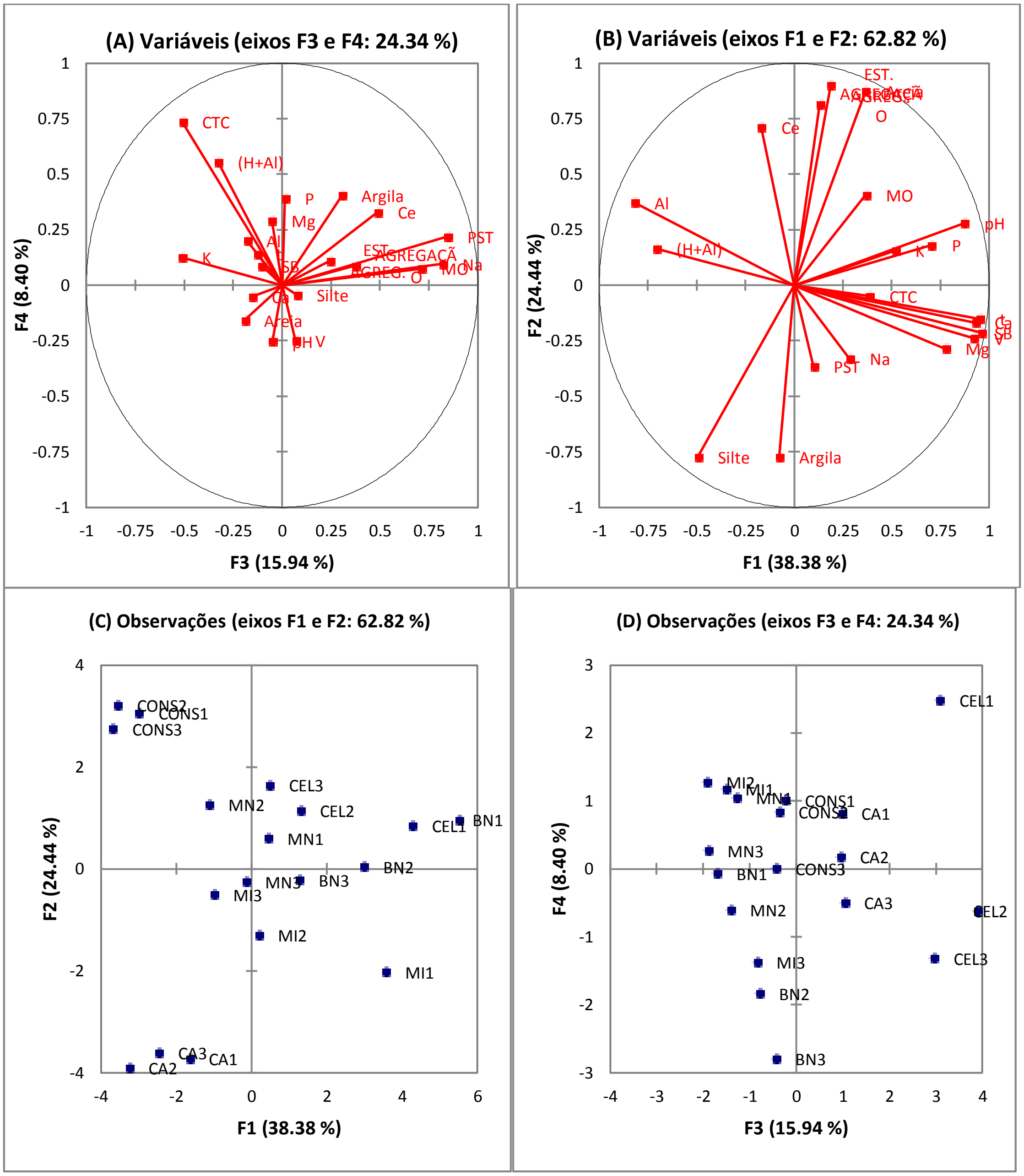

Figure 1. Vector projection diagram for chemical and physical attributes, in function of systems of agricultural use, 01 – joint corn, bean, and cassava (JNT); sugarcane monoculture (SUG); 03 banana monoculture (BN); 04 elephant grass monoculture (EG); 05 - corn monoculture (CM); and 06 – native scrub (NS), with this being considered as the reference area, in the 0.00-0.10, 0.10-20, and 0.20-0.30 m layers, and the principle component ordination diagram, for the municipality of Martins, RN, in the semi-arid region of Brazil.

quadrant (Figure 1 C), assume low values in both components, which equate to Eigen values for Al, H+Al, K and CEC, and low pH, Ca^{2+}, Mg^{2+}, SB, e, V, EC, Na and SEP values (Table 2). This can be explained by the soils in the semi-arid Northeast of Brazil generally being characterized by an alkaline pH (pH>7.0). However, the municipality of Martins, RN, comprises an area with an average annual rainfall greater than 1,000 mm (Beltrão et al., 2005), which may have contributed to soil acidification, due to leaching of exchangeable bases, and the location of the soil in the landscape, since the native scrub (NS) and joint corn, bean, and cassava (JNT) area are located inter-river (a flat and higher area). The BN area, in the fourth quadrant (Figure 1D), presented an Eigen value for PC1 and a low value for PC2, that is, high pH, Ca, Mg, SB, e, V, K, and CEC values, and low Al,

Table 2. Correlation matrix of the chemical and physical attributes of the soil obtained by principle component analysis (PCA) in function of the systems of agricultural uses, 01– joint corn, bean, and cassava (JNT), 02– sugarcane monoculture (SUG), 03– banana monoculture (BN), 04– elephant grass monoculture (EG), 05– corn monoculture (CM), and 06– native scrub (NS), with this being considered as the reference area, in the 0.00-0.10, 0.10-20 and 0.20-0.30 m layers, and the principle component ordination diagram, for the Bela Vista Ranch, in the municipality of Martins, RN.

Variables	pH	ec	OC	Ca	Mg	P	K	Na	Al	(H+Al)	SB	E	CEC	V	SEP	Sand	Silt	Clay	AGREG.	EST. AGREG.
pH	1.00																			
ec	-0.01	1.00																		
OC	0.37	0.53	1.00																	
Ca	0.81	-0.33	0.18	1.00																
Mg	0.47	-0.27	0.08	0.69	1.00															
P	0.67	0.26	0.33	0.64	0.46	1.00														
K	0.34	-0.35	-0.07	0.40	0.52	0.21	1.00													
Na	0.05	0.05	0.57	0.15	0.35	0.06	-0.15	1.00												
Al	-0.64	0.46	-0.34	-0.78	-0.64	-0.35	-0.34	-0.55	1.00											
(H+Al)	-0.67	0.21	-0.33	-0.65	-0.45	-0.31	-0.10	-0.43	0.74	1.00										
SB	0.75	-0.32	0.18	0.95	0.85	0.67	0.50	0.25	-0.80	-0.65	1.00									
E	0.75	-0.25	0.18	0.94	0.85	0.72	0.50	0.19	-0.73	-0.61	0.99	1.00								
CEC	0.18	-0.13	-0.15	0.43	0.53	0.49	0.51	-0.20	-0.14	0.34	0.49	0.53	1.00							
V	0.78	-0.35	0.24	0.90	0.73	0.50	0.37	0.35	-0.89	-0.87	0.92	0.88	0.14	1.00						
SEP	-0.08	0.19	0.47	0.02	0.18	0.12	-0.43	0.87	-0.31	-0.26	0.10	0.08	-0.20	0.18	1.00					
Sand	0.64	0.38	0.37	0.24	-0.05	0.35	0.39	-0.34	0.00	-0.10	0.16	0.20	0.10	0.13	-0.45	1.00				
Silt	-0.66	-0.39	-0.53	-0.35	-0.05	-0.53	-0.44	0.16	0.15	0.14	-0.30	-0.33	-0.24	-0.22	0.28	-0.92	1.00			
Clay	-0.42	-0.26	-0.04	-0.02	0.18	0.01	-0.21	0.50	-0.22	0.02	0.09	0.05	0.12	0.03	0.56	-0.83	0.55	1.00		
AGREG.	0.20	0.75	0.57	-0.12	0.02	0.13	0.16	0.13	0.15	-0.07	-0.06	-0.02	-0.14	-0.03	0.02	0.62	-0.57	-0.51	1.00	
EST.AGREG.	0.31	0.75	0.57	-0.07	0.01	0.25	0.25	0.01	0.15	-0.02	-0.02	0.03	-0.03	-0.03	-0.10	0.76	-0.71	-0.61	0.96	1.00

pH – hydrogenionic potential; ec – electical conductivity; p – phosphorus; OC – organic carbon; ca^{2+} - calcium; mg^{2} = magnesium; k^{+} – potassium; na^{+} – sodium; al^{3+} aluminum; (h +a1) – potential acidity; sb – sum of bases; e – effective cation exchange capacity; cec – potential cation exchange capacity; v – base saturation; m – aluminum saturation; sec – sodium exchange percentage; ca^{2+} - calcium; mg^{2} – magnesium; al^{3+} - aluminum; (h-al) – potential acidity; sb – sum of bases; e – effective cation exchange capacity; cec – potential cation exchange capacity; v – base saturation; m – aluminum saturation; sep – sodium exchange percentage.

H+Al, EC, Na and SEP values (Table 2). The joint corn, beans and cassava (JNT) area presented low values for PC1 and values close to the average for PC2, therefore the EC, Na, and SEP values were proportionate with K and CEC and it also has high Al and H+Al indices and low pH, Ca, Mg, SB, e and V values.

And among the chemical attributes, those that most stood out statistically for distinguishing between the agricultural uses were: banana monoculture (BAN), joint corn, beans and cassava (JNT), elephant grass monoculture (EG) and native scrub (NS), thus presenting the greatest correlations, that is, greater module weights, following the order of importance between the components (PC1 > PC2 > PC3 > PC4).

The correlation matrix obtained with the principle components analysis (PCA) of the chemical attributes of the soil is presented in Table 2. The high positive correlation of SB can be explained by the exchangeable base correlation, with the exception of Mg, which presented a negative correlation.

The high and positive correlation between P, K, Na and Ca was in function of the increase in pH liberating these nutrients and the unavailability of A1 in the soil, and consequently, consequently, lower potential acidity (H+A1) and aluminum saturation (m), explained by the negative correlation existing between these elements. Carneiro et al. (2009), by studying the soil attributes of *cerrado* savanna under different systems of agricultural use, obtained similar results, in which an increase in pH raised exchangeable base levels, with a reduction in soil acidity.

Arruda et al. (2014), by analyzing the correlation matrix for areas of Martins in Rio Grande do Norte, verified that principle component analysis (PCA) of the chemical attributes of the soil presented a positive correlation for SB, which can be explained by the exchangeable base correlation, with the exception of Mg, which presented a negative correlation. The high and positive correlation between P, K, Na and Ca was in function of the increase in pH liberating these nutrients and the unavailability of A1 in the soil, and consequently, lower potential acidity (H+Al) and aluminum saturation (m), explained by the negative correlation existing between these elements.

The correlation matrix showed inter-relationships obtained for the chemical and physical attributes studied in the systems of agricultural uses: joint corn, bean and cassava (JNT), sugarcane monoculture (SUG), banana monoculture (BN), elephant grass monoculture (EG), corn monoculture (CM) and native scrub (NS), as in Table 2. The high positive correlations (values above 0.7) between the physical and chemical attributes were found in hydrogenic potential (pH), calcium (Ca^{2+}), sum of bases (SB), effective cation exchange capacity (e), and base saturation (V), with a direct relationship between these, that is, the greater the SB, the greater the relationship between cations such as Ca^{2+}, as well as pH. Thus, the sum of exchangeable bases (SB) represents the sum of exchangeable cation levels (SB = Ca^{2+} Mg^{2+} K^+ and Na^{2+}). However, negative correlations occurred between pH and H^+ and Al^{3+}, showing an inverse correlation existing between these attributes, except for H^+ and Al^{3+}. The high, positive correlation of SB can be explained by the exchangeable base correlation, with the exception of Mg, which presented a negative correlation. Arruda et al. (2014), by studying Latosol in Martins, RN, verified a high and positive correlation between P, K, Na and Ca, explained by an increase in pH liberating these nutrients, and the unavailability of A1 in the soil, and consequently, lower potential acidity (H+A1) and aluminum saturation (m), explained by the negative correlation existing between these elements.

It is worth highlighting, in light of the results found, that the soil attributes studied were efficient in distinguishing between the environments studied, with regards to agricultural uses and the location of soils in the landscape.

Agricultural use involving crops with a root system and fasciculated aerial part, such as grasses (EG) and joint corn, bean, and cassava (JNT), with plant diversity, was more favorable to maintaining agricultural sustainability, thus improving organic carbon contributions in the soil and the percentage and stability of additives in greater levels than in native scrub. This can be explained by the location of the soil in the landscape, showing that the landscape had a direct influence in the interpretation of the results obtained.

This thus allows for appropriate future practices to be established for mitigating inappropriate use caused by the agricultural activities developed, especially in neosols, which were the focus of this study. This is due to these being little evolved soils and without any type of B horizon, as well as them presenting a low water storage capacity. Consequently, it becomes necessary for good judgment to be used in the activities developed, depending on the potentialities and limitations presented.

Conclusions

1. The soils presented acidity reactions for native scrub (NS) and joint corn, bean and cassava (JNT), with neutrality for elephant grass (EG), corn (CM) and banana (BN), with the presence of Al^{3+} and H+Al and without raised salinity.
2. The higher total organic carbon (TOC) level in the elephant grass (EG) agricultural use, followed by joint corn, bean and cassava (JNT), favored the maintenance of the agricultural systems.
3. The chemical attributes pH, Ca^{2+}, Mg^{2+}, sum of bases, e, V, EC, Na^+ and SEP were indicators of separation between the environments. However, the most sensitive were Al^{3+} and H+Al.
4. The chemical attributes in the banana monoculture (BN), joint corn, bean and cassava (JNT), elephant grass (EG) agricultural uses and native scrub (NS) were the ones that stood out the most, reflecting greater module weights, following the order of importance of components: PC1> PC2> PC3> PC4.

Conflict of interest

The authors have not declared nay conflict of interest

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