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Physical, chemical and structural attributes of soil in agroecosystems in the Brazilian Semiarid region[1]

Atributos físicos, químicos e estruturais do solo em agroecossistemas na região semiárida brasileira

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ABSTRACT - The soil attributes can be easily changed according to its management and use, compromising the productive capacity of the areas. The objective of this research was to evaluate the variability and interrelationships of soil physical, chemical and structural attributes in agroecosystems in the Brazilian Semiarid region (Rio Grande do Norte State), pointing out the most sensitive attributes in the environment distinction through multivariate analysis. The research was carried out in the rural community of Piracicaba, Upanema municipality, Rio Grande do Norte State, Brazil. Four agroecosystems were selected: Native Forest Area (ANF), Corn Bean Consortium Area (ACBC), Pasture Area (AP) and Cashew Area (AC). Undisturbed and deformed soil samples were collected in the 0.00-0.10, 0.10-0.20 and 0.20-0.30 m layers, and the physical, chemical and structural attributes were analyzed. The data were submitted to multivariate statistical techniques, using the correlation matrix, cluster analysis, factor analysis and principal component analysis. Factorial analysis revealed the most sensitive attributes in distinguishing agroecosystems: microporosity, field capacity (FC), permanent wither point (PWP), available water (AW), sand, clay, flocculation degree (GF), Ca^{2+}, Mg^{2+} and sum of bases (SB) (F1) and soil density (SD), total porosity (PT), macroporosity, electrical conductivity (EC) and total organic carbon (TOC) (F2). Cluster analysis formed three distinct groups. The TOC was discriminant to group the native forest and cashew tree areas, showing the influence of soil management. The other environments were grouped according to the texture differentiation, influencing the attributes variability.

Key words: Inorganic fractions. Multivariate statistics. Total organic carbon. Soil management.

RESUMO - Os atributos do solo podem ser facilmente alterados pelo uso e manejo, comprometendo a capacidade produtiva das áreas. O objetivo da pesquisa foi avaliar a variabilidade e inter-relações dos atributos físicos, químicos e estruturais do solo em agroecossistemas no Semiárido Potiguar Brasileiro, apontando os atributos mais sensíveis na distinção dos ambientes por meio da análise multivariada. A pesquisa foi realizada na comunidade rural de Piracicaba, município de Upanema, Rio Grande do Norte, região Semiárida Brasileira. Foram selecionados quatro agroecossistemas: Área de Mata nativa (AMN), Área de consórcio milho feijão (ACMF), Área de Pastagem (AP) e Área de Cajueiro (AC). Foram coletadas amostras de solo indeformadas e deformadas nas camadas 0,00-0,10, 0,10-0,20 e 0,20-0,30 (m), e realizadas as análises dos atributos físicos, químicos e estruturais. Os dados foram submetidos a técnicas de estatística multivariada, por meio da matriz de correlação, análise de agrupamento, análise fatorial e componentes principais. A análise fatorial revelou os atributos mais sensíveis na distinção dos agroecossistemas, sendo microporosidade, capacidade de campo (CC), ponto de murcha permanente (PMP), água disponível (AD), areia, argila, grau de floculação (GF), Ca^{2+}, Mg^{2+} e soma de bases (SB) (F1) e densidade do solo (DS), porosidade total (PT), macroporosidade, condutividade elétrica (CE) e carbono orgânico total (COT) (F2). A análise de agrupamento formou três grupos distintos. O COT foi discriminante para agrupar as áreas de mata nativa e de cajueiro, evidenciando a influência do manejo do solo. Os demais ambientes foram agrupados pela diferenciação da textura influenciando na variabilidade dos atributos.

Palavras-chave: Frações inorgânicas. Estatística multivariada. Carbono orgânico total. Manejo do solo.

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INTRODUCTION

Soil is a finite natural resource, that is, it is not renewable over the human time scale (decades) and is subject to degradation by natural and anthropogenic factors (LAL, 2015). Thus, it is of fundamental importance to develop proper activity planning and maintenance of its productive capacity (LOPES *et al*., 2019).

Inadequate soil use represents major degradation. Data from the Food and Agriculture Organization (FAO) report that worldwide 25% of the areas are highly degraded, 8% moderately degraded, 36% are stable and/or mildly degraded and 10% are in recovery. The degradation is attributed to inappropriate agricultural practices, causing erosion, loss of nutrients, soil compaction, pollution, and salinization. These factors lead to the loss and/or reduction of the productive capacity of the areas (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2011).

Soil and crop management with no conservation techniques and cover maintenance can alter soil attributes (ASSIS *et al.*, 2015). Conventional soil preparation can cause compaction and compromise structure, interfering in plant root growth and development, water infiltration and retention capacity (KLEIN; KLEIN, 2015; LOSS *et al.*, 2015). The change in porous space culminates in high soil density, causing physical constraints that compromise the availability of water, oxygen and nutrients, limiting the agricultural production (GENNARO *et al*., 2015).

Besides the anthropic actions, the soil inherent characteristics result in attributes variability. Variations in the formation factors as source material, relief, and vegetation, associated with climatic conditions, attribute a significant diversity of the semiarid soils. The climatic pattern, with less rainfall than evaporation, makes the soils, mostly shallow, with physical limitations. However, the soil can present good fertility due the water deficit characteristic of limiting chemical weathering, minimizing base leaching and nutrient losses (ANGELIM; MEDEIROS; NESI, 2006; BRASIL, 1971; SANTOS *et al.*, 2018).

Studies on the physical, chemical, and structural attributes of the soil and their interrelationship with agroecosystems are important, especially in family farming areas where these growers depend essentially on the soil resource. Thus, it is necessary to evaluate these attributes to characterize the environments regarding their potentialities and/or limitations, seeking subsidies to direct proper planning of agricultural activities and conservation of the soil productive capacity (LOPES *et al.*, 2019; MARINHO *et al.*, 2016).

In this context, multivariate statistical analysis emerges as an efficient auxiliary tool, enabling the analysis of attributes and their relationships. It is a statistical model that allows, besides identifying the difference between the studied environments, to observe which attributes contribute most to the distinction between the studied agroecosystems (HAIR JR *et al.*, 2009; LOPES *et al.*, 2019).

Thus, the objective of the research was to evaluate the variability and interrelationships of soil physical, chemical and structural attributes in agroecosystems in the Brazilian Semiarid, pointing out the most sensitive attributes in the environment's distinction through multivariate analysis.

MATERIAL AND METHODS

Studied area

The study was conducted in the rural community of Piracicaba, family farming area, with an extension of 600 ha, located in the municipality of Upanema, Rio Grande do Norte State, Brazil, whose geographic coordinates are 05° 38' 31" S and 37° 15' 28" W, altitude 93 m. It presents a climate classification according to Köppen, BSh type, hot semiarid, annual average rainfall of 715 mm, and annual average temperature of 26 °C. Annual precipitation presents a unimodal distribution with 79% concentrated from February to May.

The studied areas were defined considering the topographic position, covering the toposequence between the top of the plateau and the peripheral depression, as well as the different agricultural uses of the soil. Four agroecosystems were selected (Table 1), where profiles were opened for later collections. Soils were classified in the first categorical level, according to the Brazilian Soil Classification System - SiBCS (SANTOS *et al*., 2018) and World Reference Base (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2014). Soil collections were carried out in January 2019 (rainy period in the region).

It presents a climate classification according to Köppen, BSh type, hot semiarid, annual average rainfall of 715 mm, and annual average temperature of 26°C. Annual precipitation presents a unimodal distribution with 79% concentrated from February to May (Figure 2).

Soil samples with a deformed structure were collected, having five composite samples from 15 subsamples in each layer layers 0.00-0.10, 0.10-0.20, 0.20-0.30 m, totaling 180 samples in four areas, with triplicate in the laboratory. They were taken with the aid of a Dutch auger, packed in properly identified plastic bags and taken to the Soil, Water and Plant Analysis Laboratory (LASAP) of the Federal Rural University of Semi-Arid (UFERSA). Subsequently, samples were air-dried, harrowed and sieved in a 2 mm sieve to obtain the fine air-dried soil (FADS). Analyzes of particle density (DP) and the following chemical attributes were performed in triplicate: sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), phosphorus (P), electrical conductivity (EC), hydrogen potential (pH), potential acidity (H + Al) and total organic carbon (TOC).

Figure 1 - Study area location

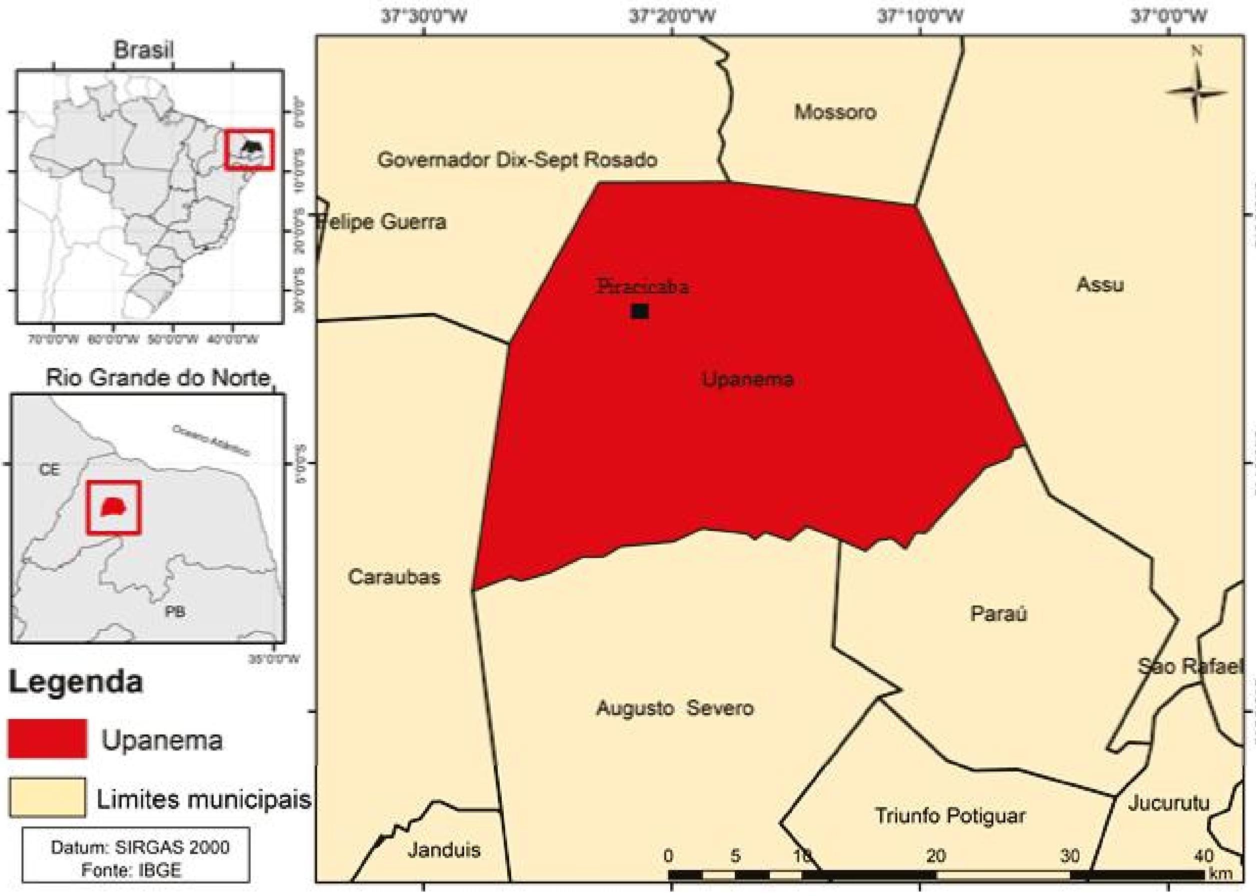


Figure 2 - Rainfall pattern in 2019 in Piracicaba community, Upanema – Rio Grande do Norte

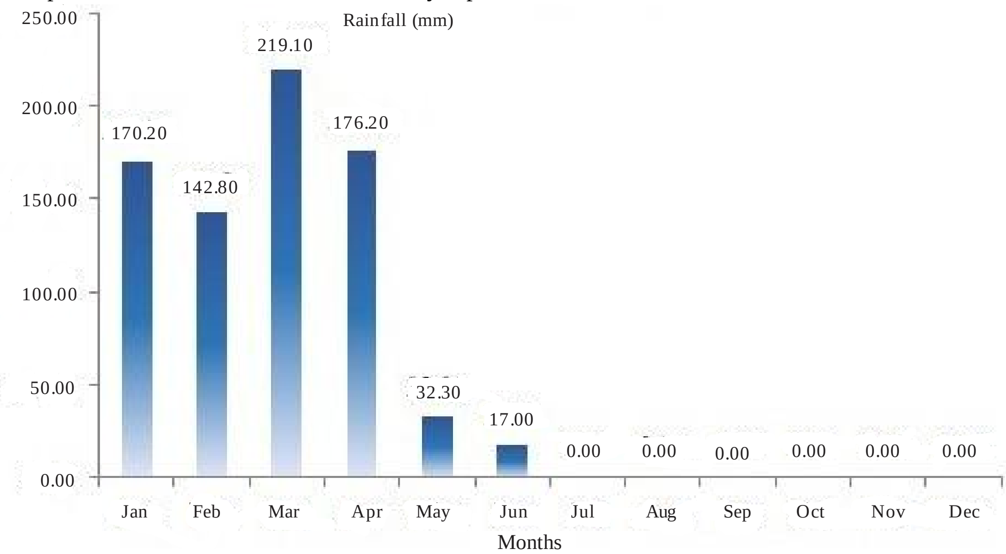


Table 1 - Land use, classification soil, localization and history use of agroecosystems

Profile, land use and soil class SiBCS and WRB	Localization	History use of agroecosystems
P1 - Native Forest Area (ANF-Latossolo/Ferralsol) 	05° 36' 01" S 37° 22' 40" W	Preserved forest area, with in the history of deforestation or cultivation in it. With the presence of characteristic species of the Caatinga biome and located at the top of the Plateau.
P2 - Corn Bean Consortium Area (ACBC- Cambissolo/Cambisol) 	05° 36' 31" S 37° 22' 38" W	Until 2015, the area was a remnant of native forest with species from the Caatinga. As of 2016, the land was prepared with a leveling grid tractor and cultivation began. First year with watermelon (Citrullus lanatus L.), 2017- maize (Zea mays L.), and 2018-2019 maize and string beans (Vigna unguiculata L.). Area cultivated only in the rainy season, in dryland system. In the dry period it is fallow. It is noteworthy that there is no application of correctives/fertilizers in the area.
P3 - Pasture Area (AP-Argissolo/Acrisol) 	05° 36' 31" S 37° 22' 38" W	The area was used for raising cattle until mid-2014. Between 2015 and 2016 sorghum (Sorghum bicolor L.) and string beans (Vigna unguiculata L.) were cultivated. Since then, until today it is used for sheep grazing, with Panasco grass (Aristida adscensionis L.) as the predominant vegetation.
P4 - Cashew Area (AC-Latossolo/Ferralsol) 	05° 36' 50" S 37° 22' 38" W	Area located at the lowest level of the landscape, close to the weir. Initially, until 1996, annual crops were already cultivated. Since then, the first cashew trees (Anacardium occidentale L.) were planted and in 2003 new seedlings were replanted, forming the orchard, which currently produces 1 to 1.5 tons of the fruit per year. It is noteworthy that there is no application of correctives/fertilizers in the area.

Soil samples and analysis

Undeformed samples were collected using Uhland-type apparatus and rings with dimensions of 0.05 m in height and 0.05 m in diameter. Ten samples per layer were collected, with a total of 120 samples. The rings were coated with laminated paper and subsequently taken to LASAP-CCA-UFERSA Lab, maintaining the original soil structure and moisture. From these samples, total porosity (PT), macro and microporosity, field capacity (FC), permanent wilting point (PWP), available water (AW) and soil density (SD) were evaluated.

For the evaluation of total macro and micro porosity the undeformed samples were saturated for 48 hours and weighed (to determine the total porosity). Microporosity was determined at a voltage of 6 kPa and by difference the macroporosity was estimated. The FC value was defined at the voltage of 10 kPa and the PWP obtained at the voltage of 1500 kPa. Soil density was determined by the volumetric ring method as described by Forsythe (1975) by calculating the relationship between dry soil mass and total ring volume (TEIXEIRA *et al.*, 2017).

The particle size was obtained by the pipette method (GEE; OR, 2002). The sand (2 to 0.05 mm) was quantified by sieving, the clay (<0.002 mm) by sedimentation and the silt (0.05 to 0.002 mm) by difference. Particle density was performed by the volumetric balloon method (BLACK *et al.*, 1965). Soil pH, potential acidity ($H^+ + Al^{+3}$), assortment complex components calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+), as well as available concentrations of phosphorus (P) and electrical conductivity (EC) were determined according to the method proposed by US Salinity Laboratory Staff (1954). Subsequently, cation exchange capacity (CEC), sum of bases (SB), base saturation (V) and exchangeable sodium percentage (PST) were calculated. Total organic carbon (TOC) was determined by digestion of organic matter (YEOMANS; BREMNER, 1988).

For the aggregates study, soil samples were collected in blocks, preserving the structure, passed in sieves with 4.00 and 2.00 (mm) of mesh size, being the soil retained in 2 mm reserved for the analysis. The wet sieving method was used (KEMPER; ROSENAU, 1986), with a set of four sieves with mesh diameters of 4.76 to 2 mm; 2 to 1 mm; 1 to 0.5 mm and 0.5 to 0.25 mm. The aggregates were separated stirring in water using a vertical oscillating apparatus (42 oscillations/minute) and samples were dried in an oven at 105 °C. Obtaining the dry mass, the sand content was discounted, and the aggregate size distribution and the weighted average diameter for each layer under study was calculated according to equation 1:

$$DMP = \sum_{i=1}^{N} X_i . W_i \quad (1)$$

Where:

DMP - wet weighted average diameter in mm.

X_i - average diameter of each class, in mm.

W_i - proportion of aggregates in each class/sieve, in%.

Statistical analysis

The results were submitted to statistical analysis using the multivariate analysis technique as the main tool, used in the detection of the most sensitive attributes in the distinction of soil environments under different uses. Pearson's correlation analysis ($p \leq 0.05$) was performed. Data were standardized by the correlation matrix and submitted to hierarchical clustering (AAH), factorial (AF) and principal component analysis (PCA) analyzes using the Software Statistics 7.0 (STATSOFT, 2004).

Cluster analysis was performed using a hierarchical clustering process by the Ward's method, aiming to represent the groups similarities. In the factor analysis, the factors were extracted by principal components and the axes rotated by the Varimax method, considering those with eigenvalues above 1. A value of 0.65 was set for significant factor loads (HAIR JR *et al*., 2009). Factorial and principal component analysis were performed to reduce data and present the most discriminating variables in distinguishing environments.

RESULTS AND DISCUSSION

Among the 26 evaluated soil attributes, 22 presented the highest correlation in the Pearson correlation matrix and higher influence on the total variation in factor analysis and principal components, as follows: SD); (PT); (Macro); (Micro); (FC); (PWP); (AW); Sand; Silt; Clay; (GF); (MPD); (pH); (EC); (TOC); (P); (K^+); (Na^+); (Ca^{2+}); (Mg^{2+}); (SB) (V).

In the correlation matrix (Table 2) can be observed that the studied variables presented a high number of significant correlations ($p \leq 0.05$). This good correlation demonstrates the adequacy of the data for the use of factor analysis (FA), principal component analysis (PCA) and hierarchical cluster analysis (AAH).

The predominance of correlations between the attributes studied proves the adequacy of the data for analysis multivariate. Numbers in red indicate significant correlations that allow continuity for further multivariate analyses (HAIR JR *et al*., 2009).

The main significant correlations were observed between the attributes of total porosity with EC and TOC (positive), and negative with SD. Microporosity was correlated with water storage data (FC, PWP and AW), with the sum of bases, degree of flocculation and silt and clay contents (BRADY; WEIL, 2013; KLEIN; KLEIN, 2015). The sand was positively correlated with macroporosity.

In the formation of the groups by the hierarchical cluster analysis (AAH) we seek the maximum similarity within the group and heterogeneity between the groups (HAIR JR *et al.*, 2009). In the dendrogram (Figure 1) the reading is taken from right to left, where the y axis indicates the distances between the formed groups, and the x axis represents the joined groups in descending order of similarity, with high dissimilarity indicating that two individuals are distinct from the set.

Considering the maximum level of dissimilarity between the groups with the cut-off line at 50% of the Euclidean distance value and allowing the formation of groups between individuals with similarity degree above 50%, three groups were formed. Group I was represented by P1 (ANF - Latossolo) in the layers 0.00-0.10; 0.10-0.20 m and P4 (AC - Latossolo), layer 0.00-0.10 (m); group II aggregated P3 (AP Argissolo) in all layers and P4 subsurface layers. Group III was formed by P2 (ACBC- Cambissolo) and with the P1 layer 0.20-0.30 (m).

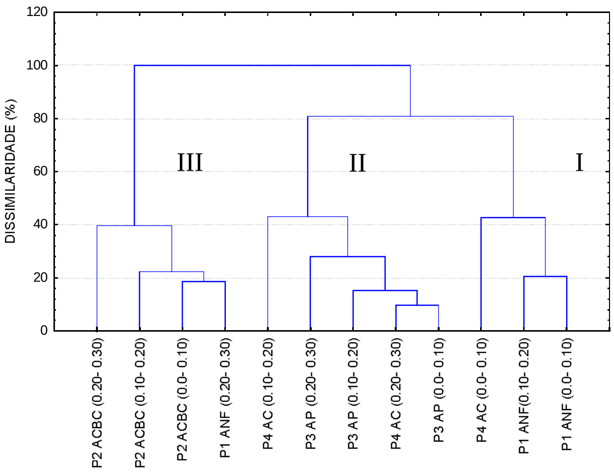
Group I P1 (ANF - Latossolo) in the layers 0.00-0.10; 0.10-0.20 m and P4 (AC - Latossolo) layer 0.00-0.10 m presented similarities regarding the higher TOC content. These agroecosystems present better conservation of the soil surface, with consequently better maintenance of the

Table 2 - Simple linear correlation matrix between soil physical, chemical and structural attributes

	SD	PT	Macro	Micro	FC	PWP	AW	SAND	SILT	CLAY	GF	MPD	pH	EC	TOC	P	K+	Na+	Ca2+	Mg2+	SB	V
SD	1.00																					
PT	-0.81	1.00																				
Macro	-0.65	0.45	1.00																			
Micro	0.21	0.13	-0.83	1.00																		
FC	0.05	0.35	-0.64	0.93	1.00																	
PWP	0.00	0.34	-0.57	0.85	0.92	1.00																
AW	0.08	0.32	-0.62	0.89	0.94	0.74	1.00															
SAND	-0.22	-0.10	0.73	-0.87	-0.91	-0.93	-0.78	1.00														
SILT	0.33	-0.22	-0.73	0.67	0.52	0.46	0.51	-0.54	1.00													
CLAY	0.15	0.18	-0.60	0.78	0.87	0.91	0.73	-0.96	0.30	1.00												
GF	0.02	0.16	-0.52	0.68	0.68	0.75	0.54	-0.74	0.79	0.59	1.00											
MPD	-0.39	-0.16	0.14	-0.25	-0.39	-0.35	-0.38	0.34	0.13	-0.42	-0.02	1.00										
pH	-0.11	-0.09	0.42	-0.52	-0.46	-0.43	-0.43	0.40	-0.77	-0.21	-0.68	0.10	1.00									
EC	-0.69	0.71	0.67	-0.30	-0.10	0.05	-0.22	0.21	-0.46	-0.09	-0.12	-0.01	0.29	1.00								
TOC	-0.65	0.70	0.53	-0.15	-0.01	0.15	-0.15	0.14	-0.31	-0.06	-0.01	0.04	0.09	0.94	1.00							
P	-0.27	0.17	0.24	-0.16	-0.27	-0.04	-0.43	0.25	0.00	-0.29	0.09	0.34	0.02	0.54	0.69	1.00						
K+	0.31	-0.25	-0.66	0.58	0.41	0.57	0.23	-0.58	0.58	0.48	0.63	0.13	-0.15	-0.13	-0.01	0.43	1.00					
Na+	-0.41	0.14	0.20	-0.13	-0.22	-0.25	-0.17	0.41	0.21	-0.53	0.04	0.55	-0.30	0.06	0.23	0.38	-0.12	1.00				
Ca2+	-0.04	0.39	-0.47	0.77	0.81	0.78	0.74	-0.66	0.50	0.59	0.60	-0.31	-0.60	0.09	0.31	0.08	0.33	0.19	1.00			
Mg2+	0.00	0.37	-0.39	0.67	0.77	0.71	0.73	-0.58	0.47	0.50	0.60	-0.45	-0.52	0.04	0.14	-0.14	0.23	0.15	0.82	1.00		
SB	-0.01	0.37	-0.50	0.79	0.83	0.80	0.75	-0.68	0.53	0.60	0.65	-0.31	-0.60	0.08	0.29	0.08	0.38	0.19	1.00	0.86	1.00	
V	-0.04	-0.12	0.08	-0.16	-0.11	-0.14	-0.08	0.15	-0.43	-0.03	-0.43	0.11	0.70	0.12	0.07	-0.06	-0.02	0.10	-0.05	0.02	-0.04	1.00

Note: SD - Soil density; PT - Total porosity; Macro - Macroporosity; Micro - Microporosity; FC - field capacity; PWP - Permanent withering point; AW - available water; GF - Degree of flocculation; MPD - weighted average diameter; pH - hydrogen potential; EC - electrical conductivity; TOC - total organic carbon; P - Phosphorus; K^+ - Potassium; Na^+ - Sodium; Ca^{2+} - Calcium; Mg^{2+} - Magnesium; SB - Sum of bases; V - base saturation

Figure 2 - Vertical dendrogram of the distance matrix by the single bond grouping method



total organic carbon, which reflected in a higher total porosity (KLEIN; KLEIN, 2015). Orchard area management allows the maintenance of the soil cover with minimal reduction of TOC values (MARINHO *et al*., 2016).

Group II (P3 - AP Argissolo and the subsurface layers of P4 AC Latossolo) were discriminated due to the higher sand content and consequently lower water availability and flocculation degree. Although P3 is an Argissolo, it was not observed, in the achieved depth, diagnostic horizons P3 and P4, being these environments sandier than the others. The sand fraction increases soil macroporosity, reducing retention with increased water infiltration (SILVA *et al*., 2018).

Group III was formed by P2 ACBC - Cambissolo environments and layer 0.20-0.30 m of P1 ANF - Latossolo. These were grouped by presenting similarities with higher clay content, sum of bases, microporosity and water availability amount. This reflects the characteristics of clay as an active fraction of soil for fertility, as well as its influence on water storage (BRADY; WEIL, 2013; KLEIN; KLEIN, 2015).

The summary of the factor analysis highlights the factors obtained, their respective factor loads, the eigenvalues and the percentage of variance explained by each factor (Table 3). Six factors were obtained, with eigenvalues above 1, and the cumulative ratio of Factor 1 (F1) to Factor (F6), explained 95.59% of the total variance of the obtained results.

The F1 grouped the variables Micro, FC, PWP, AD, Sand, Clay, GF, Ca^{2+}, Mg^{2+} and SB, representing 44.34% of the dataset variability. F2 evidenced the variables

Table 3 - Factorial axes extracted for soil attributes. Rotated by the Varimax method. Factor loadings ≥ 0.65 were considered significant for interpretation purposes, numbers in red indicate significant factor loadings

Attributes	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
SD	0.04	-0.88	-0.16	0.13	0.01	0.41
PT	0.30	0.91	0.05	-0.17	0.09	0.03
Macro	-0.64	0.70	0.04	-0.12	-0.07	0.04
Micro	0.93	-0.21	-0.01	0.03	0.13	-0.03
FC	0.98	0.02	-0.10	-0.11	0.09	0.07
PWP	0.93	0.11	-0.21	0.15	0.12	0.05
AW	0.90	-0.05	0.01	-0.32	0.06	0.08
SAND	-0.91	0.15	0.34	-0.04	-0.12	0.02
SILT	0.55	-0.45	0.29	0.19	0.51	-0.21
CLAY	0.86	-0.03	-0.47	-0.02	-0.02	0.05
GF	0.72	-0.05	0.02	0.24	0.50	-0.20
MPD	-0.29	0.01	0.30	0.20	-0.04	-0.87
pH	-0.44	0.13	-0.39	0.02	-0.78	-0.09
CE	-0.09	0.90	-0.06	0.32	-0.14	0.12
TOC	0.03	0.85	0.13	0.45	-0.08	0.14
P	-0.17	0.35	0.20	0.87	0.07	-0.08
K^+	0.51	-0.32	-0.17	0.72	0.02	-0.25
Na^+	-0.11	0.16	0.92	0.09	0.04	-0.29
Ca^{2+}	0.85	0.16	0.34	0.13	0.09	0.25
Mg^{2+}	0.79	0.10	0.35	-0.06	0.05	0.33
SB	0.87	0.13	0.34	0.15	0.08	0.23
V	0.01	-0.02	0.14	0.00	-0.98	-0.04
Eigenvalue	**9.75**	**4.34**	**2.66**	**1.80**	**1.42**	**1.06**
Total variance (%)	**44.34**	**19.71**	**12.10**	**8.20**	**6.44**	**4.80**
Variane cumulative % (%)	**44.34**	**64.05**	**76.15**	**84.35**	**90.79**	**95.59**

Note: SD - Soil density; PT - Total porosity; Macro - Macroporosity; Micro - Microporosity; FC - field capacity; PWP - Permanent withering point; AW - available water; GF - Degree of flocculation; MPD - weighted average diameter; pH - hydrogen potential; EC - electrical conductivity; TOC - total organic carbon; P - Phosphorus; K^+ - Potassium; Na^+ - Sodium; Ca^{2+} - Calcium; Mg^{2+} - Magnesium; SB - Sum of bases; V - base saturation

DS, PT, Macro, EC and TOC (19.71%). Together they represented cumulative variance of 64.05%, allowing to affirm that these factors grouped the most discriminating variables in the distinction of the studied environments. The other factors were formed by the attributes: Na^+ (F3), P and K^+ (F4), pH and V (F5) and DMP (F6), respectively representing 12.10%; 8.20%; 6.44% and 4.80% of the total variance of the data.

The highlighted variables (F1) demonstrate the interrelations between inorganic fractions, especially clay, with the chemical and structural attributes of the soil (LOPES *et al.*, 2019). Since texture is an intrinsic property of soil, it is difficult to change and directly influences structure, fertility and water retention (KLEIN; KLEIN, 2015).

The Na^+ and K^+ contents were low, with small contribution to the sum of bases, being more expressive Ca^{2+} and Mg^{2+} presented in F1. These contents express the influence of the local lithology, being the region located under the Jandaíra limestone geological formation, composed basically of carbonate rich rocks, providing high amounts of calcium and magnesium (ANGELIM;

MEDEIROS; NESI, 2006). Phosphorus (P) was not significant in the studied environments, being recognized the deficiency of this nutrient for the Brazilian semiarid region (BRASIL, 1971; BRITO *et al*., 2017).

It is noteworthy that all studied soils had a pH close to neutral (6.0 to 7.3) and eutrophic characteristic (V ≥ 50%), including the Latossolo (Profiles 1 and 4), being a particularity of the region to find this class with high base saturation (LOPES *et al*., 2019; SILVA *et al*., 2018). This occurs due to the climate pattern of the semi-arid region, with low rainfall, which minimizes the leaching process of exchangeable bases, keeping fertile soils, in addition to the influence of the source material with basic or limestone rocks (SANTOS *et al*., 2018).

In the Principal Component Analysis (PCA), the correlation circle between factors 1 and 2 is observed (Figure 3 A). The longer the vector, the greater the influence on the analysis (SOUZA *et al*., 2018). Thus, the variables closest to the circle are more representative and are the most discriminating in the correlated environments (Figure 3 B).

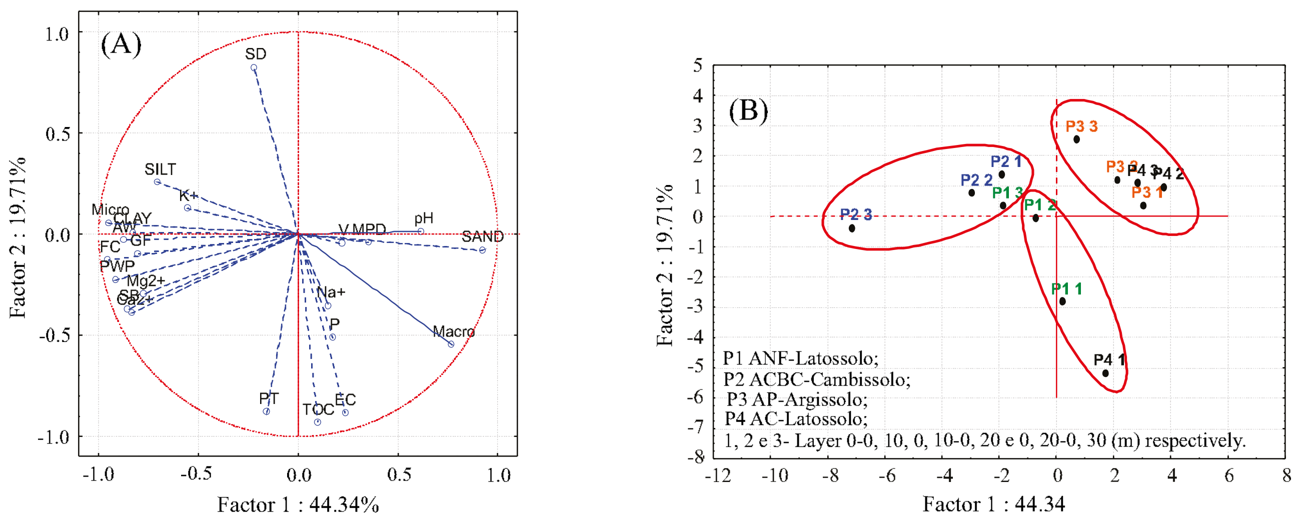
The graphs represented in the PCA confirm the result obtained with the cluster analysis, observing that the approximation of the environments in the point cloud coincides with the groups formed in the dendrogram. The circle of correlation has been demonstrating the discriminating variables in their differentiation and/or similarity.

The inorganic fractions (sand, silt and clay) were distant within the correlation circle, showing texture variability and inferring its influence on the distinction of the studied environments (LOPES *et al*., 2019). Clay and sand were more determinant, both being present in F1, with negative interactions (Table 3), being presented in opposite positions in the circle of correlations (Figure 3 A).

The variables TOC, EC and PT were the most sensitive for distinguishing the environments P1 (Native Forest-Latossolo) in the layers 0.00-0.10 and 0.10-0.20 (m) and P4 (Cashew Area - Latossolo) in the layer 0.00-0.10 (m). The attributes presented positive correlations with each other, whereas soil density in the opposite quadrant indicates negative correlation. Total porosity and organic matter are attributes strongly influenced by soil management and are easily modified by the adopted practices (ASSIS *et al.*, 2015; LOSS *et al.*, 2015). In turn, the accumulation of organic matter causes changes in the susceptibility to soil compaction, reducing the density and increasing the total soil porosity (REIS *et al.*, 2016).

The sand and macroporosity attributes were the most prominent in distinguishing the P3 (Pasture Area-Latossolo) environments and the subsurface layers of P4 (Cashew Area -Latossolo). The physical-structural attributes Clay, Micro, FC, PWP, AD, GF and chemical Ca^{2+}, Mg^{2+} and SB were the most discriminating in P2 (Corn Bean Consortium Area - Cambissolo) and in the 0.20-0.30 (m) layer of P1 (Native Forest Area - Latossolo) Figure 2 (A and B). Ca^{2+} had the largest contribution to the sum of bases, evidenced by the high correlation in the matrix (Table 1). As a regional characteristic, soils present high levels of exchangeable Ca^{2+} and Mg^{2+} (BRITO *et al.*, 2017).

Figure 3 - Variable cloud distribution in the correlation circle (A) and point cloud distribution (B), representing the relationship between factors 1 and 2 and the environments under study



CONCLUSIONS

1. The evaluated attributes presented variability regarding the uses and soil classes, being sensitive in the environment distinction. However, the most discriminating variables were: microporosity, field capacity, permanent withering point, available water, sand, clay, flocculation degree, exchangeable calcium and magnesium, sum of bases, soil density, total porosity, macroporosity, electrical conductivity and total organic carbon;
2. The total organic carbon was discriminant to group the native forest and cashew tree areas in the superficial layers, evidencing the influence of soil management. The other environments were grouped according to the soil intrinsic characteristics, with texture differentiation influencing the attributes variability.

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