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Soil attributes in agricultural uses and in the Semiarid RN-Brazil in eutrophic Cambisol

Rauny Oliveira de Souza[1], Jeane Cruz Portela[2]*, Carolina Malala Martins[2], Nildo da Silva Dias[2], Jussiara Sonally Jácome Cavalcante[3], Jucirema Ferreira da Silva[1], Francisco Souto de Sousa Júnior[4] and Francisco Vanies da Silva Sá[3]

[1]Master of Soil and Water Management, Department of Environmental and Technological Sciences – DCAT, Universidade Federal Rural do Semi-Árido – UFERSA. Caixa Postal 137, CEP 59.625-900 Mossoró (RN), Brazil.
[2]Department of Environmental and Technological Sciences – DCAT, Universidade Federal Rural do Semi-Árido – UFERSA. Caixa Postal 137, CEP 59.625-900 Mossoró (RN), Brazil.
[3]Program of Post-Graduate in Soil and Water Management, DCAT/UFERSA, Brazil.
[4]Department of Environmental and Technological Sciences – DCAT, Universidade Federal Rural do Semi-Árido – UFERSA. Caixa Postal 137, CEP 59.625-900 Mossoró (RN), Brazil.

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Soil attributes are an important tool to identify appropriate practices for crop management. This study aimed at evaluating physical, chemical and mineralogical properties of soil in agricultural uses, regarding its potential and/or restrictions in the municipality de Governador Dix-Sept Rosado (RN). Soil samples with deformed structure were collected with the aid of an auger Dutch-type zigzag layers in the 0.00-0.10; 0.10-0.20 and 0.20-0.30 m layers. Four composite soil samples, derived from 15 subsamples, were collected in: native forest (AMN), orchard cajaraneiras (AP), a traditional cropping area (AC), and an area of colluvium (ACOL). Samples were placed in plastic, bags identified and referred to the Laboratory Analysis of Soil and Plant Water LASAP/UFERSA. Subsequently, samples were air dried, broken into smaller pieces, and sieved through 2.0 mm mesh to obtain the dried soil air (TFSA) for physical, chemical and mineralogical analyzes. Results were submitted to Principal Component Analysis (Multivariate Statistics) to distinguish attributes in different agricultural uses. The first factor generated for soil properties in the areas surveyed explained 48.33% of the total variation in the studied area, and the highest correlation coefficients (≥ |70|) identified were the variables: sand, silt, pH, Ca^{2+}, H+Al, SB, T, T, V in the layer 0.00-0.10 m. These variables are probably influenced by the source material, and consequently the management practices adopted in farming areas. Primary minerals type 2:1 such as illite and mica in the horizon A and the horizon Bi predominated in diffraction peaks of X-ray, which can be justified by the presence of clay minerals in the clay fraction, young soil characteristics and limited weathering. Properties differed between areas, and presented physical limitations on the soil resistance to penetration, and have excellent chemical characteristics such as high levels of exchangeable calcium and total organic carbon.

Key words: Mineralogical analysis, diffraction, environment, different management.

INTRODUCTION

Soil is an unconsolidated material and a product of action of physical, chemical and biological weathering. It contains living matter and can be vegetated. Soil consists of near parallel sections, arranged in horizons, or layers, that differ from the original source material. The horizons reflect soil formation processes from weathering of bedrocks or various types of sediment. The layers, however, could be to a limited extent affected or not by pedogenetical processes; maintaining in greater or lesser extent the characteristics of the original source material (Santos et al., 2013). The soil should be seen as a fundamental source of national wealth, because it contains minerals and organic materials indispensable to the existence of agriculture and livestock activities (Bertone and Lombardi Neto, 2010).

The degradation of soil's physical and chemical properties is one of the main processes responsible for the loss of structural quality, increased erosion and consequent reduction of its productivity. Some soil management practices cause changes in soil properties, mainly in its structure. Such changes may be permanent or temporary (Bertol et al., 2012). Depending on the level of degradation, intensive use of the soil, without observing agricultural suitability and lack of conservation practices, contributes to soil degradation processes (Tavares Filho et al., 2012). This study was conducted to evaluate physical and chemical properties of the soil on the basis of various agricultural uses, aiming to identify the potential use, and restrictions and conservation in Terra de Esperança Settlement Project in the Chapada do Apodil, located in the municipality of Governador Dix-Sept Rosado (RN).

MATERIALS AND METHODS

Study area

The study was conducted from November 2013 to May 2014 on the Terra da Esperança Settlement Project, located in the municipality of Governador Dix-Sept Rosado in the state of Rio Grande do Norte. It is located in the meso-region Oeste Potiguar, micro-region Chapada do Apodi, in the Brazilian semiarid region.

The city of Governador Dix-Sept Rosado islocated at coordinates; 05°27'32.4" S and 37°31'15.6" W. Its boundaries are the municipalities of Baraúna, Natal, Upanema, Caraúbas, Felipe Guerra, Apodi and the state of Ceará, covering an area with 1,263 km². Its climateis hot (indicate mean annual temperatures for summer and winter), semi-arid with an average rainfall of 712 mm during the months from February to May (Beltran et al., 2005).

The rural settlement consists of 113 families located on 6,297 ha, consisting of agro-ecological land and a forest reserve (20% legal reserve). Also indicate typical natural vegetation found in this area (– as it influences the soil characteristics, structure and mineral composition through cation exchange).

Study sites

The study was conducted in four areas with each having unique characteristics concerning management and agricultural use. One hectare from each study area was selected: (01) a traditional cropping area (CA) with tillage (one plowing and two diskings), and maize and cowpea intercropping; (02) a colluvium area (ColA), in a lower area cut by a temporary stream, which is responsible for the saturation of the site (the cultivation area is only worked at the end of the rainy season, when soil moisture decreases); (03) a trees cajaraneiras orchard area (SA), with numerous trees cajaraneiras of the genus *Spondia* (the harvesting of cajaraneiras occurs from mid-February to April; these plants are deciduous during this period, with little or no foliage, or inflorescences, and with dry leaves and fruit kernels shed, resulting in an increase of organic matter in the soil); and (04) a native forest area (NFA), with species from the hyper-xerophilic Semiarid RN-Brazil: *Combretum leprosum* L. ("mofumbo"), *Astronium fraxinifolium* (Aroeira), *Croton sonderianus* M. Arg. and *Mimosa hostilis* B. (Jurema-preta). In Mid-November 2013, the Semiarid RN-Brazil was in a good condition, with plant residues on soil surfaces even after a prolonged drought.

Data collection

Soil samples with deformed structures were collected with the aid of a zigzag Dutch type auger in the 0.00-0.10, 0.10-0.20 and 0.20-0.30 m layers, being four samples of soil from 15 subsamples of each area (CA, ColA, SA and NFA). The samples were placed in plastic bags, identified and forwarded to the Soil Analysis Laboratory. Subsequently, the samples were air-dried, soil clods were broken, and then sieved with 2.0 mm sieves to obtain an air-dried fine-ground (ADFG) in preparation of physical, chemical and mineralogical analyses.

The particle size distribution was obtained with a pipette using the chemical dispersant sodium hexametaphosphate in distilled water and 20 g of ADFG, with slow mechanical agitation in a shaker (Wagner 50 rpm) for 16 h (Donagema et al., 2011). The sand (2.00-0.05 mm) was measured by sieving; the clay (<0.002 mm) by sedimentation, and the silt (0.05-0.002 mm) by the difference between the sand and clay fractions.

The particle density analysis (ρ_p) was made with the volumetric flask method using greenhouse-dried fine-ground (GDFG) at 105°C and ethanol (Donagema et al., 2011):

$$\rho_p = \frac{m_s}{V_p}$$

Where: ρ_p = particle density (kg.dm^{-3}); m_s = dry mass at 105°C (kg); and V_p = solid volume (m³).

To evaluate mechanical resistance to soil penetration (MRSP), readings were taken directly into the ground in each treatment with a static penetrometer with a 1.28 cm diameter ferrule and a 1,287 m^2 cross-sectional area. Soil resistance readings were taken concurrently to penetrating the layers at 0-0.10, 0.10-0.20 and 0.20-0.30 m, at random locations within each area, taking as a reference the average of 30 reading repetitions. The results were expressed in kPa (Foster and Meyer, 1977). At the same time, soil samples were collected for evaluation of moisture for gravimetric measurements at the above-mentioned depths. The gravimetric water content (GWC), based on mass was obtained by the equation:

$$GWC = \frac{wsm - dsm}{dsm} * 100$$

where: GWC = gravimetric water content (%); wsm = wet soil mass (g.kg^{-1}); and dsm = dry soil mass (g.kg^{-1}).

*Corresponding author. E-mail: jeaneportela@ufersa.edu.br

Table 1. Correlation coefficient of the main components (Factors 1 and 2) for physical and chemical attributes on the basis of potential and/or restrictions of agricultural uses in Terra da Esperança Settlement Project.

Variable	Layer (m)					
	0.00-0.10		0.10-0.20		0.20-0.30	
	F1	F2	F1	F2	F1	F2
Sand	0.82	0.49	0.84	-0.18	-0.83	0.47
Silt	-0.86	-0.26	-0.73	0.23	0.82	0.16
Clay	-0.64	-0.58	-0.85	0.12	0.65	-0.69
Dp	0.63	-0.6	0.04	-0.36	-0.53	-0.59
pH	-0.83	0.28	-0.93	-0.21	0.92	-0.06
EC	-0.47	0.66	-0.31	0.77	0.56	0.25
TOC	-0.32	0.78	-0.65	-0.24	-0.06	0.25
P	-0.56	-0.18	-0.95	-0.07	0.37	-0.56
K	0.32	0.76	0.15	-0.23	0.08	0.83
Na	-0.45	0.5	-0.46	0.59	0.37	0.28
Ca	-0.98	-0.07	-0.99	-0.03	0.98	-0.03
Mg	0.43	-0.4	-0.03	-0.75	-0.1	0.22
H+Al	0.81	-0.22	0.86	0.1	-0.92	-0.11
SB	-0.91	-0.19	-0.96	-0.2	0.96	0.05
t	-0.91	-0.19	-0.96	-0.2	0.96	0.05
T	-0.81	-0.28	-0.92	-0.22	0.9	0.02
V	-0.81	0.22	-0.88	-0.13	0.92	0.12
PST	-0.3	0.19	-0.45	0.66	0.17	0.53
Variance (%)	48.33	19.01	55.09	13.83	49.18	14.72
Accumulated variance (%)	48.33	67.34	55.09	68.92	49.18	63.9

Correlation coefficients > |0.70| are significant (Manly, 1994).

Soil consistency tests were determined based on the liquidity limits (LL) using the Casagrande apparatus, according to Donagema et al. (2011), and calculated by the equation: LL = GWC $(N/25)^{0.12}$, where LL is the liquidity limit ($g.100.g^{-1}$), represented by the gravimetric water content (%) adjusted to 25 device rotations; GWC is gravimetric water content ($g.kg^{-1}$), corresponding to the rotation of determination; and N is the number of rotations. The plasticity limit (PL) was determined with three replicates by withdrawing representative samples from the central part of the soil shear stress in the metal ball of the equipment. It comes from the determination of the liquidity limit, forming a ball that is pressed on a plate glass until forming a cylindrical rod with a 3.0 to 4.0 mm diameter without breaking or flowing. The gravimetric water content was determined in plasticity condition for soil rods. The plasticity index (PI) was determined by the difference between LL and PL.

The evaluated chemical elements were hydrogen potential (pH) in water, electrical conductivity (EC) in water, total organic carbon (TOC) by digestion of organic matter, exchangeable calcium content (Ca^{2+}) and exchangeable magnesium (Mg^{2+}) with a potassium chloride extractor. Potential acidity (H+Al) using calcium acetate, phosphorous (P), sodium (Na^{+}) and potassium (K^{+}) analyses were made with a Mehlich-1 extractor. Consequently, cation exchange capacity (CEC), base sum (BS) and base saturation (V) were calculated and analyzed according to Donagema et al. (2011).

In the mineralogical analysis, ADFG minerals, after being separated by sieving and sedimentation, were identified by X-ray powder diffractometry (XRPD). A diffractometer was used in the kα1 issuance of cobalt, with a wavelength of 0.17902 nm. The potential of the source was 40 kV and 30 mA current. A scan speed with a 0.02º pitch every second was used. The scanning range (2θ) was from 4° to 45° (Mehra and Jackson, 1958).

Multivariate analysis techniques, specifically Principal Component Analysis (Statistica, 2004), were used as a main tool to distinguish studied areas in the light of potential or environmental restrictions.

As agricultural use area distinction tools, two diagrams of the main components (Factor 1 and 2) were made for physical attributes (particle size and particle density) together with chemical properties (pH, EC, TOC, P, K, Na, Ca, Mg, H+Al, BS, t, T, V, PST).

RESULTS AND DISCUSSION

Factor 1 which was generated for the attributes of studied areas, explained 48.33% of the total variation of the studied attributes. The highest correlation coefficients (≥ |70|) identified were the variables; sand, silt, pH, Ca^{2+}, (H+Al), BS, t, T and V at a 0.00-0.10 depth (Table 1). These elements were more evident among agricultural uses.

In the 0.00-0.10, 0.10-0.20 and 0.20-0.30 m layers, the sand fraction was significant in Factor 1 (48.33, 55.09 and 49.18%, respectively) (Figures 1a, b and c). There was a variation in texture class according to the adopted management, because the native forest area presented a clay-sandy texture class, unlike the traditional cropping

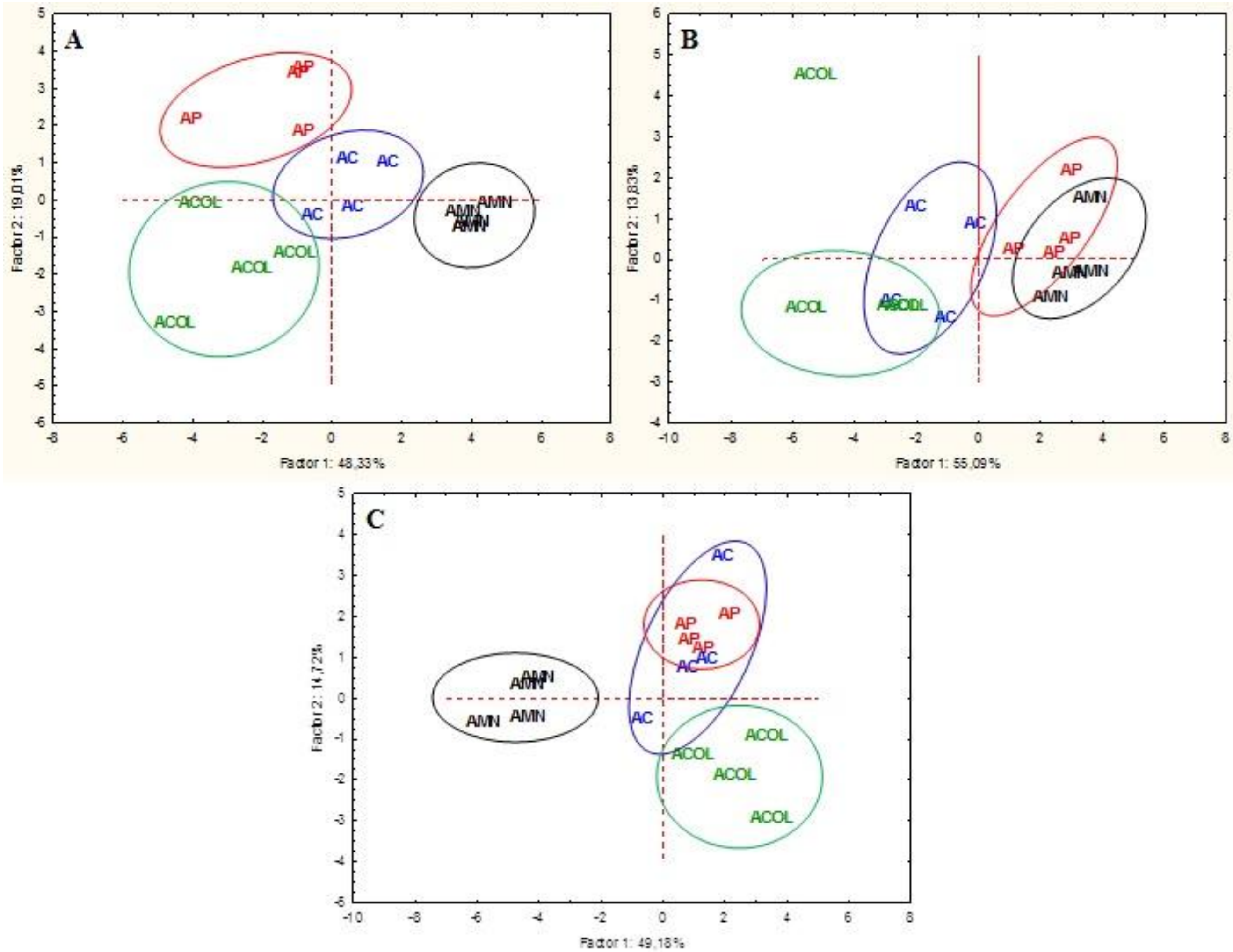

Figure 1. Ordination diagram of the main components of the native forest area (NFA), the Spanish plum orchard area (SA), the traditional cropping area (CA), and the colluvium area (ColA) in 0.00-0.10 m (A), 0.10-0.20 m (B) and 0.20-0.30 m (C) layers in Terra da Esperança Settlement Project.

area, the colluvium area (ColA) and the Spanish plum orchard area (SA), which showed a clay class texture (Table 2).

In NFAs, the sand fraction distinction is probably related to the preservation of the area over the years, since there was no disturbance of soil horizons via agricultural practices. It had contributions of plant residue to the surface, thus resulting the consolidation of surface material (Table 1). High sand fraction values were found in forest fragment soils when compared to degraded areas, being its significant values in the surface layer (Nogueira Junior, 2000).

The silt fraction was significant to distinguish the areas studied inside areas with agricultural use in the three analyzed layers (Table 1). In Table 2, a higher average of this fraction was observed in the colluvium area.

An increase in the silt fraction was found when a natural forest area was compared to an agricultural crop area, which supports the notion that an eroded soil can influence its texture. It is worth noting that soil texture changes occur over time, since its characteristics are difficult to be changed, because they are inherent to the original material. Silt fraction is very susceptible to water erosion, since the particles are small enough to be carried by active agents of erosion (Oliveira, 2009; Omuto, 2008).

The clay fraction was not significantly different over the studied areas. However, the areas surveyed showed a high clay content, with most areas with values above 35%, being texturally classified as clay soils (Table 2).

The clay soil fraction has colloidal properties (particle sizes less than 0.002 mm), and for this reason it is considered as an active fraction of soil due to its electric charges. However, it is more susceptible to compaction due to animal and machinery traffic, without observing essential criteria regarding inorganic fractions and water

Table 2. Physical attributes of the areas with agricultural uses in the Terra da Esperança Settlement Project.

Depth	Particle size			Texture classification	Dp	MRSP	GWC	Consistency		
	Sand	Silt	Clay					LL	LP	IP
m	-------kg.kg^{-1}-------				kg.dm^{-3}	kPa	----------------%-------------			
Native forest area										
0.00-0.10	0.514	0.113	0.373	Sandy clay	2.59	1030.10	4.81	34.95	28.57	6.40
0.10-0.20	0.459	0.105	0.436	Sandy clay	2.56	1837.70	7.98	34.96	18.58	16.40
0.20-0.30	0.456	0.107	0.437	Sandy clay a	2.60	2122.20	8.80	35.91	25.69	10.20
Trees cajaraneiras orchard area										
0.00-0.10	0.437	0.188	0.375	Sandy clay	2.41	1366.90	5.37	37.09	32.06	5.00
0.10-0.20	0.361	0.176	0.463	Clay	2.48	1196.80	8.45	34.95	29.75	5.20
0.20-0.30	0.336	0.186	0.478	Clay	2.45	1478.04	10.73	38.66	27.75	10.90
Traditional cropping area										
0.00-0.10	0.394	0.152	0.454	Clay	2.49	941.76	3.76	38.28	27.98	10.30
0.10-0.20	0.369	0.15	0.481	Clay	2.50	1883.50	12.32	34.35	23.76	10.60
0.20-0.30	0.359	0.152	0.489	Clay	2.49	1978.40	13.38	33.57	26.35	7.20
Colluvium area										
0.00-0.10	0.209	0.245	0.546	Clay	2.53	941.76	2.83	41.25	25.69	7.00
0.10-0.20	0.208	0.216	0.576	Clay	2.54	1883.50	8.61	39.97	31.65	8.30
0.20-0.30	0.195	0.181	0.624	High contents of clay	2.56	1978.40	10.71	39.51	32.49	7.00

content in the soil (Santos et al., 2009).

Regarding mechanical resistance to penetration (MRP), there was a tendency of increased values in trees cajaraneiras orchard areas (PA) and in native forest areas (NFA) in the 0.00-0.10 m layer: 1,366.90 kPa and 1,030.10 kPa, respectively (Table 2). In the 0.10-0.20 m layer, all studied areas presented values close to 2,000 kPa, considered as critical for root growth. This was also observed in the 0.20-0.30 m layer (Table 2). Such values of mechanical resistance to penetration in the deepest soil layers may be associated to low humidity and consequent packing of granulometric fractions of the soil (mainly clay), since the clay fraction obtained high averages considering depth (Table 2). Cruz et al. (2014) observed elevated MRP values regarding depth due to the clay fraction present in the soil, with critical values at 0.40 m in natural savanna areas in the state of Roraima. The compression indexes are divided according to the following: 0 - optimal environment or not limiting rooting (MRP <1000 kPa); 0.5 - good environment, with little limitation to rooting (MRP between 1000 and 2000 kPa); 1 - environment restrictive to rooting and not suitable for plant growth (MRP >2000 kPa) (Gomes and Filizola, 2006).

Low gravimetric water contents (GWC) were observed, possibly due to the dry season in the region. The following water content percentages were observed: GWC = 2.83% (lowest value) in the colluvium area, and GWC = 13.83% (highest value) in the conventional area (Table 2). This may have influenced cohesive forces of soil particles that are intensified in the dry season and certainly provided a greater mechanical resistance to penetration. Gravimetric water content values were lower in the CA (941.76 kPa) and ColA (941, 76 kPa) in the 0.00-0.10 layer, and higher in NFA (2122.20 kPa), PA (1978.40 kPa) and ColA (1978.40 kPa) in the 0.20-0.30 m layer, certainly due to the amount of clay in the subsurface and its water content retention capacity in the structural arrangement.

Regarding the liquidity limit (LL), the percentage of soil moisture needed to reach that threshold was observed (Table 2). This indicates that, upon achieving this percentage, the soil has no fluidity. From the moment that water content increases, certainly the soil will become saturated, occurring soil fluidity. Considering the percentage of humidity in the plasticity limit (PL), the soil will have reached its maximum water content capacity without compromising the structure. In ColA, the values of LL and PL were higher, influenced by the increase of clay in the underlying layers (Table 2). This increase in plasticity limits in the studied areas requires certain attention to crops and soil management with respect to excessive tillage influencing soil structure. Its physical properties are easily modified by the improper use, becoming thus difficult for the soil to be recovered. However, the sooner a set of practices aimed at maintaining and/or improving conservation on the ground is adopted, the better. Gravimetric water content found in PL is due to the increase in the clay fraction, increasing thus water retention in the soil micro-pores (Luciano et al., 2012).

As to the plasticity index (PI), its value was between 7

Table 3. Chemical attributes of areas with agricultural use in the Terra da Esperança Settlement Project.

Depth (m)	pH (water)	EC ($dS.m^{-1}$)	TOC ($g.kg^{-1}$)	P ($Mg.dm^{-3}$)	K^+	Na^+	Ca^{2+}
					------------$cmol_c.dm^{-3}$----------		
Native forest area							
0.00-0.10	6.95	0.07	37.60	0.38	0.27	0.03	11.54
0.10-0.20	6.63	0.03	28.93	0.28	0.19	0.02	9.29
0.20-0.30	6.59	0.02	27.79	0.58	0.17	0.03	9.27
Trees cajaraneiras orchard area							
0.00-0.10	7.95	0.29	125.97	4.48	0.33	0.08	18.26
0.10-0.20	6.63	0.03	28.93	0.28	0.19	0.03	9.29
0.20-0.30	7.78	0.06	26.42	0.13	0.27	0.04	15.63
Traditional cropping area							
0.00-0.10	7.41	0.06	31.98	1.43	0.32	0.07	15.11
0.10-0.20	7.59	0.03	29.79	1.84	0.26	0.08	15.14
0.20-0.30	7.55	0.02	27.16	1.78	0.21	0.06	15.98
Colluvium area							
0.00-0.10	7.79	0.14	32.55	9.01	0.17	0.06	19.80
0.10-0.20	8.03	0.04	29.86	2.53	0.14	0.05	17.53
0.20-0.30	8.01	0.04	26.92	5.53	0.11	0.04	17.44
Mg^{2+}	**Al^{3+}**	**H+Al**	**BS**	**CEC**	**V**		**PST**
----------------------------$cmol_c.dm^{-3}$----------------------------					----------------%--------------		
Native forest area							
3.61	0.00	1.89	15.46	17.35	89.13		0.00
2.40	0.00	2.07	11.91	13.98	85.33		0.00
2.41	0.00	1.93	11.88	13.81	86.05		0.00
Trees cajaraneiras orchard area							
1.88	0.00	0.00	20.54	20.54	100.00		0.13
2.40	0.00	2.07	11.91	13.98	85.33		0.00
1.83	0.00	0.00	17.76	17.76	100.00		0.00
Traditional cropping area							
2.53	0.00	0.00	18.02	18.02	100.00		0.25
2.33	0.00	0.00	17.82	17.82	100.00		0.25
2.16	0.00	0.00	18.41	18.41	100.00		0.06
Colluvium area							
2.12	0.00	0.00	22.15	22.15	100.00		0.25
2.52	0.00	0.00	20.24	20.24	100.00		0.25
2.28	0.00	0.00	19.87	19.87	100.00		0.00

and 15 in most areas, indicating a moderately compressible type of clay (moldable). The plasticity of clay influences soil structures, especially when it is moistened beyond its capacity, with risks of compression if it is not properly handled. It is worth noting that the PI is a function of LL and PL by mathematical difference (Table 2).

The pH and the potential acidity (H+Al) were significant to distinguish the areas under study, especially NFAs (Table 1). It may be related to the greater abundance of vegetable waste from litter found in NFAs and to the dissociation of H^+ ions through organic acids, thus observing a lower pH when compared to other areas. In other areas with agricultural use, the pH had neutral to basic values. In the SA, this may have been influenced by the original source material. In ColA and CA, it may have been influenced by the fertilizer applied in previous years (Table 3). It should be considered that a neutral to basic pH may make some nutrients unavailable to plants (Souza et al., 2010).

The observed exchangeable calcium values varied in the areas with agricultural use for 0.00-0.10, 0.10-0.20 and 0.20-0.30 layers. They directly influenced the effective CEC results (t), CEC at pH 7.0 (T) and base

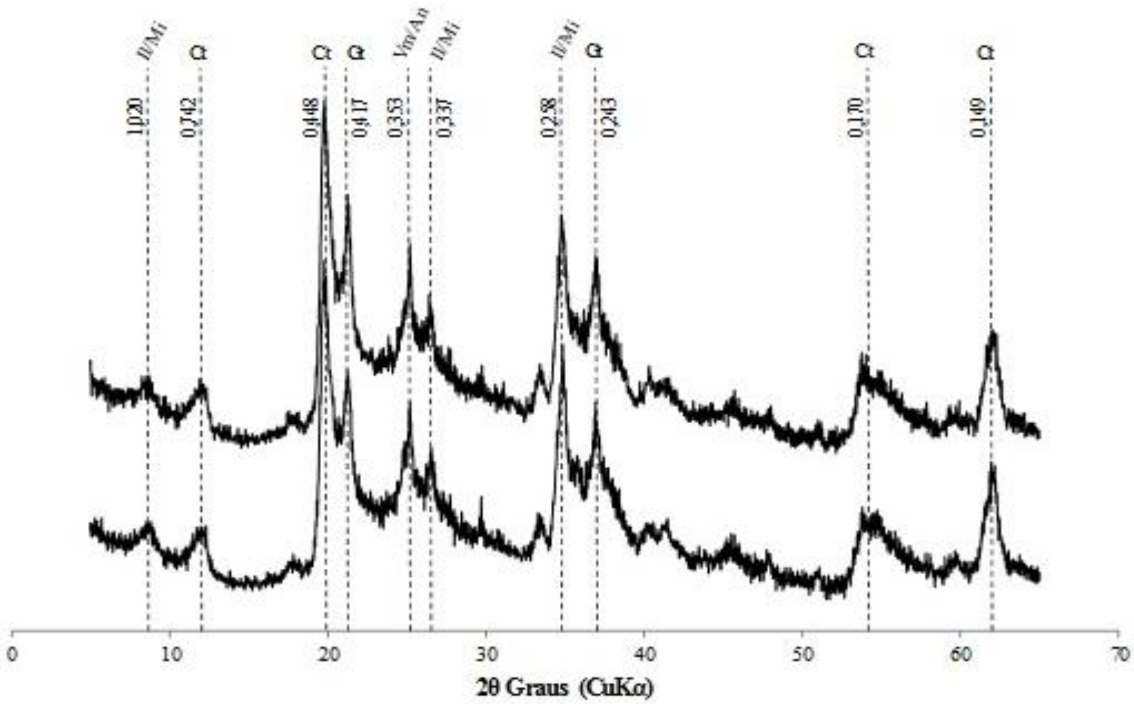

Figure 2. X-ray diffractometry of the clay fraction (natural) of eutrophic typical HAPLIC CAMBISOL profile, with interplanar distance in nanometers (nm). I1: Illite; Mi: Mica; Ct: Kaolinite; Gt: Goethite; Vm: Vermiculite; An: Anatase.

saturation (V) (Table 1). The exchangeable calcium values showed a variance of 48.33%, 55.09% and 49.18 on Factor 1 (with values of 0.98, 0.99, 0.98, respectively, in 0.00-0.10, 0.10-0.20 and 0.20-0.30 m layers) (Table 1). This behavior may probably be related to the original source material (jandaíra limestone), which, in the weathering process, dissociates calcium carbonate into the soil system. Because it is a semi-arid region, the environment has low weathering, irregular rainfalls and high temperatures, being conditioning factors for the maintenance of exchangeable bases (Beltran et al., 2005).

The cation exchange capacity at pH 7.0 (CEC) represents the nutrient release capacity favoring the maintenance of soil fertility. If most of the soil CEC is occupied by essential cations such as Ca^{2+}, Mg^{2+} and K^{+}, depending on the type of clay mineral from the original source material (jandaíra limestone), with predominance of clay minerals type 2:1 such as illite, mica and vermiculite, one can infer a larger natural soil fertility, especially in arid and semi-arid regions (Ronquim et al., 2010).

Base saturation values above 50%, as shown in Table 3, possibly indicate soil fertility conditions. Soils can be divided according to the percentage of saturation as eutrophic soils V% ≥ 50% and dystrophic soils V% < 50% (Ronquim et al., 2010).

The total organic carbon (TOC) in Factor 2 showed a correlation coefficient of 0.77 and a variance of 19.01%, being an important attribute to distinguish studied areas, mainly in the 0.00-0.10 m layer. High TOC values were observed mainly in Spanish plum orchard areas (SAs) in the 0.00-0.10 m layer, and lower values in other evaluated layers (Table 3). This may be related to the excess of plant organic materials found visibly (leaves and fruit cores). Another contribution may be related to animal grazing throughout the orchard area, releasing feces on the ground, a fact that may have influenced TOC values. In NFAs, the TOC showed high values and in CA and ColA low values. These values were nevertheless representative within an environment with semi-arid conditions (Table 3).

The X-ray diffractogram with 10-degree 2θ peaks and between 20 and 30-degree 2θ peaks (which indicates the occurrence of the primary mineral type 2:1 such as mica and illite), and in the Bi horizon are probably clay minerals that prevail in the clay fraction of studied areas, that is, characteristic of little weathered soils. The frequency of clay minerals found in horizons A and Bi may be related to its small thickness and to the intensity of weathering (Figure 2).

Conclusions

The attributes differed between areas and presented a physical limitation as to mechanical resistance to soil penetration and good chemical characteristics as to exchangeable calcium and total organic carbon. The soil properties influenced the distinction of areas with agricultural use due to local particularities.

Conflict of Interest

The authors did not declare any conflict of interests.

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