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Chemical attributes of traditional agriculture and Caatinga managed at different depths in an Inceptisol

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Key words:
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ABSTRACT
The objective of this work was to evaluate changes in the chemical attributes of an Inceptisol in two areas of sustainable management of the Caatinga Biome and a conventional tillage, compared with the native forest. The areas were managed in the following way: in areas under sustainable management, the Caatinga was thinned in a savanna system (1), and in the other area, the Caatinga was thinned in strips (2); the area under conventional tillage was burned, plowed and harrowed (3), and the native forest (4). The following chemical attributes were analyzed: pH, electrical conductivity, Ca^{2+}, Mg^{2+}, H + Al, P, Na^{+}, K^{+} and soil organic matter (SOM), calculating CEC and base saturation. The treatments were evaluated using multivariate analysis, at different depths up to 0.52 m. In the Caatinga areas thinned in a savanna system and in strips, the greater availability of exchangeable bases and SOM occurs close to the depth of 0.20 m and, in the area with traditional agriculture, it is limited to 0.10 m. In the area thinned in a savanna system, sodium showed a negative correlation with the other elements.

Palavras-chave:
qualidade do solo
pH
bases trocáveis
semiárido

Atributos químicos em área agrícola tradicional e Caatinga manejada em diferentes profundidades em um Cambissolo

RESUMO
Objetivou-se, neste trabalho, avaliar mudanças nos atributos químicos de um Cambissolo háplico em duas áreas de manejo sustentável da caatinga e em uma área de cultivo agrícola convencional e se optou, para efeito de comparação, pela mata nativa (Caatinga). As áreas foram manejadas da seguinte forma: Nas áreas em que houve manejo sustentável foi feito raleamento na caatinga com sistema de savana (1) e na outra área raleamento em faixas (2); na área de cultivo agrícola convencional foram realizadas queimada, aração e gradagem (3) e a mata nativa (4). Os atributos químicos analisados foram: pH, condutividade elétrica, Ca^{2+}, Mg^{2+}, H + Al, P, Na^{+}, K^{+} e matéria orgânica do solo (MOS) calculando-se CTC e saturação por bases. Os tratamentos foram avaliados por meio de análises multivariadas, em várias profundidades até 0,52 m. Verificou-se que na área de caatinga raleada em savana e em faixa, houve maior disponibilidade de bases trocáveis e MOS próximos aos 0,20 m de profundidade e na área com agricultura tradicional se restringe a 0,10 m. Na área raleada com sistema de savana o Na apresentou correlação negativa com os demais elementos indicando situação de antagonismo.

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Introduction

The agriculture practiced in the Caatinga biome is generally itinerant or migratory since the period of colonization, i.e., the farmer deforests, burns for a period of two years and the area is then left at rest to recover its productive capacity, which in the current days is not achieved because of the use of these areas as pasture, not allowing the rest necessary to its recovery (Nunes et al., 2009).

In semi-arid regions, characterized by high temperatures, reduced rainfall, poorly weathered soils and low phytomass production, the situation is even more delicate. The conventional production systems considered as traditional, with soil disturbance and incorporation of plant residues, contribute even more to the degradation of soil physical, chemical and biological (Ashagrie et al., 2008; Guimarães et al., 2013; Marinho et al., 2016).

As an option of soil use, agroforest systems (AFSs) have emerged as an alternative to small farmers, as a sustainable management of the Caatinga, due to its potential to reduce soil degradation and decrease the pressure on forest areas (McGrath et al., 2000), which are characterized by the combination of arboreal species and agricultural crops and/or domestic animals, simultaneously, or alternated over time and space, which contributes to the reduction of the dependence on external inputs. The AFSs showed the best results for soil chemical quality, exhibiting higher values of soil organic matter (SOM) and effective and potential CEC, which characterize it as a promising system for soil use and conservation in the Amazon's context (Veiga et al., 2014).

Maia et al. (2006), in studies in the Caatinga, reported that the AFSs obtained net dry matter supplies of approximately 4.0 and 4.48 Mg ha^{-1} $year^{-1}$ for agrosilvopastoral and silvopastoral systems, respectively, with annual rates higher than those observed for native forest (3.7 Mg ha^{-1} $year^{-1}$). These treatments proved to be more efficient in the supply of SOM, which also means higher efficiency in nutrient cycling. In Red Yellow Argisol in Cerrado areas of the Piauí state, Iwata et al. (2012) observed, in the soil under AFSs, that in all evaluated layers there was a reduction in the contents of Al^{3+} and H + Al and increase in pH, contents of nutrients and total organic carbon. In the Amazon biome, Freitas et al. (2013) observed that 22 years after the conversion of forest to agroecosystem through cutting and burning of the natural vegetation, the agroforest system also showed soil quality indicators similar to those of the forest area, evidencing the longevity and, therefore, the use of the soil.

The sustainable management of the Caatinga, despiteits little expression, has been spread in the rural communities of the Brazilian semi-arid region, as in the case of the Caatinga Management Unit of the Moacir Lucena Settlement Project in the municipality of Apodi-RN, Brazil (Lira et al., 2012), with the same philosophical bases of the agroforest systems. There is the hypothesis that this management system contributes to the improvement in the quality of soil physical, chemical and biological attributes. However, information with scientific basis is scarce and, since the Caatinga is a fragile system, the monitoring of soil fertility is essential to maintain it productive.

This study aimed to evaluate the alterations in the chemical attributes of a Haplic Cambisol subjected to two types of sustainable management of the Caatinga in contrast with an area of traditional agricultural cultivation and the native forest.

Material and Methods

The study was carried out in 2012, in the Moacir Lucena settlement, constituted of 20 settled families and 7 aggregated families, with total area of 549.91 ha, whose average area divided per family per lot is of approximately 19.6 ha. In addition, there are 50 ha deforested and around 59.07 ha of collective area (Lira et al., 2012). The settlement is situated in the municipality of Apodi, in the microregion of the Apodi Plateau, in the West Potiguar mesoregion, in the state of Rio Grande do Norte, between the coordinates 5° 39' 55"S and 37° 48' 13" W, at altitude of 60 m.

The climate of the region, according to Köppen's classification, is BSw'h', semi-arid hot tropical, with mean annual rainfall of 550 to 940 mm and mean annual temperature of 23 °C, marked by two well defined periods: dry (prolonged) and humid (short and irregular). The natural vegetation is hyperxerophilic Caatinga. The soil of the area was classified as typic eutrophic Ta Haplic Cambisol (EMBRAPA, 2013), with moderate A horizon, clayey texture, hyperxerophilic Caatinga, flat relief derived from limestone.

The studied areas with different agricultural uses were: (a) Area under sustainable management, where the Caatinga was thinned in strips (AST) – started in November 2003, when 10-m-wide strips were thinned and interspersed with 10-m-wide strips of native vegetation. This area was also used for other purposes, such as flowering for beekeeping during the rains and, in the dry period, as protein bank, where the herd of 43 caprine animals remained all day long. (b) Area under sustainable management where the Caatinga was thinned in a savanna system (ASV) – it followed the same model of the area thinned in strips, but a totally thinned area of 1 ha was left, in which the stubbles were placed in 5-m-wide ridges perpendicular to the direction of the terrain slope, in order to contain soil erosion. The management was followed by the random transplantation of seedlings of native and exotic essences: 'catingueira' (*Caesalipnia pyramidalis)*, 'sabiá' (*Mimosa caesalpiniifolia*), 'aroeira' (*Schinus terebinthifolius*), among others. In addition, every year, at the beginning of the rainy season, 1.5 kg of seeds were sown broadcast in the area using random amounts of Leucaena (*Leucaena leucocephala*), 'feijão guandu' (*Cajanus cajan*), 'mucuna' (*Mucuna* spp), 'flor de seda' (*Calotropis procera),*'mata pasto' (*Senna uniflora* L.) applied in the first three years of implementation. This area was also used as pasture for caprine animals and apiculture.

Area of traditional agriculture (ATA) - started in 2003, when 4 ha were deforested and the woody and leafy stubbles were burned. Subsequently, conventional soil tillage was performed through plowing and heavy harrowing. This area was cultivated with maize and bean in all years since 2004. In the dry period, the forage and the crop residues were used as pasture for food supply to small ruminants.

Area of native vegetation (ANV) – legal reserve area of the settlement considered as the natural condition (control);

however, this area was used in the dry period as pasture for caprine animals and beekeeping.

For the evaluation of soil chemical attributes, four soil pits were open with dimensions of 1.10 x 1.00 x 0.90 m of length, width and depth, respectively, in each site that represented the conditions of the above-mentioned management systems and each composite sample was formed by three single samples. After the litter around the soil pit was removed, the soil was collected in the vertical direction removing the soil layers with a spatula and a square point shovel in the layers of: 0.01-0.02; 0.02-0.03; 0.03-0.04; 0.06-0.07; 0.07-0.08; 0.08-0.09; 0.10-0.13; 0.13-0.16; 0.16-0.19; 0.19-0.22; 0.22-0.27; 0.27-0.32; 0.32-0.37; 0.37-0.42 and 0.42-0.52 m. The area was georeferenced using a GPS, in order to map and obtain the exact location of the profiles.

The soil samples intended for the analyses were air-dried, pounded to break up clods, sieved through a 2-mm mesh, placed in plastic bags and taken to the Laboratory of Soil, Water and Plant (LASAP/UFERSA). As to the soil chemical attributes, the following analyses were performed: potential of hydrogen (pH) in water, electrical conductivity range for 1:2,5 soil:water suspension ($EC_{1:2,5}$) contents of exchangeable calcium (Ca^{2+}) and exchangeable magnesium (Mg^{2+}) with potassium chloride as extractor, potential acidity (H + Al) using calcium acetate and analyses of phosphorus (P), sodium (Na^{+}) and potassium (K^{+}) with the extractor Mehlich-1, all according to EMBRAPA (2009). After that, the cation exchange capacity (CEC) and base saturation were calculated. Soil organic matter was determined through the oxidation of total organic carbon by the potassium dichromate, wet method, with external heating, subsequently titrated with ferrous ammonium sulfate (Mendonça & Matos, 2005).

The mean values of soil chemical attributes of the different depths and areas of Caatinga management (AST, ASV, ATA and ANV) were interpreted using multivariate analysis tools: factorial analysis (FA) and cluster analysis (CA).

Results and Discussion

Table 1 shows the summary of the factorial analysis, highlighting the factors obtained in each management area, the factorial loads subjected to the varimax rotation method, the Eigenvalues and the percentage of variance explained by each factor. Thus, the number of factors was fixed based on the percentage of explanation of the cumulative variance, which was established at values higher than 70% (Manly, 1994).

In the area under traditional agriculture (ATA), the first two factors were responsible for Eigenvalues that explained, respectively, 65.22 and 14.75% of the variance, i.e., they explained together 79.97% of the total data variance. In the first factor (F1), the attributes that obtained higher factorial load were soil organic matter (SOM) (0.98), pH (0.93), exchangeable cations (Ca, Mg, K and Na) and soil CEC (0.96), which were considered as most important inside the factor, while in factor 2 (F2) only potential acidity (0.91) was significant.

Based on the analysis of the areas under sustainable management of the Caatinga, in the areas thinned in a savanna system (ASV) and thinned in strips (AST), the first two factors explained 67.98 and 72.55% of the total data variance, respectively (Table 1). In the ASV in F1, which explained 52.59% of the total variance, the most important attributes for the distinction of this factor were EC (0.75), SOM (0.88), K (0.92), Na (-0.89), Mg (0.73) and soil CEC (0.77), while the F2, formed by pH (-0.83) and potential acidity (0.78), explained 15.39% of the total variance. As to AST, the most important chemical attributes in the distinction of F1 explained 58.51% and were pH (0.80), SOM (-0.84), K (-0.94), Ca (0.90) and Mg (-0.84) and in F2, potential acidity (0.95) and CEC (0.75). It should be pointed out that, in the area of native forest (ANV), the first two factors did not explain much the total data variance; only 31.55%, especially SOM (-0.80) and Mg (0.82) in F1 and K (0.86), Na (-0.86) and H + Al (0.94) in F2.

According to the obtained results and regardless of the type of management, SOM, K and Mg were the most sensitive indicators in the alteration of the management systems. In Haplic Cambisol, also in the semi-arid region, Marinho et al. (2016) demonstrated through principal components of the multivariate analysis that the soil organic matter and some chemical attributes (P, K^{+} and Ca^{+2}) were also indicators of separation of the environments.

Table1. Factors extracted through principal components highlighting the soil chemical variables with loads higher than 0.7 (modulus) for: ATA – Area of agricultural cultivation, ASV – Area thinned in savanna system, AST – Area thinned in strips and ANV – Area of native vegetation, in the layers studied along the profile

Attributes	ATA		ASV		AST		ANV	
	F1	F2	F1	F2	F1	F2	F1	F2
pH	0.93	-0.21	-0.06	-0.83	0.80	0.42	0.48	-0.67
EC	0.56	0.58	0.75	0.40	0.59	0.44	-0.12	0.42
OM	0.98	-0.05	0.88	0.36	-0.84	-0.33	-0.80	0.33
P	0.23	0.19	0.46	-0.04	-0.48	-0.35	-0.49	0.29
K	0.94	-0.05	0.92	0.14	-0.94	-0.13	0.22	0.86
Na	0.75	-0.41	-0.89	0.14	0.58	0.36	-0.17	-0.86
Ca	0.99	-0.02	0.11	0.19	0.90	0.24	0.00	0.02
Mg	-0.84	0.26	0.73	0.55	-0.84	-0.14	0.82	0.28
(H + Al)	-0.20	0.91	-0.16	-0.78	0.23	0.95	-0.12	0.94
CEC	0.96	0.17	0.77	0.29	0.26	0.75	0.41	0.58
Eigenvalues	7.17	1.62	5.78	1.69	6.44	1.54	0.87	2.59
% of variance	65.22	14.75	52.59	15.39	58.51	14.04	7.95	23.56
Cumulative A.	7.17	8.80	5.78	7.48	6.44	7.98	8.86	7.56
Cumulative %	65.22	79.97	52.59	67.97	58.51	72.55	80.50	68.76

pH_{H2O} in water; $EC_{1:2,5}$ - Electrical conductivity range for 1:2,5; OM - Organic matter; P - Phosphorus; K^{+} - Potassium; Na^{+} - Sodium; Ca^{2+} - Calcium; Mg^{2+} - Magnesium; (H + Al) – Potential acidity; CEC - Cation exchange capacity (at pH 7.0); V - Base saturation. Coefficients of correlation > |0.70| are significant (Manly, 1994); F1 and F2 - Factorial loads that represent the coefficients of correlation between each factor and the variables

The soils under native forest (ANV) with Caatinga have vegetal formation with low trees, bushes, cactuses and bromeliads, among other species (Alves et al., 2009), and the deposition of these plant residues on the soil forms a more recalcitrant litter, causing the organic matter content to be higher than those of other soil managements. Associating the supply of plant residues with the release of root exudates, washing of soluble constituents of the plant by the rainwater and transformation of these carbonated materials by the macro and microorganisms of the soil, the system remains balanced in terms of nutrients, especially regarding the contents of Mg and K. However, when the native forest was removed for the installation of the management system, there was an imbalance in the content of SOM, intensifying its mineralization, especially in the conventional cultivation. In the Northeastern semi-arid region, the degradation of natural resources has been caused by the increase in the intensity of soil use and reduction of the native vegetal cover (Menezes & Sampaio, 2002).

The highest values of SOM, Ca, K, Na, CEC and base saturation (V) were found in the first 10 cm of depth, while the highest values of Mg and potential acidity were found in the deeper layers, whereas P and EC of the soil did not differ under the studied conditions (Figure 1A). The factorial analysis (FA) and cluster analysis (CA) tend to the same result, which is the division of the soil profile into two well defined layers regarding the fertility levels of the area under traditional agriculture (ATA).

Except for Mg and H + Al, the highest values of soil fertility and SOM are limited to the superficial soil layers until 0.10 m (Figure 1A and 1B). These results agree with Souza & Melo (2003), who evaluated the effects of different maize production systems on the dynamics of C in the soil and observed that soil management involving the conventional cultivation with disturbance showed the lowest value of organic carbon in the layer of 0.10-0.20 m and the overlying layers showed significantly higher values, which was attributed to the soil disturbance. Marinho et al. (2016) also observed, in different management and soil use systems in the semi-arid region, greater soil fertility and total organic carbon (TOC) in the superficial layer (0-5 cm).

As to the area thinned in savanna system (ASV), the factor 1 showed positive correlation with OM, CEC, Mg, K and $EC_{1:2,5}$ and negative correlation with Na (Figure 2 A). The factor 2 was positively correlated with base saturation and showed negative correlation with pH and potential acidity. Regarding the grouping of the studied layers in four different groups, there was a proximity between the first and second groups and the layers belonging to these groups were positively correlated with the Factor 1 and did not differ regarding the content of OM, CEC, $EC_{1:2,5}$, K and Mg, thus being grouped in only one layer, 0.01-0.06 m (Figure 2 A and 2B). On the other hand, the group formed by the layers comprehended in the interval of 0.07-0.27 m did not differ and showed positive correlation with base saturation and negative correlation with potential acidity and pH. The group that encompasses the layers in the interval of 0.19-0.42 m showed positive correlation with potential acidity and pH, and negative correlation with base saturation. In the area thinned in savanna system (ASV), the highest availability of exchangeable bases occurs close to the depth of 0.20 m.

Unlike the area under agriculture (ATA), in which the Na was positively correlated with OM, CEC, K and EC in the superficial layers of the soil profile, in the area thinned in savanna system (ASV), this element showed negative correlation with the others, indicating a situation of antagonism with greater availability in the lower layers, which can be explained by the displacement of exchangeable Na to the soil solution through exchange reactions promoted by the higher concentration of Mg^{2+} and K^+ in the superficial layers.

In the area thinned in strips (AST), the soil Ca and pH showed positive correlation with the Factor 1, while OM, K and Mg were negatively correlated (Figure 3A). The Factor 2 showed positive correlation with potential acidity and CEC and negative correlation with base saturation. Considering the most relevant chemical attributes (load > 0.70) in the factorial analysis, the different layers studied along the soil profile of the area thinned in strips (AST) formed three different groups (Figure 3B). The first group encompasses the layers in the interval of 0.01-0.06 m, which was positively correlated with OM, K and Mg, indicating greater expression of these attributes

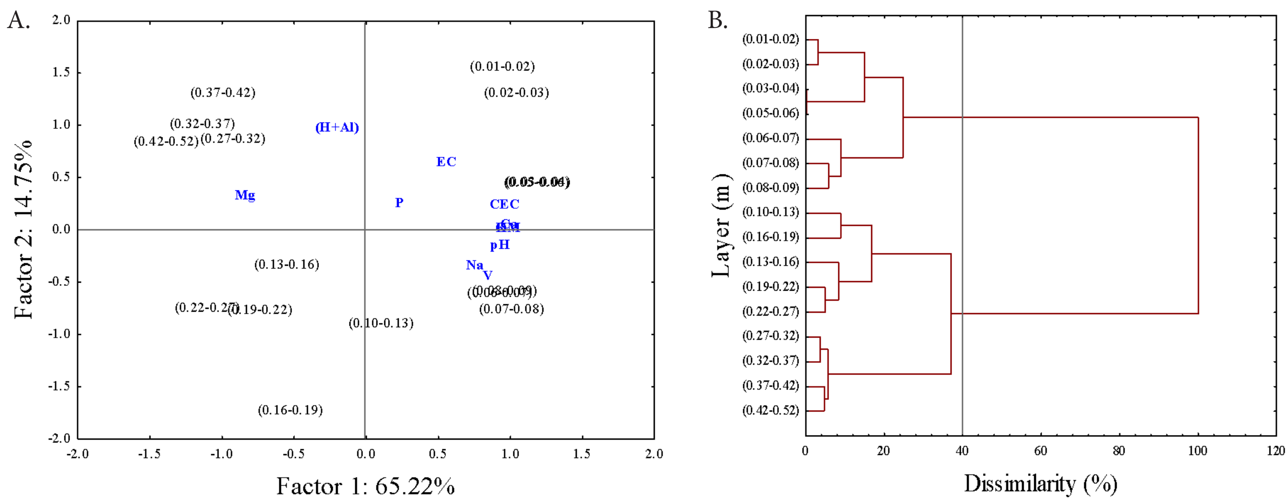

Figure 1. Factorial plan: Factor 1 x Factor 2, with highlight for the chemical attributes and the different layers evaluated along the soil profile of the area under traditional agriculture (ATA) (A). Cluster dendrogram of the layers showing the dissimilarity with the cut line at 40%, according to the chemical attributes with factorial loads higher than 0.7 (modulus) (B)

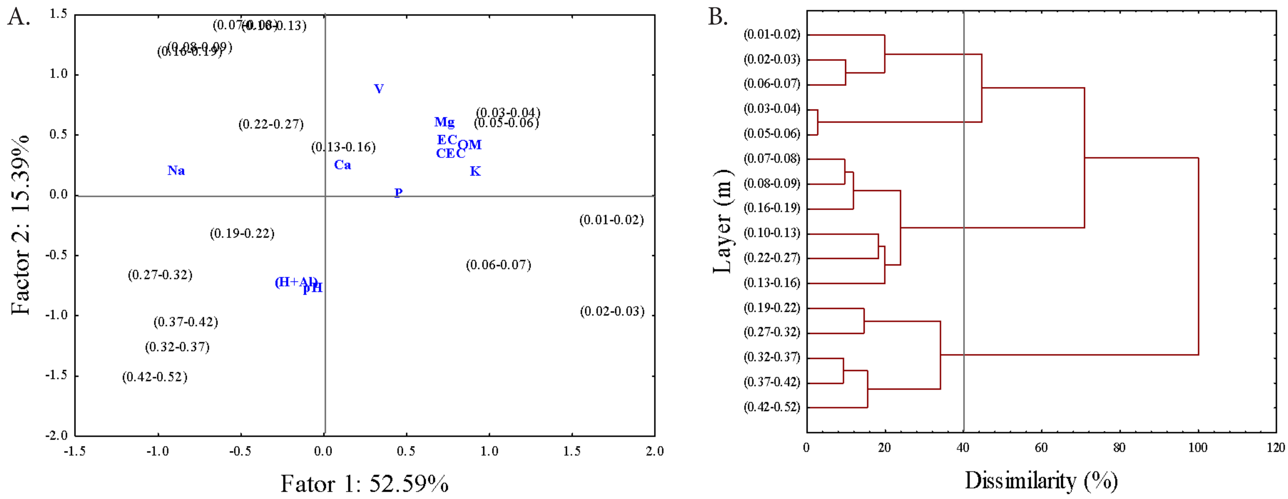

Figure 2. Factorial plan: Factor 1 x Factor 2, with highlight for the chemical attributes and the different layers evaluated along the soil profile of the area thinned in savanna system (ASV) (A). Cluster dendrogram of the layers showing the dissimilarity with the cut line at 40%, according to the chemical attributes with factorial loads higher than 0.7 (modulus) (B)

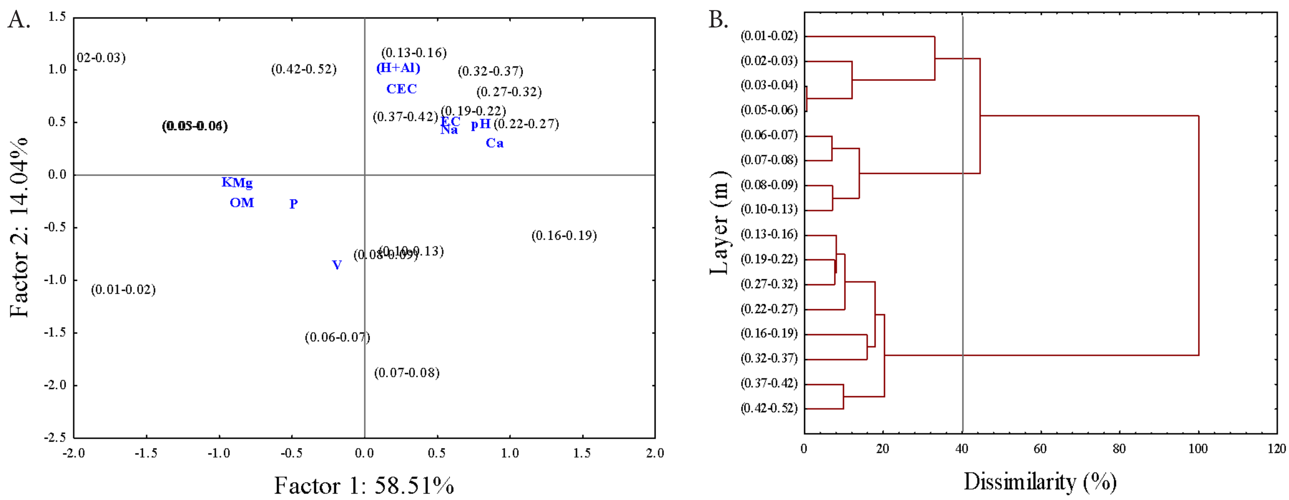

Figure 3. (A) Factorial plan: Factor 1 x Factor 2, with highlight for the chemical attributes and the different layers evaluated along the soil profile of the area thinned in strips (AST) (A). Cluster dendrogram of the layers showing the dissimilarity with the cut line at 40%, according to the chemical attributes with factorial loads higher than 0.7 (modulus) (B)

in the superficial layers of the soil profile. The second and third groups were formed from the factor 2, in which V, (H + Al) and CEC were the most expressive attributes (load > 0.70).

Conclusions

1. Regardless of the type of use, SOM, K and Mg were the most sensitive indicators in the alteration of the management systems.

2. In the areas of Caatinga thinned in savanna system and in strips, the greater availability of exchangeable bases and SOM occurs close to the depth of 0.20 m and, in the area under traditional agriculture, it is limited to 0.10 m.

3. In the area thinned in savanna system (ASV), sodium showed negative correlation with the other elements, indicating a situation of antagonism, with greater availability in the lower layers.

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