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Full Length Research Paper

Land Use Effects on the Electrochemical Environment and Nutrient Availability of Tropical Oxisols

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Management and land use is one of the practices that tend to modify the chemical characteristics of the topsoil by tillage and deployment of diverse cultures isolated or consortium. From this perspective, the objective of this study was to evaluate changes in the availability of cations (calcium, aluminum and magnesium) and influence the potential of zero charge and the point and salt effect null in oxisols under different management systems and use (preserved Cerrado, eucalyptus monoculture, corn under no-tillage and pasture with baquiária grass) in the Triângulo Mineiro region. Noting that the use and soil management changes the electrochemical conditions and a correlation between the availability of calcium and magnesium, with potential of zero charge and the point and salt effect null of the soils, but shows no correlation with the organic matter for the Cerrado soils in use with corn, pasture, eucalyptus and native Cerrado vegetation.

Key words: Nutrients, potential of zero charge, point of zero salt effect, Cerrado.

INTRODUCTION

The Cerrado is located primarily in central and west-central Brazil and covers 1.8 million squared kilometer. Approximately 85% of Cerrado soils are oxisols (Demattê and Demattê, 1993), consisting primarily of clay (1:1) and oxides (typically iron and aluminum in the clay fraction). Hydroxyl (OH^-) groups on the surface of the clay and on the broken edges of kaolinite particles mean that charges are largely pH dependent and can be considered as variables (Chaves, 1999). Organic matter and amorphous materials in the soil also affect charge availability (Van Raij, 1973).

Point zero charge (PZC) occurs when the balance between positive and negative charges is zero and can determine the double-layer potential and charge distribution of the soil (Van Raij, 1973; Chaves, 1999). At PZC, soil aggregation and disaggregation are based on

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Table 1. Physical and chemical characteristics of the Oxisol under different managements and uses with cultivation of pasture, corn, eucalyptus and savanna in two layers 0.0 - 0.2 and 0.2 - 0.4 m soil in the region of Minas Gerais, Brazil.

Parameter	Sand	Silt	Clay	pH	P	Mg^{2+}	Ca^{2+}	K^{1+}	Al^{+3}	H+Al
		$g\ kg^{-1}$			mgm^{-3}			$cmol_c\ dm^{-3}$		
0.0 -0.2 m										
Pasture	780.25	54.75	164.75	6.1	37.5	0.2	1.5	0.07	0	1.6
Corn	674.25	29.75	296.00	5.5	82.4	0.4	2	0.09	0	2.4
Eucalyptus	794.75	44.00	161.25	5.2	4.5	0.3	0.3	0.09	0.4	3.3
Savanna	783.50	25.25	190.75	5.1	1.5	0.1	0.1	0.06	0.4	2.7
0.2 - 0.4 m										
Pasture	785.75	41	173.7	6	4.2	0.1	0.8	0.07	0	1.6
Corn	698.25	32	270	5.5	17.4	0.3	1.1	0.05	0	2.4
Eucalyptus	794.75	44	161.25	5.2	4.5	0.3	0.3	0.09	0.4	3.3
Savanna	759.25	25.75	215.5	5.5	0.7	0.1	0.1	0.05	0.3	2.3

pH water (Soil Acidity); Al^{3+}, Aluminum; K^{+1}, Potassium; Ca^{+2}, calcium; Mg^{+2}, magnesium; P, Phosphorus - P_2O_5; H+Al, pH in SMP.

electrochemical changes (Padro, 2003). Another important parameter affecting the electrochemical behavior of the soil is the point of zero salt effect (PZSE) (Mendonça, 1998). PZSE is defined as the pH at the intersection of two or more potentiometric titration curves from solutions with different ionic strengths (Alleoni and Camargo, 1992).

PZSE and PCZ values in Cerrado soils are usually similar and are therefore good electrochemical parameters (Benites and Mendonça, 1998). Despite this similarity, it is still necessary to distinguish between the pH of PCZ and PZSE (Fernandes et al., 2008), correlations with soil properties (Silva et al., 1996) and management systems that contribute to increases in organic matter, availability of exchangeable Al and nutrients (Teixeira et al., 1994).

Thus, the objective of this study was to evaluate available Ca^{2+}, Al^{3+} and Mg^{2+} and soil organic carbon (C-org) and correlate these with pH of PCZ and PZSE in oxisols under different land use and soil management systems in the Triângulo Mineiro region of Brazil.

MATERIALS AND METHODS

Area characterization

The study area was conducted in the farm Santa Teresinha, located in the region of Triângulo Mineiro, Minas Gerais, Brazil (19° 12'11 "S and 48° 11'30" W) in the Ribeirão Bom Jardim basin on the left tributary of the Uberabinha River. The average elevation of the region is 830 m and the climate is tropical rainy with dry winters (Aw) (Antunes, 1986). The soil was classified as yellow oxisol, according to Embrapa (2000).

The experiment was completely randomized (CRD - 4x2 factorial) with four land use types (Cerrado - CE, Pasture - PA, Corn - CO and Eucalyptus - EU), two soil layers (0.0 – 0.2 and 0.2 – 0.4 m) and four replications. The environments studied had distinct land use and management types: (a) native Cerrado with woody vegetation and dark soil, due to accumulated organic material (19º12'51. 54"S latitude and 48º08'04.17"W longitude); (b) Eucalyptus: planted 30 years before the study (in place of native Cerrado) with dark soil due to accumulated vegetation and leaf litter (19º12´40.01"S latitude and 48º08´34.90"W longitude); (c) Corn (19º12'40.01" S latitude and 48º08'34.90"W longitude) and (d) Brachiaria pasture (19º13'00.22"S latitude and 48º08'24.80" W longitude). The corn and pasture areas employed a no-till system and a crop rotation of 1 year of corn followed by 5 years of pasture, Santa Fe system (Embrapa, 2000). The pasture was fertilized annually with turkey litter. Soil samples were collected four times at different points within a 1-hectare area and at depths of 0 - 0.2 and 0.2 - 0.4 m. These samples were homogenized into a composite sample which was tagged and sent to a laboratory for physical and chemical testing according to the methodology recommended by Embrapa (1997) (Table 1).

Variables and statistical analysis

Al^{3+}, Mg^{2+} and Ca^{2+} availability in soil solution and C-org were evaluated using methodologies recommended by Embrapa (1997). PZSE was determined by first establishing potentiometric titration curves at different concentrations of NaCl (0.1, 0.01, 0.001N) and of NaOH (0.8, 1.6, 2.4, 3.2, 4.0 meq H^+) in solution. PZSE was then found by determining the intersection of the titration curves where adsorption of H^+ and OH^- is equal (RAIJ, 1973). All PZSE results curves fit the model with R^2 greater than 0.90.

The estimated Point of Zero Charge PZC(est) was determined using the equation PZC(est) = pH KCl - pH H_2O (Keng and Uehara, 1974). Here, ΔpH represents the difference between the pH of soil in 1M KCl and the pH of soil in H_2O, both at a 1:2.5 ratio of soil:solution (Tan, 1982).

The results were submitted to homogeneity of variance and normality of residuals tests and then analyzed by F-test. Significant means were then compared by the Tukey test ($p < 0.05$).

RESULTS AND DISCUSSION

Significant differences ($p < 0.05$) in Ca^{2+} availability were found between different soil layers and environments (Figure 1).

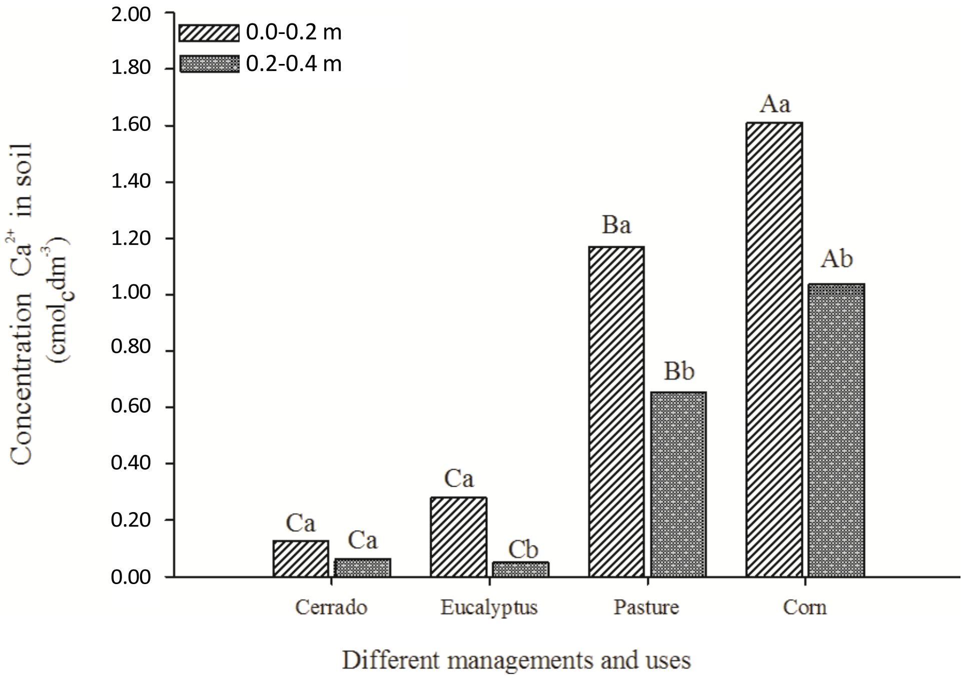

Figure 1. Availability of Calcium (Ca^{2+}) ($cmol_c$ dcm^{-3}) in oxisoils of different managements and land uses (Savanna, Eucalyptus, Pasture and Corn) in two depths (0-0.2 m and 0.2-0.4 m). The uppercase letters represent the different uses and management of land, while the lowercase letters represent the two depths; when they are distinct, distinguish among themselves by Tukey test ($p > 0.05$).

Ca^{+2} concentrations in the top 0.2 m of the soil was 43.39% higher than in the 0.2 - 0.4 m. Available Ca^{+2} were higher in CO and PA than in CE and EU because of the fertilizer amendments and crop rotations employed in these land use types.

Even though soil Ca^{+2} availability was lower in CE and EU, it was still sufficient for the requirements of the vegetation. The absence of animal and machine traffic in these environments meant that organic matter was conserved and could provide nutrients to the soil.

Significant differences in Mg^{2+} and Al^{3+} levels were also observed between soil layers and environments, but no interactions were observed between them (Table 2). Mg^{2+} was lowest in CE and significantly different from the other environments. Specifically, concentration of this macronutrient in CE was 71.15% less than in CO, which had the highest Mg^{2+} concentration.

This result is due to the absence of soil amendments in CE, which would increase Ca^{2+} and Mg^{2} levels (Fageria, 2001). Low levels of Ca^{2+} and Mg^{2+} in CE and EU led to higher levels of available Al^{3+} with greatest concentrations in the 0.0 - 0.2 m layer. These results corroborate those from a study by Souza and Alves (2003) on available Al^{3+} in Cerrado soils.

Therefore, there is a definite relationship between increasing and decreasing Ca^{2+}, Mg^{2+} and Al^{3+} in the soil. The relationship between Ca^{2+} and Mg^{2+} is positive, demonstrating that these elements increased jointly in the evaluated soils (r = 0.708). The relationship between Ca^{2+} and Al^{3+} was negative given that increasing Ca^{2+} caused available Al^{3+} to decrease (r= -0.659).

The pH values of PZC (est) and PZSE responded the same whether in water or KCl (Figure 2). The PZC (est) values for PA and CO were 23.63 and 24.27% higher than in CE while PZSE values for PA and CO were 55.83 and 54.30% higher than in CE.

According to Meurer (2010) and Van Raij (1973), lower PZC (est.) and PZSE values in CE are a result of higher C-org concentrations. This occurs because C-org can bind clay minerals, reducing positive charges and increasing negative ones.

Nevertheless, C-org was lowest in PA, followed by CEand EU and significantly higher in CO (Figure 3).

Additionally, there was no correlation between available C-org and pH - KCl (r = 0.154), pH - H2O (r = 0.149) and PZC (r = 0.143).

One possible explanation is that tropical soils have a higher ratio since iron and aluminum oxides influence soil PZSE and PZC. According to Silva et al. (1996), the absence of this interaction is due more to the type and degree of SOM (C-org) decomposition and interaction with the soil than C-org quantity.

The interaction between PZC (est.) and PZSE was positive (r= 0.54), which corroborates the results of a

Table 2. Availability of aluminum (Al^{3+}) and magnesium (Mg^{2+}) in oxisol with the uses of Savanna – CE, eucalyptus – EU, pasture- PA and corn – MI at 0-0.2 m and 0.2-0.4 m in soil profile, Fazenda Santa Terezinha, Triângulo Mineiro region.

Soil uses	Mg^{2+}			Al^{3+}		
	0 - 0.2	0.2 - 0.4	Average	0 - 0.2	0.2 - 0.4	Average
Savanna	0.11	0.08	0.091^{B}	0.45	0.28	0.362^{B}
Eucalyptus	0.31	0.14	0.223^{A}	0.40	0.30	0.350^{B}
Corn	0.40	0.23	0.248^{A}	0.14	0.05	0.000^{A}
Pasture	0.30	0.20	0.312^{A}	0.00	0.00	0.093^{A}
Média	0.279^{A}	0.158^{B}		0.246^{B}	0.156^{A}	

*Availability of Al^{3+} and Mg^{2+} expressed in cmolcdm^{3} and the layers meter (m). Averages followed by distinct capital letters in the column identifying management systems and land use. Identifying the row and lower layers of the soil profile, differ by Tukey test (p > 0.05).

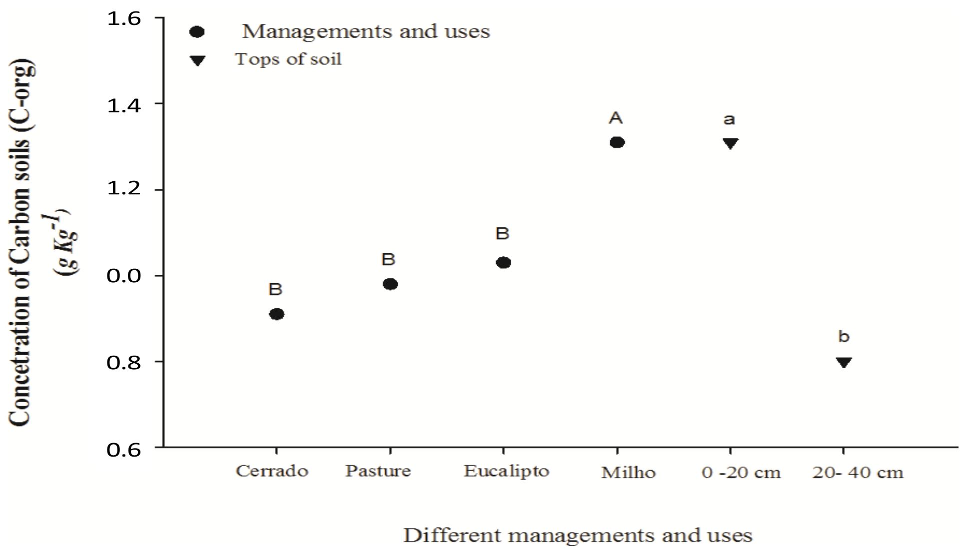

Figure 2. Values of potential zero charge (PZC est), pH in water and in KCl and the point of null saline effect (PESN) of the oxisoils in different managements and land uses (Savanna, Eucalyptus, Pasture and Corn). The uppercase letters represent the uses and management of land, when they are distinct, distinguish among themselves by Tukey test (p> 0.05).

study by Fernandes et al. (2008) on different soils of the Caatinga (dry savanna unique to northeastern Brazil). According to Benites and Mendonça (1998), PZC (est.) and PZSE are similar and positively correlated in highly weathered soils where electric charges are almost entirely pH dependent.

In addition, available Ca^{2+} (r = 0.82) and Mg^{2+} (r = 0.49) were significantly correlated with PZC (est.) and Ca^{2+} (r= 0.41) was significantly correlated with PZSE. This demonstrates that the electric potential of the soil was more significantly associated with the availability of these cations.

This positive correlation between PZC and cations is due to electrochemical phenomena of soils with variable charges, which affect properties such as cation exchange and nutrient availability (Fontes et al., 2001). Greater availability of Ca^{2+} and Mg^{2+} increases the specific adsorption of the inner sphere complex, leading to the formation of positive charges on colloid surfaces (Sposito, 1989). Moreover, the cation exchange capacity (CEC) of oxisols is pH dependent, affecting negative charges arising from the reaction of lime.

There were no significant differences in PZC (est.) and PZSE relative to the two soil layers studied. Similar results were found in a study (Demattê, 1993) in Planaltina, Brazil that compared an area of native Cerrado vegetation to 16 areas with different types of soil management and land use in clayey Oxisol. However, Van Raij (1973), working with the Ap and B2 horizons of an Oxisol, found differences in PZC (est.) in the surface

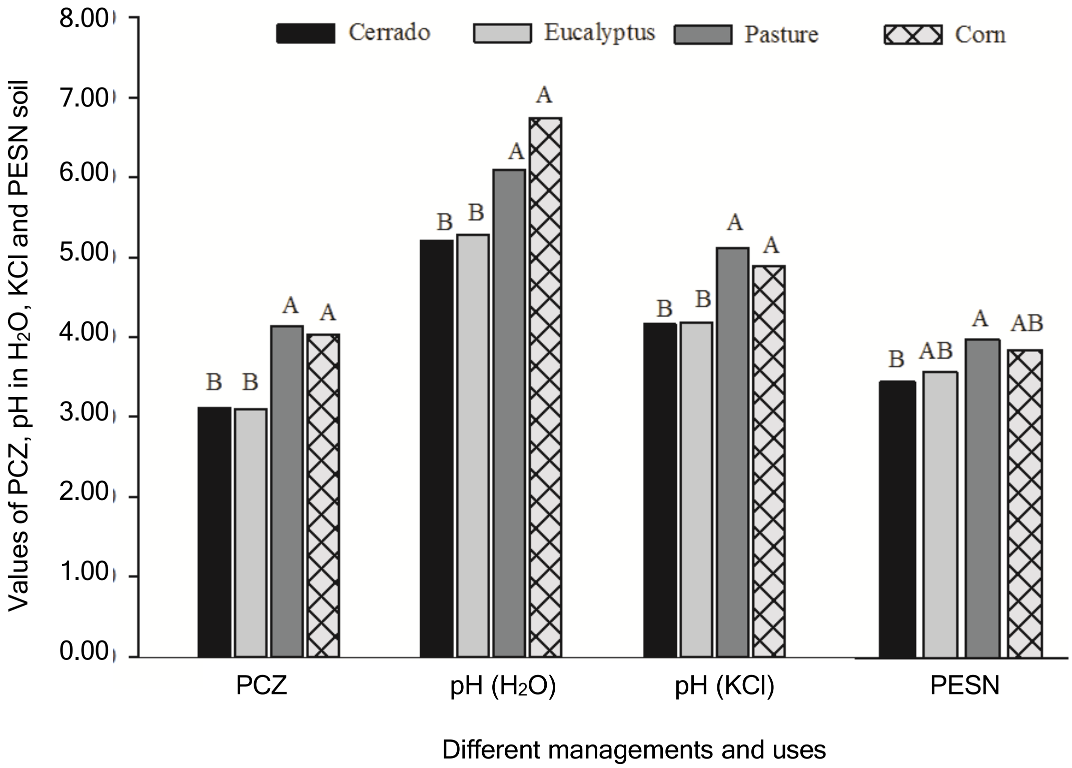

Figure 3. Effect of the use and management of soil in two soil depths (0-0.2 and 0.2-0.4 m) in the levels of soil organic carbon (C-org - g kg^{-1}). Points on the graph marked with different uppercase letters differ from each other between the types of use and soil management. Points marked with lowercase letters distinguish among each other soil depths by the Scoott-Knott test (p <0.05).

Table 3. Delta pH (ΔpH) in Oxisol with usage with savanna, eucalyptus, pasture and corn in layers of 0-0.2 0.2-0.4 m in the Santa Terezinha, Triângulo Mineiro region.

Management and land use ¹	ΔpH*		Average
	0 - 0.2 m	0.2 - 0.4 m	
Savanna	-1.052	-1.022	-1.042^{A}
Eucalyptus	-1.152	-1.040	-1.096^{AB}
Pasture	-0.927	-1.027	-0.982^{AB}
Corn	-0.900	-0.810	-0.850^{B}

* Delta pH (ΔpH): difference between the pHKCl and pH H_2O ¹ - Table averages accompanied with uppercase column identifies the land uses and managements when distinct differ among themselves by Tukey test (p > 0:05).

layers due to organic matter accumulation on the soil surface.

ΔpH was negative (Table 3) in all environments. This indicates the predominance of negative charges on the surfaces of minerals and organic matter, which increase CEC. This situation occurs in tropical soils due to acidity and significant quantities of oxides, mainly iron and aluminum (Meurer, 2010). The PCZ (est.) of these oxides, both in crystalline (gibbsite, hematite and goethite) and amorphous forms ranges from 5.5 to 6.0 regardless of cation content (Demattê, 1993).

Conclusion

Land use and soil management tend to alter the electrochemical conditions of the soil with a positive correlation between Ca^{+2} and Mg^{+2} availability and PZC (est.) and PZSE. However, PZC (est) and PZSE are not correlated with C-org in Oxisol soils under CO, PA, EU and CE land use in the Triangulo Mineiro region of Brazil.

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Conflict of Interests

The author(s) have not declared any conflict of interests.

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