academicJournals

Vol. 9(31), pp. 2436-2442, 31 July, 2014
DOI: 10.5897/AJAR2014.8637
Article Number: 7F4571B46406
ISSN 1991-637X
Copyright ©2014
Author(s) retain the copyright of this article
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Changes in soil chemical properties under different farming systems exploration in semiarid region of Paraíba

J. D. S. Barros[1] and L. H. G. Chaves[2]*

[1]Department of Natural Resources, Federal University of Campina Grande Avenue Aprigio Veloso, 882, 58429-140, Campina Grande Program - PB, Brazil.
[2]Department of Agricultural Engineering, Center for Technology and Natural Resources, Federal University of Campina Grande Avenue Aprigio Veloso, 882, 58429-140, Campina Grande - PB, Brazil.

Received 24 February, 2014; Accepted 16 June, 2014

The change of Caatinga natural vegetation in the Brazilian semiarid region, to different systems of agricultural exploitation, that is, the replacement of complex and stable systems by simple and unstable systems has caused changes in soil properties that are dependent on the climate, the type of crops and the management adopted. Based on areas of Caatinga native vegetation, this study aimed to evaluate the changes in the chemical characteristics of soils under different farming systems in Paraiba backwoods. Vertissol samples were collected at 0 to 10, 10 to 20, 20 to 30 and 30 to 40 cm and chemically characterized. Selected systems were native vegetation, sparse vegetation, pasture, annual and permanent crops. Based on the statistical analysis, it was concluded that the replacement of native vegetation by agricultural farming systems in the region of watershed Riacho Val Paraiso, PB, caused changes only in pH, potassium and sodium in the soil attributes. There was a trend of soil chemical properties increasing in the areas of agricultural cultivation and with depth. In all areas of agricultural farming systems, soil fertility is suitable for most crops.

Key words: macronutrients, land use, soil depth.

INTRODUCTION

The caatinga biome, occupying an area of about 850,000 km², about 11% of the national territory, is the main existing ecosystem in the Brazilian Northeast region under semiarid climate. The population in this area corresponds to about 20 million inhabitants. This area has significant socioeconomic and ecological importance.

The complex and stable systems of the natural vegetation of the caatinga has been replaced by simple and unstable crop systems. This has caused changes in soil chemical and physical properties which are dependent on climate, crop type and management type (Santana and Souto, 2011). This change may result in decreased vegetation cover causing soil loss and, consequently, reduced soil fertility.

According to Chaves et al. (2006) the indiscriminate use of natural vegetation, intensive pasture and

---

*Corresponding author. E-mail: lhgarofalo@hotmail.com irrational use of agriculture are factors that have contributed to accelerate the process of environmental imbalance. The consequence of this process is related to the reduction of soil fertility and biodiversity (Travassos and Souza, 2011). Barros et al. (2013), for example, noted that carbon and nitrogen stocks in the soil under cultivation of sugar cane decreased compared to the soil under native forest. Likewise, agricultural cultivation in soils of the floodplains of the river Guamá caused a reduction in the concentration of P and K (Lopes et al., 2006).

The characterization of soil in a particular area is fundamental for sustainable models aiming to maximize output and mitigation of natural resource degradation. Among the soils found in the semiarid region are the Vertisols characterized as clayey or loamy soils with high content of expandable clay minerals (2:1) causing the appearance of "slickensides" and splitting the subsurface layers of soil in dry season, and may or may not provide the "Gilgai"-type microrelief (EMBRAPA, 1999). Generally, there are high amounts of exchangeable bases (S) and saturation (V%) and a reaction ranging from moderately acidic (on the surface of some of these soils) to strongly alkaline (at the horizon C) (EMBRAPA, 1999). It was evident in the surveys that the depth profile of the AC ranges from 60 to 130 cm.

In agricultural systems, the soil chemical properties are altered, positively or negatively, depending on the soil management adopted. In this sense, Santos and Ribeiro (2002), when studying the effects of irrigated agriculture on chemical properties of soils of the São Francisco submedium region found that the chemical properties were affected differently, depending on the adopted management. With the objective of evaluating land use, Corrêa et al. (2009) found that in relation to native vegetation, uses of cultures with short cycles, discarded areas, pastures, and fruit cultures were higher in the three analyzed layers of pH, exchangeable Ca and Mg attributes, sum bases, base saturation, and available P. Lopes et al. (2006) also observed that the pasture showed greater sustainability of fertility than the system under rice cultivation.

Generally, in environments under natural vegetation, less variation occurs in chemical and physical soil properties when compared to farm management systems; thus, the natural vegetation is a sure indicator to evaluate different types of land use, allowing the evaluation of the sustainable or unsustainable use of certain agricultural practices (Menino et al., 2012).

Based on areas of Caatinga native vegetation, this study aimed to evaluate the changes in the chemical characteristics of soils under different farming systems in Paraiba backwoods.

MATERIALS AND METHODS

The study area is located in the watershed of Val Paraiso stream, between the cities São João do Rio do Peixe and Sousa, inserted in the Northwest portion of Paraíba State, Brazil (situated in the parallel of latitude 6°37'54" to 6°44'29" South and meridians of longitude 38° 18'21" to 38°24'12" West). According to Koppen classification, the climate is warm tropical climate of severe drought, reaching over 35°C at times of higher temperatures. In the study area the average annual temperature is 27°C and the index average annual rainfall is 967.23 mm; however during the survey, an average temperature of 28.6°C and pluviometric index of 6.2 mm were recorded. The vegetation is basically composed of Caatinga Hiperxerófila and the predominant soil in the Val Paraiso watershed is classified as Vertisol (Fernandes Neto, 2009).

In the watershed, five farming systems exploration were identified: native vegetation, taken as reference (area covered by arboreal natural vegetation); sparse vegetation (area covered by natural vegetation typical of the caatinga in recovery; this area was deforested ten years ago, submitted by three consecutive years for agricultural cultivation, and currently is in the process of forest recovery), pasture (area covered by a sparse vegetation and planted; this area under pasture was deforested for over 40 years and yet is being used as pasture for ruminant animals); annual crops (areas of temporary crops; this area is being used for over 60 years with annual crop under constant activities of burning, disking and plowing) and permanent agriculture (crop with high vegetation cover, mainly composed of permanent crops; this area was deforested for 5 years and is under permanent cultivation agriculture).

For each farming systems, exploration were opened for profiles occurring in the same soil class. In each profile, the soil samples were collected from July to August 2012, at depths of 0 to 10, 10 to 20, 20 to 30 and 30 to 40 cm. These samples, after being air dried and passed through a sieve of 2 mm, were characterized chemically according to the methods recommended by Embrapa (1997). The chemical elements analyzed were: calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), hydrogen (H), aluminum (Al) and phosphorus (P). From these data, the sum of exchangeable bases (EB), cation exchange capacity (CEC) and base saturation percentage (BS%) were calculated.

The experimental design was completely randomized in factorial scheme 4 × 5, with four replicates (four profiles) that is four depths (0 to 10; 10 to 20; 20 to 30 and 30 to 40 cm) and five sites (native vegetation, sparse vegetation, pastures, annual agriculture and permanent agriculture).

Data were analyzed using descriptive statistics by calculating the maximum, minimum, mean and coefficient of variation. Analysis of variance (ANOVA) and Tukey test at 5% probability were made for comparison of means of the results, according to Ferreira (2000).

RESULTS AND DISCUSSION

Soil pH was significantly affected ($p < 0.01$) by the different environments studied likewise, there were significant difference ($p < 0.05$) in the amounts of electrical conductivity (EC) and potassium. In relation to depth, there was a significant effect ($p < 0.01$) on the pH results and on the sodium (Na) and potassium (K) amount; there was a significant effect ($p < 0.05$) on the hydrogen (H) amount. However, the interaction of areas of farming systems exploration x depths showed a significant effect ($p < 0.05$) on the H amount (Table 1). The pH is the mechanism used either to identify the soil acidity, or the hydrogen ions concentration in soil solution. Regardless of the depth of soil samples, in accordance with the minimum (6.30) and maximum

Table 1. Summary of variance analysis for the chemical soil properties.

Source of variation	DF	Mean square										
		pH	CE	Ca	Mg	Na	K	H	Al	EB	CEC	P
Local	4	1.5**	0.006*	122.0	28.5	8.3	0.15*	0.16	0.0	115.1	118.1	28.1
Res.(a)	12	0.2	0.002	53.5	22.1	7,6	0.05	0.06	0.0	81.3	79.23	20.3
Depths	3	1.6**	0.001	2.9	2.8	6.7**	0.10**	0.32*	0.0	10.5	5.96	0.9
Dep.x Loc.	12	0.1	0.001	13.3	4.6	1.9	0.01	0.13*	0.0	7.8	5.62	7.3
Res.(b)	36	0,1	0.001	7.1	2.7	1.3	0.008	0.06	0.0	4.9	5.78	9.4

*, ** Significant at 5 and 1% (F test), respectively; Local = areas of farming systems exploration (native vegetation (NV); sparse vegetation (SV); pasture (P); annual crops (AC) and permanent crops (PC)).

(8.86) pH values (Table 2), it was observed by Cardoso et al. (2009) and Lopes and Guilherme (2004), that the soil of the region under study as a whole, presents reaction ranging from moderately acidic to highly alkaline. These pH levels are due mainly to the high levels of exchangeable bases found in the soil of the study area. Among the factors that may have contributed to these high levels, stands out the characteristics of the soil, Vertisol, and regional climate. This soil is young, little weathered, clayey with expandable clay minerals (2:1) and located in semiarid region. Therefore, due to the origin of the soil, low permeability soil, hindering drainage and low rainfall of the region, hindering the leaching of chemical elements, the soil still has naturally high levels of exchangeable bases.

Native vegetation showed minimum and maximum pH values of 6.70 and 8.08; sparse vegetation of 6.30 and 8.15; pasture of 6.70 and 7.80; annual crops of 8.86 and 6.60 and permanent agriculture of 7.60 and 8.17, respectively (Table 2) as can be seen in Figure 1.

According to the results presented in Table 3, the highest average pH values were found in areas under agricultural cultivation. This is probably due to the residual effects of anthropogenic interventions more pronounced along the cycles of crops disagreeing de (Melo et al., 2010). These authors observed no significant differences in the pH of the soil due to different ways of using the watershed Riacho do Tronco in Boa Vista, Paraíba State.

In general, the soil pH increased with depth in all profiles (Table 2) which probably is related to elevation concentrations of calcium carbonates and bicarbonates ions.

The Coefficient of Variation (CV) should be used as a parameter to validate the mean values since, according to Vanni (1998), CV above 35% shows that the average has little meaning and values greater than 65% reflect data very heterogeneous nullifying the trustworthiness of average. According to the CV classification proposed by Warrick and Nielsen (1980), the pH of the soil for all farming systems exploitation at all depths were low (CV <12%), corroborating Cavalcante et al. (2007), Souza et al. (2008) and Neves Neto et al. (2013). This can be attributed to the fact that this variable may be measured on a small scale of values and be a logarithmic function (Neves Neto et al., 2013).

According to Santana et al. (2007), electrical conductivity expresses the salts amount present in the soil solution. Thus the greater the amount of salts presents in the solution, the greater the value of the electrical conductivity. Although there was no difference between the averages of EC in different farming systems and in the depths of the profiles, there was a trend towards higher values in areas under agricultural cultivation (Table 3). According to the classification of Warrick and Nielsen (1980), the coefficients of variation were classified as low (CV < 12%) for all treatments and depths.

Data calcium (Ca) ranged from 10.70 (annual agricultural area) to 29.65 kg cmol$_c$ kg^{-1} (in the permanent agriculture area) and magnesium (Mg) from 4.93 (pasture area) to 17.34 cmol$_c$ kg^{-1} (in the sparse vegetation area) (Table 4) showed that all contents of these elements were classified as high (Lopes and Guilherme, 2004) corroborating Melo et al. (2010) and Chaves et al. (2006). Considering that levels 2 to 3 cmol$_c$ kg^{-1} Ca and around 4 cmol$_c$ kg^{-1} Mg (Raij, 1981) are adequate to crop development, it can be stated that the study areas do not exist deficiencies of these elements.

Although the results of Ca and Mg soil have not shown significant differences in farming systems exploration and different depths, disagreeing with Vasconcelos et al. (2010) and Lima et al. (2011), there was a trend of increasing values in areas of cultivation as well as increase and decrease in the levels of Ca and Mg, respectively, relative to depth.

Data sodium (Na) ranged from 1.54 (in the permanent agriculture area) to 7.62 cmol$_c$ kg^{-1} (in the sparse vegetation area) not presenting significant differences in studied treatments. However, the Na$^+$ increased with depth, presenting significant differences (Table 4).

According to Santos and Ribeiro (2002), the increase of Na with depth may be related to the addition of this element by irrigation water, as may have occurred a displacement of said element of colloids soil by Ca^{2+}, Mg^{2+} and K$^+$, from fertilizer applied, due to its lower

Table 2. Descriptive statistics for pH and electrical conductivity (EC) of soil samples collected at depths of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm in different areas of farming systems exploration (native vegetation (NV); sparse vegetation (SV); pasture (P); annual crops (AC) and permanent crops (PC))

Depth (cm)	pH				Electrical conductivity (mmhos/cm)			
	Minimum	Maximum	Mean	CV (%)	Minimum	Maximum	Mean	CV (%)
Native vegetation								
0-10	6.70	7.20	6.91	0.03	0.08	0.12	0.10	0.18
10-20	7.06	7.28	7.16	0.01	0.06	0.13	0.01	0.37
20-30	7.40	8.03	7.65	0.04	0.06	0.11	0.08	0.31
30-40	7.83	8.08	7.93	0.01	0.07	0.12	0.09	0.24
Sparse vegetation								
0-10	6.30	7.23	6.75	0.07	0.06	0.10	0.09	0.23
10-20	6.70	7.32	7.04	0.04	0.06	0.12	0.08	0.37
20-30	6.70	7.36	7.11	0.04	0.06	0.09	0.08	0.17
30-40	7.08	8.15	7.55	0.06	0.07	0.14	0.09	0.31
Pasture								
0-10	6.70	7.22	6.93	0.03	0.08	0.10	0.09	0.09
10-20	6.85	7.52	7.26	0.04	0.08	0.13	0.10	0.25
20-30	7.25	7.80	7.61	0.03	0.06	0.14	0.09	0.37
30-40	7.90	7.43	7.75	0.03	0.06	0.13	0.09	0.37
Annual crops								
0-10	6.60	7.82	7.41	0.08	0.09	0.17	0.13	0.26
10-20	6.42	8.86	7.57	0.14	0.07	0.27	0.15	0.58
20-30	6.67	8.63	7.75	0.11	0.07	0.14	0.10	0.32
30-40	7.90	8.50	8.11	0.03	0.11	0.13	0.12	0.08
Permanent crops								
0-10	7.60	8.17	7.91	0.03	0.11	0.21	0.15	0.30
10-20	7.80	7.92	7.87	0.07	0.09	0.15	0.13	0.21
20-30	7.70	8.05	7.86	0.02	0.09	0.20	0.12	0.43
30-40	7.80	8.03	7.91	0.01	0.08	0.12	0.10	0.18

CV= coefficient of variation.

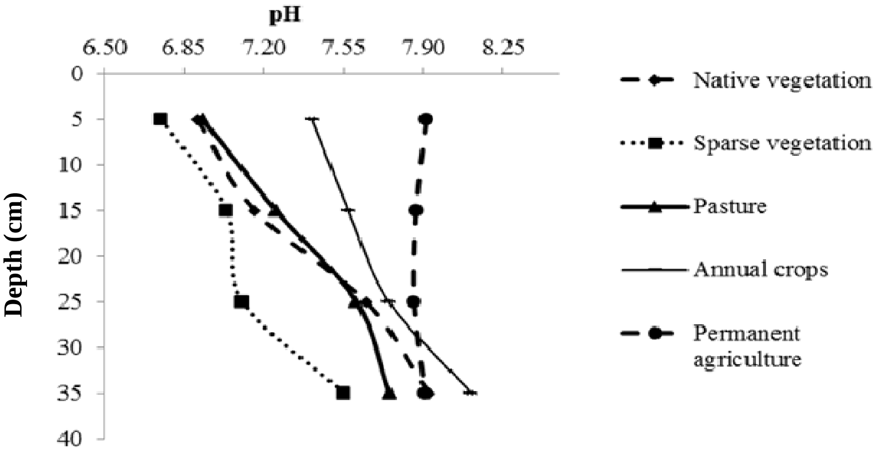

Figure 1. pH values for each area: native vegetation, sparse vegetation, pasture, annual crops and permanent crops at four depths.

Table 3. Mean values of soil pH and electrical conductivity (E.C.) depending on the areas of farming systems exploration and depth.

Attribute	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent crops
		Farming systems exploration			
pH	7.41^{ab}	7.11^{b}	7.39^{ab}	7.71^{a}	7.89^{a}
E.C. (mmhos/cm)	0.09^{a}	0.08^{a}	0.09^{a}	0.12^{a}	0.12^{a}
		Depth (cm)			
		0-10	10-20	20-30	30-40
pH		7.18^{c}	7.38^{bc}	7.60^{ab}	7.85^{a}
E.C. (mmhos/cm)		0.11^{a}	0.11^{a}	0.09^{a}	0.10^{a}

Means followed by same letters in the lines do not differ by Tukey test to 5% probability.

Table 4. Mean values of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), the sum of exchangeable bases (EB) and phosphorus (P) depending on the areas of farming systems exploration and depth.

Attribute	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent crops
		Farming systems exploration			
Ca (cmol$_c$ kg^{-1})	22.58^{a}	17.43^{a}	22.37^{a}	20.47^{a}	24.82^{a}
Mg (cmol$_c$ kg^{-1})	9.21^{a}	11.12^{a}	9.56^{a}	12.50^{a}	11.13^{a}
Na (cmol$_c$ kg^{-1})	1.13^{a}	2.42^{a}	1.09^{a}	2.63^{a}	2.11^{a}
K (cmol$_c$ kg^{-1})	0.41^{b}	0.55^{ab}	0.47^{ab}	0.52^{ab}	0.67^{a}
Al (cmol$_c$ kg^{-1})	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
EB (cmol$_c$ kg^{-1})	33.49^{a}	31.78^{a}	33.48^{a}	36.11^{a}	38.61^{a}
P (mg dm^{-3})	52.10^{a}	52.47^{a}	54.38^{a}	54.16^{a}	55.21^{a}
		Depth (cm)			
		0-10	10-20	20-30	30-40
Ca (cmol$_c$ kg^{-1})		21.00^{a}	21.63^{a}	21.58^{a}	21.92^{a}
Mg (cmol$_c$ kg^{-1})		11.25^{a}	10.50^{a}	10.62^{a}	10.44^{a}
Na (cmol$_c$ kg^{-1})		1.18^{b}	1.66^{ab}	2.15^{b}	2.51^{a}
K (cmol$_c$ kg^{-1})		0.61^{a}	0.54^{b}	0.45^{c}	0.49^{bc}
Al (cmol$_c$ kg^{-1})		0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
EB (cmol$_c$ kg^{-1})		34.04^{a}	34.22^{a}	34.86^{a}	35.64^{a}
P (mg dm^{-3})		53.95^{a}	53.69^{a}	53.48^{a}	53.53^{a}

energy retention. Furthermore, for environments that are not irrigated, the increase in sodium in the lower horizons can be related to more restricted drainage in the soil profile, but also because the lowest position in the landscape. The fact sodicity increase in subsurface horizons is worrying, since the plant roots reach those horizons being impaired by the presence of the element sodium. However, the Na content in the samples of the present research is not harmful, once the exchangeable sodium percentage in the complex is below 8%, that samples classified as normal in relation to sodicity.

Data potassium (K) ranged from 0.18 (in the annual crops area) to 0.88 cmol$_c$ kg $^{-1}$ (in the permanent agriculture area) that is from the average level (0.16 to 0.30 cmol$_c$ kg^{-1}) to very high (> 0.60 cmol$_c$ kg^{-1}). However, in all areas and depths analyzed, the average values ranged from high to very high (Table 4) corroborating Chaves et al. (2007).

The potassium levels were significantly different in both studied areas with lowest values of depths occurrence in areas with native vegetation and layers below 10 cm depth (Table 4), corroborating with Pereira et al. (2009), Leite et al. (2012) and Lira et al. (2012).

The highest values in the area of permanent agriculture and topsoil are probably associated with a continuous supply of plant residues favoring the retention of this nutrient, the absence of tillage, which favors' the accumulation of nutrients in the sampled depth (Barreto et al., 2008) beyond the addition of potassium fertilizers, because it is a cultivated area corroborating according to Matias et al. (2009).

Calcium presented itself as the main contributor to the total exchangeable bases (EB), followed by magnesium, sodium and potassium, reflecting thus the nature of the source material. Aluminum not detected in soil samples (Table 4) with low hydrogen contents the values of the total exchangeable bases of these samples represent practically the values of cation exchange capacity (CEC), which ranged from 30.01 to 39.26 $\text{cmol}_c\ \text{kg}^{-1}$ classified as high. Due to equivalence of high values of sum of bases to the cation exchange capacity, percentage saturation of exchangeable bases corresponded to 100% in all systems of farming operation, showing high nutritional potential for plants.

Data phosphorus (P) ranged from 32.30 (in the native vegetation area) to 58.60 mg dm^{-3} (in the pasture area) shows that all contents of these elements were classified as high (Lopes and Guilherme, 2004). According Falleiro et al. (2003) and Leite et al. (2012) the high levels of P in the soil may be due to the residual effect of previous fertilizations, maintenance of plant residues on the soil surface, which favors the cycling of phosphorus of no soil disturbance, which promotes the formation phosphorus sites (Sa, 2004) and the very origin of the soil.

Although the results of soil P have not shown significant differences in agricultural farming systems and different depths, disagreeing Leite et al. (2012), there was a trend of increasing values in the areas of crop and decrease the levels of P in relation to depth corroborating Leite et al. (2012). The highest levels apparently in the topsoil, is related to the fact that P move by diffusion in the soil, which results in low mobility profile, contributing to its accumulation in this layer (Zalamena, 2008).

According the classification of CV proposed by Warrick and Nielsen (1980), it was observed that the levels of exchangeable bases and P in all environments and at all depths, showed low variability (CV <12%) reflecting homogeneous data with high reliability.

Conclusion

The replacement of native vegetation by agricultural farming systems in the region of watershed Riacho Val Paraiso, PB, caused changes only in pH, potassium and sodium in the soil attributes. The highest concentrations of carbonates and bicarbonates of calcium in the deeper horizons of the soil increased the pH in these horizons. Soil leaching, although low, due to the semiarid climate, causes increased concentration of cations, especially potassium and sodium, in the deeper soil horizons. There was a trend of soil chemical properties increasing in the areas of agricultural cultivation and with depth.

The Vertisol is a young, little weathered and very clayey soil, with low soil permeability because it is located in semiarid region with low rainfall; thus, in all areas of agricultural farming systems, soil fertility is suitable for most crops (high levels of nutrients for plants).

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENT

The first author is grateful to CNPq for providing a fellowship.

REFERENCES

Barreto PAB, Rodrigues EFG, Rodrigues ACG, Barros NF, Fonseca S (2008). Atividade microbiana, carbono e nitrogênio da biomassa microbiana em plantações de eucalipto, em sequência de idades. Rev. Bras. Ci. Solo. 32(2):611-619. http://dx.doi.org/10.1590/S0100-06832008000200016

Barros JDS, Chaves LHG, Chaves IB, Farias CHA, Pereira WE (2013). Estoque de carbono e nitrogênio em sistemas de manejo do solo, nos Tabuleiros Costeiros paraibanos. Rev. Caatinga. 26(1):35-42.

Cardoso EL, Fernandes AHBM, Fernandes FA (2009). Análise de solos: finalidade e procedimento de amostragem. Comunicado Técnico79. Corumbá – MS.

Cavalcante EGS, Alves MC, Souza ZM, Pereira GT (2007). Variabilidade espacial de atributos químicos do Solo sob diferentes usos e manejos. Revi. Bras. Ci. Solo. 31:1329-1339. http://dx.doi.org/10.1590/S0100-06832007000600012

Chaves LHG, Chaves IB, Vasconcelos ACF (2006). Propriedades químicas dos solos da bacia hidrográfica do Açude Namorado, PB. Principia 10(14):68-75.

Chaves LHG, Tito GA, Barros AD, Guerra HOC (2007). Características químicas de solo do perímetro irrigado de Sumé, PB. Rev. Caatinga. 20(4):110-115.

Corrêa RM, Freire MBGS, Ferreira RLC, Freire FJ, Pessoa LGM, Miranda MA, Melo DVM (2009). Atributos químicos de solos sob diferentes usos em perímetro irrigado no Semiárido de Pernambuco. Rev. Bras. Ci. Solo 33(2):305-314. http://dx.doi.org/10.1590/S0100-06832009000200008

EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solo (1997). Manual de métodos de análise de solo. 2 ed., Rio de Janeiro: EMBRAPA.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos (1999). Sistema brasileiro de classificação de solos. Rio de Janeiro: EMBRAPA.

Falleiro RM, Souza CM, Silva CSW, Sediyama CS, Silva AA, Fagundes JL (2003). Influência dos sistemas de preparo nas propriedades químicas e físicas do solo. Rev. Bras. Ci. Solo. 27:1097-1104. http://dx.doi.org/10.1590/S0100-06832003000600014

Fernandes Neto S (2009). Planejamento do uso racional dos recursos naturais da microbacia hidrográfica do riacho Val Paraíso - PB, através de mapeamento geoambiental. 117f. Dissertação (Mestrado em Recursos Naturais) –Universidade Federal de Campina Grande. Campina Grande – PB.

Ferreira DF (2000). Análise estatística por meio do SISVAR (Sistema para Análise de Variância) para Windows versão 4.0. In: Reunião Anual da Região Brasileira da Sociedade Internacional de Biometria, 45, 2000, São Carlos. Anais. São Carlos: UFSCar.

Leite MJH, Santos RV, Bezerra RMR, Lucena RJ, Sousa KL (2012). Avaliação da fertilidade do solo em perímetros irrigados: Engenheiro Arcoverde e São Gonçalo, PB. Rev. Verde. 7(4):214-225.

Lima SS, Leite LFC, Oliveira FC, Costa DB (2011). Atributos químicos e estoques de carbono e nitrogênio em Argissolo Vermelho-Amarelo sob sistemas agroflorestais e agricultura de corte e queima no norte do Piauí. Rev. Arvore. 35(1):51-60.

http://dx.doi.org/10.1590/S0100-67622011000100006

Lira RB, Dias NS, Alves SMC, Brito RF, Sousa Neto ON (2012). Efeitos dos sistemas de cultivo e manejo da caatinga através da análise dos indicadores quimicos de qualidade do solo na produção agrícola em Apodi, RN. Rev. Caatinga. 25(3):18-24.

Lopes AS, Guilherme LRG (2004). Interpretação de análise do solo: conceitos e aplicações. Boletim Técnico 2. São Paulo: Comitê de Pesquisa/Técnico/ANDA.

Lopes ELN, Fernandes AR, Grimaldi C, Ruivo MLP, Rodrigues TE, Sarrazin M (2006). Características químicas de um Gleissolo sob diferentes sistemas de uso nas margens do rio Guamá, Belém, Pará. Bol. Mus. Para. Emílio Goeldi. Ciências Naturais 1(1):127-137.

Matias MCB, Salviano AAC, Leite LFC, Galvão SRS (2009). Propriedades químicas em Latossolo Amarelo de Cerrado do Piauí sob diferentes sistemas de manejo. Rev. Ci. Agron. 40(3):356-362.

Melo JAB, Pereira RA, Dantas Neto J, Lima ERV (2010). Propriedades do solo e propensão à desertificação na microbacia do Riacho do Tronco, Boa Vista, PB. Rev. Bras. Agric. 5(2):234-246.

Menino IB, Moraes Neto JM, Barros AD, Santos ES (2012). Atributos físicos como indicadores da qualidade dos Vertissolos em diferentes sistemas de manejo. Rev. Edu. Agron. Sup. 27(2):106-112.

Neves Neto DN, Santos AC, Santos PM, Melo JC, Santos JS (2013). Análise espacial de atributos do solo e cobertura vegetal em diferentes condições de pastagem. Rev. Bra. Eng. Agríc. Amb. 17(9):995-1004.

Pereira RG, Albuquerque AW, Cunha JLXL, Paes RA, Cavalcante M (2009). Atributos químicos influenciados por sistemas de manejo. Rev. Catinga. 22(1):78-84.

Raij B van (1981). Avaliação da fertilidade do solo. Piracicaba: Instituto da Potassa & Fosfato. Instituto Internacional da Potassa.

Sa JCM (2004). Adubação fosfatada no sistema plantio direto. In: Yamada T, Abdalla SRS e (Eds.). Simpósio Sobre Fósforo Na Agricultura Brasileira, 1., 2003, São Pedro. Anais. Piracicaba: Potafos.

Santana MJ, Carvalho JÁ, Souza KJ, Sousa AMG, Vasconcelos CL, Andrade LAB (2007). Efeitos da salinidade da água de irrigação na brotação e desenvolvimento inicial da cana-de-açúcar (*Sacchrum* spp) e em solos com diferentes níveis texturais. Ci. Agrot. 31(5):1470-1476. http://dx.doi.org/10.1590/S1413-70542007000500030

Santana JAS, Souto JS (2011). Produção de serapilheira na Caatinga da região semiárida do Rio Grande do Norte, Brasil. Idesia 29(2):87-94. http://dx.doi.org/10.4067/S0718-34292011000200011

Santos EEF, Ribeiro MR (2002). Influência da irrigação e do cultivo nas propriedades químicas de solos da região do Submédio São Francisco. Acta Sci. Agric. 24(5):1507-1516.

Souza GS, Lima JSS, Silva AS, Oliveira RB (2008). Variabilidade espacial de atributos químicos em um Argissolo sob pastagem. Acta Sci. Agric. 30:589-596.

Travassos IS, Souza BI (2011). Solos e desertificação no Sertão paraibano. Rev. Cad. Logepa. 6(2):101-114.

Warrick AW, Nielsen DR (1980). Spatial variability of soil physical properties the soil. In: Hill D. (Ed.) Applications of soil Physics. New York: Academic Press. PMCid:PMC349946.

Vanni SM (1998). Modelos de regressão: Estatística aplicada. São Paulo: Legmar Informática. PMCid:PMC2232225.

Vasconcelos RFB, Cantalice JRB, Oliveira VS, Costa YDJ, Cavalcante DM (2010). Estabilidade de agregados de um latossolo amarelo distrocoeso de Tabuleiro Costeiro sob diferentes aportes de resíduos orgânicos da cana-de-açúcar. Rev. Bras. Ci. Solo. 34(2):309-316.http://dx.doi.org/10.1590/S0100-06832010000200004

Zalamena J (2008). Impacto do uso da terra nos atributos químicos e físicos de solos do rebordo do Planalto – RS. 2008. 79f. Dissertação (Mestrado em Ciência do Solo)–Universidade Federal de Santa Maria, Santa Maria.