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Carbon and nitrogen stocks under different management systems in the Paraiban "Sertão"

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The change in land use leads to significant changes in carbon (C) and nitrogen (N) stocks in the soil and consequently in the global cycle of these elements. The purpose of this study was to evaluate C and N stocks in soils under different management systems in the Paraiban "Sertão". This study was carried out in the watershed of Val Paraiso stream, State of Paraiba, Brazil. The climate is warm tropical with severe drought, reaching over 35°C in times of higher temperatures. The vegetation is basically composed of Caatinga Hiperxerófila and the predominant soil in this area is classified as Vertisol. The following systems treatments were tested: native vegetation, sparse vegetation, pasture, annual and permanent agriculture. Soil sampling was performed in four respective sites (four profiles). Samples were stratified in four layers: 0-10, 10-20, 20-30 and 30-40 cm. Soil attributes determined and calculated were: bulk density, organic C and N contents, and C and N stocks. The lower values of bulk density were presented in the area of native vegetation and in 0-10 cm soil layer, compared to other management systems and layers. The implementation of agricultural systems in areas that had native vegetation decreased the C and N contents and stocks, in the same way, these values decreased relative soil layers analyzed. The agricultural production and livestock systems are functioning as CO_2-C emitter when compared with the native vegetation.

Key words: Native vegetation, sparse vegetation, pasture, annual agriculture and permanent agriculture.

INTRODUCTION

With the transformation of natural ecosystems into agricultural systems, complex and stable biological systems are replaced by simple and unstable systems. This modification in the land use leads to change in soil organic components stocks by altering the addition and decomposition rates of organic matter. Thus, the balance of the carbon (C) and nitrogen (N) cycles is changed, and C inputs become lower, which leads to the reduction of the quantity and modification of soil organic matter quality (Boddey et al., 2012).

When deploying agricultural systems, the soil organic carbon stocks may suffer reductions of 20 to 50%, depending on depth. In tropical regions this process occurs faster due to climate conditions that cause intense microbial activity, accelerating the decomposition of organic residue that is deposited on the soil.

In farming areas, soil disturbance by cultivation practices (plowing, harrowing) improves the porosity of the soil and thus accelerates the oxidation of organic matter causing mineralization thereof. This can result in a negative difference between the uptake and loss of organic matter. However, farming systems subjected to an appropriate management practice reduce erosion and tend to present increase in organic matter in the soil surface (Portugal et al., 2008).

In the Brazilian semi-arid tropics, the conventional agriculture contributes to the increase of degraded areas, thus causing increased losses of nutrients and organic matter in soils (Nogueira et al., 2008). The human intervention has led to a process of environmental degradation in the region by the uncontrolled use of this environment.

Estimates of C and N stocks in Brazilian semi-arid tropics, mainly in the biome Caatinga, where the research was conducted, are few and are faced with the lack of information available on the soil's organic C and N contents under different land uses. Inadequate management of natural resources for exploration of Caatinga biome as extensive cattle, vegetation over-grazing, predatory extractivism, replacement of native vegetation by crops, clearing new area for planting using fire are some of the degradation of this ecosystem (Giongo et al., 2011).

According to Silva (2000), a great proportion of semi-arid soils, about 82% of the area, where the Paraiba Sertão is included, present low productivity potential due to poor nutrient content, soil profile depth, deficient drainage, low organic matter content and high exchangeable N concentration.

Several researchers have evaluated and assessed the effects of replacement of native vegetation by crops in relation to the carbon stock. To exemplify, Fracetto et al. (2012) found that the areas under natural vegetation promoted the maintenance of C (90 Mg ha^{-1}) and N (10 Mg ha^{-1}) stocks for the 0 to 30 cm layer. The change of land use for the castor (*Ricinus communis* L.) cultivation caused decreases of approximately 50% in soil C and N stocks in relation to the reference area in the first ten years of the adopted crop. To assess the potential of the impact of different land uses on the issue of C emissions and / or increase of C and N stocks is necessary to effectively quantify these changes in relation to a reference management, such as the soil, under native vegetation (Giongo et al., 2011). The objective of this study was to evaluate changes in carbon and nitrogen contents and stocks under different land use in Paraiba"Sertão.

MATERIALS AND METHODS

The study area is located in the watershed of Val Paraiso stream, inserted in the Northwest portion of Paraíba State, Brazil (6°37'54" to 6°44'29" S and 38° 18'21" to 38°24'12" W). According to the Koppen classification, climate is warm tropical with severe drought, reaching over 35°C in times of higher temperatures. The vegetation is basically composed of Caatinga Hiperxerófila and the predominant soil in the Val Paraiso watershed is classified as Vertisol (FAO, 1990).

In the watershed, five management systems were identified: native vegetation, taken as reference (area covered by arboreal natural vegetation); sparse vegetation (area covered by natural vegetation typical of the Caatinga), pasture (area covered by sparse vegetation and planted); annual crops (areas of temporary crops, for example, corn and beans cultivation) and permanent agriculture (crop with high vegetation cover, mainly composed of permanent crops, for exemple, guava, coconut palm, cactus pear, mango and papaya).

For each management systems were opened four soil profiles occurring in the same soil class. In each profile, the soil samples were collected from July to August 2012, at layers of 0-10, 10-20, 20-30 and 30-40 cm, using auger. Two simple undisturbed samples were collected in all layers by the volumetric ring method using a stainless steel cylinder of 90.21 cm^3 for determination of bulk density; each constituting a repetition. In addition, at each layer was collected one single sample deformed. These samples, after being air-dried and passed through a 2 mm sieve, were characterized chemically according to the methods recommended by Embrapa (1997).

Walkley-Black method (Black et al., 1965) was used to determine the soil organic carbon (SOC). The carbon stock was calculated at layers of 0-10, 10-20, 20-30 and 30-40 cm, from the expression:

$$CStock=(OC \times Ds \times e)/10 \qquad (1)$$

where CStock is the stock of organic carbon in the layer (Mg ha^{-1}), OC is the concentration of total organic carbon (g kg^{-1}), Ds is the soil bulk density of the average layer of the soil (kg dm^{-3}), "e" is considered the layer thickness (cm). The nitrogen stock was calculated in a similar way to carbon stock, having used the expression:

$$NStock=(Nt \times Ds \times e) \qquad (2)$$

where NStock is the stock of total nitrogen in certain depth (Mg ha^{-1}) and Nt is the total N content (dag kg^{-1}).

To compare in different management situations of the sampling areas that showed significantly different values in soil bulk density, the soil C and N stock was corrected by a fixed mass, that is, considering a soil density of 1 g cm^{-3} following the calculations presented by Sisti et al. (2004).

$$S_c=\sum_{n-i}S+\{[M_{ai}-(\sum_nM_a-\sum_nM_r)]Q_i\} \qquad (3)$$

where S_c is the corrected C stock by the soil mass (Mg ha^{-1}); $\sum_{n-i}$ S is the sum of the C stocks of layers without the last sampled layers; M_{ai} is the soil mass of the last layer of soil sampled; ($\sum_nM_a$ is the sum of the total mass of sampled soil; $\sum_nM_r$ is the sum of the mass of soil reference, and Q_i is the C content in the last layer sampled.

To check the tendency to accumulate or lose organic C in relation to the reference system (native vegetation), the variation of the C stock was calculated in relation to native vegetation (Δ CStock, Mg ha^{-1}) as the difference between the mean values of carbon stock in this system and in each other, in the layers studied.

The experimental design was completely randomized in factorial scheme 4 x 5, with four replicates (four profiles), that is, four layers (0-10; 10-20; 20-30 and 30-40 cm) and five management systems

Table 1. Analysis of variance summary for the soil chemical attributes.

Source of variation	DF	Mean square				
		Ds	OC	TN	CStock	NStock
Local	4	0.29**	20.15**	0.002**	19.06*	0.20*
Res.(a)	15	0.03	1.86	0.0002	6.55	0.07
Layer	3	0.16**	36.78**	0.004**	51.95**	0.53**
Layer x Local	12	0. 009	4.34**	0.0005**	9.71**	0.10**
Res.(b)	45	0.02	1.26	0.0001	3.68	0.04

*, ** Significant at 5 and 1% (F test), respectively; Local = areas of management systems; Res = residue; Ds= soil bulk density; OC= organic carbon; TN= total nitrogen; CStock= carbon stocks; NStock = nitrogen.

Table 2. Soil bulk density of the management systems as a function of depth and means of all layers and of all management systems.

Depth (cm)	Management systems					
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture	Means
0-10	1.34	1.53	1.43	1.73	1.50	1.51 [c]
10-20	1.32	1.59	1.53	1.78	1.61	1.57 [bc]
20-30	1.49	1.60	1.57	1.84	1.71	1.64 [ab]
30-40	1.65	1.66	1.91	1.86	1.74	1.72 [a]
Means	1.45 [c]	1.60 [bc]	1.55 [bc]	1.81 [a]	1.64 [ab]	

Means followed by same letters in the rows and columns do not differ as function of management systems and as function of depth, respectively, by Tukey test to 5% probability.

(native vegetation, sparse vegetation, pastures, annual crops and permanent agriculture).The analyses 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

The bulk density (BD), organic carbon (OC), nitrogen (N), carbon stocks (CStocks) and nitrogen stocks (NStocks) values, analyzed statistically presented significant differences in relation to management systems (local) and depths. For these attributes, with the exception of soil bulk density, there was also significant difference in relation to the Local X Layers interaction (Table 1).

According to the use of the soil, the BD values of agricultural systems were higher than Ds under native vegetation (Table 2). This demonstrates that systems with low and / or absence of soil management practices are had the best physical conditions of the soil preventing the compaction process of the same. Likewise, the larger amount of organic carbon in the natural vegetation system favors the soil porosity and consequently lower values of the same density. This behavior is similar to that reported by Lima et al. (2011) that found lower density values for native vegetation system compared to conventional soil cultivation system in the semi-arid region of Piauí. Similar results were found by Colonego et al. (2012) and Guareschi et al. (2012).

The native vegetation (NV) presented the lowest mean values of soil BD, probably due to other management systems which have suffered mechanical pressures in soils (harrowing, seeding, fertilization, machine traffic) and animal trampling. The average soil BD values increased with increasing depth (Table 2) supporting Coutinho et al. (2010), who observed that the forest, grassland and eucalyptus plantations systems increased values of soil bulk density from the soil surface up to a depth of 60 cm. The lowest Ds value of topsoil occurred due to increased input of organic matter in this layer compared with the other subsurface corroborating Bernardi et al. (2007), who found in the environment Caatinga, increased values of bulk density with increasing depth.

Generally the higher the density values, the higher the degree of soil compaction thereby causing negative effects on root penetration, water infiltration and soil aeration, storage and availability of water for plants. In the present study, the Ds values for all management systems were higher than the density of 1.27 g cm^{-3}, including, in some cases, over the range of 1.27 and 1.57 g cm^{-3} which, according to Corsini and Ferraudo (1999) is restrictive to root growth and water infiltration into the soil. The soil OC contents under vegetation native were higher than those found in soils under permanent agriculture, pasture and annual crops systems and only in the permanent agriculture system there was no significant

Table 3. Average contents of organic carbon (g kg^{-1}) of the management systems as a function of depth

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	11.10 ^{aA}	8.83 ^{aAB}	7.68 ^{aBC}	6.95 ^{aBC}	6.05 ^{aC}
10-20	9.10 ^{aA}	5.88 ^{baB}	5.60 ^{abB}	4.80 ^{bB}	5.18 ^{aB}
20-30	6.23 ^{bA}	5.00 ^{bA}	4.35 ^{bA}	6.00 ^{abA}	5.15 ^{aA}
30-40	6.18 ^{bA}	4.45 ^{bA}	5.18 ^{bA}	3.95 ^{bA}	6.03 ^{aA}

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

difference in OC with depth (Table 3). Probably, this is because farmers, after the installation of permanent crops, do not care about organic fertilizer and / or soil management.

In the others systems (native vegetation (NV), sparse vegetation (SV), pasture (P), annual crops (AC)), due the greater amount of organic material on the soil surface, from the fall of leaves, twigs and bark of trees in the forest, forming the organic litter and higher density of fine roots, the OC decreased with increasing depth. This fact was observed in research of Vasconcelos et al. (2010) and Campanha et al. (2009) that evaluated soil carbon under natural vegetation, agroforestry and traditional cultivation.

Nunes et al. (2009) found values of total OC of 18.72 and 1.86 g kg^{-1} for forest and conventional tillage, respectively. According to Oliveira et al. (2008), the fact that agricultural systems have shown lower C contents and irregularity in the reduction of the carbon in the subsurface layers probably occurred due to soil tillage management in these systems.

Evaluating soil OC contents in the topsoil (0-10 cm) of different tillage systems, we observed that there was a reduction in relation to NV, of 20, 31, 37 and 45% for SV, P, AC and PA, respectively. Maia et al. (2006) evaluating the impact of four agroforestry system and conventional systems on soil quality, in Sobral - CE, (Caatinga biome: highly fragile, soil degradation, low soil fertility, high organic matter decomposition rates, high soil erosion, limited water availability and sporadic precipitation greatly limit agricultural production) found a reduction in the carbon content in the order of 40.3, 38.4 and 35% for treatments that have intensive cultivation of the soil, agro-silvopastoral system and traditional culture, respectively, in the 0-6 cm layer, compared to native forest.

This reduction in OC with agricultural land use is similar to that observed by Fracetto et al. (2012) that found higher values of C and N in the natural environment Caatinga in all layers sampled; likewise the C and N contents decreased with increasing depth. This situation was expected and typical of native vegetation environment in order that the greatest input of plant residues on the soil surface allows a slow and gradual

decomposition of soil organic matter.

According to Stevenson (1982), the reduction of the input of soil OC should not be only reduction of the amount of residue added, but also to increased microbial activity caused by better aeration conditions, higher temperatures and more frequent alternation of wetting and drying of the soil, by the continued use of implements, by fires, and losses caused by erosion.

In general, when the partial and/or complete substitution of NV by agricultural and pasture cultivation has a reduction in soil OC and TN; however, the establishment of these cropping systems with high biomass production species that are adapted to the Paraiba Sertão region, can generate an additional benefit in increasing soil organic carbon and total nitrogen, as can be seen in the values found in Tables 3 and 4.

Similar to the results for C, the highest values of N found in the soil of native vegetation system followed by sparse vegetation, pasture, annual crops and permanent agriculture systems (Table 4); in the environments analyzed, with the exception of permanent agriculture system, the average nitrogen values decreased with a significant difference with increasing depth, corroborating Lima et al. (2011) that found soils of semi-arid Piauí, in the layer 0-10cm, amounts of nitrogen of 0.22 g kg^{-1} for native vegetation and 0.20 g kg^{-1} for traditional soil management system. Similar result was found by Costa (2011) evaluating soil nitrogen levels in semi-arid regoins; this author found that the nitrogen content was 0.52 g kg^{-1} for pastures that is similar to the result of this research.

Mean values of N decreased with increasing depth; similar results were found by Bernardi et al. (2007) in Piraipaba, CE, which found nitrogen values 0.77, 0.33 and 0.30 g kg^{-1} in Caatinga environment in the depths 0 to 10, 10 to 20 and 20 to 40 cm, respectively.

The organic carbon (CStock) and nitrogen (NStock) stocks were also significantly altered by management systems and depth (Tables 5 and 6) where the depth of 0-10 cm, the lowest values of C and N stocks were observed in PA system, probably due to the lower input of organic material deposited on the soil. Even in this management system there was no significant difference in values of C and N stocks in relation to the depths of

Table 4. Total nitrogen (g kg^{-1}) of the management systems as a function of depth.

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	1.1[aA]	0.8[aB]	0.7[aBC]	0.7[aBC]	0.6[aC]
10-20	0.9[aA]	0.6[bB]	0.5[abB]	0.5[bB]	0.5[aB]
20-30	0.6[bA]	0.5[bA]	0.5[bA]	0.6[abA]	0.5[aA]
30-40	0.6[bAB]	0.4[bAB]	0.4[bAB]	0.4[bB]	0.6[aA]

Means followed by the same lowercase letters in columns and uppercase letters in the lines do not differ by Tukey test up to 5% probability.

Table 5. Carbon stocks (Mg ha^{-1}) of the management systems as a function of depth

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	14.93[aA]	13.49[aA]	11.37[aAB]	11.98[aAB]	9.04[aB]
10-20	12.04[abA]	9.52[bA]	8.59[abA]	8.49[abA]	8.36[aA]
20-30	9.32[bAB]	8.07[bAB]	6.79[bB]	11.06[abA]	8.81[aAB]
30-40	10.17[bA]	7.27[bA]	8.38[abA]	7.53[bA]	10.49[aA]

Means followed by the same lowercase letters in columns and capital letter in the lines do not differ by Tukey test up to 5% probability.

the soil layers corroborating Maia et al. (2007) that evaluated management systems in Sobral, CE, found that the values of C stock did not decrease with increasing depth.

In all other management systems analyzed in this study, at a depth of 0-10 cm, the values of C and N stocks were higher, especially in NV and SV systems, corroborating Campanha et al. (2009) and Pinheiro et al. (2007). However, in general, the total of the values of C stocks corresponding to the depth of 0-40 cm, was observed in descending sequence NV (46.46 Mg ha^{-1}) > AC (39.06 Mg ha^{-1}) > SV (38.35 Mg ha^{-1}) > PA (36.70 Mg ha^{-1}) > P (35.13 Mg ha^{-1}). Smaller soil carbon stocks in the areas of permanent agriculture and pasture may be related to their low productivity and intensive grazing, which in course of time, contribute to a lower contribution of vegetable residue.

According to Canellas et al. (2007), the maintenance of the native vegetation is important because it is able to promote and maintain minimal soil fertilization. Pulrolnik et al. (2009) studying the soil C and N stocks under different management systems, observed the CStocks of 2.95; 2.78 and 6.96 Mg ha^{-1}; and NStocks 0.071; 0.071 and 0.180 Mg ha^{-1} in soils under Cerrado, pasture and cultivated with eucalyptus, respectively. Giongo et al. (2011) evaluating the carbon stocks in semi-arid Pernambuco, found that carbon stocks in preserved Caatinga, altered Caatinga and Buffel grass pasture area and irrigated mango systems at a depth of 0-20 cm were 15.48; 12.26, 9.60 and 6.92 Mg ha^{-1}, respectively.

These last three results are similar to those observed in the present study related to natural vegetation, sparse vegetation and pasture (Table 5).

Variations of average values of NStocks as a function of management systems and the depths of the soil layers followed the same pattern of changes in the values of CStocks, as can be seen in Table 7. Similar results were found by Barros et al. (2013). In other depths, soil carbon and nitrogen stocks, suffered the effect of soil density in view of their significant difference between the environments studied, corroborating Pedra et al. (2012).

The removal of native vegetation to the introduction of agriculture leads to important changes in the dynamics of organic substances. In this study, it was observed that the values of the carbon stocks in the management systems under the SV, P, AC and PA were lower around 22.57, 28.82, 28.05 and 30.96%, respectively, in relation to the corrected C stocks in the soil of NV (Figure 1). Thus, during the period of this research, probably the NV is performing the role of sequestering (Storer) carbon, as presented Cstocks values superior to other management systems (SV, P, AC and PA) which are playing a role of emitting CO_2-C. So it is important to maintain the areas of NV to offset emissions arising from crop and livestocks production systems in Paraiba Sertão.

Conclusions

The lower values of bulk density were presented in the

Table 6. Nitrogen stocks (Mg ha$^{-1)}$ of the management systems as a function of depth.
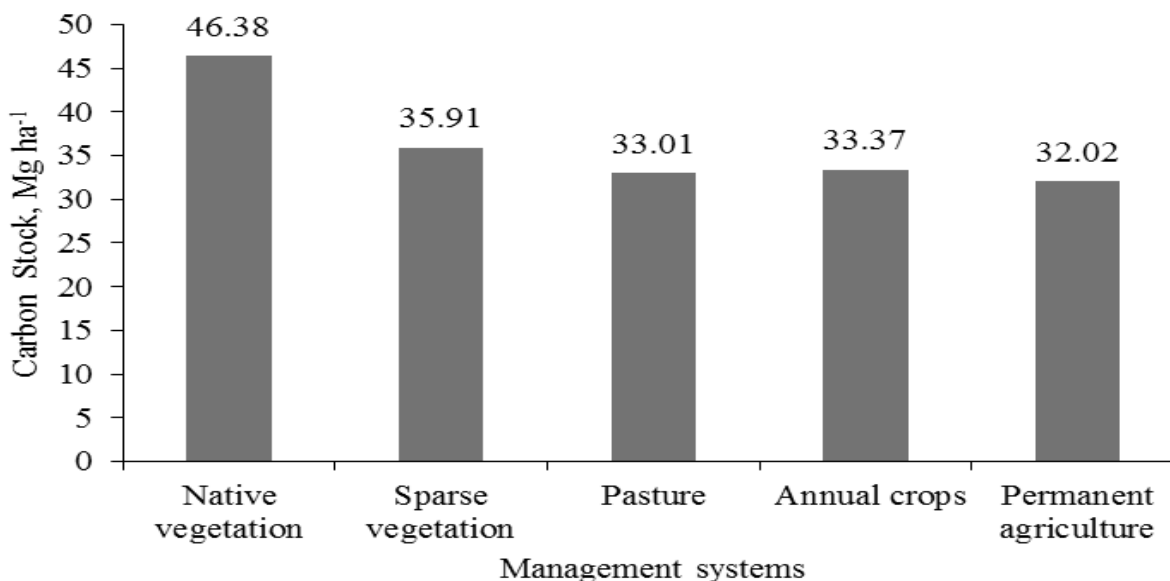
Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	1.45^{aA}	1.26^{aA}	1.03^{aAB}	1.16^{aAB}	0.82^{aB}
10-20	1.16^{abA}	0.89^{bA}	0.81^{abA}	0.80^{bA}	0.77^{aA}
20-30	0.86^{bAB}	0.73^{bAB}	0.58^{bB}	1.01^{abA}	0.81^{aAB}
30-40	0.91^{bA}	0.65^{bA}	0.77^{abA}	0.67^{bA}	1.00^{aA}

Means followed by the same lowercase letters in columns and capital letter in the lines do not differ by Tukey test up to 5% probability.

Table 7. Mean values of nitrogen stock (Mg ha$^{-1)}$ of the management systems as a function of depth.

Depth (cm)	Management systems				
	Native vegetation	Sparse vegetation	Pasture	Annual crops	Permanent agriculture
0-10	1.45^{aA}	1.26^{aA}	1.03^{aAB}	1.16^{aAB}	0.82^{aB}
10-20	1.16^{abA}	0.89^{bA}	0.81^{abA}	0.80^{bA}	0.77^{aA}
20-30	0.86^{bAB}	0.73^{bAB}	0.58^{bB}	1.01^{abA}	0.81^{aAB}
30-40	0.91^{bA}	0.65^{bA}	0.77^{abA}	0.67^{bA}	1.00^{aA}

Means followed by the same lowercase letters in columns and capital letter in the lines do not differ by Tukey test up to 5% probability.

Figure 1. Soil carbon stocks corrected for each area (native vegetation (NV), sparse vegetation (SV), pasture (P), annual crops (AC); permanent agriculture (PA)) in four depths (0-40 cm).

area of native vegetation in relation to the management systems as well as in depth 0-10 cm in relation to depths of all management systems. The implementation of agricultural systems in areas that had native vegetation decreased the C and N contents and stocks, in the same way, these values decreased relative soil layers analyzed. The various systems of agricultural and livestock production performed the role of C- CO_2 emitter

when compared with the native vegetation.

Conflict of Interest

The authors have not declared any conflict of interest.

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