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Soil organic matter and soil acidity in Mangrove areas in the river Paraiba Estuary, Cabedelo, Paraiba, Brazil

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Abstract

Mangrove ecosystems are of great environmental significance, because of their fragility and role in feeding and breeding various animal species. In northeastern Brazil, the disorderly occupation of estuarine areas and the urban sprawl have led to a considerable loss of the original area occupied by mangroves. In the municipality of Cabedelo, State of Paraíba, there are about 4,900 ha of remnant mangrove areas in the estuarine complex of the Paraíba River. However, information about the attributes of mangrove soils at this location is quite scarce. The aim of this study was to quantify the soil organic matter and soil acidity in mangroves located in the estuary of the Paraíba River, State of Paraíba, Brazil, in order to increase the database of soil attributes in this region. The study area is in local influence of the Restinga de Cabedelo National Forest (Flona), an environmental conservation unit of the Chico Mendes Institute for Biodiversity Conservation. For the choice of sampling points, we considered an area that receives direct influence of the eviction of domestic and industrial effluents. The soil of the study area is an "Organossolo Háplico" in Brazilian Soil Classification (Histosol), and was sampled at four point sites: one upstream of the effluent discharge (P1), one in the watercourse receiving effluent water (P2), one downstream of the effluent discharge (P3) and another near Flona (P4), at 0-20 and 20-40 cm, in four replications in time (28/08/2012 in the morning and afternoon, and 21/01/2013 in the morning and afternoon). Potential acidity, pH and soil organic matter (SOM) were determined. No significant differences were detected in the potential acidity of the four collection sites, which ranged from 0.38 to 0.45 $cmol_c\ dm^{-3}$. Soil pH was greatest at point P4 (7.0) and lowest at point P1 (5.8). The SOM was highest at point P1 (86.4 %) and lowest at P2 (77.9 %). The attributes related to soil acidity were not sensitive to indicate differences in the environments we evaluated, and seem not to indicate the contamination of mangroves by discharge of sewage into water bodies that border these environments. The high organic matter content of soils in the mangrove may have helped avoid significant fluctuations in soil acidity, because of the large buffering capacity.

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Introduction

The mangrove ecosystems are of great environmental significance, with special features because of simultaneous influence of contact with river and marine waters. A document of the United Nations (FAO, 2007) on this environment features the mangroves as salt-tolerant evergreen forests found along sheltered coastlines, shallow-water lagoons, estuaries, rivers or deltas in tropical and subtropical countries and areas,

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and indicates that the estimates of the total area of mangroves in the world (2005 base year) are about 15.2 million hectares distributed in 124 countries, of which only five countries (Indonesia, Australia, Brazil, Nigeria and Mexico) together account for 48 percent of the total global area. In this survey, Brazil alone accounts for more than 1 million hectares of mangrove areas, half of the total area of mangroves in South America. In the State of Paraíba, Brazil, mangroves cover an area of 322.25 km^2 (Marcelino, 2000), and the most representative are located on the banks of the estuary of the Paraíba River, near João Pessoa city (the State capital), and on the estuary of Mamanguape River, about 80 miles north of that city (Nishida et al., 2008). Especially in metropolitan area of João Pessoa city, the disorderly occupations of estuarine areas and urban sprawl in recent decades have led to a considerable loss of the areas occupied by mangroves.

According to Gomes and Pereira (2011), mangroves are recognized as areas of high environmental fragility, by their susceptibility to environmental impacts and low resilience. Despite the low diversity of plant woody species in mangroves, these authors emphasize the importance of mangrove areas as foraging and reproduction of species of birds and mammals, which leads to a large ecosystem productivity due to the amount of crustaceans, fish and molluscs such an environment. Mangroves also help to ensure the environmental integrity of coastal areas and encourage the provision of resources and environmental services that support economic activities, playing an important ecological, social and economic role (Schaeffer-Novelli, 1991).

The soils of mangroves, called "Indiscriminate Mangrove Soils", have strong influence of tides and marine and freshwater sediments, and have halomorfic character (excess of salts) with strong influence of the sea. Some specific classes of soils may occur on mangrove environment as Histosols and Gleissolos with generally decreasing salinity towards margin-slope (Prada-Gamero et al, 2004). The mangrove soils are formed by mixing various fluvial-marine sediments with organic debris varied features, usually without differentiation of horizons along the profile and variable texture, according to Oliveira Neto and Silva (2011). These authors indicate deficiency of information about mangrove soils, and because there is no overall the remarkable performance of pedogenic processes such sediments can be classified as "Type Field", and not as proper soil, if there is no diagnostic horizons.

In northeastern Brazil, the disorderly occupation of estuarine areas and urban sprawl have led to a considerable loss of the original area occupied by mangroves. According to the Chico Mendes Institute for Biodiversity Conservation, it is estimated that 25% of Brazilian mangroves have been destroyed since the beginning of the 20th century. Moreover, many of which still exist are classified as vulnerable or endangered. The situation is particularly serious in the Northeast and Southeast of Brazil, providing a high level of fragmentation. Recent estimates suggest that about 40% of what was once a continuous extension of mangroves has been deleted (ICMBio, 2014).

In the year of 2004, the National Forest Restinga de Cabedelo (Cabedelo Flona) was created in the estuary of Paraíba River with the basic objectives of multiple use of forest resources and scientific research, with emphasis on methods for sustainable use of native forests (BRASIL, 2004). Despite its relevance in the ecological context, Cabedelo Flona is not free from adverse impacts caused by the rapid urbanization of the metropolitan area of Joao Pessoa: the outfall sewer Cabedelo was built on a path that skirts the Flona along their boundaries to the sewage treatment plant of the Lower Paraíba, located on the slope above the mangroves and the Paraíba river 1.5 km upstream of Flona. The situation is relevant, since approximately 55% of the area has direct influence Flona the Paraíba river. To make matters worse, the João Pessoa's Master Plan for Sewerage provides that 70% of the sewage from the capital and the entire sewage from the municipalities of Cabedelo and Bayeux (about 1 million people) that are directed to the treatment plant (Almeida, 2010).

In the municipality of Cabedelo, Paraíba State, there are about 4,900 hectares of remaining mangrove estuarine complex in the Paraíba River. However, information about the attributes of mangrove soils in this location is very scarce. Mangrove soils may undergo changes in its composition from various situations of degradation, affecting the relationships between living organisms and leading to a condition of imbalance of the ecosystem. The aim of this study was to quantify the soil organic matter and soil acidity in mangroves located in the estuary of the Paraíba River, State of Paraíba, Brazil, in order to increase the database of soil attributes in this region.

Material and Methods

The study area is in local influence of the Restinga de Cabedelo National Forest (Flona), an environmental conservation unit of the Chico Mendes Institute for Biodiversity Conservation located in the municipality of Cabedelo, PB, in the estuary of the Paraíba River (coordinates 6°51’31’’ to 8°26’21’’ S'' and 34°48’35’’ to 37°2’15’ W), Figure 1. The climate is As (tropical climate with dry summer season, according to the Köppen classification), having mainly comprised rainy season between the months of May to August (Grisi and Görlach-Lira, 2010). The vegetation of the site is considered a Hydrophilic Restinga Forest, with influence of fluvial-marine Pioneer Formation (Mangrove), according to IBGE (2007).

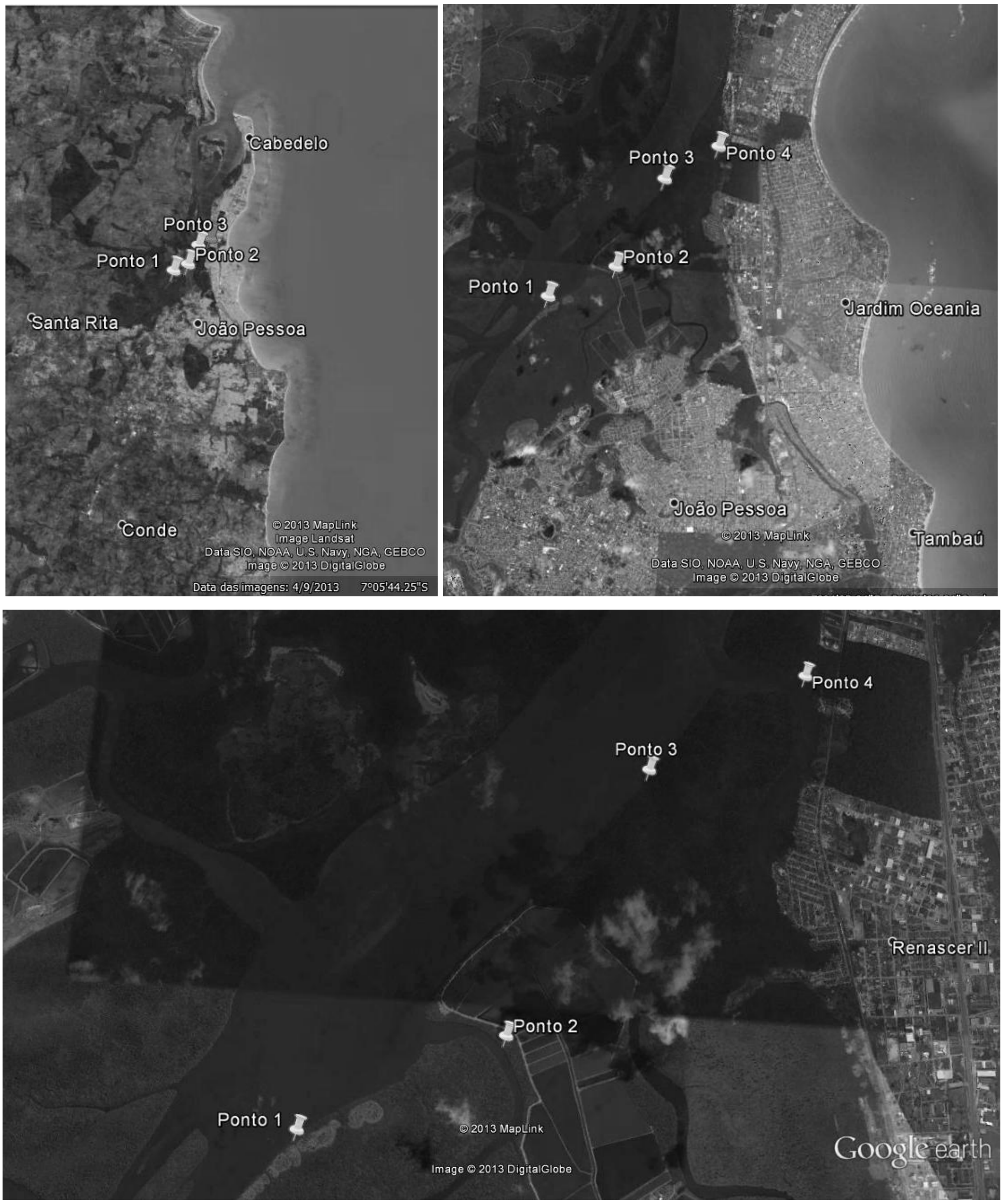

Figure 1. Map with location of soil sampling points (Ponto 1, 2, 3 and 4) in the estuary of the Paraíba River in Cabedelo, PB (Google Earth version 7.1.1.1888).

The soil of the study area was formed from sediments with strong hydromorphism and major influence of the oscillation of the water table because of the tides. For the choice of sampling points, we considered an area that receives direct influence of the eviction of domestic and industrial effluents. The soil was classified as an "Organossolo Háplico" in Brazilian Soil Classification (Histosol), and was sampled at four point sites (Table 1): one upstream of the effluent discharge (P1), one in the watercourse receiving effluent water (P2), one downstream of the effluent discharge (P3) and another near Flona (P4), at 0-20 and 20-40 cm, in four replications in time (28/08/2012 in the morning and afternoon, and 21/01/2013 in the morning and afternoon).

After sampling, the previously identified soil samples were taken to the laboratory, suffered pre-drying in air (48 hours) and then were placed in an incubator at 105-110°C (48 h). After drying, the soil was ground and passed through a sieve with an aperture of 2.0 mm. Potential acidity (H+Al) and pH were determined according to Embrapa (2011) and soil organic matter (SOM) was determined after incineration in a muffle furnace at 550°C for 3 h, according to the modified methodology indicated by Carmo and Silva (2012). Soil color was determined using the Munsell Soil Color Chart in the wet sample. The results of pH, potential acidity and SOM were subjected to analysis of variance (ANOVA), considering a completely randomized design (CRD) with structure in split plot (four replicates), with the following sources of variation: sampling points and sampling depth. All soil analyzes were performed at the IFPB Soil Physics Laboratory, campus João Pessoa, Paraíba, Brazil.

Table 1. General characteristics of the sites for soil sampling in the estuary of the Paraíba River in Cabedelo, PB.

Points	Coordinates	Location
P1	07 05' 11.9" S 34 52' 57.4" W	On the right bank of the Paraíba River, upstream of Tambiá river, distant about 1,200 meters from Point 2.
P2	07 04' 53.8" S 34 52' 20.7" W	On the right bank of the river Tambiá, effluent disposal site, distant about 500 meters from the encounter with the Paraíba River.
P3	07 04' 03.6" S 34 51' 56.0" W	On the right bank of the Paraíba River, downstream of Tambiá River (near the West border of Cabedelo Flona), distant 2 km from the river Tambiá bar with the Paraíba River and 900 meters from the river Mandacaru bar with the Paraíba River.
P4	07 03' 44.1" S 34 51' 26.7" W	On the right bank of the river Mandacaru within Cabedelo Flona, distant 450 meters from the bar with the Paraíba River, downstream of the point of discharge of the effluent.

Results and Discussion

The pH, H+Al and soil organic matter content for the four sampling points and two sampling depths are shown in Table 2. For soil pH, there was a significant effect on both the sampling point as the sampling depth, but there was no significant interaction between the two sources of variation. Thus, the behavior of pH was the same at both depths, regardless of the sampling point. In the comparison of means, the pH values were higher in P4 and lower in P1. Soil pH in the points P2 and P3 did not differ statistically from the other sampling points. There was no significant interaction between the levels of soil organic matter (SOM) and sampling depths, indicating that the behavior of this attribute in the four sampling followed the same pattern, regardless of soil depth. SOM levels were higher at the point P1, and smaller in point P2, a place directly affected by domestic sewage.

Table 2. Soil acidity in mangrove area in four sampling points and two depths in the estuary of the Paraíba River in Cabedelo, PB.

Point	pH			H+Al (cmol dm^{-3})			SOM (dag kg^{-1})		
	0-20 cm	20-40 cm	Mean	0-20 cm	20-40 cm	Mean	0-20 cm	20-40 cm	Mean
P1	6.0	5.6	5.8 b	0.4	0.5	0.5 ns	85.4	87.4	86.4 a
P2	6.0	5.7	5.9 ab	0.5	0.3	0.4 ns	78.2	77.5	77.9 b
P3	6.2	5.9	6.1 ab	0.4	0.5	0.5 ns	80.8	79.2	80.0 ab
P4	7.0	7.0	7.0 a	0.4	0.4	0.4 ns	81.8	82.6	82.2 ab
Mean	6.3 A	6.1 B		0.4 ns	0.4 ns		81.6 ns	81.7 ns	

Note: Means followed by different letters differ significantly by Tukey test at 5%. Capital letters compare means in the line and lower case letters in the column; ns: not significant. SOM: soil organic matter.

It should be noted that in all four sampling, the soil showed very high amounts of organic matter, ranging from 77.9 dag kg^{-1} (P2) to 86.4 dag kg^{-1} (P1), mean values of 0-40 cm layer. Thus, the maximum mineral constituents in soil occurs precisely at the point P2 (22.1 dag kg^{-1}), and it becomes clear that the organic fraction of the mangrove environment in the area under study is responsible for most of the soil characteristics, including the acidity attributes evaluated (pH and potential acidity). The sampling site P4 has less influence of wastewater discharge (located upstream of the point P2), and has neutral pH. All other collection sites had pH values in the acidic range. On average, the pH was always lower in the sub-surface soil layer (20-40 cm). In all sampling sites were predominant soils with chroma value 2.5 and 1, with varying hues of 2.5Y to 5Y. The color of most common ground for all samples was 2.5 Y 2.5/1. The expressive hydromorphism soil is responsible for dark colors (colors with low value) and low intensity (chroma), given the accumulation of organic matter and the virtual absence of iron oxides, which are responsible for the yellowish and reddish color of the soil.

A lot of negative electric charges of SOM is responsible for much of the buffering capacity of the soil, helping to minimize drastic changes in acidity, which can explain the lack of response of pH and acidity to the potential release of sewage. In this case, the high buffering capacity of SOM and its high concentration in the soil may have contributed to the failure to observe significant differences in soil acidity between mangrove area upstream of the discharge of sewage (point P1) and the area directly affected by the contamination, the banks of the Tambiá River (point P2).

Conclusion

There were no significant changes in attributes of soil acidity in mangroves evaluated in the estuary of the Paraíba River, due to the direct discharge of sewage in Tambiá River. The high content of organic matter in mangrove soils evaluated (over 77 dag kg^{-1}) may have contributed to avoid significant fluctuations in pH and potential soil acidity, due to contamination by discharge of sewage. The attributes of soil acidity as pH and potential acidity, were not sensitive to changes resulting from the contamination of the margins of mangroves by sewage released into water bodies that border these environments.

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