*Environmental Engineering and Management Journal* July 2021, Vol. 20, No. 7, 1137-1145
http://www.eemj.icpm.tuiasi.ro/; http://www.eemj.eu

*"Gheorghe Asachi" Technical University of Iasi, Romania*

# IMPACTS OF LAND USE ON THE CHEMICAL ATTRIBUTES OF THE RIPARIAN SOIL OF A TROPICAL SEMI-ARID REGION

**José Neuciano Pinheiro de Oliveira[1], Giulliana Karine Gabriel Cunha[1], Jéssica Freire Gonçalves Wanderley de Melo[1], Clístenes Williams Araújo do Nascimento[2], Airon José da Silva[3], Karina Patrícia Vieira da Cunha[1]***

*[1]Postgraduate Program in Environmental and Sanitary Engineering, Department of Civil Engineering, Federal University of Rio Grande do Norte, Natal,59077-080, Brazil*
*[2]Federal Rural University of Pernambuco, Department of Agronomy, Recife, 52171-900, Brazil*
*[3]Federal University of Sergipe, Department of Agronomy, São Cristovão, 49100-000, Brazil*

## Abstract

Studies on soil quality and soil potential to be a source of pollutants in aquatic ecosystems are fundamental for monitoring the environmental quality of catchment areas. Here, we studied the impact on soil quality caused by land-use changes in northeastern Brazil's riparian soil. A total of 28 riparian soil composite samples were collected from areas with different land use (native vegetation; agriculture, including family farms, fodder production, and horticulture; and exposed soil with family-owned livestock operations) and evaluated for potential acidity, pH, cation exchangeable capacity, organic matter, and phosphorus available for plants. Family farming and horticulture had less impact on soil quality and, consequently, a low potential to compromise water quality when conducted around aquatic ecosystems. However, forage grass use and extensive livestock production caused changes in soil chemical attributes that could reduce the soil quality and the water quality in nearby aquatic systems. Livestock production has a greater potential to contribute to nutrient diffusion into water bodies. The cultivation of forage grasses can also contribute to the increased alkalinity of soil and water. The minor impacts on soil chemical characteristics by the family farm management led to a statistical grouping of horticulture and family agriculture sites as native vegetation. This result highlights the crucial role of reducing soil mobilization to preserve ecosystem functions in riparian areas.

*Key words:* agriculture, alkalization of soil, family farm, livestock, phosphorus

*Received: August, 2020; Revised final: November, 2020; Accepted: December, 2020; Published in final edited form: July, 2021*

## 1. Introduction

Replacing native vegetation with indiscriminate soil exploitation reduces soil quality and the productive potential of the land, causing contamination and affecting water quality in aquatic ecosystems (de Sosa et al., 2018; Ha et al., 2018; Saad et al., 2018; Yu et al., 2016). This is particularly important in fragile environments, such as the semi-arid tropics (Cammeraat et al., 2010; Nobre et al., 2020; Valera et al., 2016; Xie et al., 2018). In the last few decades, concern has increased regarding soil quality due to losses of the capacity for soil to maintain its ecological functions (Cammeraat et al., 2010; Islam and Weil, 2000; Meneses et al., 2015; Valle Junior et al., 2014, 2015; Yang et al., 2018). Soil quality evaluations involving different natural and managed scenarios are now frequent in the literature (Francés et al., 2019; Li et al., 2020; Santos- Sun et al., 2020; Valera et al., 2016). By contrast, studies that address soil degradation after land-use changes in tropical semi-arid regions are much scarcer (Singh et al., 2017). Tropical semi-arid settings are prone to long periods of drought. In such an environment, the

* Author to whom all correspondence should be addressed: e-mail: cunhakpv@yahoo.com.br

riparian soil guarantees access to water resources for irrigation and animals while maintaining agricultural production of both small-scale and extensive livestock. However, the intensive use of riparian soils results in conflicts that are difficult to resolve as impacts on soil quality can contribute to the dispersion of pollutants into water bodies, reducing water quality and limiting the availability for multiple uses (Nobre et al., 2020; Vaezi et al., 2016).

Organic and inorganic phosphorus (P) forms are among the most important pollutants that reach the aquatic ecosystems through runoff during heavy rainfalls. The main impact of P enrichment of water bodies is the acceleration of eutrophication of aquatic ecosystems (Barcellos et al., 2019; Sharmin et al., 2020). In semi-arid regions, extreme rainy events are followed by periods of extreme drought, which leads to a reduction in the volume of aquatic systems, the concentration of nutrients, and aggravation of the eutrophication process (Braga and Becker, 2020). These changes promote the excessive proliferation of primary producers (e.g., cyanobacteria that produce toxins), reduce the water quality, adversely affect the health of the human population, and increase water treatment costs (Naselli-Flores et al., 2007).

The socioeconomic importance of human activities on soils close to water bodies in semi-arid regions of northeast Brazil is evident, but environmental impacts should not be neglected. Therefore, investigations into land use impacts on soil quality are crucial for guaranteeing that human health and environmental risks are taken into account. This risk assessment is particularly relevant to naturally fragile ecosystems, such as the Brazilian semi-arid region. In this context, studies on soil quality and on the potential of soils to act as pools of pollutants for aquatic ecosystems are fundamental for monitoring the environmental quality of catchment areas. Given this scenario, the objective of the present work was to evaluate the impact of human activities on a riparian soil on the soil quality in a semi-arid setting in northeastern Brazil.

## 2. Material and methods

### *2.1. Study area*

The study was developed in the Dourado reservoir located in Currais Novos City (Fig. 1) in the Piranhas-Açu watershed in the semi-arid region of Rio Grande do Norte state (northeast, Brazil). The reservoir has a maximum volume of 10,321.600 $m^3$, a maximum depth of 10 m, and 3.16 $km^2$ of surface area. The regional climate is tropical semi-arid, type BS'h' (Alvares et al., 2013), with an average rainfall of 550 mm $year^{-1}$, and is characterized by a rainy season between the months from February to June and a dry period during the other months. In the study area, there is an association of plant species adapted to the semi-arid climate, including *Croton blanchetianus*, *Jatopha mollisima*, *Mimosa tenuiflora*, *Caesalpinia pyramidalis*, and *Aspidosperma pyrifolim*.

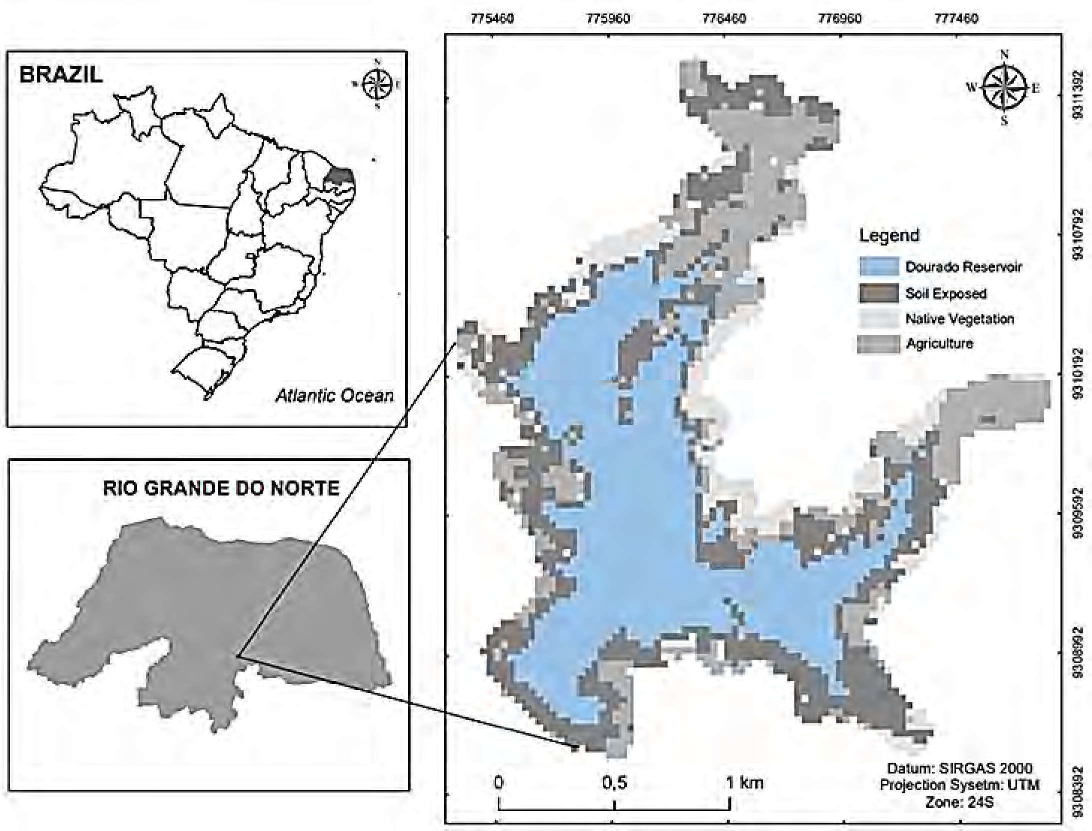


**Fig. 1.** Location of the study area and land use in the riparian zone of the Dourado reservoir in the semi-arid region of Brazil

The riparian zone is fully inserted in the metamorphic context of the Seridó Formation, whose lithology is represented by mica schists and mineral assemblages that include biotite, quartz, plagioclase, and garnet, and may also include cordierite, sillimanite, andalusite, tourmaline, muscovite, ilmenite, zircon, and apatite (de Lima, 1992). Leptosols are the major soil class in riparian zones (FAO, 2015) and represent shallow and less weathered soil profiles rich in primary minerals and rock fragments. With respect to geomorphology, the area presents >75% of slope and altitude class from 320 to 345 meters (BRAZIL, 2008).

The riparian zone covers 1.93 $km^2$, of which only 16.3% has the natural vegetation coverage required to be considered as a reference area for natural soil quality. By contrast, 34.3% is used for agriculture, while an urban setting and livestock grazing occupy 49.4% of the land. The study area has geological and geomorphological uniformity; therefore, the variations in the soil chemical characteristics can be attributed to land use changes.

*2.2. Soil sampling and analyses*

Ten soil sub-samples (0–20 cm) were collected from different locations within each area to form a composite sample to analyze. In total, 28 composite soil samples were collected and distributed as follows: native vegetation (locations 1–8), agriculture: family farms (locations 9–13), forage grasses (locations 14–19), and horticulture (locations 20–22), and exposed soil with livestock (locations 23 – 28). The samples were air-dried, homogenized, passed through a 2-mm sieve, and then chemically characterized using standard methods (Teixeira et al., 2017).

The pH was measured in water (1:2.5 ratio). The $K^+$ and $Na^+$ exchangeable contents were obtained by flame photometry after extraction with Mehlich-1. The contents of $Ca^{2+}$ and $Mg^{2+}$were determined by titration after extraction with 1 mol $L^{-1}$ KCl. Potential acidity ($H^+$ + $Al^{3+}$) was determined through titration after extraction with calcium acetate-buffered solution at pH 7.0.

The cation-exchange capacity (CEC) was calculated from the sum of $K^+$, $Na^+$, $Ca^{2+}$, $Mg^{2+}$, and ($H^+$ + $Al^{3+}$) potential acidity. The base saturation (BS) and exchangeable sodium percentage (ESP) were obtained according to Teixeira et al. (2017). Available P was measured by colorimetry after extraction with Mehlich-1. Soil organic carbon (SOC) was determined by the modified Walkley-Black method (Silva et al., 1999). The soil organic matter (SOM) was estimated by multiplying the organic carbon value by 1.724.

*2.3. Statistical analyses*

The soil chemical characteristics were submitted for descriptive statistics analysis using Statistica v.7. Pearson's linear correlation was performed to study the relationship between soil characteristics. A two-way cluster analysis was accomplished to assess similarities among samples and sites. Principal component analysis (PCA) was performed using PC-ORD® v.6 to reduce the data mass and facilitate the choice of quality indicators in future programs of environmental reclamation and monitoring.

## 3. Results and discussion

The analyzed soils were predominately alkaline, with pH values varying from 6.43 to 7.66 in soils with native vegetation and from 6.79 to 8.87 in soils with anthropic uses, including family farms, forage grass cultivation, horticulture, and livestock production (Table 1 and S1). The lowest pH values were found in native vegetation and the highest in soil samples covered with forage grasses (Table 1). Among the anthropic uses found in riparian soils, the cultivation of forage grasses caused more notable changes in pH, potential acidity, and ESP (Table 1 and S1). In addition to changing the pH, this use promoted the loss of plant nutrients and soil organic matter. Land uses increased the variability between plots, resulting in greater standard deviation compared to the studied chemical characteristics of the soil covered with native vegetation.

**Table 1.** Chemical attributes of soil under different land uses in the riparian zone of the Dourado reservoir, Rio Grande do Norte state, northeast Brazil. Variables: TPA = Total potential acidity; CEC = Cation exchange capacity; BS = Base saturation; ESP = exchangeable sodium percentage; SOM = Organic matter; P = Available phosphorus

| ***Variable*** | ***Native vegetation*** | ***Agriculture*** | | | ***Exposed soil*** |
|---|---|---|---|---|---|
| | | ***Family farm*** | ***Forage grasses*** | ***Horticulture*** | |
| pH | 7.05±0.57 | 7.60±0.35 | 8.78±0.09 | 7.63±0.07 | 7.57±0.52 |
| TPA ($cmol_c$ $dm^{-3}$) | 2.58±0.26 | 2.37±0.08 | 1.63±0.09 | 2.38±0.09 | 2.30±0.39 |
| $Ca^{2+}$($cmol_c$ $dm^{-3}$) | 4.81±1.09 | 4.26±0.73 | 2.03±0.46 | 4.93±0.74 | 7.58±1.81 |
| $Mg^{2+}$ ($cmol_c$ $dm^{-3}$) | 4.01±0.88 | 3.07±0.46 | 0.84±0.22 | 3.37±0.51 | 4.93±1.56 |
| $Na^+$($cmol_c$ $dm^{-3}$) | 0.03±0.01 | 0.03±0.02 | 0.65±0.18 | 0.09±0.01 | 0.07±0.01 |
| $K^+$($cmol_c$ $dm^{-3}$) | 0.10±0.19 | 0.02±0.01 | 0.07±0.02 | 0.02±0.00 | 0.51±0.24 |
| CEC ($cmol_c$ $dm^{-3}$) | 11.53±2.01 | 9.75±0.47 | 5.23±0.72 | 10.79±0.16 | 15.38±3.30 |
| BS(%) | 77.11±3.72 | 75.80±1.79 | 68.50±3.08 | 77.67±1.15 | 84.50±4.23 |
| ESP(%) | 0.00±0.00 | 0.40±0.55 | 18.00±2.90 | 1.00±0.00 | 0.50±0.55 |
| P (mg $kg^{-1}$) | 4.90±4.23 | 1.29±0.51 | 2.54±0.88 | 2.78±0.28 | 52.63±32.51 |
| SOM (g $kg^{-1}$) | 37.08±2.27 | 35.44±2.55 | 32.22±1.13 | 32.19±1.14 | 44.22±5.50 |

Among uses, forage grass cultivation resulted in lower $Ca^{2+}$, $Mg^{2+}$, CEC, SOM, and P levels and higher $Na^{+}$ and ESP levels when compared to soils under native vegetation. By contrast, soils used for livestock showed greater $Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$, CEC, and BS levels and excess enrichment of SOM and available P when compared to native vegetation. Replacement of native vegetation by anthropic uses resulted in an excess enrichment of organic matter, accompanied by an increase in the levels of $Ca^{2+}$ ($r=0.61$; $p<0.01$), $Mg^{2+}$ ($r=0.57$; $p<0.01$), $K^{+}$ ($r=0.53$; $p<0.01$), CEC ($r=0.61$; $p<0.01$), BS ($r=0.63$; $p<0.01$), and available P ($r=0.67$; $p<0.01$). The excess increase in P available in riparian soil under anthropogenic use occurred concomitantly with the increase in $Ca^{2+}$ ($r=0.72$; $p<0.01$), $Mg^{2+}$ ($r=0.54$; $p<0.01$) and exchangeable $K^{+}$ ($r=0.86$; $p<0.01$) and with base saturation ($r=0.72$; $p<0.01$).

Principal component analysis using eight chemical attributes explained 87.13% of the data variability in the first two axes (axis 1 = 63.94%; axis 2 = 23.19%). The most important attributes in axis 1 were SOM (-0.33), Ca (-0.42), Mg (-0.42), Na (0.35), and CEC (-0.43). For axis 2, the most important attributes were pH (-0.48), K (-0.53), and P (-0.53). The PCA results also indicated a segregation of areas under different land uses from a chemical point of view (Fig. 2). The segregation of the exposed soil and to other classes of land use can be explained by the higher SOM, CEC, and available P. Native vegetation was segregated from the rest by lower pH values.

Axis 1 segregated the sample plots of the vegetation native to the agriculture plots (family farms, forage grasses, and horticulture) (Fig. 2) mainly due to the higher concentrations of exchangeable sodium and the losses of CEC and exchangeable Ca and Mg. Axis 2 segregated the sample plots of the vegetation native to the sample plots of forage grass cultivation and exposed soil with livestock because of the higher pH, available P, and exchangeable K.

Thus, the plan defined by the first two components describes the soil uses with the potential for alkalization/salinization in axis 1 and soil uses with the potential for diffusion of sources of nutrients to accelerate eutrophication of aquatic systems.

Two-way cluster analysis demonstrated similarities between the soil characteristics and sampling sites (Fig. 3). Three main groups with different chemical characteristics were identified. The first group was characterized by low pH and low contents of organic matter in the soil, and available phosphorus and consisted of the plots of soil of native vegetation, family farm, and horticulture. The second group had a higher pH and exchangeable sodium concentration and lower soil fertility and consisted of plots with forage grass cultivation.

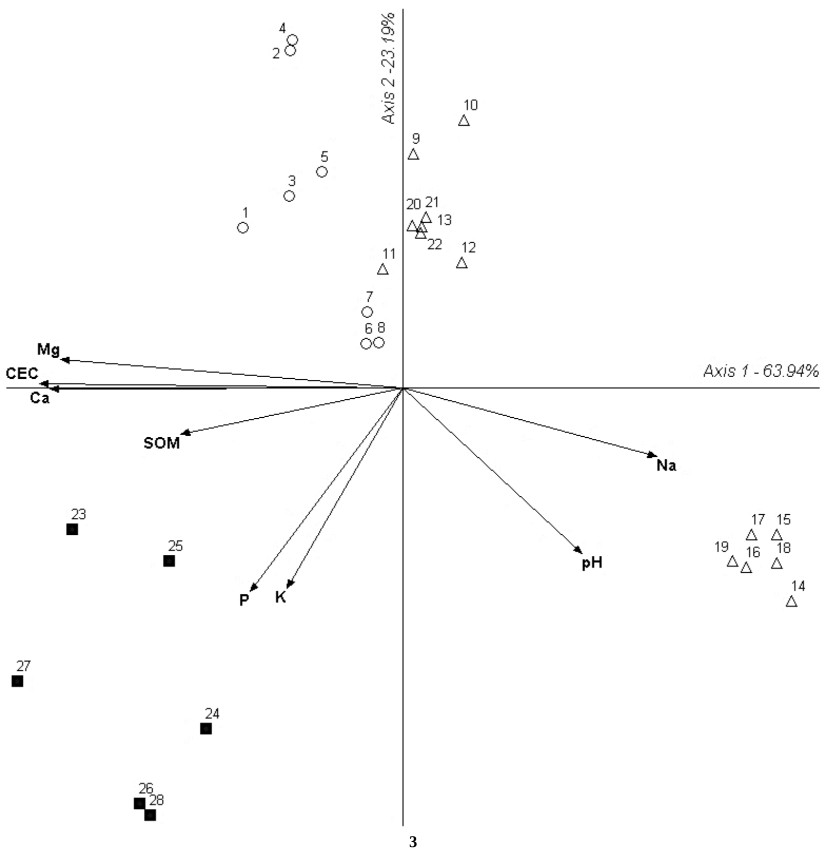


**Fig. 2.** Principal Component Analysis (PCA) of the chemical attributes of the soil under different uses in the riparian zone of the Dourado reservoir, located in a semi-arid region of the Rio Grande do Norte state in northern Brazil. Native vegetation (n=8) and anthropic use (n=20): Native vegetation: 1–8; Family farm, 9–13; Forage grasses, 14–19; Horticulture, 20–22; and Exposed soil with Livestock: 23–28. Variables: CEC = Cation-exchange capacity; BS = Base saturation; SOM = Soil organic matter; P = Available phosphorus

The third group had a greater cation exchange capacity, a higher concentration of exchangeable bases, and excess enrichment of organic matter in the soil and available phosphorus and consisted of soils with extensive livestock production. With the exception of the soil under forage grasses, the remaining agricultural plots were statistically grouped into native areas due to their minor impacts on soil quality. This grouping indicated a more conservationist management of these soils and a lower risk to the water quality in aquatic ecosystems.

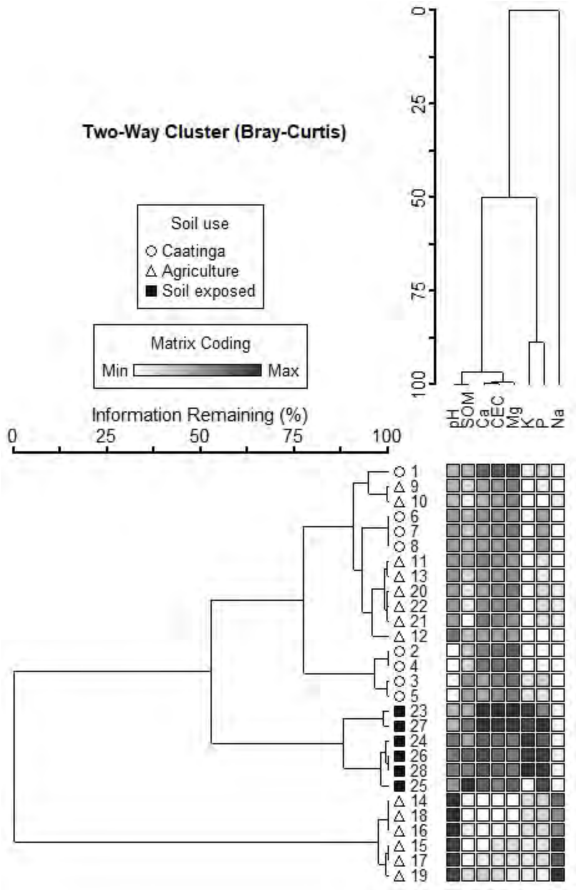


**Fig. 3.** Two-way cluster analysis diagram of soil chemical characteristics and sampling sites from the riparian zone from the Dourado reservoir, located in a semi-arid region of Rio Grande do Norte state in northern Brazil. On the matrix, dark squares represent maximum values, whereas white ones represent minimum values for each property (columns) in the sampling sites (lines). SOM = Soil organic matter; pH = Hydrogen potential; P = Available phosphorus; CEC = Cation exchange capacity. Native vegetation: 1–8; Family farm, 9–13; Forage grasses, 14–19; Horticulture, 20–22; and Exposed soil with Livestock: 23–28

The cultivation of forage grasses and extensive livestock production promoted marked changes in the chemical attributes of riparian soils and adversely affected soil quality. The alkalization and plant nutrient losses take place as a consequence of changes in land use, but they are not processes common to all land uses in riparian areas. Family farms and horticulture have low or no impacts on soil quality. Alkalization and loss of plant nutrients occurred in the cultivation of forage grasses, whereas enrichment in plant nutrients and organic matter content was common in areas under livestock grazing. We refute the hypothesis of this work that the substitution of native vegetation for land use causes negative impacts on soil quality. The conversion of natural landscape to cultivation may induce greater $CO_2$ efflux under riparian landscapes (Singh et al., 2017). We found that small-scale agricultural production with management that ensures low soil mobilization can maintain acceptable levels of soil quality and the role of soil as an environmental buffer in riparian areas.

The replacement of native vegetation in riparian soils results in intense variability in soil quality. Preserving riparian ecosystems, which constitute an interface between terrestrial and aquatic environments in river basins, is fundamental (Coelho et al., 2011; Nóbrega et al., 2020).These areas under natural soil and vegetation conditions in the surroundings of lakes and water reservoirs show high resilience and protect the water systems from degradation (He et al., 2020). The occupation of riparian zones for the development of the family farms is a cultural issue in the semi-arid region of northeastern Brazil; however, as in other regions in the world, it has shown low risk to the quality of the soil and water due to the use of fewer inputs and less movement of the land (Haileslassie et al., 2005; Lucantoni, 2020).

The cultivation of forage grasses decreased soil fertility by significantly reducing the levels of exchangeable bases, the cation exchange capacity, and the soil organic matter (Haileslassie et al., 2005; Sumithra et al., 2013). Sol impoverishment under forage grass cultivation can be explained by the constant export of nutrients by plants and the slow reconstitution of fertility (Haileslassie et al., 2005; Peron and Evangelista, 2004; Sumithra et al., 2013).

In general, the correct management contributes to the considerable increases in soil organic matter content and its productive potential, without necessarily incurring a quality loss (Roose and Barthés, 2001). Thus, no rule dictates that agricultural cultivation decreases soil quality; however, local management practices will often negatively influence this quality (Lourente et al., 2011; Santos-Francés et al., 2019; Zhang et al., 2012). Here, only the soil used to cultivate forage grasses or to produce livestock was segregated from natural soil. The cultivation of forage grasses and extensive livestock production caused changes in soil chemical attributes. These changes suggest a loss of soil capacity to sustain its ecosystem functions. Hence, this increases the potential of the soil to compromise water quality.

The semi-arid region is characterized by small farms, where farmers basically practice subsistence agriculture or local commerce. This characteristic implies low inputs of fertilizers and small soil changes (Haileslassie et al., 2005). For example, even in soils under family farming, no pH changes were observed. Studies have verified the improved food security of family farms, while positive impacts are also registered in soil quality, environmental sustainability, and resilience (Dogliotti et al., 2014; Lucantoni, 2020). The use of inadequate management techniques seems to be more evident in the area of cultivation of forage grasses and consequent alkalization. The increase in alkalization may be associated with irrigation management and the use of water with high electrical conductivity, both of which contribute to enhanced alkalization and deterioration of water bodies that receive salts through the runoff from the soil (Minhas et al., 2019; Smedema and Shiati, 2002).

The enrichment of soil with phosphorus and organic matter in areas with extensive livestock production makes the soil a source of nutrients and contaminants for other components of the watershed, such as the surface water bodies (Heathwaite et al., 2005; Li et al., 2020; Santos-Francés et al., 2019; Sun et al., 2020; Valera et al., 2016). In fact, in the present study, the increase in soil organic matter content under livestock land use caused the highest levels of Ca, Mg, K, CEC, base saturation (BS), and available P (Liu et al., 2019; Silva et al., 2010; Wang et al., 2018).

Extensive livestock production excessively increased the soil fertility and broadened the potential of the soil to act as source of contaminants and nutrients, especially P, into the water bodies. The main impact was an increased eutrophication in aquatic systems. Eutrophication is a natural process that occurs in aquatic ecosystems but has been accelerated by anthropogenic activities(Hooda et al., 2000; Liu et al., 2019; Wang et al., 2018). The main consequences are the occurrence of potentially toxic cyanobacterial blooms and excessive biomass proliferation, resulting in high turbidity in the water. In addition, eutrophication can lead to oxygen depletion and fish mortality. Reductions in the water quality affect the health of the human population and increase water treatment costs (Naselli-Flores et al., 2007).

The native vegetation land use as the local environmental quality reference does not mean that this condition would make the soil suitable for any type of use. The results reported here demonstrate the importance of land use that respects the natural soil aptitude. Soils under native vegetation in the semi-arid region studied are young, shallow, sometimes saline, sandy, and with low adsorption capacity. These characteristics can explain the greater vulnerability to erosion of the semi-arid soils (Cammeraat et al., 2010). The alkaline characteristic of these soils suggests difficulties in plant growth and development. This condition can be extended to the replacement of native vegetation by farm activities without proper management, which contributes to the formation of degraded and uncovered soils patches that have ahigh susceptibility to erosion and a high potential to transport pollutants to water bodies (Gabet et al., 2005; Nobre et al., 2020).

The relationship between changed land use with increased erosion has been emphasized in several past studies (Nobre et al., 2020; Pacheco et al., 2014; Pacheco and Sanches Fernandes, 2016). Some characteristics of soils from the Brazilian semi-arid region, such as shallow depth and little vegetation cover (Oyama and Nobre, 2004), are associated with the rainy events that occur over a few days in the year and allow hydric erosion to occur more intensely than in other regions. In addition, inadequate soil management systems in the semi-arid region favor hydric erosion, soil and nutrient loss, and pollution of surface-water bodies by accelerating degradation (Russelle et al., 2007). The combination of these natural, anthropogenic, and social factors in the Brazilian semi-arid seems to justify the fact that the water quality in aquatic systems located in the semi-arid region is more vulnerable to degradation than is the water quality in the tropical region (Nobre et al., 2020).

The principal components analysis showed that the land use changes soil chemical attributes to a greater or lesser scale, according to the type of use. The areas planted with forage grass showed that this system can play a significant role as a diffuse source of salts that contribute to increase water alkalization in the reservoir. Exposed soil under livestock use was associated with high values of available P, probably due to the intense supply of animal excreta. Nevertheless, this land use can make the soil a potential source of nutrients to the Dourado reservoir, thereby increasing eutrophication. Soils with low iron concentration, such as the ones in the present work, contribute a greater input of dissolved P and increase eutrophication (Ekholm and Lehtoranta, 2012).

The vulnerability of semi-arid soil to erosion, combined with its mineralogy poor in Fe oxides, makes these riparian soils an important source of salts, organic matter, and phosphorus for aquatic systems when exploited by poorly managed uses. This problem is systematically increased when also taking into account the natural vulnerability of aquatic ecosystems in a semi-arid tropical climate to eutrophication. In the tropical semi-arid regions, reservoirs are naturally more vulnerable to eutrophication and have a high incidence of potentially toxic cyanobacterial blooms (Braga and Becker, 2020; Nobre et al., 2020). Based on previous studies developed in the same period as this research, the Dourado reservoir presented a volume of approximately 50% of its maximum capacity, demonstrating a eutrophic state(Braga and Becker, 2020; Leite and Becker, 2019). During this period, the reservoir water showed low light availability, average chlorophyll-a concentrations of 142.175 µg $L^{-1}$, and total phosphorus of 145.24 µg $L^{-1}$ (Braga and Becker, 2020). Intense rains can transport sediments and nutrients from the soil to the water bodies, thereby explaining the increase in the concentration of phosphorus and chlorophyll-a, especially in soils with livestock land use. This process is aggravated due to the long periods of drought, as the reduction in water volume increases the concentration of nutrients, creating a favorable environment for cyanobacterial blooming (Braga and Becker, 2020; Rocha Junior et al., 2018).

At the global and regional scales, the causes and consequences of diffuse pollution have been the subject of many discussions, and several advances have been achieved in understanding the process. The results of our work indicate that preventive and corrective measures are necessary in order to maintain a proper ecological balance in the areas surrounding the water supply sources. The necessity of monitoring the pollutants in the water body and of mitigating the water quality degradation process of this important drinking water supply is clear. More studies are needed on the role of soil characteristics on the degradation of water quality after land use changes in this and other supply sources in the world. The results will be informative for local authorities and will allow the establishment of more effective targeting policies to control the spread of contaminants. They can also serve as useful reference materials for soil quality protection and improvement and for other research programs in this area.

## 4. Conclusions

We assessed the effects of anthropic use on the riparian soil quality in a semi-arid tropical climate in northeastern Brazil. We found that small-scale agricultural production with low soil mobilization can maintain acceptable levels of soil quality and support the role of soil in environmental buffering in riparian areas. By contrast, pasture production of livestock increased the exposure of riparian soil and drastically affected the soil chemical characteristics by alkalization of the soils and by depleting or excessive enrichment of plant nutrients.

Our results showed that soil pH, available P, organic matter, exchangeable bases, and cation-exchange capacity were sensitive indicators of soil quality and separated natural soils into those with low-impact land use and degraded soils with high-intensity and high-impact anthropogenic use. Therefore, these variables can be part of environmental monitoring and reclamation programs in the areas degraded by anthropic use in the semi-arid region studied here, as well as in similar climate settings in the world. The use of the soil with the highest percentage area of occupation is what causes the greatest degree of degradation of the riparian soil.

These findings highlight the importance of preservation of native vegetation for maintaining the quality of riparian soil and ultimately water security.

**Acknowledgements**

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. The authors thank to FINEP (Financier of Studies and Projects) process n. 52009 for financial support. The authors also grateful to Eduardo Coriolano de Paiva for technical support in the field.

**Appendix A - Table S1.** Chemical attributes of soil under Native vegetation and Anthropic use in the riparian zone of the Dourado reservoir, Rio Grande do Norte state, northeast Brazil. Variables: TPA = Total potential acidity; CEC = Cation exchange capacity; BS = Base saturation; ESP = exchangeable sodium percentage; SOM = Organic matter; P = Available phosphorus

| *Anthropic use* | | | | *Native vegetation* | | | | *Variable* |
|---|---|---|---|---|---|---|---|---|
| ***Max*** | ***Min*** | ***Std Dev*** | ***Mean*** | ***Max*** | ***Min*** | ***Std Dev*** | ***Mean*** | |
| 8.87 | 6.79 | 0.64 | 7.95 | 7.66 | 6.43 | 0.57 | 7.02 | pH |
| 2.75 | 1.52 | 0.4 | 2.13 | 2.93 | 2.28 | 0.26 | 2.61 | TPA ($cmol_c$ $dm^{-3}$) |
| 9.6 | 1.7 | 2.45 | 4.69 | 6.9 | 3.8 | 1.09 | 4.91 | $Ca^{2+}$($cmol_c$ $dm^{-3}$) |
| 7.2 | 0.6 | 1.84 | 3.01 | 5.5 | 3 | 0.88 | 4.06 | $Mg^{2+}$ ($cmol_c$ $dm^{-3}$) |
| 0.87 | 0.02 | 0.29 | 0.24 | 0.06 | 0.02 | 0.01 | 0.03 | $Na^{+}$($cmol_c$ $dm^{-3}$) |
| 0.65 | 0.01 | 0.25 | 0.18 | 0.59 | 0.02 | 0.19 | 0.11 | $K^{+}$($cmol_c$ $dm^{-3}$) |
| 20.06 | 4.47 | 4.41 | 10.24 | 15.45 | 9.78 | 2.01 | 11.73 | CEC ($cmol_c$ $dm^{-3}$) |
| 88 | 65 | 7 | 77 | 84 | 72 | 4 | 77 | BS(%) |
| 22 | 0 | 8 | 6 | 0 | 0 | 0 | 0 | ESP(%) |
| 90.5 | 0.75 | 29.02 | 17.29 | 11.01 | 1.08 | 4.23 | 5.34 | P (mg $kg^{-1}$) |
| 53.12 | 30.91 | 6.13 | 36.62 | 41.2 | 34.55 | 2.27 | 37.47 | SOM (g $kg^{-1}$) |

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