











## Anthropic interference in mangrove areas of the Mundaú-Manguaba estuarine lagoon complex (CELMM), Alagoas (Brazil) as a case study

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**ABSTRACT:** *The mangrove is a coastal ecosystem that is present in different parts of the world. It provides various ecosystem services from food supply to the influence of climate change. Due to the development of society, this ecosystem has been subjected to significant impacts from anthropogenic activities. Therefore, the objective of this research was to evaluate the environmental impacts caused in mangrove areas that have undergone modifications as a result of anthropic activities (agricultural cultivation, deforestation, civil construction) compared with those of conserved mangrove areas. This research took place through the analysis of the temporal sequence of aerial images (Google Earth) and soil quality analysis through field collections to evaluate the chemical and biological indicators in the different land use systems. As these are permanent changes that affect the type of soil and its coverage, significant differences were obtained between the chemical and biological characteristics of the four environments, with different usage systems. The mangrove has been negatively impacted by inadequate management and land occupation. Continuity of anthropic intervention in the mangrove will promote the disappearance of this ecosystem in the long term. Among the chemical and biological attributes used for the analyses that were performed, aluminum and edaphic organisms were the ones that allowed the greatest contribution of distinction from the degree of disturbance in areas of agricultural cultivation, deforestation and civil construction/mangrove transition.*

**Key words:** *degradation, coastal ecosystem, environmental impact.*

## Interferência antrópica em áreas de manguezal do complexo estuarino lagunar Mundaú-Manguaba (CELMM), Alagoas, Brasil: um estudo de caso

**RESUMO:** *O manguezal é um ecossistema costeiro, presente em diversas partes do mundo, provedor de diversos serviços ecossistêmicos desde a provisão de alimentos a influência das mudanças climáticas. Devido ao desenvolvimento da sociedade, este ecossistema tem sido submetido a significativos impactos proveniente das atividades antropogênicas. Diante disso, o objetivo deste trabalho foi avaliar os impactos ambientais ocasionados em áreas de mangue que sofreram modificações resultantes de atividades antrópicas (cultivo agrícola, desmatamento, construção civil) comparando com área de mangue conservado. Esta pesquisa se deu através da análise da sequência temporal de imagens aéreas (Google Earth), e análise da qualidade do solo mediante coletas em campo para avaliação dos indicadores químicos e biológicos nos diferentes sistemas de uso do solo. Por se tratarem de alterações permanentes e que afetaram o tipo do solo e a cobertura do mesmo, foram obtidas diferenças significativas entre as características químicas e biológicas dos quatro ambientes, com os diferentes sistemas de uso. O manguezal tem sofrido impactos negativos pelo manejo inadequado e ocupação do solo. A continuidade da intervenção antrópica no mangue dará prosseguimento ao desaparecimento deste ecossistema a longo prazo. Dentre os atributos químicos e biológicos utilizados para as análises realizadas, o alumínio e os organismos edáficos foram os que permitiram maior contribuição para discriminação do grau de perturbação das áreas de cultivo agrícola, desmatada e transição construção civil/manguezal.*

**Palavras-chave:** *degradação, ecossistema costeiro, impacto ambiental.*

## INTRODUCTION

Mangroves are coastal environments present in tropical and subtropical regions of the globe and have great diversity of fauna and flora (SEMADS, 2001). It contributes to the community in providing food and

water, maintaining the climate, stabilizing the soil, and controlling erosion, and nutrient cycling. Among others, it reduces the vulnerability of coastal regions to floods and storms (GASPARINETTI et al., 2018).

Mangrove forests possess a vast worldwide extension of approximately 14 million hectares

(140,000 km<sup>2</sup>) (data from 2000), distributed in 118 countries and territories (GIRI et al., 2010). In Brazil, there are 17,287 km<sup>2</sup> of this estuarine environment, from the coast of state of Amapá to Santa Catarina (BIBI et al., 2019; SEMADS, 2001). The state of Alagoas covers 5,535.27 hectares of mangroves (around 55.3527 km<sup>2</sup>) (MMA and ICMBIO, 2018).

Despite their important provisional services to society, mangroves have been suffering from threats of human activities such as tourism and resource extraction. Results consequently are pollution and land occupation. The Brazilian Northeast is between the two regions that present a critical scenario (Northeast and Southeast, among the five regions of Brazil), where around 40% of the existing mangroves have been extinct (MMA and ICMBIO, 2018).

In view of this context and a few studies undertaken in the region of Alagoas, the objective of this study was to assess the environmental impacts caused in mangrove areas of the Mundaú / Manguaba Estuarine Lagoon Complex (CELMM) due to the changes resulting from anthropic activities (cultivation agriculture, deforestation, civil construction) contrasting with the conserved mangrove.

## MATERIALS AND METHODS

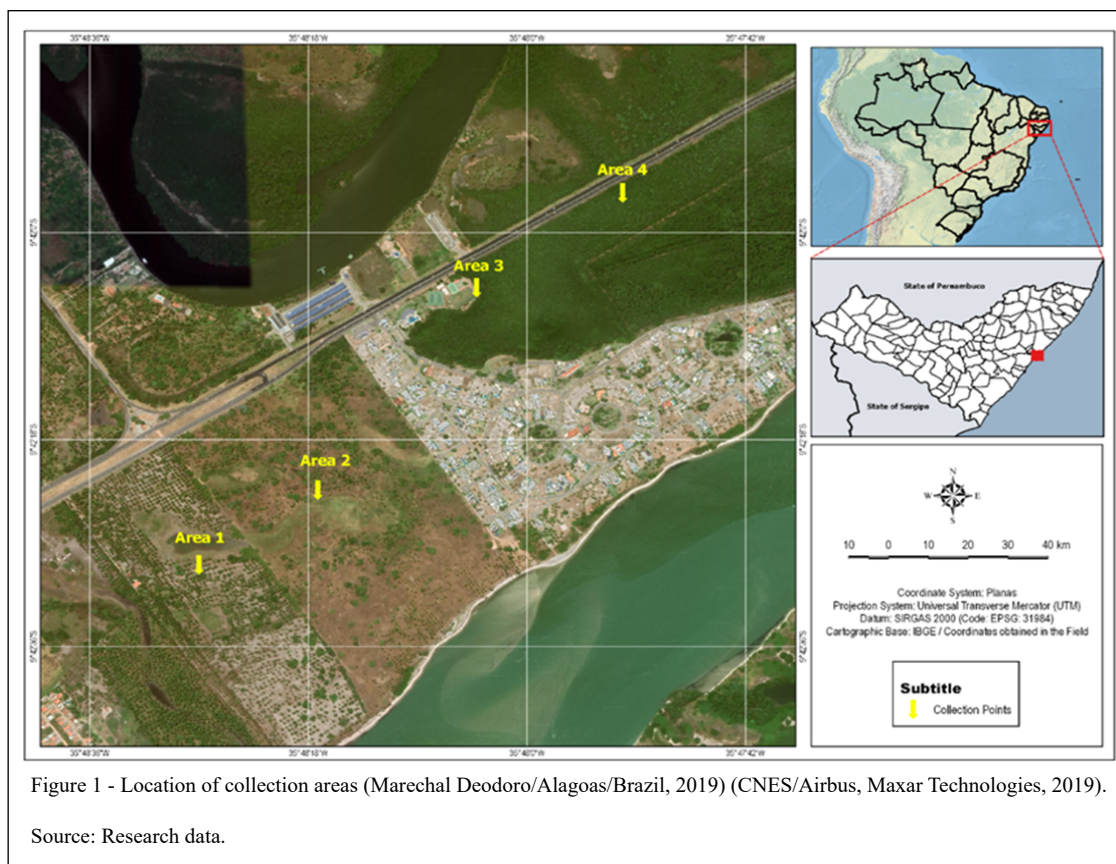
### Study area

The research was carried out in the municipality of Marechal Deodoro/Alagoas (Figure 1), located in the Metropolitan Region of Maceió, a tropical climate territory, with a dry and a rainy season during the year and an average annual rainfall of 1,648.1 mm (SEMARH, 2014). The study environments are located in the Barra Nova neighborhood, belonging to the CELMM.

The research took place in two moments: temporal analysis of the areas (between the years 2002 and 2019) carried out through the Google Earth application, through historical images obtained from satellites, and analysis of the soil indicators (chemical and biological, conducted over the period of April, May and June 2019).

### Satellite images evaluation

Utilizing the Google Earth application and *on-site* visits, four experimental areas were selected: agricultural cultivation (Area 1 - 9°42'28.9"S, 35°48'27.02"W), deforested (Area 2 - 9°42'22.39"S, 35°48'17.23"W), civil construction/mangrove



transition (Area 3 - 9°42'04.78"S, 35°48'04.16"W) and conserved mangrove (Area 4 - 9°41'56.55"S, 35°47'52.13"W).

#### *Soil samples (sampling, preparation and analyses)*

In each study area within a period of three months, soil collections were performed at a depth of 0 to 20 cm by making up simple samples (ten points from each study area) to obtain the composite samples (four samples per area) to determine the chemical indicators (pH: hydrogen potential, Na: Sodium, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Al: Aluminum, H: hydrogen, S: Sum of Bases, CTC: Cation Exchange Capacity, V: Ind de Sat. de Bases, MO: Organic Matter, C: carbon), according to EMBRAPA'S METHODOLOGY (1997).

For biological indicators, collections of macrofauna and edaphic mesofauna were carried out in all the different study areas. As a means of capturing the macrofauna organisms, ten Provid-type traps were installed per area over the course of four days - made from a 2L plastic bottle containing 200 mL of 5% neutral detergent solution and 12 drops of formaldehyde. The mesofauna was collected close to the collection points of the macrofauna, using metallic rings with a diameter of 4.8 cm and a height of 5 cm. Identification and counting took place in the laboratory by evaluating organisms between 0.2 and 2.0 mm in length for mesofauna and > 2 mm for macrofauna. Quantitative and qualitative assessments were carried out using the Shannon (H) and Pielou (e) Diversity Indices. Also the constancy of the groups was calculated according to SILVEIRA NETO et al. (1976).

#### *Statistic analyses*

In order to identify the differences between the diverse collective points of the different environments, in relation to all the variables studied, the data obtained were subjected to cluster analyses such as the Scott-Knott test, and Tocher's optimization method. This was done by using the matrix of average Euclidean distance and with standardized data as a measure of dissimilarity and principal component analysis. The GENES program (CRUZ, 2013; CRUZ, 2016) and Action Stat were used to perform the statistical procedures.

## **RESULTS AND DISCUSSION**

#### *Time series analysis*

Through the analysis of the temporal sequence of aerial images of the Google Earth application (Figure 2), it was possible to make

comparisons of the coverage of the areas of collection of this research in a seventeen-year interval (2002 to 2019).

In the first image (year 2002) (Figure 2), the vegetation cover common to the four areas is observed, which until then were indistinct. However, occupation was already underway since 1979 when the AL 101 South Highway was built. This consequently opened clearings along the margins of the highway, as well as the formation of corridors connecting the highway to banks of the Mundaú Lagoon.

In 2007, areas 1, 2 and 4 remained with natural coverage of the environment, while area 3 suffered intervention from civil construction and the incorporation of a real estate project in the region. The residential complex in area 3 had its inauguration mark with the subdivision process started in 2006.

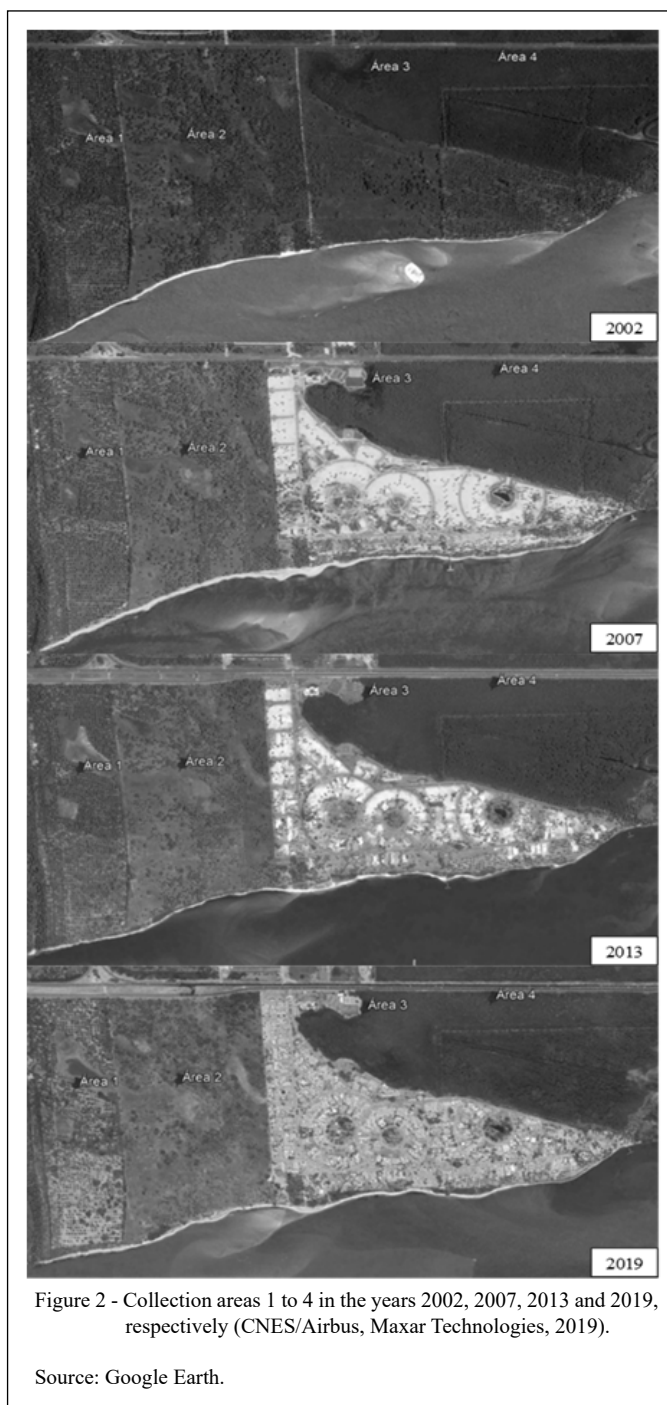
In 2013, the development of construction in relation to the previous record (2007) and the beginning of the modification of areas 1 and 2 could be seen. Until 2019, Area 1 had been converted into an agricultural area leased for family farming through low intensity soil management with cultivation of okra, cackrey and cowpeas. The usage of fertilizers and pesticides such as insecticides and herbicides were applied as crop management.

In the current year, 2019, the degree of devastation of the first three areas was notable respectively from agriculture, deforestation and real estate expansion. It was a slow and sequential process that involved routine burning, construction landfills, real estate pressure for the construction of high standard condominiums, and infrastructure associated with the AL 101 South Highway.

The occupation process of areas 1, 2 and 3 took into account a historical follow-up that was intensified with the opening of the AL 101 South Highway (1979) and its duplication (2012) which was the process that resulted from the occupation of the margins and the formation of real estate developments of high standards condominiums.

Through satellite images, information about areas and changes in mangroves has become more accessible (VALIELA et al., 2001). Studies carried out in different parts of the world, including Brazil, have shown the reduction of mangrove areas in some regions over the years (THOMAS et al., 2017; MONDAL et al., 2018; MATIAS and SILVA, 2017 and GURGEL et al., 2015).

A decrease in the global extension of mangroves was observed in the period 1996-2010, where the changes occurred due to anthropic practices, as well as natural aspects (THOMAS et al.,



2017). Changes caused by natural phenomena are short-lived. They briefly resume the structure from before on account of them being proportionately small, though the changes due to anthropic practices are long-term (MATIAS and SILVA, 2017). Consequences such as the emission of gases and the alteration of the biological diversity of the region

due to the decrease of water in the soil and biomass, come from these modifications (ALBUQUERQUE et al., 2017).

#### *Chemical soil indicators*

The chemical parameters of the different environments are shown in Table 1. It appears that

Table 1 - Average values of chemical characterization of the soil in areas of agricultural cultivation, deforested, civil construction / mangrove transition and mangrove, at a depth of 0 - 20 cm.

Indicator	Agricultural Cultivation	Deforested	Civil Construction / Mangrove Transition	Mangrove
pH	5.03c	4.83d	6.00a	5.67b
Na (cmolc dm <sup>-3</sup> )	0.03b	0.05b	0.08b	0.41a
P (mg dm <sup>-3</sup> )	8.67b	7.33b	140.67a	10.33b
K (cmolc dm <sup>-3</sup> )	0.09c	0.11c	0.14b	0.25a
Ca + Mg (cmolc dm <sup>-3</sup> )	3.63b	2.33c	4.77a	4.63a
Ca (cmolc dm <sup>-3</sup> )	2.43b	1.30c	3.50a	2.50b
Mg (cmolc dm <sup>-3</sup> )	1.20b	1.03c	1.27b	2.13a
Al (cmolc dm <sup>-3</sup> )	0.07b	0.14a	0.00c	0.02c
H + Al (cmolc dm <sup>-3</sup> )	2.47b	2.80b	1.83c	3.17a
S	3.78c	2.52d	5.03b	5.58a
CTC	6.25b	5.32c	6.86b	8.74a
V (%)	60.53b	47.37c	73.40a	63.80b
MO (g dm <sup>-3</sup> )	24.47b	17.63b	93.03a	29.60b
C (%)	1.01d	1.22b	1.32b	1.58a

pH: hydrogen potential, Na: Sodium, P: Phosphorus, K: Potassium, Ca: Calcium, Mg: Magnesium, Al: Aluminum, H: hydrogen, S: Sum of Bases, CTC: Cation Exchange Capacity, V: Ind de Sat. de Bases, MO: Organic Matter, C: carbon.

Averages followed by the same letter, on the line, do not differ statistically at the 5% probability level by the Scott-Knott cluster test.

there was significant difference between environments for all indicators, evidencing the interference of anthropic actions.

Analyzing the levels of chemical elements in the areas, greater changes were observed in the deforested area compared to the conserved mangrove area. According to some studies, fire with dead vegetation provides effects that enhance the levels of soil nutrients. This is due to ash deposition, with the record, for example, of increased phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (BATISTA et al., 1997; RHEINHEIMER et al., 2003). Contrary values were observed in this research when lower levels of P, K, Ca and Mg were obtained in this environment. One could admit the percolation of nutrients resulting from the rain within the given period in which the research was developed, as well as the occurrence of successive fires that result in the impoverishment of the soil by including the reduction of its organic matter (REDIN et al., 2011; SOUZA et al., 2019).

The soil in the deforested area showed low pH, displaying acidity, which according to SOBRAL et al. (2015) is an indicative factor of the presence of exchangeable aluminum as the presence that was also found in this research (Table 1). The existence of exchangeable aluminum in the soil can hinder radicular growth and affect the availability of nutrients and processes, such as the mineralization

of organic matter (SOBRAL et al., 2015) which also was observed in the present study.

Obtained sodium and magnesium values from the preserved mangrove indicated the characteristic salinity of this ecosystem, whose levels are higher than other environments. This characteristic affects fertility in certain soils, such as the decrease in sodium values between areas may be related to presence of fresh water in these (EBELING et al., 2008; FIRME, 2003).

However, when comparing the quantitative of the chemical attributes of the study with the data of PRADA-GAMERO et al. (2004) of the mangrove study located on the margins of the Rio-Santos Highway, km 93, great variations were reported in respect to pH, phosphorus, sodium, calcium, aluminum, and CTC. In regard to organic carbon, a value of 1.56 was obtained by this research similarly to what was obtained by BARBOSA et al. (2015), in his research on the chemical composition of mangrove sediment from the Bragantino estuary (PA) - Brazil.

The mangrove, despite the interference of civil construction in the environment, is shown to be resilient. The construction industry impacted the existing ecosystem in interfering in the natural environment and preventing its expansion by promoting a physical barrier through the construction

of the condominium. The civil construction sector causes negative disturbance to the environment from the conception of a project until after the completion of the construction due to factors such as the extraction of natural resources, topographic alteration, changes in water courses, flora and fauna, and disposition of waste (ROTH and GARCIAS, 2009). Such factors are responsible for changes in parameters such as high organic matter content (Table 1), through the release of domestic sewage. Consequently, there are higher phosphorus values due to the possible correlation between parameters (FIRME, 2003).

#### Biological indicators

Analyzing the organisms present in the soil as to the degree of disturbance due to anthropic actions in the areas, a variability between them with a greater number of organisms in the soil (macro and mesofauna) of the deforested area was observed (Table 2). Due to the richness and diversity of the fauna groups, close values were reported between the areas of agricultural cultivation, deforestation and transition that demonstrated the biodiversity of the fauna communities (Araneae, Acarina, Collembola, Coleoptera, Diptera, Diplopoda, Hymenoptera, Orthoptera, etc.), with dominance of the Hymenoptera (macrofauna) and Acarina (mesofauna) groups in the deforested and burned areas.

These results are in opposition to those presented by REZENDE et al. (2017) and FERNANDES et al. (2009), in which they claim that the practice of burning forests brings about the loss of individuals belonging to the macrofauna. The large number of individuals in this area is justified by the resistance to the practice of burning by groups such

as Acarina and Collembola, and by the presence of Hymenoptera. They are characterized as organisms that frequent environments without adequate survival conditions (SILVA et al., 2011).

Similar results were obtained by LUDWIG et al. (2012) who also assessed the diversity of edaphic fauna in different environments which included land use for agricultural activities. The same methodology was used, in which ten taxonomic groups were present (Hymenoptera, Diptera, Coleoptera, Collembola, Chilopoda, Orthoptera, Isoptera, Acarina, Araneae and Hemiptera), in addition to the predominance of the Hymenoptera and Collembola groups in the areas.

When analyzing the constancy of the fauna groups of the macrofauna and soil mesofauna, a low number of groups considered as constant (reported in more than 50% of the collection points) and a greater number of groups considered accidental (present in less than 25% of collections) is observed. This factor pointed to the need and importance of studies to monitor and map these environments to determine the groups naturally belonging to them, as well as the explanation of the occurrence of their presence due to seasonality or other factors.

However, it was reported that the dominant groups (Acarina and Collembola) are in agreement with other studies, being exposed as the most abundant organisms of the mesofauna. In the vast majority of soil types, they are considered as parameters of the biological quality of the soil (SILVA et al., 2013). In surveys in other cultivation areas (tobacco, native field, native or reforested areas) the Acarina group has isolated appearances, while Hymenoptera, Coleoptera and Collembola are the ones with the highest occurrences (GIRACCA et al., 2003).

Table 2 - Number of Individuals (NI), richness of fauna groups, Shannon's diversity indexes (H') and Pielou's equability (e) in agricultural, deforested, transition (civil construction / mangrove) and mangrove areas.

Data / Areas	Agricultural Cultivation	Deforested	Transition	Mangrove
-----Soil macrofauna-----				
NI total	2,449.00	4,310.00	1,534.00	580.00
Richness	16.00	18.00	17.00	10.00
H'	32.76	41.72	35.30	15.41
e	63.53	61.77	41.95	27.32
-----Soil mesofauna-----				
NI total	202.00	390.00	359.00	107.00
Richness	10.00	12.00	14.00	11.00
H'	18.04	22.64	21.86	15.69
e	29.85	29.10	36.22	24.89

The principal component analysis showed that the first two components were explained with 83.7% of the total variance, with 58.4% on PC1 (horizontal axis) and 25.3% on PC2 (vertical axis) (Figure 3). This result can be considered satisfactory, considering that total variations above 80% obtained with the first two or three main components make it possible to analyze groups using scatter plots (CRUZ AND REGAZZI, 2001). At least 70% of the total variance must be explained by the first and the second main components (RENCHER, 2005). Therefore, in this research, only the first two components were used, as they are considered sufficient to explain the data and also because it facilitates the interpretation of the graph in two dimensions (GOMES et al., 2004).

The bioindicators of the edaphic fauna (mesofauna and macrofauna) proved to be of great relevance for the assessment of disturbances in the environments by presenting themselves close to the horizontal axis of the right (positive) quadrant. This results in being the axis of greatest value of the main component. This result was also demonstrated by

BARTZ et al. (2014) in his research, where he stated that the existence, plurality and abundance of edaphic fauna organisms are influenced by the use of land systems due to their sensitivity and being able to act as quality parameters.

The result of the grouping using Tocher's method is shown in Figure 4. The chemical (pH, Na, P, K, Ca, Mg, Al, H, S, CTC, V, MO and C) and biological (meso and macrofauna) attributes of the soil based on Tocher's method, allowed the points and environments studied to be divided into five groups: the first formed by points 8 and 9 belonging to environment 3 (transition); the second through points 4, 5 and 6 belonging to environment 2 (deforested); the third group formed by points 10, 11 and 12 belonging to environment 4 (mangrove); the fourth group formed by points 1, 2 and 3 (agricultural cultivation) and the fifth group formed by point 7 (transition). It appears that only point 7 was outside the expected, forming an isolated group when it should have been part of group 1 (transition). It was reported that the variables mesofauna, aluminum, and macrofauna were the ones that contributed the most to

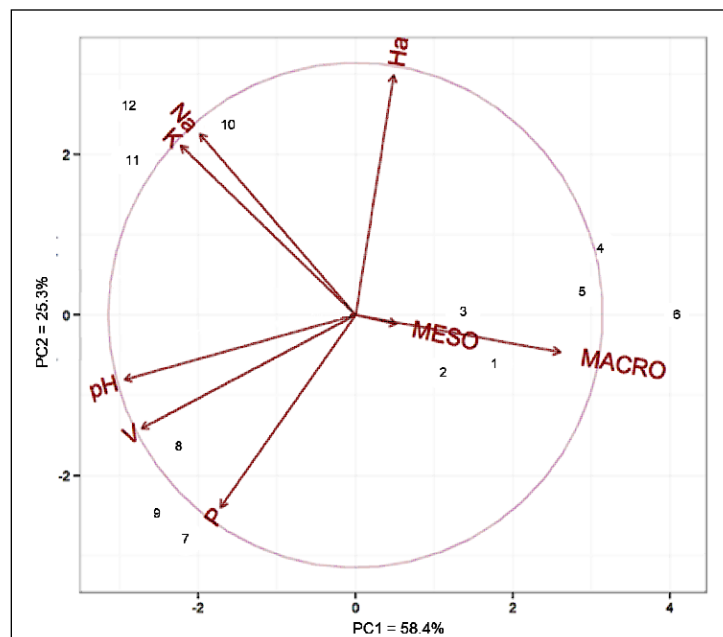
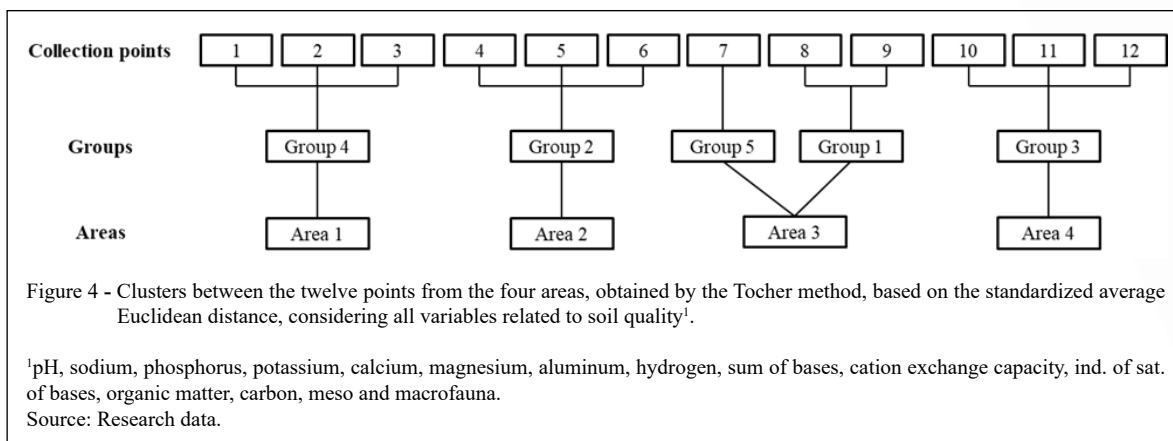


Figure 3 - Relationship between the main components (PC1 and PC2) and land use systems and bioindicators.

V: base saturation index, Na: sodium, P: phosphorus, K: potassium, pH: hydrogenionic potential, Ha: H + Al (hydrogen + aluminum), MESO: mesofauna, MACRO: macrofauna.

1, 2 and 3: area 1 / 4, 5 and 6: area 2 / 7, 8 and 9: area 3 / 10, 11 and 12: area 4.  
Source: Research data.



the distinction of groups (environments) with 16.7%, 18.2% and 19.7% respectively. The groups formed using Tocher's method were, in part, confirmed through the ACP.

## CONCLUSION

Anthropic actions caused successive changes in the environment. As these are permanent changes that affect the type of soil and its coverage. Significant differences were obtained between the chemical and biological characteristics of the four environments, with the use of different systems in which a few years ago belonged to the mangrove as their singular ecosystem.

The mangrove has suffered negative impacts due to inadequate management and soil occupation, demonstrated by the chemical alteration of the soil and modification of the landscape. This has led to the degradation process. The continuity of anthropic intervention in the mangrove will promote the disappearance of this ecosystem in the long term.

Among the chemical and biological attributes used for the performed analyses, aluminum and edaphic organisms were the ones that allowed the greatest contribution to discriminate the degree of disturbance in areas of agricultural cultivation, deforestation and civil construction/mangrove transition.

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## DECLARATION OF CONFLICTS OF INTERESTS

I declare that there are no conflicts of interest between the authors of the article entitled: "Anthropic Interference Assessment in Mangrove Areas of the Mundaú-Manguaba Estuarine Lagoon Complex (CELMM), Alagoas, Brazil" submitted for consideration in the Revista Ciência Rural.

## AUTHORS' CONTRIBUTIONS

Amanda Medeiros, Velber Xavier, Mayara Andrade, Kallianna Dantas, João Gomes, Selenobaldo Alexinaldo, Acácia Rodrigues and José Adenilson performed the experiments and laboratory analyzes. Kallianna Dantas and Mayara Andrade supervised and coordinated the experiments. João Gomes performed statistical analysis of experimental data. Amanda Medeiros, Velber Xavier and Mayara Andrade prepared the draft of the manuscript. All authors critically reviewed the manuscript and approved the final version.

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