Environmental Vulnerability of the Environmental Protection Area of the Mamanguape River Bar - PB

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Abstract. *The fragility of the environment is the join of the vulnerabilities of each component present in nature. The present work aimed to identify the environmental fragility of the Environmental Protection Area (EPA) of the Mamanguape River Barrier, in order to identify the vulnerability present in the area. The research used fundamentals of the geosystemic method, observing the interconnections of the parameters geology, geomorphology, pedology, rainfall and land use and coverage. The EPA was classified as low fragility (1%) and medium fragility (69%). The remaining of the EPA was classified as high fragility (30%). The diagnosis of the environmental fragility of the EPA showed that only geomorphology is stable, but geology, pedology and land use and cover are unstable.*

1. Introduction

In an intrinsic way the environment has a potential (natural) fragility, that is, it presents vulnerable aspects in the composition of the elements that constitute it. Thus, the fragility of the environment is the junction of the vulnerabilities of each component present in nature.

The theory of eco-dynamics proposed by Tricart (1977), studies the dynamics of the environment based on its morphogenetic (relief) and pedogenetic characteristics (soil modification). Crepani et al (2001, p.83) point out that "a natural landscape unit is considered stable when the natural events that occur in it favor the processes of pedogenesis".

The elements present in the landscape of the Environmental Protection Area (EPA) of Mamanguape River Barrier are: mangroves and floodplains, coastal reefs, Atlantic forest, forest of restinga, dunes, and cliffs. Although the EPA is a conservation unit of sustainable use that seeks to reconcile nature conservation with the sustainable use of natural resources, allowing activities involving the use of natural resources, practiced in a way that the permanence of renewable environmental resources and ecological processes is assured (MMA, 2015), environments are changing. External factors such as human activities can intensify the fragility of the environments, making them even more susceptible to intense changes that can cause irreversible damage.

In view of the importance of EPA ecosystems, the present work aimed to identify the environmental fragility of the EPA of the Mamanguape River Barrier, in order to identify the vulnerability present in the area.

These variations are reflected in the landscape that is constantly altered by the most diverse factors, be they positive or negative, that influence directly or indirectly on any system, which, even in the face of perturbations, tends to remain in a dynamic equilibrium. These characteristics can be spatialized through geotechnologies such as Remote Sensing, Geographic Information System (GIS), Global Positioning System (GPS) and Geoprocessing, which aid in the analysis of the data, allowing an integration of the elements present in the landscape.

2.Material and Methods

2.1Area of study

The Environmental Protection Area of the Mamanguape River Barrier was implemented by Decree 924 of September 10, 1993. The EPA has an area of 14,640 ha and is located in the mesoregion of the forest zone, north coast of the State of Paraíba, (Figure 1).

EPA is home to the main mangrove remnants of northeastern Brazil and has natural habitats that house endemic and endangered species. The EPA is also represented by floodplains, coastal reefs, Atlantic forest, restinga forest, dunes and cliffs (BRAZIL 1993, ICMBIO 2015, EMBRAPA 2008).

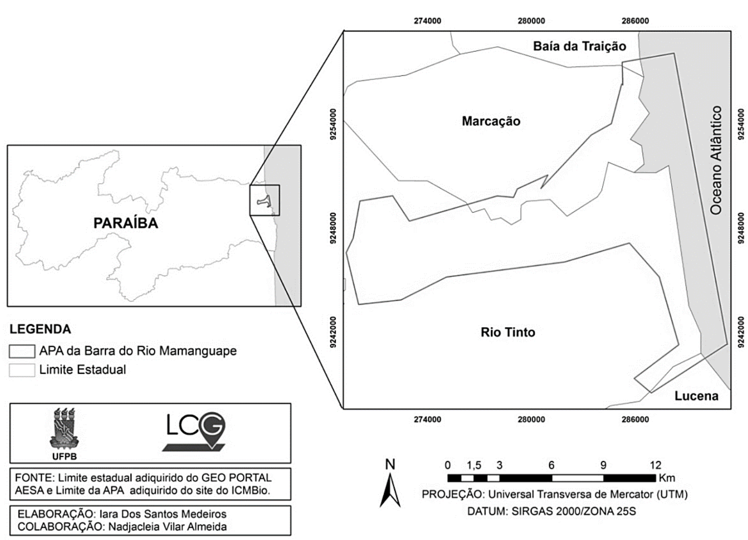

Figure 1. Location map of the APA of Barra do Rio Mamanguape, Paraíba, Brazil.

2.2 Methodological Procedures

The research used fundamentals of the geosystemic method, observing the interconnections of the parameters geology, geomorphology, pedology, rainfall, and land use and coverage. In the methodological process, the geoenvironmental and eco-dynamic analyzes were carried out where the procedures outlined in figure 2 were applied, which were performed using the arcgis software version 10.6.1.

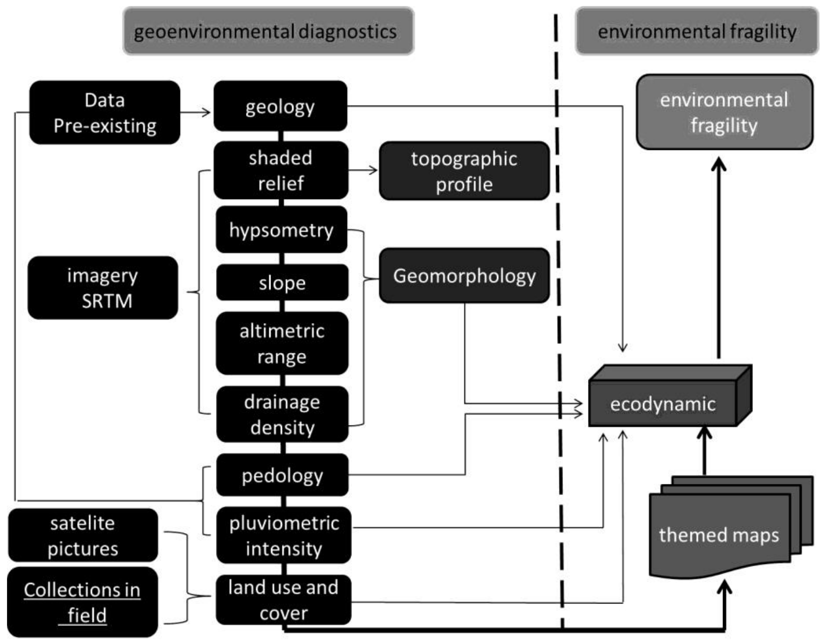

Figure 2. methodological procedures

For the geoenvironmental diagnosis, a vector file containing EPA geological information made available by the Geological Survey of Brazil (CPRM) was used through the GEOBANK1 website.

The geomorphological characteristics were analyzed through three cartographic products: slope, drainage density, and altimetric amplitude, all of which were generated based on SRTM (Radar Topography Mission) with the spatial resolution of 30 meters, referring to SB-25- YA provided by the TOPODATA2 website which contains the morphometric data of Brazil. The slope was established through the slope tool being expressed in percentage values according to the classification of Embrapa (1979). The altimetric amplitude based on Crepani et al. (2001) and drainage density according to Christofoletti (1980, p. 115).

The value of the rainfall intensity was obtained by dividing the average annual rainfall value (in mm) by the duration of the rainy season (in months). The spreadsheet with the data was exported to the GIS and through the interpolation tool, the data were converted to pixels generating the EPA pluviometric intensity map. The method of interpolation chosen was the IDW-Inverse of the Weighted Distance because it represents better the results for the study area and because it is a widely used method. According to Miranda (2005), this method estimates a value for a non-sampled location as an average of the data values within a neighborhood.

The soil and physical aspects of soil formation were considered for pedological characterization. The soil map of the State of Paraíba, dated 1997, with a scale of 1: 1,200,000, was used as the Cartographic basis.

For the analysis of land use and land cover, a LANDSAT 8 image with a spatial resolution of 30x30m dated 11/02/2016, made available by the United States Geological Survey (USGS) 3 was used. The steps of radiometric conversion, generation of false color composition (RGB), fusion of the multispectral image to color Panchromatic in order to convert the spatial resolution of the used satellite image, which initially was of 30x30, resulted in an image of 15x15 meters, ending with supervised classification using the maximum likelihood method, where it is considered that "objects belonging to the same class will present spectral responses close to the average values for that class" (RIBEIRO et al., 2007).

Based on the theory of eco-dynamics proposed by Tricart (1977) and adapted by Crepani et al. (2001) all components were analyzed separately. Through reclassification procedures, vulnerability values were assigned to each theme.

Tabela 1. Categorias ecodinâmicas e seus respectivos valores de vulnerabilidade

Ecodynamic Categories	**Relationship between pedogenesis and morphogenesis**	**Vulnerability Values**
Stable	Pedogenesis Prevails	1,0 – 1,3
Moderately Stable		1,4 – 1,7
Average Stability	Pedogenesis / Morphogenesis Balance	1,8 – 2,2
Pedogenesis / Morphogenesis Balance		1,8 – 2,2
Unstable	Morphogenesis Prevails	2,7 – 3,0

Source: adapted from Almeida (2012).

After applying the eco-dynamics for each theme individually, through equation 1, the general fragility of EPA was obtained.

$$\boldsymbol{v} = \frac{(G+R+S+VG+C)}{5} \quad \text{Equation 1.}$$

At where:

V = Vulnerability; G = vulnerability to the theme Geology; R = vulnerability to the theme Geomorphology; S = vulnerability to the theme Solos; Vg = vulnerability to vegetation; C = Climate Vulnerability

Thus, the units with the highest stability are represented by values closer to 1.0, intermediate values by values around 2.0 and the most vulnerable units present values closer to 3.0 (CREPANI, 2001).

3.Results and Discussion

The fragility diagnosis consists in the classification of the studied environments in degrees of vulnerability and is based on the information obtained from the geoenvironmental diagnosis, being of primary importance to guide the use and occupation of the land and to identify the activities that cause negative impacts in the EPA.

According to the geological diagnosis, the EPA is in the domain of the Pernambuco-Paraíba Basin (Brazil, 2002). The study area has three lithologic units: colluvium-eluvial reservoirs and fluvial-marine and barriers group. The colluvium-eluvial deposits and the fluvial-marine deposits are classified as unstable because they are unconsolidated sediments and because they are in constant modification are easily removed and deposited by means of chemical, physical and biological weathering. The Barriers Group presents as moderately unstable because it is composed of siltstones and argillites, which, although fragile, are little more resistant than the fluvial-marine and colluvial-eluvial deposits.

When analyzing the geological fragility of the Tambaba EPA on the southern coast of the state of Paraíba composed by the Barriers Indiviso Group, marine deposits, and the continental deposits, Almeida (2012) found results similar to those presented here and classified the environment as geologically unstable.

According to Crepani et al. (2001, p.60), rocks considered unstable are "poorly cohesive, prevailing erosive processes, modifiers of relief forms (morphogenesis)". Thus, we can say that the geology of the EPA is fragile and susceptible to transformations that can directly influence all other elements of the landscape since the geological formations are the substrate where the whole environment develops.

The geomorphological analysis performed from the arithmetic mean of the morphometric indices, altimetric amplitude, slope, and drainage density confer stability and moderate stability to the studied area, presenting a greater stability when compared to the geology. It is a flat area with moderate dissection where pedogenesis prevails. But this stability is not static, and the most endangered geomorphological units are the dunes that suffer from vehicular traffic and the building of houses beyond the natural action of the wind and the cliffs that are suffering from the ravine process. According to

Medeiros et al (2018), morphometric indexes, whether high or low, are directly related to erosion.

The types of soil present in the EPA are Red-Yellow Argisol, Quartzarenic Neosols, and Flubic Neosols, most of them confer instability because they are poorly drained soils, possessing high Vulnerability and corroborate with the instability found in the APA geology since the soils are formed from the weathering of the geological substrate.

The Red-Yellow Argisol with medium stability has characteristics such as deep soil, very porous, strongly or strongly drained, which means that it has a medium degree of stability. In the case of the Quartzeneic Neosols, Mangrove Soils, and Flossic Neosols, both have similar characteristics, eg., they are poorly drained soils, to which instability is conferred. being classified as unstable.

A natural landscape unit is considered to be vulnerable when relief modifying processes prevail (morphogenesis) and, therefore, there is a predominance of erosion processes to the detriment of soil formation and development processes.

According to Bertoni, (2010), precipitation is the most important climatic element in the process of soil erosion, with the intensity being the precipitation factor determining erosion. After analyzing the pluviometric intensity data, the entire territory of the PA was classified as medium stability. According to Crepani et al. (2001, p. 95), "the greater the values of rainfall intensity the greater the rainfall erosivity and we can create a rainfall erosivity scale that represents the influence of climate on morphodynamic processes." Thus, we can affirm that the influence of rain on the erosive processes of EPA is medium. However, this influence can be aggravated if the soil is directly exposed to raindrops, with no vegetation present to intercept or cushion the erosive effects of rainfall.

For the use and land cover, six classes were identified: forest, water, mangrove, board vegetation, restinga, cultivation, and soil exposed. Two were classified as stable, the remainder ranging from moderately stable to unstable.

According to Crepani et.al (2001, p.88), "the density of the vegetation cover is of paramount importance to avoid morphogenetic processes, so the high coverage densities are close to 1.0". According to ICMBio (2014, 84), "the increase of sugarcane cultivation in the Mamanguape EPA has increased the degradation of the forest remnants of the Coastal Table and of the Atlantic Forest, generating discontinuous fragments, highly impacted by trails and paths along the woods. "

Pessoa (2016), when analyzing the vegetation of the EPA of the Mamanguape River Barrier, found that between 1974 and 2013 there was a dense vegetation loss of 54.3 km corresponding to 36.43%. With the exception of the Oiteiro forest, all other fragments have a reduced area and, consequently, with little or no presence of core areas, these fragments are fragile from the ecological point of view, since the fact that they are small fragments and isolates prevent or hinder the permanence of some species of flora and mainly of fauna that needs bigger and interconnected areas so that there is a greater availability of habitats and food that facilitates the gene flow among the species.

Water: Although not a class of vegetation, it was inserted in the mapping because it is one of the main elements and with greater representativity in the CU. It was classified as stable because it represents a type of cover of the soil and for propitiating the maintenance of adjacent ecosystems such as mangrove.

The removal of the riparian forest that has been replaced by sugarcane is the main cause of the degradation of the rivers, since it generates silting of the rivers and migration of the springs causing them to have their flow reduced, this causes several consequences that reflect not only the hydrography of the EPA more in the species of fauna and flora associated to her. Thus, it was observed that these classes have an ecological fragility that minimizes their role in the ecosystem.

Mangrove: The mangrove vegetation is dense and has an arboreal stratum, so it receives the value of 1.7 being classified as moderately stable. Because it is a very specialized environment with fluvial-marine influence, type of soil, specific fauna and flora, it needs a balance that allows its full development. However, this balance is being threatened by human activities. With this, it can be stated that the mangrove may eventually lose its stability and become an unstable environment, as a consequence of the continuity and intensification of negative impacts.

Board Vegetation: It is an ecosystem constituted of two strata, one arboreal-shrub, and another herbaceous, drained and discontinuous, (Environmental Sensitivity Primer: Ecosystems of Rio Grande do Norte, 2016). Because it is a transition environment (ecotone), it is more fragile, because it develops in an environment such as soil, relief, and vegetation. Therefore it is classified as average stability receiving value of 2.2.

Restinga: According to Assis (2014) the EPA restingas are very susceptible to degradation due to the activities developed by the local population and tourists, mainly by the trampling and illegal transit of motor vehicles and where they concentrate houses built for summer, changing their features and negatively impacting the environment.

Cultivation: being a introduced vegetation with shrub stratus is classified as unstable. In the case of the EPA, as most of the crop is composed of sugarcane, this causes other problems, making the environment even more fragile.

According to Costa and Andrade (2012, p.10) "the sugar and ethanol industries through the use of agrochemicals cause contamination of soil, rivers, and aquifers, as well as harming human health, biodiversity and causing damage to one's own agriculture. "This means that in addition to being fragile, it contributes to making other fragile elements such as soil and rivers.

Soil Exposure: Much of the soil classified as exposed represents areas of sugarcane cultivation that was cut, leaving the soil without vegetation.

3.1 Environmental Fragilityof the EPA of the MamanguapeRiverBarrier

Only a small portion of the EPA, in the Oiteiro forest region, was classified as low fragility (0.53km2, 0%). In the areas where the mangrove is inserted, most of the rivers, the forest, the lower altitudes, and declivities were classified as average fragility occupying 79.62 km and 69% of the UA. The rest of the EPA was classified as high fragility with 34.77 km totaling 30% of the area that corresponds to the regions of soil without vegetation, more pronounced slopes and recent soils (figure 3).

According to Almeida (2012 p.70), "the vulnerability of geo-environments to erosive processes (predominance of morphogenesis) reflects geoenvironmental (potential) fragility ... which means that the more fragile the more vulnerable to erosion is the". Thus, through this diagnosis, it is possible to identify the environmental fragility of EPA.

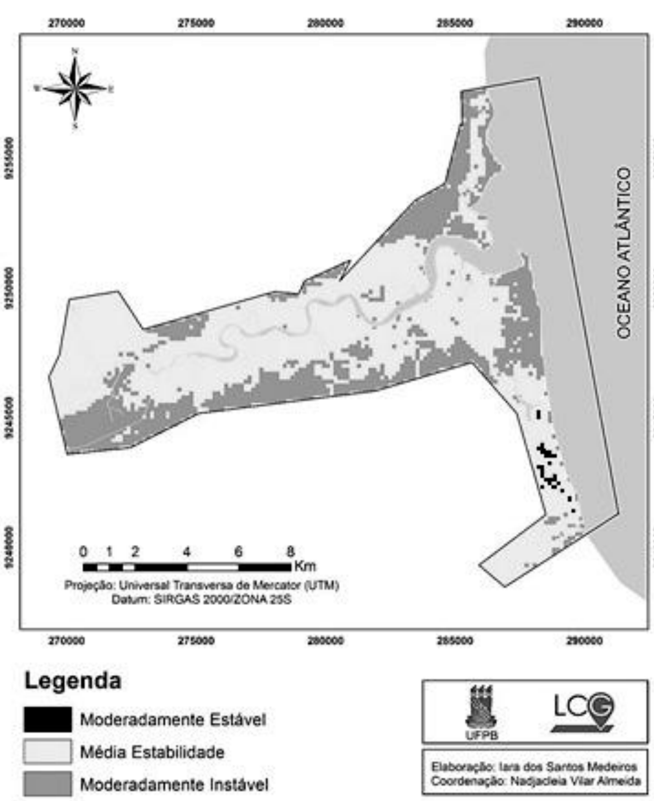

Figure 3. Vulnerability of the APA of Barra do Rio Mamanguape, Paraíba, Brazil.

There are some activities that cause direct negative impacts and may intensify the fragility of EPA. The following stand out:

Urbanization: The city of Rio Tinto, the indigenous villages of Jaraguá, Brejinho, Caieira, Camurupim, Tramataia, and Akaju-tibiró, and the communities of Aritingui, Barra de Mamanguape, Cravassu and Lagoa de Praia, Pacaré, Praia de Campina, Taberaba, Tanques, Tatupeba and Tavares (ICMBIO, 2014).

Agriculture: Silvestre et al (2011, p.30) say that the EPA is an "area surrounded by extensive cane fields. The great deforestation of the Atlantic Forest has motivated expansion of cane farms, resulting from the implementation of the Pró-alcohol program in 1970 by the Federal Government. "

Carciniculture: Carciniculture is present in a greater number of tanks in the northern portion of the EPA, of indigenous domain, which became an important source of local income, but the little planning carried out for the implantation caused that the tanks were abandoned in a short space and the replanting of the flora species is not carried out, leaving a huge void in the mangrove, fragmenting it. There is also a presence in the southern portion, but in smaller number, totalizing two farms, where one is not in operation due to IBAMA intervention, however, it was not reforested. This crop poses some risks to the local biota due to antibiotics and other chemicals harmful to the environment, besides, of course, the deforestation of the mangrove for the implantation of the tanks, (ASSIS 2014).

Deforestation: "The great deforestation of the Atlantic Forest in this area was motivated by the expansion of cane farms, resulting from the implementation of the pro-alcohol program in 1970 by the Federal Government," (ICMBIO 2014).

6. Conclusion

The diagnosis of the environmental fragility of EPA showed that only geomorphology is stable, but geology, pedology, and land use and cover are unstable. The rainfall intensity of the UC was only in the middle-class stability, with this it is observed that the landscapes that compose the EPA are in the limit between stability and instability, tending naturally to keep in balance, but the anthropic activities that act in the area, intensify and accelerate morphogenetic processes, making the environment more conducive to instability.

Therefore, a more targeted management is necessary, so that the fragile environments are restored and do not exceed their recovery threshold and the environments that are still stable can be preserved, thus ensuring the maintenance of the ecosystems present in the UC.

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