MODELS OF ENVIRONMENTAL RECOVERY IN ECOSYSTEMS OF MANGROVES ASSOCIATED WITH SALT PRODUCTION IN BRAZILIAN SOLAR SALT WORKS

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EXTENDED ABSTRACT

The northern coast of the Rio Grande do Norte (Brazil) state has mangroves running the length of its main estuaries, which have been subjected to a series of anthropological pressures for many years. This ecosystem is highly fragile due to natural processes and human interventions on the coastal zone. Such fragility is typical of the entire Brazil northeast coast, where the adverse climatic conditions and accelerated process of occupation of the coastal zone, that includes shrimp farms and urban expansion, with other activities, is a permanent pressure for this ecosystem. The mangroves work as barriers along with saltworks in order to reduce the spread of pollution in waters of the estuary, assuring the quality and the development the local salt production. The survey presented in this study was developed by the saltworks located in the northern coast of the state do Rio Grande do Norte (Brazil), at geographic coordinates of 5° S/36° 43 ' 49.0 " W. The major saltworks in the country are installed on that coast; being responsible for 95% of the produced and exported marine salt. Thus, the central objective of the survey was the identification of the degraded areas of mangrove swamps near the solar saltworks, with later implementation of methods and models of environmental recovery in those areas. From the survey data, the mangrove swamp vegetation in the area under analysis was characterized as a mangrove swamp strip, with the occurrence of discontinuous stretches of good developed vegetation, followed by stretches with damaged vegetation and/or in regeneration. Taking the structure and organization into consideration of the analyzed vegetation, in several areas suggests the artificial forestation with young specimens of Rhizophora mangle, Laguncularia racemosa, Avicennia germinans and A. schaueriana, once the formation of a mixed forest comes to guarantee a viability of the vegetation as a supportive element of the biological estuarine basis. The accomplishment of actions for recovery of damaged areas in ecosystems of saltworks has demonstrated the evident necessity to promote environmental restoration against the specific diversity for each unit of habitat.

Key words: viability, management, mangroves, saltworks.

1. INTRODUCTION

Mangrove ecosystems occupy about 92% of the Brazilian coast line (± 6800 km), extending from north in Oiapoque / AP (4 ° 30'N), to its southern limit in the Praia do Sonho in Santa Catarina (28 ° 53'S). These ecosystems play a fundamental role in the stability of coastal geomorphology, in biodiversity conservation and maintenance of large fish, usually used by the local population (TOMLINSON, 1986; SCHAEFFER-NOVELLI, 1986, 2005).

Particularly along the northern coast of the northeast region, due to the semi-arid region, the oligotrophic conditions of coastal waters and the importance of artisanal fisheries for the coastal population, these properties of mangroves are highlighted, making them ecosystems of immense ecological and environmental value (LACERDA & MAIA, 2005). Based on these properties, the Brazilian legislation considers the areas of mangrove as Areas of Permanent Protection (BRAZIL, 1965; CONAMA 303, 2002). However, despite their conservation efforts, mangroves are constantly threatened by various human activities undertaken both on the coast and interior.

In local and regional scale, this ecosystem is closely related to water quality and integrity of soil, besides providing shelter and sustenance for wildlife (TOMLINSON, 1986). To saltworks (see Figure 01), the importance of mangroves is even more emphasized because mangrove forests act as barriers, reducing the spread of polluting and contaminant elements in the estuary waters, ensuring the quality and development of local economic activities. On a global scale, these forests fix carbon, contributing to the reduction of greenhouse effect gases (KJERFVE & LACERDA, 1993).

Mangroves also maintain the sedimentological processes of morphogenesis, which is evidenced in an unstable morphology, modified by the action of cyclic hydrodynamic currents and waves. There is relevant characteristic in this environmental by showing low mobility and traffic areas, with high environment vulnerability facing the human order pressures (TOMLINSON, op. cit.; VANUCCI, 2002, 2004).

The solar salt along the mangroves as representative ecosystems, such as wetlands have high vulnerability due to natural processes and human interventions in the coastal zone (DAVIS, 2000; MOOSVI, 2006). This fragility is higher mainly in the northeast portion of Brazil, where adverse weather conditions and an occupation-accelerated process, which includes from breeding of crab and other crustaceans in addition to urban sprawl, among other activities, resulting in permanent environmental pressures on these ecosystems. Due to their proximity to urban areas, the saltworks and mangroves located in the northern coast of the state of Rio Grande do Norte (Brazil), have been targets of a range of anthropogenic pressures (see Figure 02).

In mangrove ecosystems located in arid areas, the availability of nutrients depends mainly on the recycling and fixation in situ, since the external contributions are minimal. In changed ecosystems which usually have affected the microbial community in addition to losing the organic layer, recycling and setting of essential elements is restricted by limiting the development of mangrove (SOARES, 1999).

As important environmental aspect for the mangrove establishment and development areas in semi-arid tropics, is the low rainfall (> 800 mm / year) and high evaporation in that estuarine region. In addition to environmental factors, anthropogenic factors such as pressure on the ecological quality of water resources, intensive land use together with urban growth on the banks of the estuary, all play an important role as agents leading to environmental stress (TOMLINSON, 1986).

It is also worth noting that

microtopography, rainfall and tide cycles affect the concentration of salts in sediment and the flooding level. These two aspects directly influence the availability of nutrients, seed production, mechanisms of dispersal and establishment of mangrove species (VANUCCI, 2004). In most cases, these factors are interrelated and their effect cannot be attributed to a single condition.

However, the recovery actions of those ecosystems are concentrated in the management of these abiotic factors, such as flooding and salinity, by restoring the water system and changes in the land topography. Biotic factors such as seed production, its retention on the site and herbivores are not always considered, although they have a major impact on the abundance and development of mangrove seedlings and thus should be included in the process of restoration (MCKEE, 1993; LEWIS, 2002).

It is worth highlighting that the efficiency of projects for environmental restoration should be discussed based on a historical context on issues involving environmental law, planning, and establishment of environmental parameters, while ensuring the conservation of biodiversity and sustainability of restored ecosystems (LEWIS, op. cit.). In areas of mangrove, both reforestation and the impact assessment has become often exhaustive, in terms of materials to be used as well as by the working group, since the environment imposes temporary restrictions on access, mainly because of being subject to the tides.
The research presented in this work was developed in saltworks located in the northern coast of Rio Grande do Norte (Brazil) state, having as main objective the identification of degraded mangrove areas in its vicinity.

The location of these companies throughout the estuaries of the main rivers is due to the conjuncture of environmental factors like semi-arid climate, high temperatures (> 28 ° C), low precipitation (<800 mm / year) and high evaporation rates, with water availability of estuary. The major solar saltworks are installed in country coast, being responsible by 95% of the produced and exported marine salt.

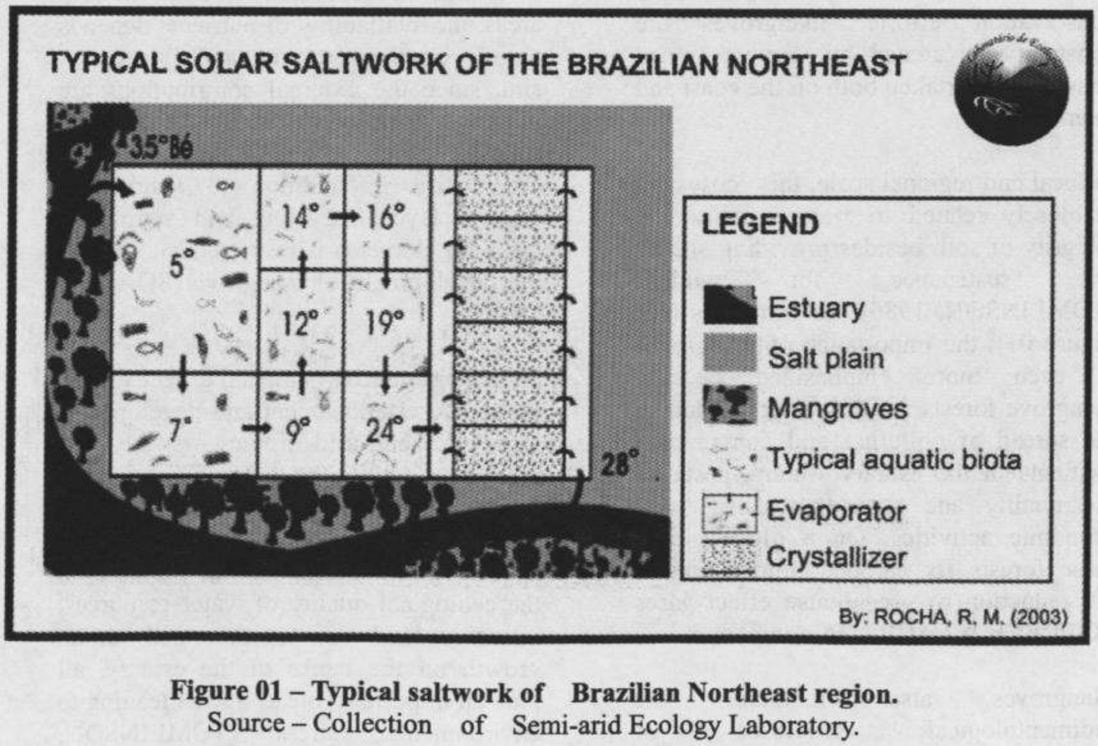

Figure 01 – Typical saltwork of Brazilian Northeast region.
Source – Collection of Semi-arid Ecology Laboratory.

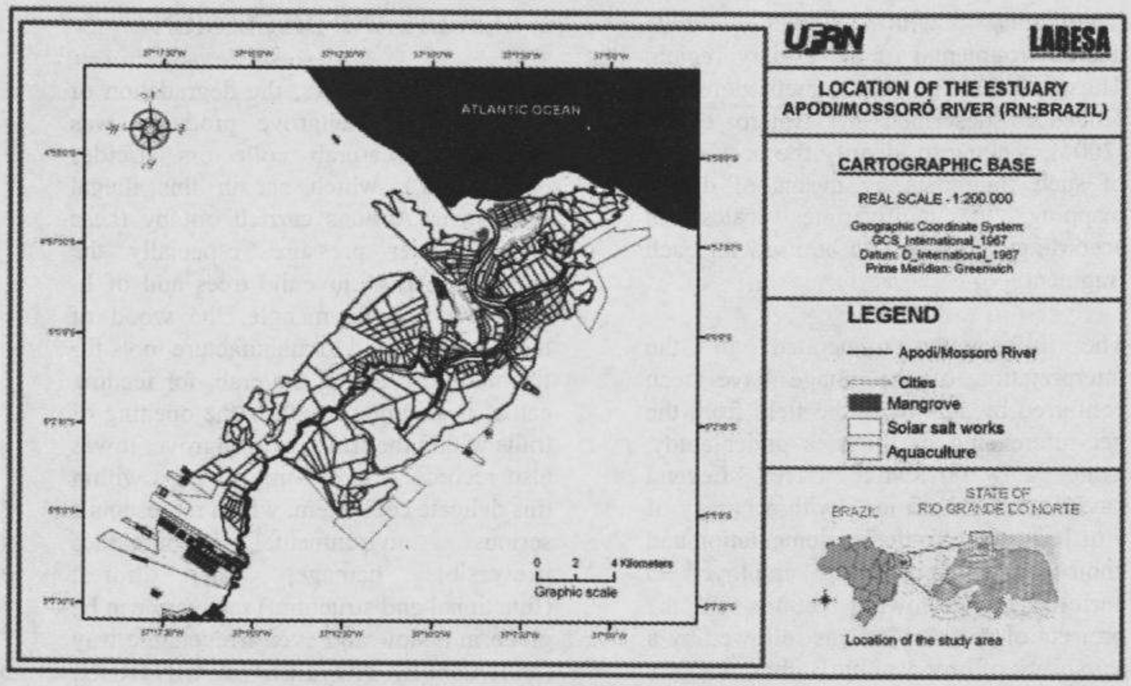

Figure 02 – Intensive occupation of estuary borders of Apodi/Mossoró river for solar saltworks (RN – BRAZIL).

Source – Collection of Semi-arid Ecology Laboratory.

2. MATERIAL AND METHODS

The northern coast of Rio Grande do Norte-Brazil state, where saltwork businesses are located, is between 4 ° 56 '/ 5 ° 09' south latitude and 37 ° 09 '/ 37 ° 17' west longitude (see Figure 01). As adopted methods of survey, the first stage in the bibliographical revision about the ecology of saltworks and the occurrence of those ecosystems in Brazil was carried out.

Considering this discontinuous nature of vegetation, as well as its structure only along a narrow strip (<30 meters), is chosen method of Quadrant Centric (SCHAEFFER-NOVELLI & CINTRON, 1986, MITCHELL, 2007) for structural analysis of vegetation. This method is to draw a transect along the strip of vegetation to be examined, with systematic stops for the marking of analysis points. This method provided a preliminary systematic knowledge about the evolution and development stage of mangrove vegetation of the area examined.

In the sampling sites, the botanical material was collected and identified. Sediment samples in mangrove were also collected by a dredger, which were analyzed for particle size and concentration of macro and micronutrients.

The assembly and preparation of digital map material was made from images of satellites: IKONOS II (collected in 2002), QuickBird (collected in 2006) and CBERS (2008). These images went through a Digital Image processing using the software ArcGIS 9.2 and Er-Mapper 6.4. These resources were used to identify possible degraded areas in the fragments of analyzed mangroves, using the digital photograph as an additional resource and appliance Global Positioning System (GPS) for the georeferencing of the sample areas.

Regarding the mapping and production of cartographic products to support the hypotheses raised in this paper, the strategy developed aims at identifying, analyzing and characterizing the occurrence and distribution of mangrove vegetation along the estuary, is seeking integration with other units geo-environmental of the estuary region. Thus, following the methodological procedure described by Amaro et al. (2004), seeking to identify the occurrence of such fragments by means of digital mapping in multivariate scales in according to analysis to be used for each fragment.

The information generated in the interpretation of the image have been conferred by surveying the field from the geo-referencing of the area under study, using a GARMIN ETrex Legend navigation GPS device , with accuracy of 7 to 10 meters. To the implementation and choice of methods to be employed to perform the following actions on the projects of recovery, it was followed by a suitability of proposal by Barbosa (2006), taking the peculiar characteristics of the environment into consideration to be recovered.

The field and laboratory works occurred during the years 2007 and 2008, based on changes in the tidal environment studied, to identify the influence area of same about the mangrove vegetation component, as well as human actions and practices in the area. A vegetal component analysis was also performed from the estuary with the aid of a boat, for the geo-referencing of areas devastated by possible boats that on site and other anthropogenic impacts to be identified. As additional resources and for further analysis, it was made use of digital photography.

This procedure was complemented with geo-referenced data and the digital image processing of multispectral remote sensing of high satellite IKONOS II resolution, obtained in the years from 2000 to 2002, Quick Bird in 2006 and CBERS 2008. The multispectral digital images of the high-resolution satellites used in mapping were supported for land control and improvement for the official products of National Mapping, including the topographic letters topographic of SUDENE, on the scale of 1:50,000 and 1:100,000 and letters in the collection of the Semi-Arid Ecology Laboratory of Universidade Federal do Rio Grande do Norte.

3. RESULTS AND DISCUSSION

From the field works, the degradation of environmental mangrove produced was found by Uça-crab collectors (Ucides cordatus L.), which act in this illegal ecosystem. Actions carried out by these people under pressure, especially the cutting down of juvenile trees and of L. racemosa and R. mangle, the wood of these trees is used to manufacture tools for fishing and catching the crab, for feeding cattle, in addition to allow the opening of trails within the fringe of mangrove. It was also recorded the opening of gaps within this delicate ecosystem, which represents a serious environmental, sometimes irreversible damage, where forest (functional and structural) recovery can be given in a slow and even irreversible way (SCHAEFFER-NOVELLI & CINTRÓN, 1986; MAIA et. al., 2005).

The examined area was classified within the unit geo-environmental as river-estuarine Flood Plain in order to characterize it. This compartment occurs along the estuary where forms from flat to gently sloping surfaces, few meters above the average level of river or estuarine water, flooding in times of floods and syzygy tides (AMARO, 2004; SILVA, 2004). The origin of this plain is linked to the old areas of estuarine tidal flat, currently subject to the river dynamics and channel overflow during floods.

These areas have low topographic gradient near the coast, with low slope toward the sea and / or main drainage channels, being characterized as mixed area covered during the flood tides and found out during the low water. Such a sedimentary environment is often cut by markedly curvilinear tidal channels.

The area studied has presented a multiplicity of environments, whose description can be given in a way that leaving from the river-sea plains toward the continent, terraces are common, horizontal or slightly inclined estuarine areas, with altitude from 0 to 2 meters on the level of water. These terraces, the edges of existing beds and / or inside in the form of islands, are traces of land accumulation of estuarine ancient plains in higher levels, mainly characterized by alluvial deposits, especially deposits occurring in periods of extensive flooding (DUKE et. al., 1998; SCHAEFFER-NOVELLI, 2005).

In terms of soil and sedimentological characterization, on the soil of the estuarine region, above the portion of the area of and inter low tide, type "SK1" is found in low areas (cultivated and flooding plains), influenced by the sea between the prevailing altitudes of about 2 to 3 meters. This soil type shows the presence of crystallized salt surface crusts in the annual drought periods, and consist of clayey-sandy sediments not consolidated Holocene (AMARO, 2004; SILVA, 2004).

According to field observations, these plains are identified situations of extreme stress for typical mangrove vegetation, with the occurrence of parts classified as hyper saline plains (apicuns or salt flats). These environments are topographically higher than the mangrove forest, where evaporation promotes the accumulation of salts in the sediment and soil temperature may reach values above 40 ° C (DUKE et. al., 1998; SCHAEFFER-NOVELLI, 2005; MEDINA et. al., 2001).

From the study data, the vegetation in the area in question was characterized as a swamp strip (fringe-like mangrove) with the occurrence of discontinuous and well developed vegetation stretches, followed by stretches with vegetation impacted and / or regeneration.

Regarding the occupation process of the vegetation in the study area, is that this process can occur through a number of factors, which are related to the rate of propagulum dispersal, as well as a number of physical factors of environment. This can be seen by the fact that some species tolerate better than others variations in water, soil and climate conditions, as well as the long-term changes, whether natural or anthropogenic ones(KATHIRESAN & BINGHAM, 2001).

Therefore, the structure of the mangrove vegetation of an area and its biodiversity vary in time and space. Besides, it is worth highlighting that the mangrove forests occur in a variety of structural types, with different specific compositions and levels of diversity. Taking the vegetation structure and organization into consideration seen in many areas, it is suggested the artificial population of young specimens with artificial Rhizophora mangle, Laguncularia racemosa and Avicennia germinans, since the formation of a mixed forest is to ensure a sustainability of vegetation as a maintaining element of estuarine biological basis.

The need for greater diversity of species both the environment of saline and in associated ecosystems is also reflected in the potential risk of vegetation death due to some disturbance (human or natural), since the area is now occupied by a predominantly monotypic vegetation, it is potentially sensitive to such disturbances.

In order to recover degraded areas identified from the integrated analysis of the area and from the impacts identified, it was proposed the following strategy for the management and recovery of the same:

1. Characterization of degraded areas: type of degradation, the substrate condition, vegetation cover and mechanisms for the supply of propagulums.

2. Survey of vegetation and soil and use in the area.

3. Identification and registration of human aggression that threaten the environmental preservation.

4. Definition of revegetation systems (establishment, enrichment, and / or natural regeneration).

5. Topographic reconstruction and / or topographic re-endearment (1:10.000) for the disciplining of areas and actions to be performed (adapted by Lewis, 2005);

6. Selecting of the system restoration (which may be: implementation of system, enhancement system, or only natural regeneration of little disturbed systems,

among others).

7. Planning and selection of priority areas for intervention, from the planting of seedlings, is seeking to imitate the distribution of field species (number, shape and location).

Maintenance, monitoring and evaluation of actions implemented.

Environmental education campaigns in urban areas located near the environmental studied.

Monitoring and evaluation of the recovery process will occur in a continued (quarterly) way, with pruning activities, pest and disease control, presentation of technical reports of systematic monitoring. Based on field observations of flora and subsequent identification in the laboratory, there are marginal areas of the estuary that have a high potential for their recovery, provided that the appropriate interventions are made on the environmental restoration of properties in the area.

4. CONCLUSION

The implementation of actions for recovery of impacted areas in salt ecosystems brings to light the obvious need to promote environmental restoration with specific diversity for each unit of habitat (area between tide and saltflat, for example). Moreover, the appropriate technique use and each "situation" shows the need to expand the studies on several fronts, including better knowledge of the issues involved in natural regeneration, use of endemic and / or succession species, the eco-physiological behavior of each species and technology of seed and seedling production.

According to the identified scenario, it was verified a strong pressure on the examined areas, as a result of its improper use by local human populations over an entire historical datum. Furthermore, it should be taken into account the high potential for the establishment of conservation areas in saline environments, and associated ecosystems, allowing the perpetuation of species of local biota, with minimal interference from human activities.

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