

**USE OF ENVIRONMENTAL SYSTEMS FOR ANALYSIS IN THE CHANGING  
LANDSCAPE OF THE PACOTI RIVER APA IN THE YEARS 1968-2023**

**USO DOS SISTEMAS AMBIENTAIS PARA ANÁLISE NA MUDANÇA DA  
PAISAGEM DA APA DO RIO PACOTI NOS ANOS DE 1968-2023**

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**RESUMO**

A Área de Proteção Ambiental do Rio Pacoti abriga diversos ambientes traduzidos em uma paisagem exuberante. A beleza cênica proporcionada pela mistura dos ambientes dunares, com estuário e demais sistemas encontrados, vêm sofrendo com pressões antrópicas de especulação imobiliária e do setor turístico. Embora seja uma Unidade de Conservação a área encontra-se com uma elevada ocupação humana. Diante disso, foi analisada, através dos sistemas ambientais, como a paisagem foi modificada do ano de 1968 para o ano de 2023. A teoria dos sistemas ambientais organiza a paisagem setorizando os ambientes a partir dos fluxos de matéria e energia. As análises realizadas pela equipe do projeto “Planejamento, Criação e Implementação de Unidades de Conservação no Ceará: subsídios científicos para políticas públicas ambientais” do Programa Cientista-Chefe Meio Ambiente, mostraram que a porcentagem da área das dunas móveis decaiu ao passo que a de dunas fixas aumentou, enquanto o tabuleiro pré-litorâneo manteve estabilidade com o passar dos anos. Ainda que bastante modificada, as análises mostraram, um aumento das planícies fluviomarinhas com manguezais, sugerindo que a criação da UC auxiliou na recuperação desse importante ambiente, dessa forma evidencia-se a importância da criação de espaços protegidos, como forma de conservação da paisagem, auxiliando na sustentabilidade.

**Palavras-chave:** Proteção Ambiental; Sistemas ambientais; Pacoti

**ABSTRACT**

The Environmental Protection Area of Rio Pacoti encompasses diverse environments translated into a lush landscape. The scenic beauty, created by the combination of dune

environments, estuaries, and other systems, has been facing anthropogenic pressures from real estate speculation and the tourism sector. Despite being a Conservation Unit, the area experiences high human occupation. Considering this, an analysis was conducted through environmental systems to examine how the landscape has changed from 1968 to 2023. The theory of environmental systems organizes the landscape by segmenting environments based on flows of matter and energy. Analyses conducted by the team of the project "Planning, Creation, and Implementation of Conservation Units in Ceará: Scientific Subsidies for Environmental Public Policies" from the Chief Scientist Environment Program showed that the percentage of mobile dune areas decreased, while fixed dunes increased, and the pre-littoral tableland remained stable over the years. Despite significant modifications, the analyses indicated an increase in river-marine plains with mangroves, suggesting that the creation of the Conservation Unit contributed to the recovery of this important environment. Thus, the importance of establishing protected areas is highlighted as a means of landscape conservation, aiding in sustainability efforts.

**Keywords:** Environmental Protection; Environmental systems; package

## INTRODUCTION

Among the various coastal areas in northeastern Brazil, the estuary of the Pacoti River has been suffering from intense environmental impacts due to negative anthropogenic interventions, being occupied in a disorderly manner and with intense real estate speculation activities, including the construction of vacation homes, gated communities, and tourism-related infrastructure (GORAYEB; SILVA; MEIRELES, 2005; SEMACE, 2010; LIMA, et al., 2019), despite being a State Conservation Unit. Conservation Units (UCs) are areas protected by law (Law No. 9.985/2000) and are part of the list of instruments adopted by the National Environmental Policy (PNMA – Law No. 6.938/1981) in pursuit of sustainability.

The theory of environmental systems exposes the classification of ecodynamic units, organizing and sectorizing phenomena based on the flows of matter and energy (TRICART, 1977). Such organization allows for an analysis of landscape aspects regarding changes in the environment, making it possible to calculate changes that have occurred over time in areas, and thus enabling a better understanding of the factors that caused such changes.

Thus, this analysis aims to understand how the landscape of the studied area was modified from 1968 to 2023, based on environmental systems, by the team of the project "Planning, Creation, and Implementation of Conservation Units in Ceará: scientific support for environmental public policies" integrated into the Chief Scientist Environment Program of the Secretariat of Environment and Climate Change (SEMA) of Ceará, which served

as a technical basis in the production of the Management Plan of the APA of the Pacoti River.

## **MATERIALS AND METHODS**

The study area of this analysis is the APA of the Pacoti River, located in the estuary of the Pacoti River in the state of Ceará. It is a UC of Sustainable Use and is under great pressure from the real estate sector due to its location and scenic beauty. Despite being an environment protected by law, it has suffered from disorderly occupation and the progressive process of urbanization (GORAYEB; SILVA; MEIRELES, 2005). It is an area composed of fragile and unstable environments.

The methodology used is based on the theory of environmental systems diffused by various authors (BERTALANFFY, 1973; TRICART, 1977; BERTRAND, 2004) who, although working with environmental systems on different scales and approaches, are concerned with studying the interaction between the variables that make up space and anthropogenic activities. In this sense, the application of this methodology allows for a holistic view of land use and landscape modification.

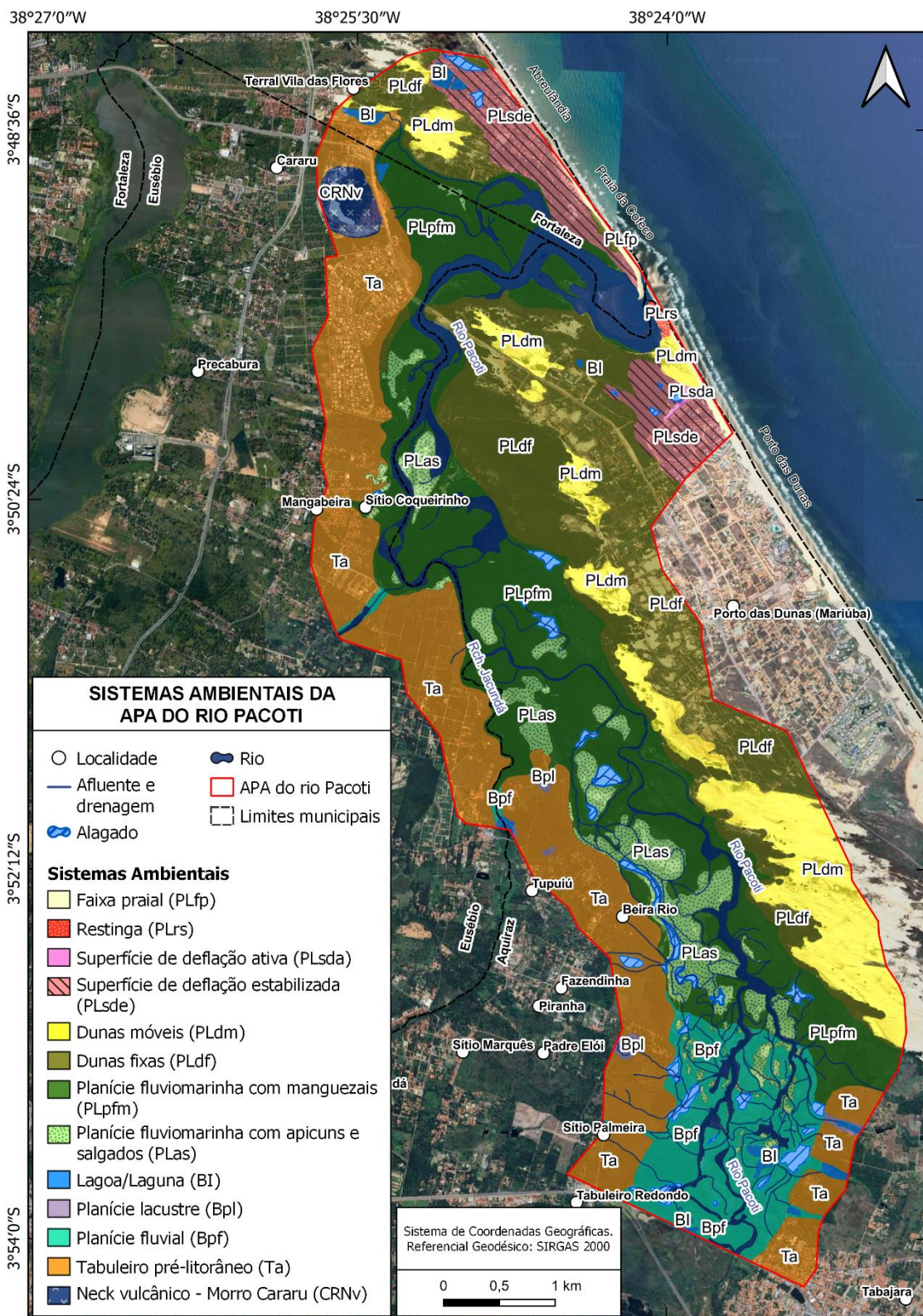
For the construction of maps and other data processing, the free software QGIS 3.22 was used. The mapping of environmental systems in 1968 was done through the digitization and interpretation of a mosaic of aerial images from 1968, analyzing primarily the textures and characteristics of the environment. For the map of environmental systems in 2023, the Coastal Ecological-Economic Zoning (ZEEC, 2022) was used as a base, making the necessary adaptations based on field visits and satellite images used (SPOT 6/7, 2 meters (NAOMI), June to July 2019; Google, ©2022 CNES/Airbus, Landsat/Copernicus, Maxar Technologies, US Geological Survey). From the analysis, it was possible to perceive the visual characteristics of each system.

## **RESULTS AND DISCUSSION**

With the application of the described methodology, two distinct maps were produced: the first presents the environmental systems of 2023 (Figure 1) and the second the environmental systems of 1968 (Figure 2). With the data in hand, it was possible to analyze the changes that occurred over the years. The environmental systems found in the area include: Beach Strip, Restinga, Active Deflation Surface, Stabilized Deflation Surface, Mobile Dunes, Fixed Dunes, Fluvial-Marine Plain with mangroves, Fluvial-

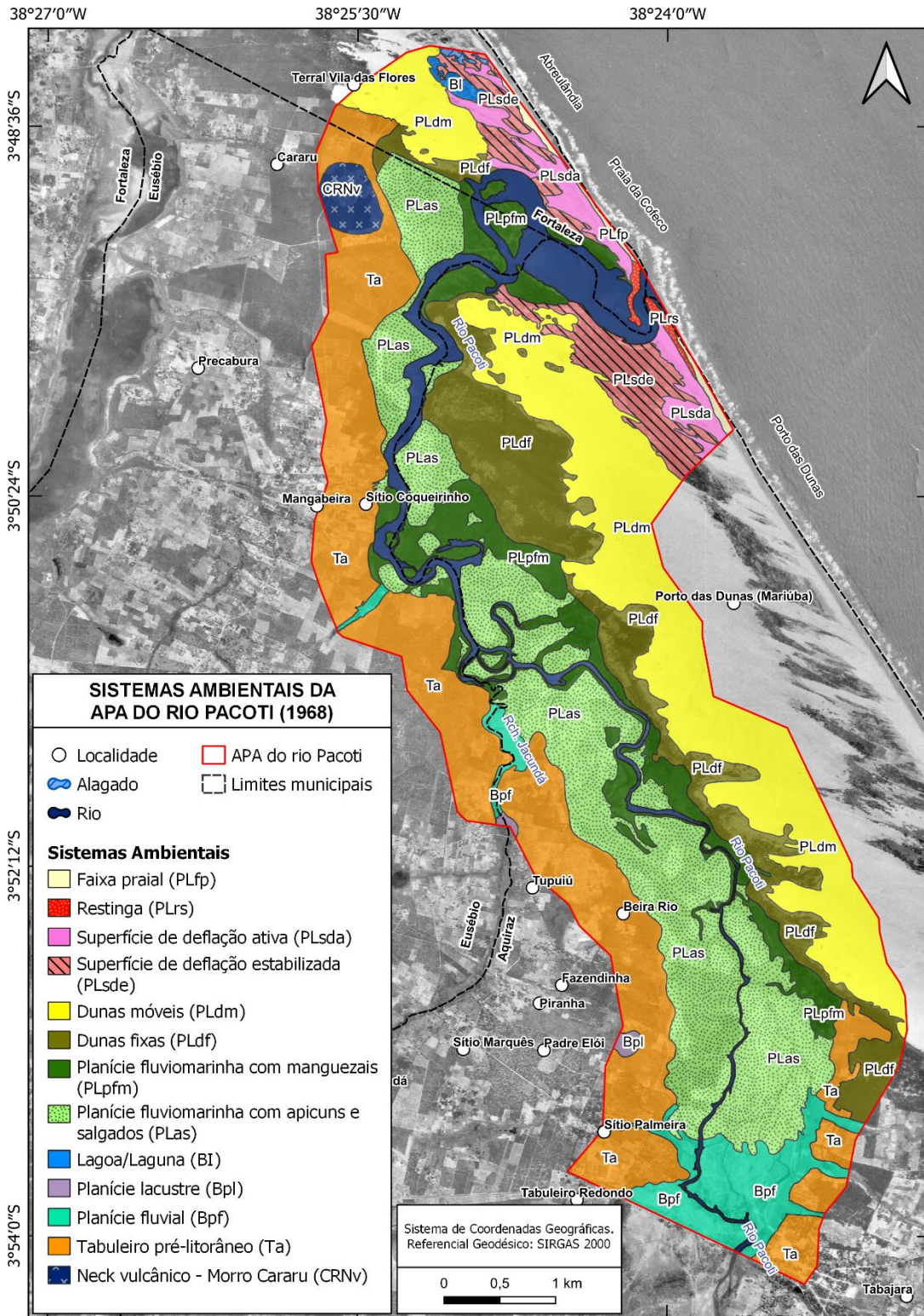
Marine Plain with apicuns and salt marshes, Wetlands, Lakes/Lagoons, Lacustrine Plain, Fluvial Plain, Pre-Littoral Plateaus, and Volcanic Necks.

**Figure 1** - Map of Environmental Systems for the year 2023.



Elaboration: Authors (2024), based on the APA Rio Pacoti Participant Guide (2023).

Figure 2 – Map of Environmental Systems in 1968.



**Elaboration:** Authors (2024), based on the Participant Guide of the APA of Rio Pacoti (2023) and Master Plans of Eusébio (2008), Fortaleza (2009) and Aquiraz.

Table 1 shows the areas for each environmental system, considering the different years of analysis. It is possible to observe that the area of Fixed Dunes increased from 324.86 ha in 1968 to 574.63 ha in 2023, accounting for a 9% increase in its total area. This increase may be correlated with the decrease in Mobile Dunes, which accounted for an area of 512.70 ha in 1968 and decreased to 254.77 ha in 2023, a decrease of 9%, suggesting that a portion of the mobile dunes underwent the process of stabilization over the years.

The pre-littoral plateau did not show significant changes in its area, reflecting its stability compared to the other systems. With the creation of Conservation Units in the region, such as the APA itself and the Ecological Corridor of the Pacoti River, created in 2000 through Decree No. 25,777, of February 15, 2000, some potentially polluting and impactful activities were discouraged, considering the penalties provided by law. This may be one of the causes of the 14% increase in the area of Fluvial-Marine Plain with mangroves.

**Table 1** – Description of changes in the areas of environmental systems from 1968 and 2023.

ENVIRONMENTAL SYSTEM	PERÍODO				Variação %
	1968		2023		
	ha	%	ha	%	
Flooded	2,61	0,09	45,17	2	+ 42,56%
Residual ridges and volcanic necks	27,72	0,95	27,72	1	+ 0,05%
Fixed Dunes	324,86	11	574,63	20	+ 9%
Mobile Dunes	512,70	18	254,67	9	- 9%
Beach Strip	13,27	0,46	13,08	0,45	- 0,01%
Lagoon/Laguna	7,43	0,25	22,24	1	+ 0,75%
River Plain	138,25	5	198,40	7	+ 2%
Fluviomarine Plain with apicuns and saltfish	639,28	22	175,19	6	- 16%
Fluviomarine Plain with mangroves	246,35	8	631,05	22	+ 14%
Lake Plain	5,38	0,18	8,43	0,29	+ 0,11%
Restinga	8,46	0,29	2,70	0,09	- 0,20%
River	171,82	6	199,48	6,84	+ 0,84%
Active deflation surface	63,91	2	2,92	0,10	- 1,90%
Stabilized deflation surface	121,40	4	130,23	4,46	+ 0,46%
Pre-coastal board	633,48	22	630,99	22	0%

**Elaboration:** Authors (2024), based on the APA Rio Pacoti Participant Guide (2023). **CONCLUSIONS**

From the presented results, it is evident that understanding the organization and alteration of the geographical space is directly associated with human activities over the years. However, there is a need for further research and detailed analysis of changes in land use in the area for a better understanding of anthropogenic influences on environmental systems. The creation of protected areas is highlighted as effective legal instruments in the maintenance, regeneration, and conservation of certain environments. Similarly, urban occupation and real estate speculation aimed at the tourism sector are determining factors in the decrease of important environments.

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### **ACKNOWLEDGMENTS**

We would like to thank the Environmental Scientist Chief Program of the Government of the State of Ceará, the Cearense Foundation for Support to Scientific and Technological Development (Funcap - Process No. 07321726/2023), the Secretary of the Environment (SEMA), and the Federal University of Ceará (UFC).

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