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Lençóis Maranhenses PARNA and APA of the Mouth of the Preguiças River: Spatial-temporal Analysis of the Dynamics of Land Use and COVER (1985 - 2022)

Parna dos Lençóis Maranhenses e APA da Foz do Rio das Preguiças: Análise Espaço-temporal da Dinâmica do Uso e Cobertura do Solo (1985 - 2022)

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Abstract: In recent years, there has been an increasing interest in analyzed the spatiotemporal dynamics of land use and occupation in the Lençóis Maranhenses National Park and Foz do Rio das Preguiças Environmental Protection Area Conservation Units. The free QGIS software and classified data from the MapBiomas platform were used for the period 1985 to 2022. The results revealed a 3.18% reduction in natural areas, an increase in non-vegetated areas and areas used for agricultural purposes, as well as a decrease in water bodies and non-forested natural formations. Around eighty-eight species were identified as declining in population: 47 vulnerable, 27 endangered, and 19 critically endangered. This evidence reinforces the urgency of interdisciplinary studies to understand and mitigate the impacts of anthropization and ensure the preservation of biodiversity and the biosphere.

Keywords: Geosciences; Protected Area; Lan use land change.

Resumo: Neste estudo, foi analisada a dinâmica espaço-temporal do uso e ocupação do solo nas Unidades de Conservação Parque Nacional dos Lençóis Maranhenses e Área de Proteção Ambiental da Foz do Rio das Preguiças. Para isso, utilizou-se o software livre QGIS e dados classificados da plataforma MapBiomas, considerando o intervalo entre 1985 e 2022. Os resultados revelaram uma redução de 3,18% das áreas naturais, aumento de áreas não vegetadas e de uso agropecuário, além da diminuição de corpos d'água e formações naturais não florestais. Identificaram-se 88 espécies com tendência de declínio populacional: 47 vulneráveis, 27 em perigo e 19 criticamente ameaçadas. Tais evidências reforçam a urgência de estudos interdisciplinares para compreender e mitigar os impactos da antropização e garantir a preservação da biodiversidade e da biosfera.

Palavras-chave: Geociências; Unidade de Conservação; Uso e cobertura da Terra.

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1. Introduction

The Lençóis Maranhenses National Park and the Preguiças River Mouth Environmental Protection Area (APA) constitute a coastal mosaic of high ecological and socio-environmental relevance in the state of Maranhão, characterized by mobile dunes, interconnected lagoons, lagoon systems, and extensive mangroves. The Lençóis Maranhenses National Park (PNLM), created in 1981, covers more than 150,000 hectares and protects unique dune formations in the Brazilian coastal context, while also harboring landscape, hydrological, and biodiversity values that justify its conservation (ICMBio, 2022; MMA, 2021).

The APA da Foz do Rio das Preguiças - a sustainable use conservation unit created by state decree in 1991 - serves as a buffer zone and regulatory space for anthropic activities at the river mouth and adjacent lagoon areas, seeking to reconcile human use with the preservation of local natural resources. The delimitation and management instruments of the APA are essential for reducing pressures on coastal ecosystems and maintaining connectivity between protected areas and occupied territories (SEMA-MA, 2022; ISA, 2023).

In recent decades, the dynamics of land use and cover on the Maranhão coast have been marked by significant transformations - loss of native vegetation, changes in mangrove areas, and expansion of anthropogenic uses - influenced by direct factors (land use, tourism, fishing, and infrastructure) and indirect factors (climate change, hydrological variations). Regional studies have identified patterns of gain and loss in mangroves around the Lençóis Maranhenses, highlighting both recovering areas and areas under anthropogenic pressure (Souza-Filho et al., 2021; Ferreira et al., 2022).

The availability of land cover time series (1985–2022) by the MapBiomas project made detailed multitemporal analysis of the evolution of use and cover classes viable at the protected unit scale, allowing the quantification of annual transitions, long-term trends, and use mosaics surrounding conservation areas (MapBiomas, 2023a; MapBiomas, 2023b).

The combining satellite image time series analysis, classification techniques, class transition analysis, and spatial evaluation of the influence areas of conservation units allows the identification of trends, critical land cover conversion points, and possible vectors of anthropogenic alteration. Furthermore, integrating local data and studies on climate and land use contributes to interpreting the causes and consequences of the observed changes in the Maranhão coastal landscape (Andrade et al., 2021; Nascimento; Pereira, 2022).

Given this context, this study proposes a spatiotemporal analysis of the land use and cover dynamics in the Lençóis Maranhenses National Park and the APA of the Mouth of the Preguiças River in the 1985–2022 period, with the objectives of: (i) quantifying alterations in the main cover classes; (ii) mapping spatial patterns of gain and loss in sensitive areas; and (iii) evaluating the relative effectiveness of the conservation units and buffer zones against anthropogenic pressures (ICMBio, 2022; MapBiomas, 2023a).

2. Methodology

2.1 Study area

Maranhão is one of Brazil's 27 federative units, located in the Northeast Region. The study area comprises the Lençóis Maranhenses National Park (Federal Conservation Unit - Full Protection) and the Preguiças River Mouth APA - Small Lençóis - Adjacent Lagoon Region (State Conservation Unit - Sustainable Use), characterized by a biogeographic mosaic of vegetation typologies forming gradients between fields, savannas, and forests. Figure 1 shows the location of these conservation units.

The Lençóis Maranhenses National Park is located on the semi-arid coast of northern Maranhão (02°19'S to 02°45'S and 42°44' to 43°29'W), about 370 km from the capital São Luís. With 155,000 hectares, the park includes dunes, restinga, and mangroves, with 90,000 hectares covered by free dunes and interdunal lagoons. It spans the municipalities of Barreirinhas (44.86%), Santo Amaro do Maranhão (42.15%), and Primeira Cruz (6.89%). The park was created on June 2, 1981, as a result of the RADAMBRASIL project's efforts to address deficits in the 1970s conservation unit system.

The Preguiças River Mouth APA was created by Decree No. 11,899 on June 1, 1991, aiming to preserve various vegetation configurations, including mangroves, dunes, restingas, buriti groves, lagoons, and riparian forests, essential for local and regional fauna and flora, as well as rare species. Follow the figure 1, about location of the study area for the two Conservation Units.

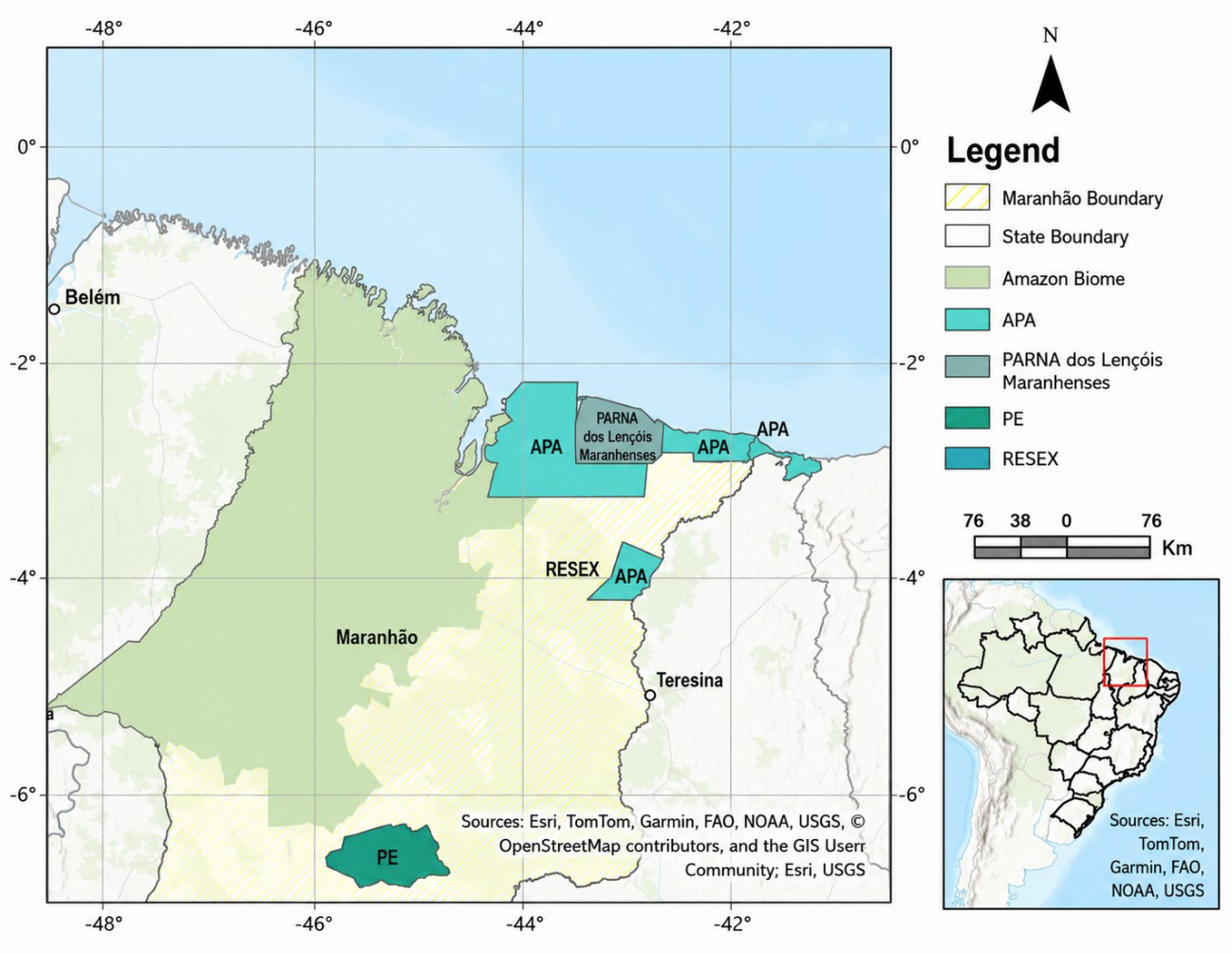

Figure 1 – Location of the study area for the two Conservation Units.
Source: Authors (2026).

2.2 Data Acquisition, Procedures, and Research Tools

This study used data from MapBiomas Collection 8.0, which provides pixel-by-pixel classification of images captured by Landsat satellites under the U.S. government's Earth monitoring program. Data collection was performed via downloads using the MapBiomas user tool, operating as a script on the Google Earth Engine platform. Four raster images of the study area were analyzed, starting in 1985, followed by 1995, 2010, and 2022. Multitemporal analysis was conducted using free QGIS software (version 3.28), beginning with MapBiomas classified data reprojected to the SIRGAS 2000 system.

Images were reclassified to distinguish natural and anthropic formations according to MapBiomas Collection 8.0, enabling detailed visualization of classes for creating thematic maps with representative layouts. Areas corresponding to classes of interest were calculated for each base year, allowing observation of vegetation and land occupation class evolution.

The images were reclassified to distinguish natural and anthropogenic formations, enabling a detailed visualization of the classes. Data were organized and processed in Microsoft Excel 365 (2023) to analyze area losses and gains. Species grouped in the 'Vulnerable', 'Endangered', and 'Critically Endangered' categories were searched for on the IUCN Red List of Threatened Species platform.

3. Results and Discussion

The visualization of land use and cover in the PARNA APA is presented in Figure 2, with dominant classes showing 44.61% forest formation, followed by natural formation at 10.23%; other classes are detailed in Table 1.

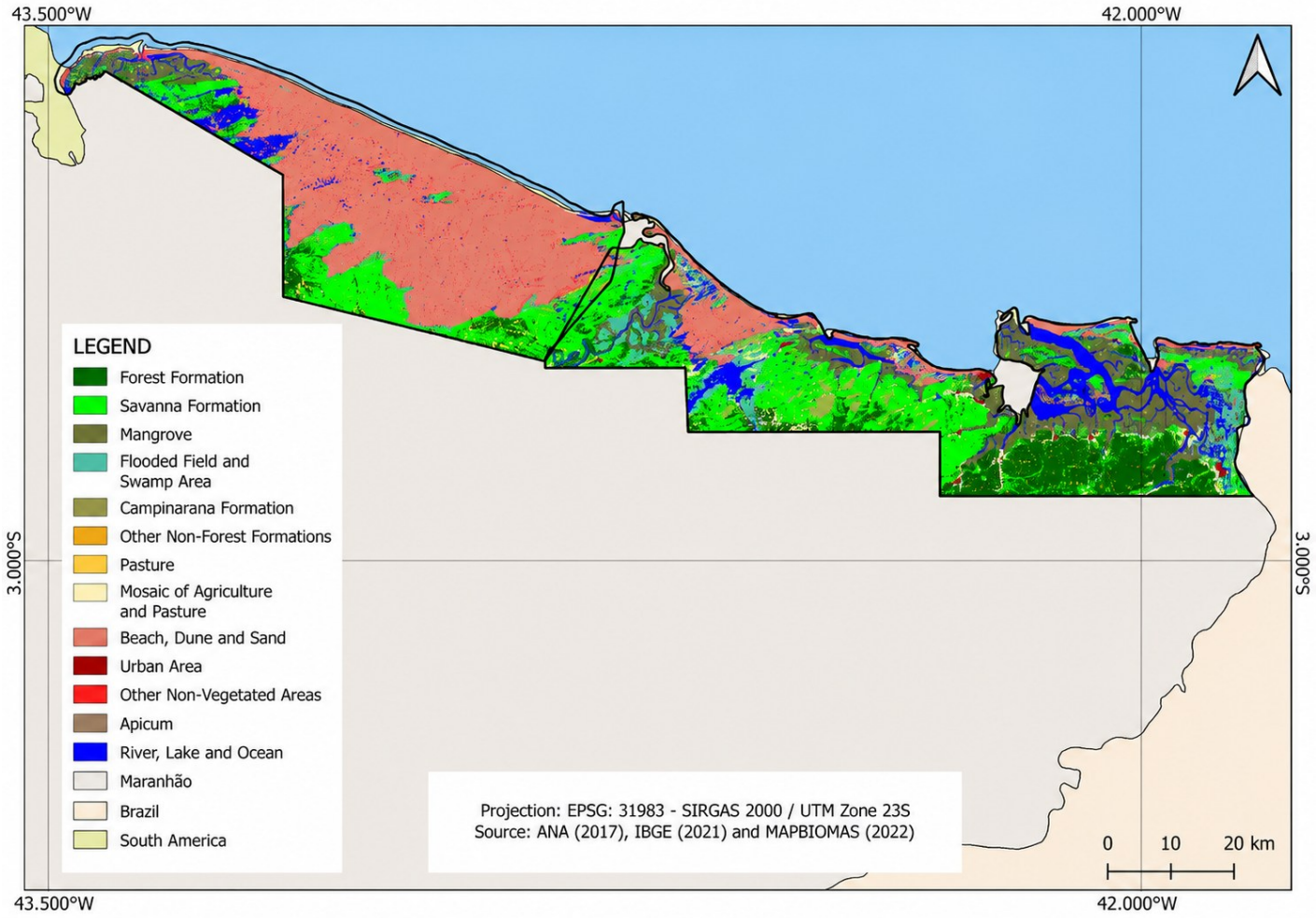

Figure 2 – Map of the total Conservation Units area in 1985.
Source: Authors (2026).

Table 1 – Land use and occupation classes for base year 1985.

Land Use and Occupation Classes	Total area in ha (1985)	Percentage of total area
Forest	155821 ha	44,61%
Non-Forest Natural Formation	35736 ha	10,23%
Agriculture/Livestock	7423 ha	2,12%
Non-Vegetated Area	113533 ha	32,50%
Water	36707 ha	10,51%
Unobserved	109 ha	0,03%

Source: MapBiomas (2025).

In 1985, anthropic presence in the Lençóis Maranhenses PARNA and Preguiças River Mouth APA was still discreet, with predominant forests, mangroves, dunes, and natural beaches. The largest areas were forests and natural formations (155,821 ha) and non-vegetated areas like beaches and dunes (113,533 ha), indicating low urban development and anthropic pressure at the time (ICMBIO, 2019; SARTOELLO; ALVES FILHO; SMALL, 2024).

Mangroves are rare ecosystems, representing a small fraction of global tropical forests, with Brazil holding some of the largest continuous areas. Their conservation is essential to mitigate negative biodiversity impacts (National Animal Defense Association—AND A, 2022) (ANDA, 2022), (MONTEIRO, 2011).

According to the IUCN Red List, the study area hosts 1,565 species, of which 19 are 'Critically Endangered,' 27 'Endangered,' and 47 'Vulnerable.' This study shows more species in 'Endangered' and 'Vulnerable' categories than Tyski et al. (2023), which reported 24 vulnerable and 6 endangered.

In the 'Vulnerable,' 'Endangered,' and 'Critically Endangered' IUCN categories, there is 1 species with stable population trend, 1 unknown, 2 increasing, and 88 decreasing. Protecting rare, endemic, and threatened species is crucial, with habitat conservation fundamental for natural capital maintenance (Tyski et al., 2023).

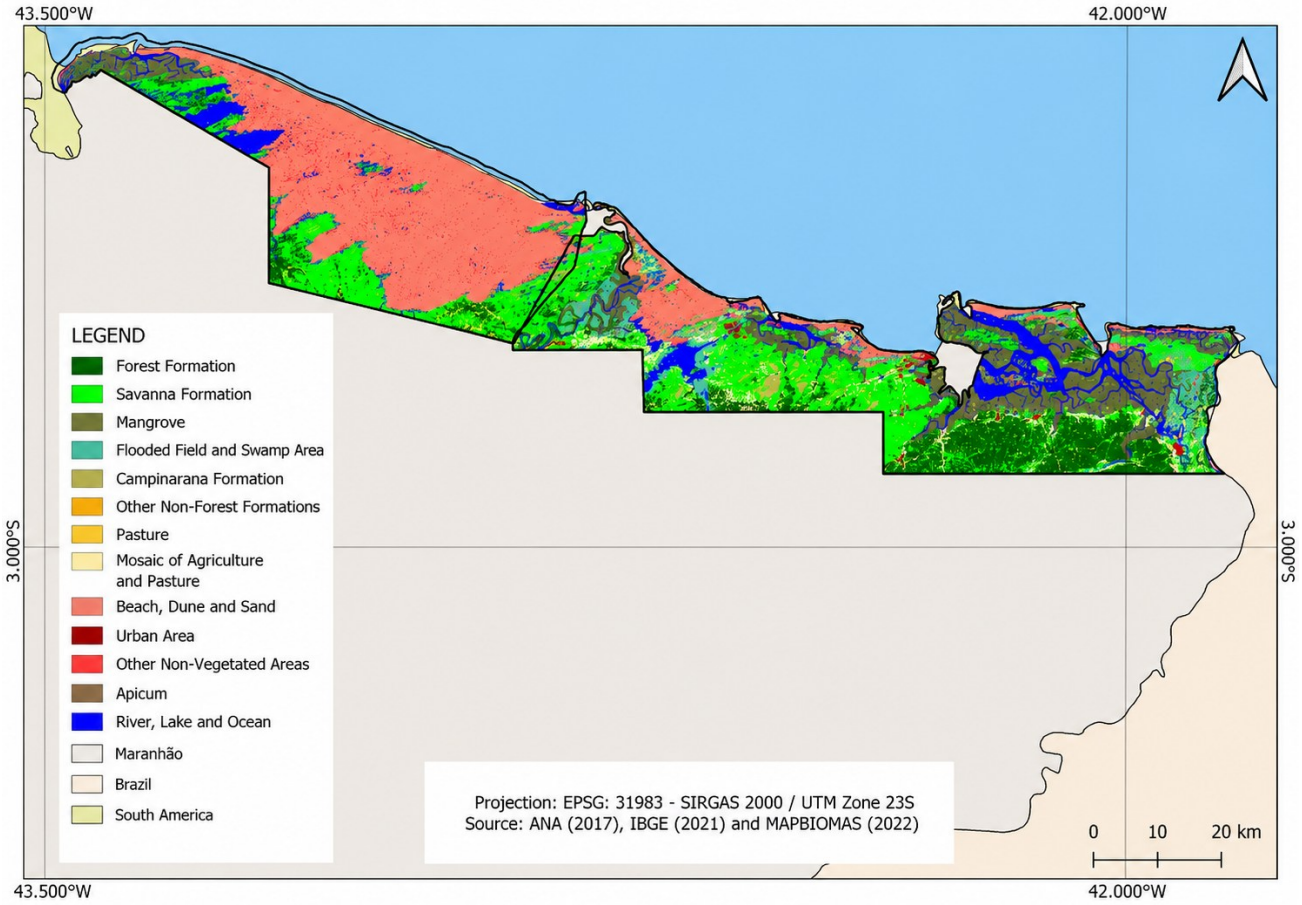

Figure 3 – Map of the total Conservation Units area in 1995.
Source: Authors (2026).

Table 2 – Areas in percentage for base years 1995.

Land Use and Occupation Classes	Total Area in ha (1995)	Percentage of Total Area
Forest	153037 ha	43,81%
Non-Forest Natural Formation	29657 ha	8,49%
Agriculture/Livestock	14158 ha	4,05%
Non-Vegetated Area	116708 ha	33,41%
Water	35706 ha	10,22%
Unobserved	62 ha	0,02%

Source: MapBiomas (2025).

Table 3 – Avaliable dinamic classes in 1990 and 1995.

Land Use and Occupation Class	Dinamic area percentage (1995)
Forest	-1,8%
Non-Forest Natural Formation	+0,22%
Agriculture/Livestock	+1,91%
Non-Vegetated Area	+0,46%
Water	-0,79%
Unobserved	0%

Source: MapBiomas (2025).

In 1995, the presence of anthropogenic agents increased, with the expansion of farming and infrastructure, along with growth in canopy areas, mangroves, and natural areas without vegetation. Pressures such as pollution, invasion of exotic species, and deforestation due to land conflicts were observed. Between 1990 and 1995, farming increased by 1.91% and non-vegetated areas by 0.46%, while forests decreased by 1.80% and water bodies by 0.79% (SILVA et al., 2023).

Table 4 – Dynamics Assessment of Increase/Decrease in Percentage for Natural and Anthropic Delimitation (1985-2005).

Classes	Total de area (hectares)				
	1985	1990	1995	2000	2005
Forest	155821	159330	153037	163224	162250
Non-Forest Natural Formation	35736	28890	29657	31746	32053
Agriculture/Livestock	7423	7492	14158	7217	7734
Non-Vegetated Area	113533	115100	116708	115964	117587
Water	36707	38450	35706	31103	29645
Unobserved	109	67	62	75	59

Source: MapBiomas (2025).

Table 5 – Dynamics Assessment of Increase/Decrease in Percentage for Natural and Anthropic Delimitation (1990-2005).

Dinamic areas				
	1990	1995	2000	2005
Forest	+1%	-1,8%	+2,92%	-0,28%
Non-Forest Natural Formation	-1,96%	+0,22%	+0,60%	+0,09%
Agriculture/Livestock	+0,02%	+1,91%	-1,98%	+0,14%
Non-Vegetated Area	+0,45%	+0,46%	-0,21%	+0,46%
Water	+0,50%	-0,79%	-1,32%	-0,41%
Unobserved	-0,01%	0%	0%	0%

Fonte: MapBiomas (2025).

Between 1985 and 2005, there was a continuous reduction in the water body class, while forest areas and non-forested natural formations saw some regeneration around the year 2000. The expansion of agriculture and livestock, often associated with the conversion of forest areas, has contributed to ecosystem fragmentation. In 1995 and 2005, the simultaneous reduction of forests and water bodies evidenced negative impacts from replacing native vegetation with pastures. In response to these pressures, Law No. 528/2005 prohibited soy cultivation to preserve the regional ecosystem (FREITAS, 2022; Amaral et al., 2020).

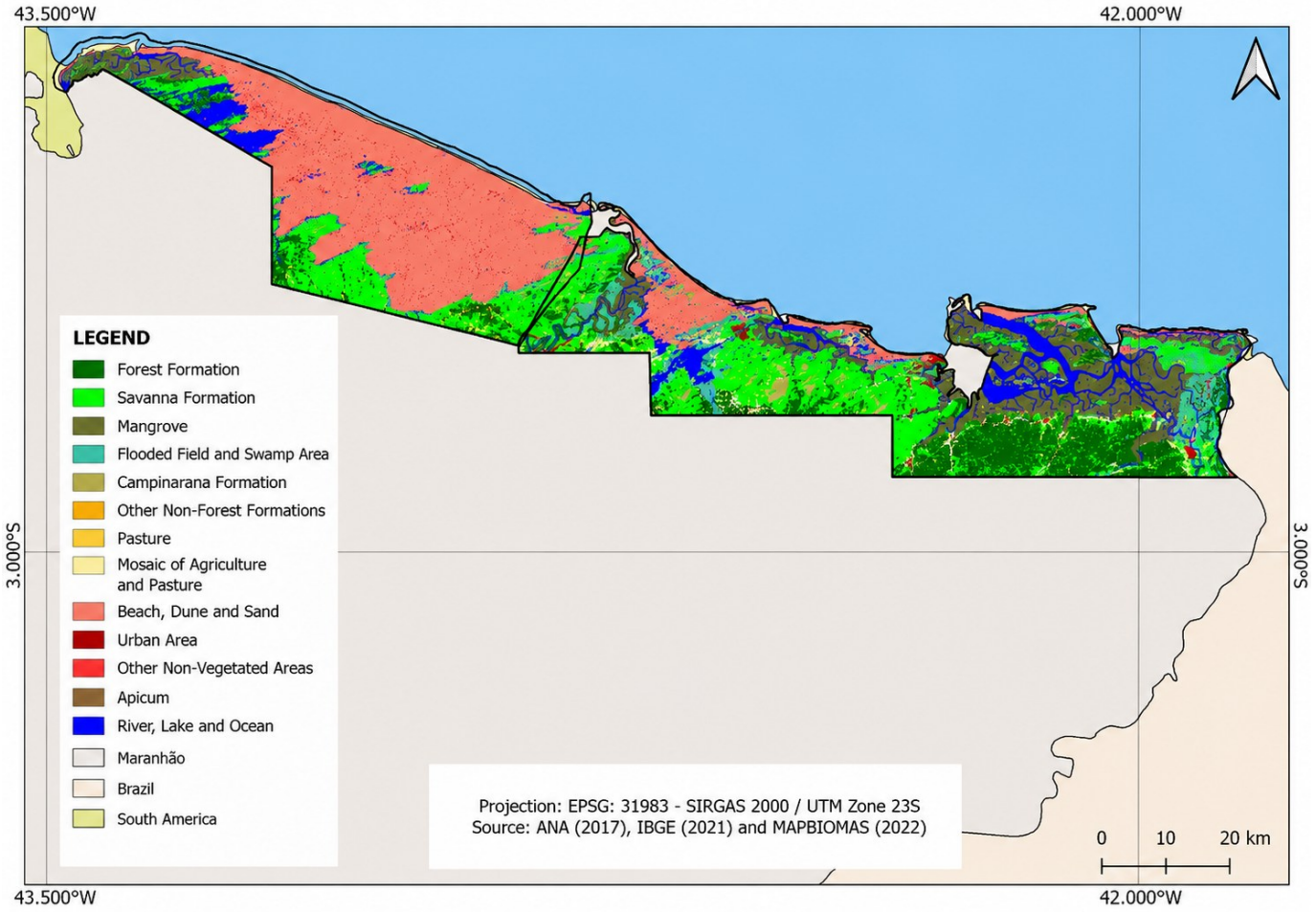

Figure 4 – Map of the total Conservation Units area in 2010.
Source: Authors (2026).

Table 6 – Land Use and Occupation Classes for Base Year 2010.

Land Use and Occupation Classes	Total de área em ha (2010)	Porcentagem da área total
Forest	162739 ha	46,59%
Non-Forest Natural Formation	31938 ha	9,14%
Agriculture/Livestock	7925 ha	2,27%
Non-Vegetated Area	117452 ha	33,62%
Water	29192 ha	8,36%
Unobserved	84 ha	0,02%

Source: MapBiomas (2025).

Table 7 – Dynamics Assessment of Increase/Decrease in Percentage for Natural and Anthropic Delimitation a 2010.

Land Use and Occupation Classes	Dinâmica da área em porcentagem (2010)
Forest	+0,14%
Non-Forest Natural Formation	-0,04%
Agriculture/Livestock	+0,06%
Non-Vegetated Area	-0,04%
Water	-0,13%
Unobserved	0%

Source: MapBiomas (2025).

In 2010, natural formations and non-vegetated areas predominated, with a slight increase in forest areas (+0.14%) and farming (+0.06%), while water bodies (-0.13%) and non-forested natural formations (-0.04%) decreased compared to 2005. Blind land use development not only increases the risk of landscape fragmentation but also destroys the ecological balance (JIANG et al., 2023).

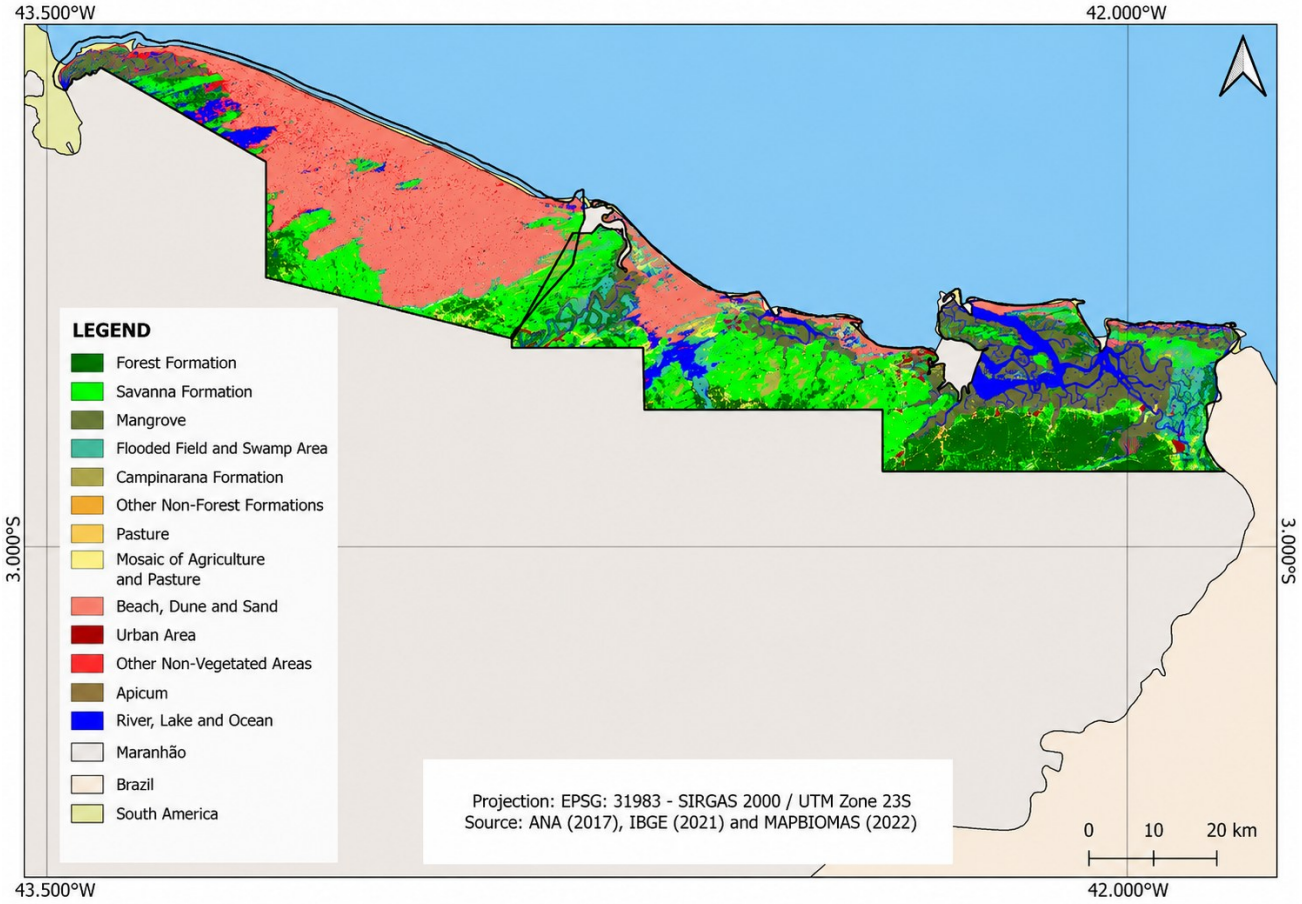

Figure 5 – Map of the total Conservation Units area in 2022.
Source: Authors (2026).

Table 8 – Land Use and Occupation Classes for Base Year 2022.

Land Use and Occupation Classes	Total Area in ha (2022)	Percentage of Total Area
Forest	158758 ha	45,45%
Non-Forest Natural Formation	32533 ha	9,31%
Agriculture/Livestock	11481 ha	3,29%
Non-Vegetated Area	122038 ha	34,94%
Water	24359 ha	6,97%
Unobserved	159 ha	0,05%

Fonte: MapBiomas (2025).

Table 9 – Dynamics Assessment of Increase/Decrease in Percentage for Natural and Anthropic Delimitation 2020 and 2022.

Land Use and Occupation Classes	Dynamics
Forest	-0,65%
Non-Forest Natural Formation	-0,54%
Agriculture/Livestock	+0,55%
Non-Vegetated Area	+0,61%
Water	+0,05%
Unobserved	0%

Source: MapBiomas (2025).

By 2022, anthropogenic pressures persisted, with an increase in cities, infrastructure, mangroves, and dunes. Between 2020 and 2022, non-vegetated areas increased by 0.61% and agriculture by 0.55%, while forests decreased by 0.65% and non-forested natural formations by 0.54%. This indicates an expansion of degraded and farming areas simultaneously with the reduction of natural ones (CRUZ et al., 2025; IEE-USP, 2024).

In the Parnaíba River Delta, erosion exposed mangroves previously covered by sand, altering 60% of the Brazilian coastline.

Table 10 – Natural and anthropogenic classes and their respective areas in hectares for the base years 2010, 2015, 2020 e 2022.

Land Use and Occupation Classes	Total area - hectares			
Forest	2010	2015	2020	2022
Non-Forest Natural Formation	162739	162897	161026	158758
Agriculture/Livestock	31938	34042	34424	32533
Non-Vegetated Area	7925	8371	9589	11481
Water	117452	118393	119938	122038
Unobserved	29192	25563	24172	24359
Land Use and Occupation Classes	84	63	180	159

Source: MapBiomas (2025).

Table 11 – Evaluation of increase or reduction of natural and anthropogenic classes for the base years 2010, 2015, 2020, and 2022.

Dinamic areas				
	2010	2015	2020	2022
Forest	+0,14%	+0,04%	-0,53%	-0,65%
Non-Forest Natural Formation	-0,04%	+0,60%	+0,11%	-0,54%
Agriculture/Livestock	+0,06%	+0,13%	+0,34%	+0,55%
Non-Vegetated Area	-0,04%	+0,27%	+0,44%	+0,61%
Water	-0,13%	-1,04%	-0,40%	+0,05%
Unobserved	0%	0%	+0,03%	0%

Source: MapBiomas (2025).

The urban mosaic grew due to invasions and expansion of settlements on the edges of the Conservation Units, associated with limited land regularization and territorial enforcement. An analysis of the components between 1985 and 2022 showed the largest area increases in 'Other Non-Vegetated Areas' (+5,873 ha), 'Mangrove' (+3,883 ha), and 'Pasture'

(+2,821 ha). Conversely, the largest reductions occurred in 'River, Lake, and Ocean' (-12,070 ha), 'Flooded Grassland and Swamp Area' (-4,952 ha), and 'Savanna Formation' (-2,040 ha). Overall, between 1985 and 2022, natural areas decreased by 3.18%, while anthropogenic areas grew by 1.48% (JIANG et al., 2023).

Table 12 – Evaluation of the dynamics of increase and reduction of the categories that constitute the classes of interest in the interval 1985 – 2002.

Class constituents	1985	2022	Dinamic	Area - ha
Forest Formation	13,54	13,85	+0,31	1095
Savana	20,36	19,77	-0,59	-2040
Mangrove	10,70	11,81	+1,11	3883
Flooded Grassland and Swamp Area	6,59	5,17	-1,42	-4952
Grassland Formation	2,57	3,05	+0,48	1684
Apicum (Salt Flat)	1,07	1,09	+0,02	63
Pasture	0,47	1,27	+0,80	2821
Agriculture	0	0,02	+0,02	74
Temporary Crop	0	0,02	+0,02	74
Soy	0	0	0	6
Other Temporary Crops	0	0,02	+0,02	68
Mosaic of Land uses	1,66	1,99	+0,33	1165
Beach, Dune, and Sand Area	27,42	27,77	+0,35	1243
Urbanized Area	0,33	0,73	+0,40	1390
Other Non-Vegetated Areas	4,75	6,43	+1,68	5873
River, Lake, and Ocean	10,42	6,96	-3,46	-12070
Aquaculture	0,09	0,01	-0,08	278
Unobserved	0,03	0,05	+0,02	109

Fonte: MapBiomas (2025).

The variation in land use classes between 1985 and 2022 highlights the largest increases in Other Non-Vegetated Areas (+5,873 ha), Mangrove (+3,883 ha), and Pasture (+2,821 ha). The largest reductions occurred in River, Lake, and Ocean (-12,070 ha), Flooded Grassland and Swamp Area (-4,952 ha), and Savanna Formation (-2,040 ha). Deforestation is a severe impact, with the Maranhão Cerrado being the most devastated between 2020-2022. Law No. 434/2023 prohibited large-scale plantations in the Lençóis Maranhenses National Park, motivated by the advance of eucalyptus monoculture in Barreirinhas.

Table 13 – Area percentage of classes for the base years 1985 and 2022.

Classes	1985	2022	Dynamics
Forest	44.61%	45,45%	+0,84%
Non-Forested Natural Formation	10,23%	9,31%	-0,92%
Agriculture/Livestock	2,12%	3,29%	+1,17%
Non-Vegetated Area	32.50%	34,94%	+2,44%
Water	10,51%	6,97%	-3,54%
Unobserved	0.03%	0,05%	+0,02%

Source: MapBiomas (2025).

Table 14 – Areas, in hectares, of classes for the base years 1985 and 2022.

Classes	1985	2022
Natural	323756	312663
Anthropogenic	8875	14044
Undefined	16698	22621

Source: MapBiomas (2025).

Table 15 – Evaluation of the dynamics of increase or reduction in percentage for the Natural and Anthropogenic delimitation in the interval 1985 – 2022.

Classes	1985	2022	Dinâmica
Natural	92,68%	89,50%	-3,18%
Anthropogenic	2,54%%	4,02%	+1,48%
Undefined	4,78%%	6,48%	+1,70%

Source:MapBiomas (2025).

Between 1985 and 2022, natural areas in the Lençóis Maranhenses PARNA and the APA of the Mouth of the Preguiças River decreased by 3.18%, while anthropogenic areas grew by 1.48%.

4. Final considerations

Over the past 37 years, the region of the Lençóis Maranhenses and the Delta of the Americas has suffered significant transformations caused by human action, such as deforestation, fires, urbanization, and sea-level rise, affecting the landscape and water resources. The IUCN identified 1,565 species in the area, with 88 in decline, highlighting the urgency of local biodiversity conservation.

A relationship is observed between the loss of natural areas and the advance of agriculture and non-vegetated areas. The "Forest" class saw an increase between 2010 and 2015, but declined after 2020. "Water bodies" decreased between 1995 and 2022, while "Farming" expanded continuously, notably with soy. Even with mangrove growth, the ecosystem still suffers from erosion and sea advancement.

Despite conservation unit regulations, recent laws seek to contain the advance of silviculture and monoculture. Integrating the "Route of Emotions", the area has great potential for Environmental Education, Citizen Science, and Bioeconomy . Interdisciplinary studies are essential to understand the socio-environmental dynamics and ensure the sustainability of the PARNA and the APA.

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