Geotemas, Pau dos Ferros, RN, Brasil
ISSN: 2236-255X, v. 15, 2025.

TOURISM AND SPATIO-TEMPORAL DYNAMICS OF LAND USE AND OCCUPATION ON THE COAST OF PIAUÍ: CONTRIBUTIONS TO TERRITORIAL MANAGEMENT

Turismo e dinâmicas espaço-temporais do uso e ocupação do solo no litoral do Piauí: subsídios para a gestão territorial

Turismo y dinámicas espacio-temporales del uso y ocupación del suelo en el litoral de Piauí: aportes para la gestión territorial

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Article History
Reveived: 17 august, 2025
Accepted: 06 november, 2025
Published: 08 december, 2025

ABSTRACT

Tourism has become one of the main drivers of territorial transformation by integrating geographic and natural elements into different practices and segments. Along the coast of Piauí, which includes the municipalities of Ilha Grande, Parnaíba, Luís Correia, and Cajueiro da Praia, the intensification of human occupation has led to significant socioenvironmental changes, reflected in population growth, urban expansion, and landscape reconfiguration. This research aimed to analyze land use and land cover dynamics in the coastal region of Piauí, seeking to understand the processes of vegetation cover transformation and their relationship with urban expansion and tourism development over time. It is characterized as an exploratory study with a quali-quantitative approach, based on descriptive and geospatial analyses. Data from MapBiomas, Collection 9 (1995–2023), were used to produce thematic maps of land use and land cover. The processing and spatial analysis stages were carried out using QGIS 3.30 software and involved the reclassification of land use and occupation categories, as well as the application of landscape metrics to assess environmental transformation dynamics. The results revealed significant changes in land use and land cover between 1995 and 2023, showing a progressive replacement of native vegetation by urban and tourist areas driven by the expansion of sun-and-beach tourism. The processes of anthropization and real estate speculation have altered the landscape and intensified socioenvironmental impacts, especially in mangrove and river areas, which are more vulnerable to the pressures

https://doi.org/10.33237/2236-255X.2025.7422

of population growth. However, the lack of adequate planning has contributed to spatial disorder and the consequent pressure on natural resources, compromising both environmental sustainability and the region's tourism appeal.

Keywords: Tourism; Territory; Territorial Planning; Landscape.

RESUMO

O turismo configura-se como um dos principais vetores de transformação territorial, ao integrar elementos geográficos e naturais em diferentes práticas e segmentações. No litoral piauiense, que abrange os municípios de Ilha Grande, Parnaíba, Luís Correia e Cajueiro da Praia, a intensificação da ocupação humana tem promovido alterações socioambientais significativas, refletidas no crescimento populacional, na expansão urbana e na reconfiguração da paisagem. A pesquisa teve como objetivo analisar as dinâmicas de uso e ocupação do solo na região litorânea do Piauí, buscando compreender os processos de transformação da cobertura vegetal e suas relações com o avanço urbano e o desenvolvimento do turismo ao longo do tempo. Caracteriza-se como um estudo de natureza exploratória e de abordagem quali-quantitativa, fundamentando-se em análises descritivas e geoespaciais. Utilizaram-se dados do MapBiomas, Coleção 9 (1995–2023), a partir dos quais foram elaborados mapas temáticos de uso e cobertura da terra. As etapas de processamento e análise espacial foram realizadas no software QGIS 3.30, envolvendo a reclassificação das categorias de uso e ocupação e a aplicação de métricas de paisagem para avaliar as dinâmicas de transformação ambiental. Os resultados evidenciaram mudanças significativas no uso e cobertura da terra entre 1995 e 2023, revelando a substituição progressiva da vegetação nativa por áreas urbanas e turísticas, impulsionadas pela expansão do turismo de sol e praia. O processo de antropização e a especulação imobiliária modificaram a paisagem e intensificaram os impactos socioambientais, especialmente nas áreas de manguezais e rios, que são mais vulneráveis às pressões do crescimento populacional. Contudo, a ausência de um planejamento adequado tem favorecido o desordenamento espacial e a consequente pressão sobre os recursos naturais, comprometendo a sustentabilidade ambiental e a atratividade turística da região.

Palavras-chave: Turismo; Território; Planejamento Territorial; Paisagem.

RESUMEN

El turismo se configura como uno de los principales vectores de transformación territorial, al integrar elementos geográficos y naturales en diferentes prácticas y segmentaciones. En la zona costera de Piauí, que abarca los municipios de Ilha Grande, Parnaíba, Luís Correia y Cajueiro da Praia, la intensificación de la ocupación humana ha promovido cambios socioambientales significativos, reflejados en el crecimiento poblacional, la expansión urbana y la reconfiguración del paisaje. La investigación tuvo como objetivo analizar las dinámicas de uso y cobertura del suelo en la región costera de Piauí, buscando comprender los procesos de transformación de la cobertura vegetal y su relación con el avance urbano y el desarrollo del turismo a lo largo del tiempo. Se caracteriza como un estudio de naturaleza exploratoria y con un enfoque cuali-cuantitativo, basado en análisis descriptivos y geoespaciales. Se utilizaron datos de MapBiomas, Colección 9 (1995–2023), a partir de los cuales se elaboraron mapas temáticos de uso y cobertura del suelo. Las etapas de procesamiento y análisis espacial se realizaron en el software QGIS 3.30 e incluyeron la reclasificación de las categorías de uso y ocupación, así como la aplicación de métricas de paisaje para evaluar las dinámicas de transformación ambiental. Los resultados evidenciaron cambios

significativos en el uso y la cobertura del suelo entre 1995 y 2023, mostrando la sustitución progresiva de la vegetación nativa por áreas urbanas y turísticas, impulsada por la expansión del turismo de sol y playa. Los procesos de antropización y la especulación inmobiliaria modificaron el paisaje e intensificaron los impactos socioambientales, especialmente en las zonas de manglares y ríos, más vulnerables a las presiones del crecimiento poblacional. Sin embargo, la ausencia de una planificación adecuada ha favorecido el desordenamiento espacial y la consecuente presión sobre los recursos naturales, comprometiendo la sostenibilidad ambiental y el atractivo turístico de la región.

Palabras clave: Turismo; Territorio; Planificación Territorial; Paisaje.

1 INTRODUÇÃO

Tourism is considered one of the major cycles of a developing territory, as it is an activity that adds value and has an impact on an area by integrating various geographical and natural elements into its practices (Santos, 2014). In addition, any and all activities related to tourism seek to expand according to the needs of demand and the appeal of an attraction. In this context, various geographical areas around the world are used for different tourist activities, from mountain ranges for skiing (snow tourism) to tourism in deep caves (cave tourism), tourist activities on beaches, dunes, forests, rivers, and lakes, among many others, which allows for the creation of tourism segments (Guerra; Jorge, 2014; Panosso Netto; Lohmann, 2012)

Currently, almost the entire planet has various urban occupations, which, in addition to tourism, stand out for the expansion and transformation of these areas, allowing significant progress in the process of forming the urban perimeter and changing the landscape (Braz et al., 2021; Guerra; Jorge, 2014; Marujo; Santos, 2012).

With the emergence of new technologies, these areas tend to explore different means of supplying the tourism industry, resulting in new forms of territorial appropriation (Santos, 2014). Among these areas, the coast of Piauí stands out, recognized for its historical and socioeconomic relevance in territorial formation, covering the municipalities of Ilha Grande, Parnaíba, Luís Correia, and Cajueiro da Praia, located in the northern region of the state of Piauí.

This process of territorial appropriation by human occupation in the coastal area has brought about socio-environmental transformations in the region, influenced by the evolution and dynamics of occupation of the area, resulting in changes in the environment, commerce, way of life, culture, and population growth, which went from 190,228 inhabitants among the municipalities in 2000 (CEPRO, 2007) to 210,031 (IBGE, 2022). Given the above, the

research question is: How have the dynamics of land use and occupation, driven by urbanization and tourism, influenced the processes of vegetation cover transformation in the coastal region of Piauí between 1995 and 2023?

Within this scope of analysis, the study examined the advances in occupation and the spatial-temporal changes in the coastal area, highlighting the effective participation in the transformation of the geographical space, with the consolidation of the coast as a tourist territory, especially in the service sector, which has advanced over the years (Rocha; Assis, 2020). However, it should be noted that the growing occupation of inhabited space has resulted in processes of articulation between different possibilities of use, highlighted by interests among actors, sectors, and agents, depending on the structure and configuration of power that shaped the territory (Santos, 2014).

It is also important to emphasize that these processes are systematically integrated, with one action inducing another, especially in the relationship between structuring and landscape formation, which allows us to consider a geosystem in which anthropic actions are linked to changes in geographical spaces (Rodriguez; Silva, 2019; Vidal, 2014). In this context, the occupation of territories induced by tourism has a perspective on landscapes (Braz et al., 2021) and, with this, their natural elements in the promotion of attractions, which possibly, if there is no adequate organization and planning, may lead to the disorder of these areas.

Therefore, the objective of this study is to analyze the dynamics of land use and occupation in the coastal region of Piauí, seeking to understand the processes of vegetation cover transformation and their relationship with urban expansion and tourism development over time. The study area, where these changes are most prominent, comprises the 66 kilometers of the Piauí coastline, bounded by four coastal municipalities: Ilha Grande, Parnaíba, Luís Correia, and Cajueiro da Praia.

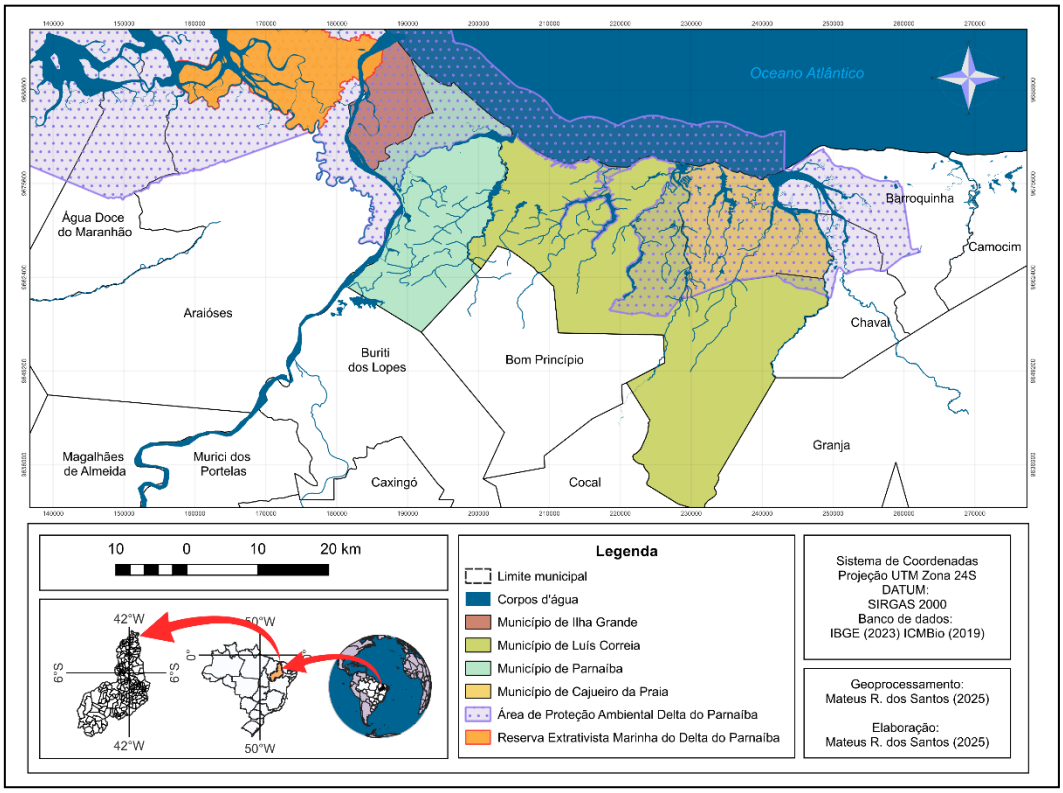
2 METHODOLOGY

2.1 Study area

The study area comprises the four coastal municipalities of the state of Piauí, Ilha Grande, Parnaíba, Luís Correia, and Cajueiro da Praia, in terms of the appropriation of geographical boundaries, which constituted the diagnosis of the studies, in addition to the

phenomena observed (Figure 01). The Piauí coastline is part of the Parnaíba Delta Environmental Protection Area and interacts with various landscape units, such as dunes and mangroves, as well as biomes such as the cerrado and the caatinga transition.

Figure 01 – Location of the Piauí coastline and tourist representation of the region



Fonte: IBGE (2003), ICMBio (2019), Mateus R dos Santos (2025).

The four municipalities have geographical characteristics that emphasize various tourist activities and other sectors of economic development, such as agriculture, livestock, fishing, aquaculture, and local commerce. The municipality of Ilha Grande, for example, is recognized for the inclusion of nautical and adventure tourism in the Parnaíba Delta, which it is part of as the largest island that makes up the deltaic configuration, formed by the lower course of the Parnaíba River (Silva et al., 2019).

Its main economic activities are linked to the rural sector, with little direct community involvement in tourism, but it is represented as having potential for various practices, such as hiking, canoeing, off-roading, birdwatching, and ecotourism activities (Silva Filho; Andrade, 2020). Its territory also falls within two important conservation units for the coastal region of the state of Piauí, the Parnaíba Delta Marine Reserve and the Parnaíba Delta

Environmental Protection Area, in addition to being located within the region's economic planning and production zones (ICMBio, 2020).

Whereas the municipality of Parnaíba is characterized as a transitional municipality in terms of the availability of easily accessible tourist facilities, such as accommodation, restaurants, supermarkets, shops, among others (Santos; Perinotto; Vieira, 2020). Its area also has potential for occupation, with settlements dating back to the 18th century, marked by the Igaraçu River and the first urban formations related to human occupation, which played an important role in the process of navigation and export in the early centuries (Santos; Silva; Lima, 2022; Vieira, 2010).

The development of real estate speculation in the region, however, occurred irregularly, resulting in the loss of the landscape environment, with the migration of the population from the interior to the coastal area. Even so, it has important natural features such as dunes, lagoons, and vegetation, which attest to the area's potential. The territory also stands out for being the second most populous municipality in the state, in addition to the large flow of visitors (Amorim; Valladares, 2024).

The municipality of Luís Correia is characterized by mass tourism activities, due to its extensive beachfront, in terms of leisure areas, environmental protection zones, and fishing. However, the municipality faces challenges, such as the precarious state of tourist facilities and difficulties with mobility and safety (Melo; Leal; Lins, 2014). The area is also highly sensitive in environmental terms with regard to river systems (Sousa; Rocha, 2024), as it is home to several marine species that use the beach as a refuge, such as sea turtles that lay their eggs on the beach.

As for Cajueiro da Praia, the last municipality on the Piauí coast, it has the smallest area of use, characterized by vegetation adapted to the sandy and dry environment (Barbosa, 2019). Its initial occupation was carried out by the caiçara communities. However, with the development of tourism in the region, some access points were occupied by the establishment of accommodation networks and other developments, a situation that ended up displacing several traditional practices and, at the same time, caused several conflicts between the local population and the private sector (Vieira; Araújo, 2015; Carvalho, 2010).

2.2 Methodological procedure

This study is exploratory and qualitative-quantitative in nature, allowing for descriptive analysis and grouping of data on perspectives regarding the survey of land use and occupation in the area, through delimitation and categorization (Lang; Blaschke, 2009). In this vein, a review of literature from books and journals, as well as documentation released by public agencies, is employed.

For the survey of land use and coverage, the products of Mapbiomas collection 9 were used as part of the georeferenced analysis. A spatiotemporal analysis was chosen, considering the years 1995, 2005, 2015, and 2023, since the municipality of Cajueiro da Praia was elevated to municipality status in 1995 and Ilha Grande in 1997. The data used were on land use and coverage over this period, at four-year intervals, with the aim of mapping the expansion of urban areas and the suppression of vegetation, thus adopting the mapping of areas of interest.

The procedures used to analyze the changes that occurred in the areas presented consisted of the creation and interpretation of thematic maps of land use and occupation (LUO), referring to the appropriation of the coastal area (Ross, et al. 2022), and calculations of landscape metrics, with regard to the classification organized for the study. Descriptive metric analysis tends to correspond to the percentage of the area of individual classes in the landscape, according to the area to be studied. In this case, Mapbiomas uses the accuracy metric (Accuracy - metrics.accuracy_score), which measures the proportion of correct predictions in relation to the total (MapBiomas, 2023).

The function calculates the accuracy, either the fraction (standard) or the count (normalize=False) of correct predictions. If the entire set of predicted labels for a sample strictly matches the true set of labels, then the accuracy of the subset is 1.0; otherwise, it is 0.0 (Scikit-Learn, 2024):

$$Area = 0{,}5 \cdot \sum((x_i+1-x_i)(y_i+1+y_i))$$

Where:

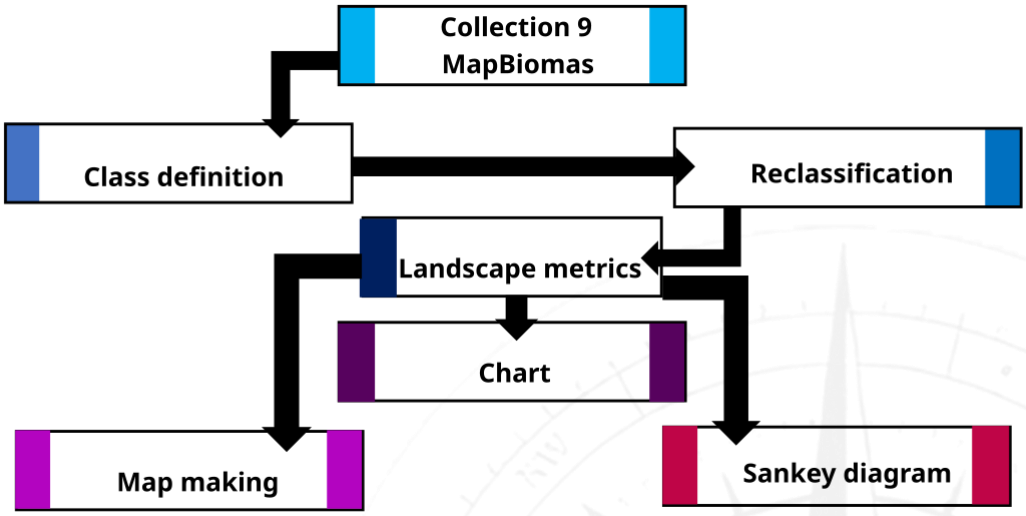
- xi + 1 − xi: Represents the difference in the x coordinate between two consecutive cells or vertices. This difference reflects the horizontal width of the cell or segment;
- Y i+ 1+ yi: Is the sum of the y coordinates of the two consecutive vertices, which reflects an “unweighted” average of the vertical position between two consecutive points;

- Sum (∑): aggregates all partial areas, calculated for each cell or segment, to compose the total area;
- Multiplication by 0.50: normalizes the calculation, since the formula derives from a geometric relationship involving determinants.

Thus, areas are calculated based on the number of cells with a particular corresponding value, in which the underlying concept of proximity (four cells) includes diagonal contacts, resulting in more neighbors (eight cells). This leads to the interpretation of computational data and allows the area to be calculated using the raster (matrix) model. It also allows the frequencies at which they are repeated to be identified, thus enabling the construction of an area (Lang; Blaschke, 2009).

Consequently, this made it possible to organize the study, since it allowed the necessary analysis steps to be followed to identify which products would be the results of the considerable classes of land use and land cover. Figure 02 illustrates the research approach through the methodological flowchart.

Figure 02 – Methodological flowchart for the preparation of thematic maps of land use and land cover and calculations of landscape metrics



Fonte: The authors (2025).

The study consisted of two stages: (i) the use of QGIS version 3.30 for geoprocessing software and the creation of maps as graphic representations, in addition to establishing parameters and metrics for the reclassification of data on land use and land cover.

Eventually, the data process obtained from Mapbiomas needed to be adapted, since the study area has characteristics that integrate with the set of elements when visiting the site. To this end, the respective elements associated with natural units preserved over time, land occupation by anthropic actions, watercourses, and the dynamics of the dunes present in the study area were reclassified (Table 01).

Thus, the classification was organized as follows: Forest Formation and Savanna Formation = Native Vegetation; Mangrove, Flooded Field/Swampy Area, and Apicum = Mangrove; Countryside Formation, Pasture, Mosaic of Uses, Urbanized Area, and Other Non-Vegetated Areas = Anthropic Action; Beach, Dune, and Sandy Area = Beaches and Dunes; Aquaculture and River, Lake/Ocean = Watercourse; and Soybean, Other Temporary Crops, and Other Perennial Crops = Anthropic Action.

Table 01 – Reclassification for the study area

Classes			New classification		
Forest Formation	3		1		Native Vegetation
Savanna Formation	4		1		
Mangrove	5		2		Mangrove
Flooded Field and Swampy Area	11		2		
Countryside Formation	12		1		Native Vegetation
Pasture	15		3		Anthropic Action
Mosaic of Uses	21		3		
Beach, Dune, and Sandy Area	23		4		Beaches and Dunes
Urbanized Area	24		3		Anthropic Action
Other Non-Vegetated Areas	25		3		
Fish Farming	31		5		Watercourse
Hypersaline Flat	32		2		Mangrove
Rivers, Lakes	33		5		Watercourse
Soy	39		3		Anthropic Action
Other Temporary Crops	41		3		Anthropic Action
Other Perennial Crops	48		3		Anthropic Action

Source: Authors (2025), adapted from MapBiomas (2023)

The next step (ii) concerns the use of the Sankey diagram, by the SankeyMATIC platform, which allows the flow to be analyzed in order to detail and identify losses in the coverage and distribution of vegetation cover in the study area. This systematization and distribution across several directions, in which each direction is represented by a line whose

thickness indicates its proportion or quantity of values distributed in the space-time process, indicates that thicker lines represent a greater quantity that constituted the higher values transmitted in one direction, while thinner lines represent lower values being transmitted, allowing the identification of the affected classes.

2 RESULTS AND DISCUSSION

Over the last three decades, between 1995 and 2023, the municipalities of the Piauí coast have seen a significant increase in coastal occupation, mainly in the expansion of urban areas, which explains the anthropization characteristics of the area. In this sense, there has been a considerable reduction in natural spaces in terms of vegetation cover and the removal of other geographical elements, such as dunes and water bodies.

This pattern can be seen in the appropriation of the coastline for the development of tourist activities and in the first forms of occupation in Brazilian territory, i.e., from the coast to the interior (Ross et al., 2022). However, it should be noted that Piauí is notable for its occupation from the interior to the coast (Alves, 2003), with the first human occupation being the territory of Parnaíba and the first cities occupied on the coast of Piauí, and consequently the others, by the establishment of river trade routes and the extraction of raw materials of plant origin that the region offered (Santos, 2021).

Table 02 shows a comparison between the areas (km²) of the thematic classes of land use and land cover, which can be understood as the formation of the latest municipalities and appropriation of the territory, tourism activities, and urban expansion in 1995 and 2023, indicating which classes varied over the years and which ones signaled a reduction or increase in vegetation cover.

Table 02 – Values of thematic classes of land use and land cover between 1995 and 2023 for coastal municipalities in Piauí

	Municipality of Ilha Grande				
Classes	**Area km² (1995)**	**% in 1995**	**Area km² (2023)**	**% in 2023**	**Change km²**
Native vegetation	82,415,475	61,3%	81,073,904	60,3%	-1,341,571
Mangrove	10,721,845	8,0%	10,848,678	8,1%	126,833
Anthropization	5,832,526	4,3%	15,654,930	11,6%	9,822,404
Beaches and dunes	20,591,587	15,3%	13,095,049	9,7%	-7,496,538
Bodies of water	14,943,951	11,1%	13,799,776	10,3%	-1,144,175

Total	134,505,384	100,00%	134,472,337	100,00%	

Source: Authors (2025), adapted from MapBiomas (2023).

Municipality of Parnaíba

Classes	Area km² (1995)	% in 1995	Area km² (2023)	% in 2023	Change km²
Native vegetation	343,322,143	78,7%	299,520,201	69,1%	-43,801,942
Mangrove	15,009,733	3,4%	15,574,163	3,6%	564,430
Anthropization	29,154,483	6,7%	76,900,282	17,7%	47,745,799
Beaches and dunes	26,037,145	6,0%	19,022,466	4,4%	-7,014,679
Bodies of water	22,799,945	5,2%	22,430,516	5,2%	-369,429
Total	436,323,449	100,00%	433,447,628	100,00%	

Source: Authors (2025), adapted from MapBiomas (2023).

Municipality of Luís Correia

Classes	Area km² (1995)	% in 1995	Area km² (2023)	% in 2023	Change km²
Native vegetation	82,415,475	61,27%	89,457,309	83,70%	7,041,834
Mangrove	10,721,845	7,97%	1,387,385	1,30%	-9,334,460
Anthropization	5,832,526	4,34%	7,482,753	7,00%	1,650,227
Beaches and dunes	20,591,587,00	15,31%	5,807,766	5,43%	-14,783,821
Bodies of water	14,943,951	11,11%	2,741,465	2,57%	-12,202,486
Total	134,505,384	100,00%	106,876,678	100,00%	

Source: Authors (2025), adapted from MapBiomas (2023).

Municipality of Cajueiro da Praia

Classes	Area km² (1995)	% in 1995	Area km² (2023)	% in 2023	Change km²
Native vegetation	197,266,150	72,54%	181,803,324	66,87%	-15,462,826
Mangrove	31,661,850	11,64%	34,018,575	12,51%	2,356,725
Anthropization	5,642,397	2,08%	18,875,214	6,94%	13,232,817
Beaches and dunes	143,438,06	5,28%	8,695,163	3,20%	8,551,725
Bodies of water	23,017,552	8,46%	28,491,293	10,48%	5,473,741
Total	257,731,387	100,00%	271,883,569	100,00%	

Source: Authors (2025), adapted from MapBiomas (2023).

This relationship allowed us to observe the accelerated dynamics between 1995 and 2015, with the progressive replacement of native vegetation by anthropogenic actions and expansion over the coastal territory, in terms of socio-spatial transformation, which is integrated with sun and beach tourism (Carvalho, 2010; Baptista; Nascimento, 2020). As the area has a transition between the cerrado and caatinga biomes, part of these areas were lost due to the dynamics and use of natural spaces for anthropization, as support for tourism in the region.

This defined a transition from natural geographical spaces to spaces intended for modernization and infrastructure for tourism. Therefore, the components involved started

from the induction of natural resources into attractions, and with that, the promotion of the tourist destination. As a result, the spaces were occupied by tourist support services and facilities (gas stations, hotels, restaurants, tourist agencies, shops, etc.), which became relevant for the organization or arrangement of new spaces to meet visitor demand, i.e., the tourism production chain. Another important issue is real estate speculation, which grew as urbanization expanded, thus allowing real estate development in the region, mainly between the municipalities of Parnaíba and Luís Correia, which correspond to a large area of the coast.

Over a period of approximately 10 years (between 1995 and 2005), there was a 22% loss of native forest, an area corresponding to the municipalities of Ilha Grande, Parnaíba, and Cajueiro da Praia, which have more vegetation linked to the delta region, since their limitations are due to their proximity to the Parnaíba, Igaraçu, and Camuripim rivers. The municipality of Luís Correia, on the other hand, showed a 10% increase in vegetation cover between 1995 and 2005, since its coastline is almost entirely linked to the dune fields. This was evident in the first steps taken to develop tourism in this area, the expansion of tourist facilities, such as accommodation, and the delimitation of irregular areas for real estate development.

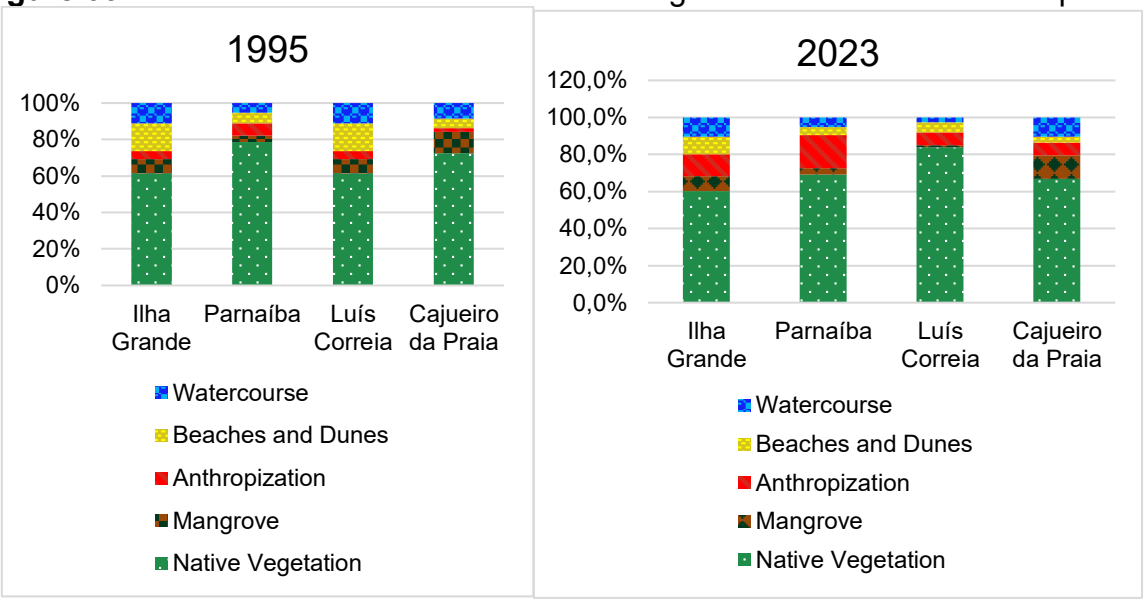
This can be seen clearly and significantly in the municipality of Parnaíba through changes in the landscape, particularly in terms of the anthropization of these locations, which contain environmental vulnerabilities and have been decharacterized by the removal of areas that were part of scenic beauty spots, now occupied by continuous or seasonal flows of visitors for tourism (Marujo; Santos, 2012).

In the past, from a tourist destination perspective, and sought after for its landscape, the occupation of the area around these attractions began to take place, allowing its surroundings to be appropriated, as in the case of Luís Correia, by means of lodging and restaurants, without any type of tourist planning or organization (Melo; Leal; Lins, 2014), and even from the perspective of socio-environmental impacts, especially in the area of the Camurupim and Cardoso rivers, given their proximity to the beaches of Macapá and Barra Grande.

Mangrove areas, which are highly vulnerable compared to other types of vegetation cover, have suffered greatly from population growth, which has resulted in a reduction in vegetation cover, especially near river areas in Parnaíba (Santos, 2021). However, the municipalities of Luís Correia and Cajueiro da Praia showed a significant reduction in their

characteristics, as shown in the comparison graphs between 1995 and 2023 (Figure 3). This is due to the intervention of aquaculture activity between the Camurupim and Cardoso rivers in the municipality of Luís Correia.

Figure 03 – Demonstration of the reduction in vegetation cover in the municipalities



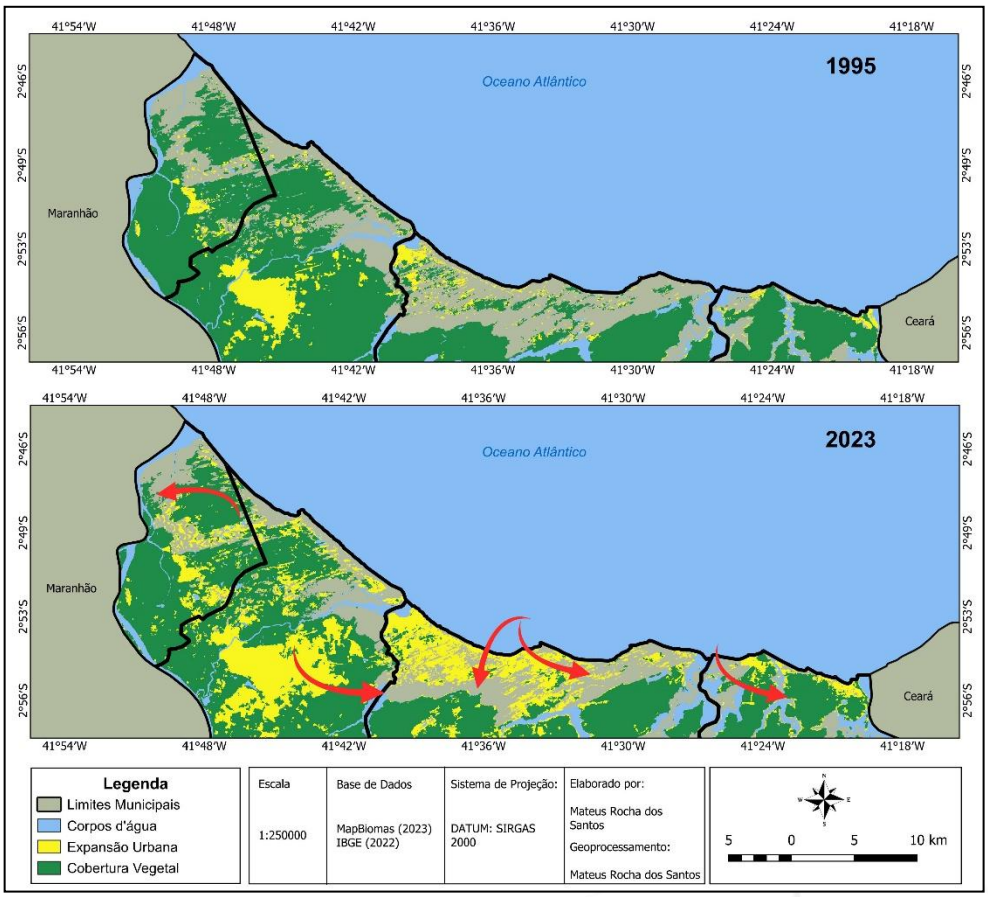
Source: Authors (2025).

This explains why the municipality of Parnaíba has grown exponentially, mainly due to the supply and demand for tourism support services, such as accommodation, restaurants, travel agencies, and local infrastructure, which has improved the lives of residents and thus attract new attention from other external populations in search of personal fulfillment in terms of housing, mainly through the promotion and enhancement of destinations with their products or services, through their travel experiences (Santos; Perinotto; Vieira, 2020). Soon, tourism also allowed the city to develop, bringing infrastructure improvements to support residents and visitors, allowing its territory to become the most prominent among the four municipalities in the coastal region of the state of Piauí (Rocha; Assis, 2020).

Ilha Grande experienced an expansion of anthropic activity, extending beyond the territorial boundaries with Parnaíba, as well as northeast toward Porto dos Tatus, a port area visited by tourists to the Parnaíba Delta. The municipality of Parnaíba, on the other hand, showed a proportional longitudinal spatial distribution of anthropic activities, from the Igaraçu River towards Lagoa do Portinho, in the SE and NW directions, both of which are water

resources in the region used for nautical tourism. Meanwhile, the municipality of Luís Correia showed the same S and SE proportion, with this area represented by inns, restaurants, and growing real estate speculation, also demonstrating support for the sun and beach tourism segment. The same is true for Cajueiro da Praia, given the growing

Figure 04 – Comparison of the expansion of anthropic action in coastal municipalities between 1995 and 2023



Source: IBGE (2022), MapBiomas (2023), Mateus R. dos Santos (2025).

These results are in line with the appropriation of tourism and the relationship of the territory, which previously had no occupation, but now has a focus on commercialization and the enhancement of tourist activities (Carlos, 1996). The municipalities of Parnaíba and Luís Correia, as shown in the previous figure, clearly illustrate how the dynamics of tourism have significantly shaped the removal of natural cover from their areas. Thus, the coastal plain of these two municipalities was appropriated both by the tourism cycle and by other economic cycles, which fostered development and advancement in the beach region.

It is important to emphasize that anthropic influence on this coastal strip through tourism dates back to the 19th century, when the first arrivals of visitors from other regions began to be attracted by the more intense development of the city of Parnaíba (Baptista; Nascimento, 2020), and with this came socio-spatial transformations, with tourism as the main driver, due to the socioeconomic changes that involved the right to leisure, with considerable changes in support areas, such as beaches and other water resources in the region (Table 2). However, the coastal strip was already a point of visitation for the local population, mainly by the elite of these cities, who had the purpose of bathing and recreational or therapeutic activities (Oliveira, 2017).

Quadro 2 – Levantamento cronológico das ações antrópicas integradas ao turismo litorâneo

Previous period	1800-1920	The beaches of Luís Correia and Parnaíba became spaces enjoyed by the Piauí elite, who initially sought their waters for therapeutic purposes and later adopted them for leisure
	1940-1970	Economic power of beachgoers expanded visitation as far as Pedra do Sal Beach
	1980	Barra Grande: the beach became frequented for vacationing purposes
	1975-1982	Implementation, construction, and later abandonment of the Port of Luís Correia
	1987	First year of boat tours to the Delta promoted by the state of Piauí
Século XXI		Tourist planning actions
Ilha Grande	2004	1st Festival do Caranguejo
	2005	Integration of the delta region into the Rota das Emoções
	2019	Implementation of the Electronic Single Voucher system
	2023	Revitalization of Porto dos Tatus
Parnaíba	2010-2021	Operation of regular flights at the airport and projection of improvements
	2021	Inauguration of the Velho Monge Marina
	2022	South American Windsurf Slalom Championship at Lagoa do Portinho
Luís Correia	2000-2006	Tourist support infrastructure, including lodging facilities
	2016	1st Surf Atalaia Championship at Praia de Atalaia
	2023	Inauguration of Porto Piauí
Cajueiro da Praia	2000	First lodging facilities and tourism services
	2005	Arrival of kitesurfing practitioners, with local infrastructure developing to support athletes and enthusiasts
	2013	Brazilian Kitesurf Championship

Fonte: Autores (2025).

Thus, it is understood that the occupation of the coastal plain, within the process of managing the Piauí tourist territory, occurred due to anthropic action on the geosystem complexes and landscape types that contributed to tourist activity in this area, defined by

the relevance of the beaches, dune fields, and mangroves found within the coastal plain and flooded fields, in addition to forest and savanna vegetation (Vidal, 2014). This denotes the ecological importance that sustains the geosystemic balance, especially in the delta area (Macambira; Sousa; Silva, 2019), which becomes vulnerable to negative impacts, in addition to conflicts generated by tourism in the local communities present (Carvalho, 2010).

In this case, the biota that is integrated into the geosystem has interrelationships with anthropic actions and relationships with the ecosystems present in these areas, mainly in relation to vegetation. This is because each municipality is close to different sets of systems, but with aspects linked to the biotic and abiotic natural environment (Rodriguez; Silva, 2019). The municipality of Ilha Grande is even closer to the deltaic biota, with dune fields, mangroves, and extensive water resources, with transitional vegetation aspects even extending to the Amazon (Andrade et al., 2012). This reinforcement allows the ecosystems present in this area to reinforce territorial combinations and protection needs, given the complexity of the elements of these biomes.

Santos, Silva, and Lima (2022) revealed the impacts that occurred in the Parnaíba area, related to natural erosion processes and the occupation of the riverbed for real estate expansion. Sousa and Rocha (2024) demonstrated the high environmental vulnerability of the Camurupim River between the municipalities of Luís Correia and Cajueiro da Praia. Other effects, such as drainage sections, impacts caused by low rainfall and natural anomalies (Santos Filho; Mesquita; Lima, 2018), and formerly by anthropic actions (Galvão, 2020), are the diversion of water resources for agricultural activities, which directly impact the area. It is also possible to observe changes in the natural coastal landscape, as several developments tend to alter the character of natural areas. As a result, the landscape of years ago is giving way to new artificial features, adding perspectives of anthropogenic actions in the geographical space, especially in relation to tourism activities.

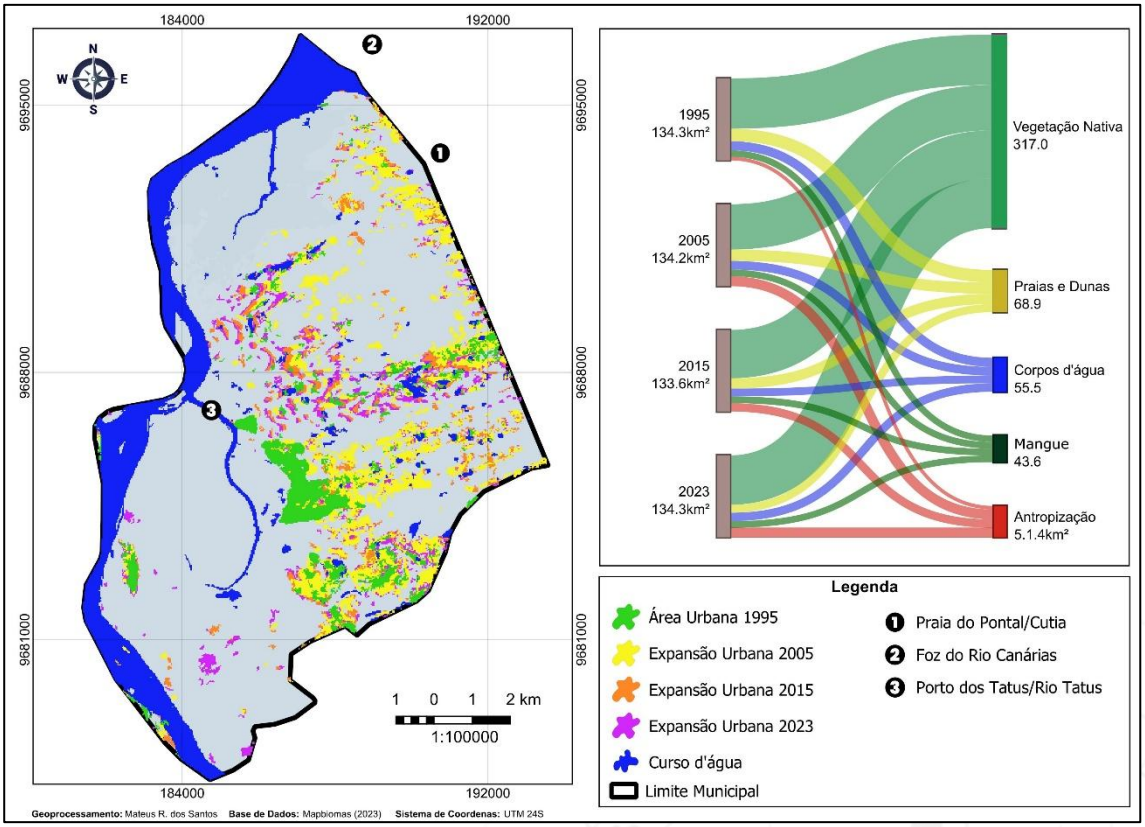
3.1 Municipality of Ilha Grande

As it is located within the deltaic configuration, the municipality's land cover and use is represented by Quaternary quartz sand deposits, which are products of the sediments of the Parnaíba River. Thus, its vegetation is characterized on the northwest side by mangroves and small areas of apicum, where specimens of Amazonian vegetation can be found (Andrade et al., 2012). However, it is in the central area in the SW to NE direction that

anthropization of the area occurs, expanding mainly between 2005 and 2023 (Figure 5), with recurring problems faced by the local population, with the construction of houses near dune hills (Macambira; Sousa; Silva, 2019).

These areas are characterized by shifting dunes and paleodunes, with shrubby tree vegetation and undergrowth, as well as sandbank vegetation (Amorim et al., 2019) in the northeast direction, with Pontal/Cutia beach as its terminus. The same area provides natural lagoons in floodplains, which, unlike Lagoa do Portinho in Parnaíba, which is supplied by a river, are formed by the concentration of rainwater.

Figure 05 – Demonstration of the spatial advance of urban expansion in the municipality of Ilha Grande between 1995, 2005, 2015, and 2023



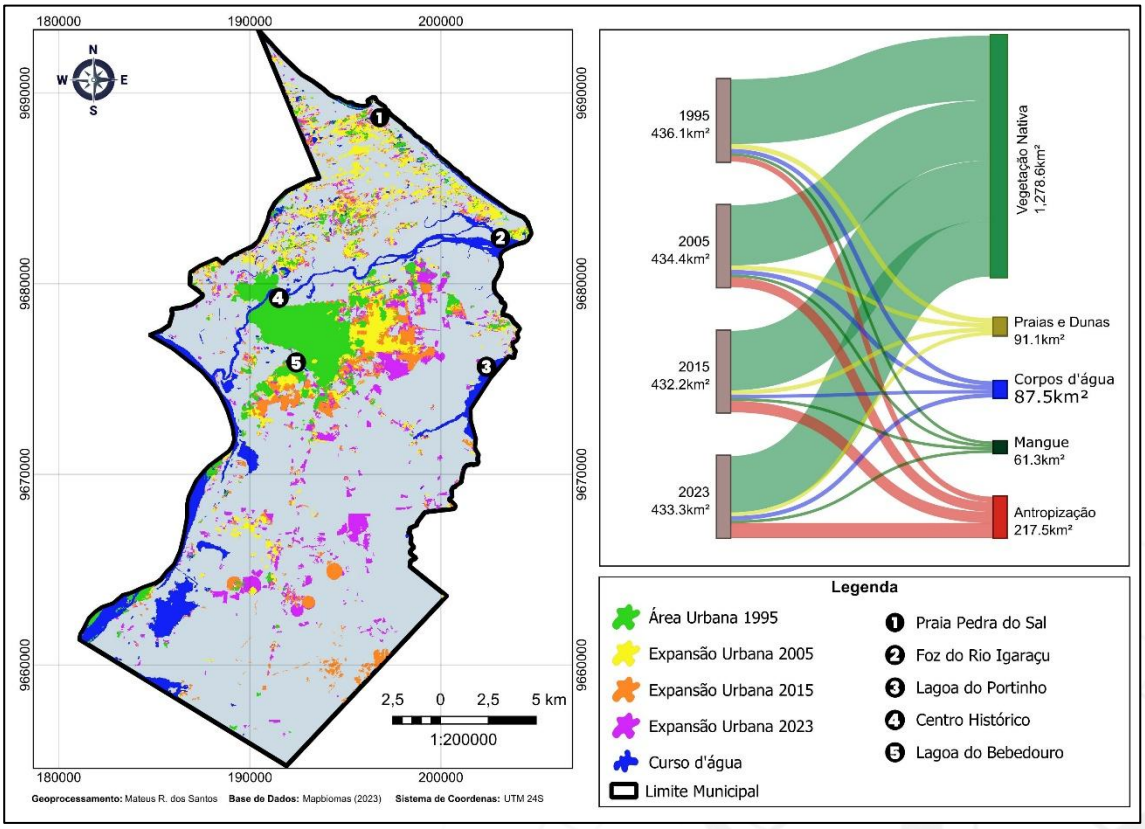
Source: Mapbiomas (2023), Mateus R. dos Santos (2025).

In this case, the connection between visitors traveling to this area of the state of Piauí occurs through the Parnaíba Delta region as a tourist destination. Thus, although the tourist facilities seem underdeveloped, the tourist flow is already a reality, mainly in terms of quantity, and therefore its proximity to areas of tourist interest is noticeable, especially in the beach, mangrove, and delta environments.

3.2 Municipality of Parnaíba

The urban expansion of this area has shown advanced development compared to other municipalities, especially in the central insertion of municipal boundaries, in an east-west direction, between the Igaraçu River and Lagoa do Portinho, these being the dividing lines between the municipality of Luís Correia. As such, a large part of the area is located in the delta transition region, which also includes dune fields. In this way, the native vegetation cover has lost its space to the appropriation of areas for the construction of buildings and streets (Figure 06).

Figure 06 – Demonstration of the spatial advance of urban expansion in the municipality of Parnaíba between 1995, 2005, 2015, and 2023



Source: Mapbiomas (2023), Mateus R dos Santos (2025).

In the case of growing real estate speculation, it was noted that this expansion continued until 2023, mainly in areas close to the banks of the Igaraçu River, allowing

several impacts to occur (Santos; Silva; Lima, 2022). In this sense, the next processes of decharacterization of the area are concentrated in the SE direction (45° in relation to the origin of the first settlements and urbanization of the city). Therefore, in subsequent years, the removal of natural cover can be observed due to the anthropization of the area, mainly due to the search for new spaces for the establishment of housing and services, many linked to tourist activities, since this expansion is located between three points of visitation, such as Pedra do Sal (1), Foz do Rio Igaraçu (2), and Lagoa do Portinho (3).

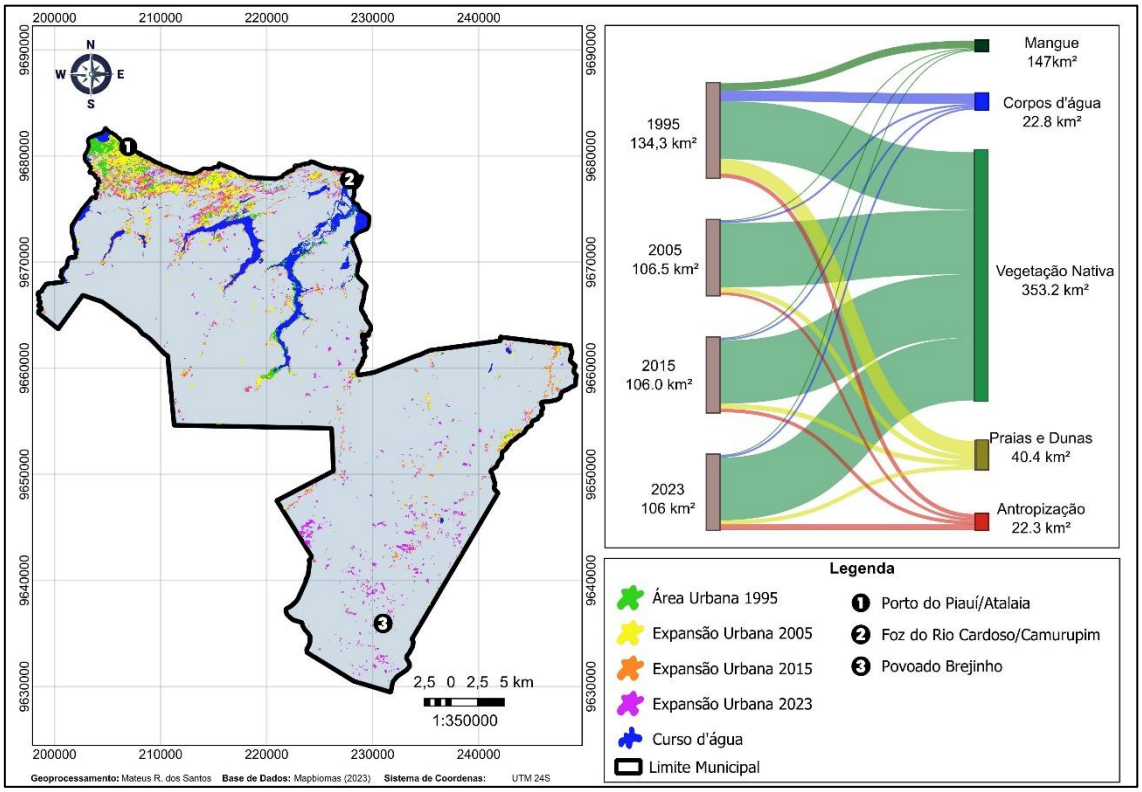
The expansion of the area was also associated with socio-spatial transformations, in addition to the modernization of urban spaces, which also extends with the arrival of new means of transportation in the region, due to its potential and geographical location among the coastal municipalities (Vieira, 2010).

3.3 Municipality of Luís Correia

Among the analyses carried out, the advance of anthropic actions on the municipality's coastline shows that mangrove coverage has been rapidly reduced, mainly due to actions carried out in the area. It was noted that this area is used for aquaculture (fish production) (Sousa; Rocha, 2024). The same area is where the tourist activity of seahorse watching takes place, which has become a unique attraction for tourists visiting the municipality, as an alternative to the sun and beach segment. Thus, among the most affected areas of use and occupation in the municipality was the mangrove, which has been significantly altered, as shown in the diagram (Figure 07).

When analyzing the diagram and map, it is possible to see how much the beaches and dunes have been occupied by urbanization, mainly linked to sun and sea tourism. However, another factor is the sociocultural construction of the territory itself in relation to visitation, in which local residents and neighboring cities carried out leisure activities on the beaches of Luís Correia, in addition to tourists, thus allowing the promotion and development of urban expansion, with the provision of tourist services and facilities over the years (Baptista; Nascimento, 2020; Oliveira, 2017).

Figure 07 – Demonstration of the spatial advance of urban expansion in the municipality of Luís Correia between 1995, 2005, 2015, and 2023



Source: MapBiomas (2023), Mateus R dos Santos (2025).

Among the most recent anthropic actions, there was also the opening of the port area, which required the reorganization of the mouth of the Igaraçu River, with the eviction of residents and the installation of infrastructure in the area. Therefore, the creation of new spaces on the surface of the coastal strip presented other characteristics, especially with regard to socio-spatial transformations. This also corroborates its role as support equipment for tourism transformations, since it provides navigation capacity, which includes the nautical tourism segment, and other activities related to water resources, linked to river and maritime activities.

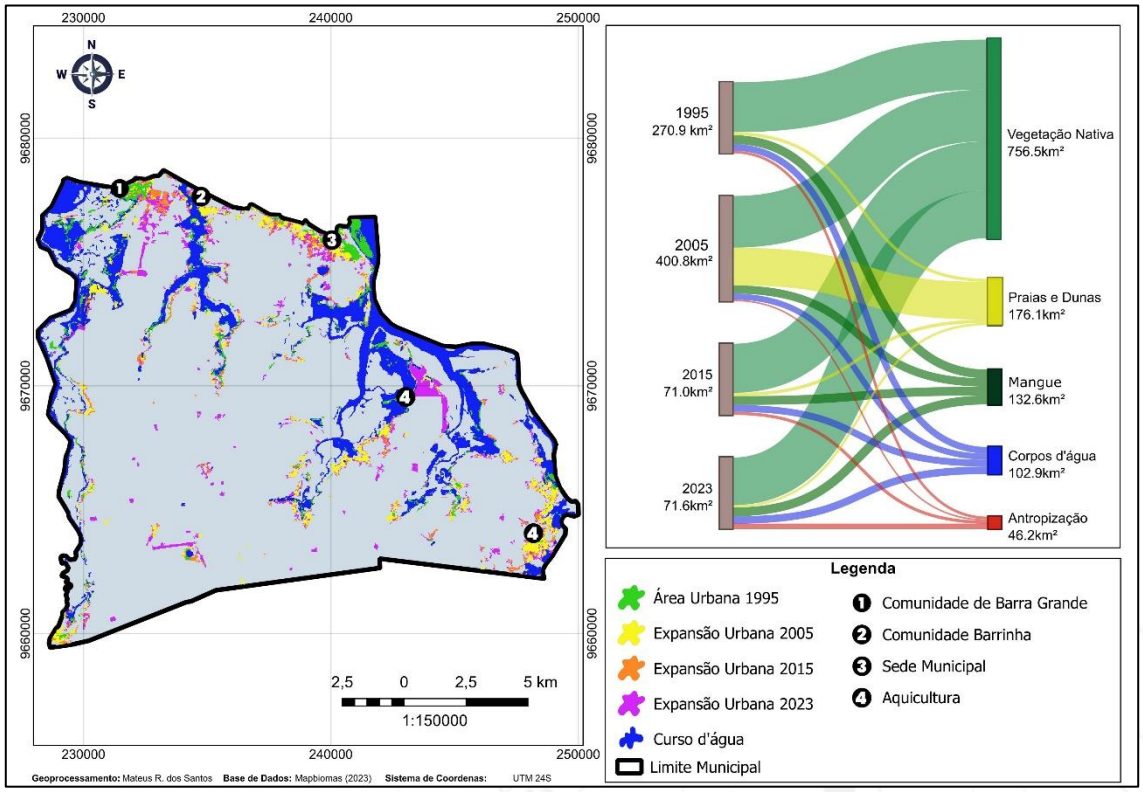
3.4 Municipality of Cajueiro da Praia

This municipality is similar to the previous ones, especially Luís Correia, in terms of the removal of natural vegetation cover. Both the map and the graph show urban expansion in relation to natural attractions, the main compon)ents being Barra Grande and Barrinha beaches, which stand out due to the expansion of the local communities that bear the same

names. Therefore, among the municipalities discussed, Cajueiro da Praia is an example of how, in less than 30 years, its urban area has grown, mainly due to the appropriation of land for tourism support facilities, especially in the hotel industry.

Only in 2023 is it possible to see the relationship between urban expansion in the north-south direction of the municipality (Figure 8) and in the west-east region of the coastal strip, reaching the municipal seat. Small patches of aquaculture are also visible within the municipal boundaries, located in areas near the Camurupim River (Luís Correia and Cajueiro da Praia), but more intensely represented in the southeast, due to the confluence with the Ubatuba River, on the border with the state of Ceará.

Figure 08 – Demonstration of the spatial advance of urban expansion in the municipality of Cajueiro da Praia between 1995, 2005, 2015, and 2023



Source: MapBiomas (2023), Mateus R dos Santos (2025).

The municipality tends to grow its anthropized expansion, given that the areas of Barra Grande and Barrinha, as national attractions, offer sun and beach tourism, in relation to nearby destinations such as Jericoacoara, which has large flows of visitors but tends to become stagnant, since consumers always seek alternatives, escaping the tourist flow.

As this area is part of the Route of Emotions, the possibilities for new alternative tourist searches become possible, allowing new areas to be explored, but also allowing vegetation cover to be removed to create new spaces for tourist support. Unlike the neighboring municipality (Luís Correia), Cajueiro da Praia still has preserved mangrove areas, as shown in the diagram. It is therefore up to the responsible governance bodies to carry out studies of the areas that are being used in an orderly manner, so as not to compromise the geosystems and ecological niches present, given the vulnerability of this vegetation cover.

CONCLUSION

Considering the importance of tourism on the coast of Piauí, it is essential that its expansion occurs with environmental responsibility, avoiding impacts on natural areas. Tourism planning should prioritize the preservation of mangroves and local biomes, with the involvement of public authorities, private initiative, and communities, defining responsibilities to ensure the conservation of ecosystems and the sustainability of activities.

Each municipality proposed a spatial-temporal differentiation of how the use of natural cover was gradually being overlaid by anthropic activities, mainly due to tourism. Therefore, it is essential to protect local biodiversity and to monitor the agencies responsible for tourism within the territory of Piauí, in addition to seeking alternatives for sustainable tourism. Therefore, it is necessary that other detailed studies be carried out before removing any vegetation, in order to ensure that the development of tourist infrastructure does not compromise vulnerable geosystems or ecological niches. In this way, a balance between tourism and environmental conservation can be achieved, promoting lasting benefits for the region and for future generations.

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