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Multitemporal land use and land cover analysis of the Iguape Bay Marine Extractive Reserve – Bahian Recôncavo

Análise multitemporal do uso e cobertura da terra na Reserva Extrativista Marinha da Baía do Iguape - Recôncavo Baiano

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Abstract: This study aimed to analyze land use and land cover dynamics at the Iguape Bay Marine Extractive Reserve (RESEX) employing Landsat images from 1986, 1994, 2003, 2017 and 2022. The Iguape Bay RESEX covers the municipalities of Cachoeira, São Félix and Maragogipe, located in the Bahian Recôncavo region. The employed methodological procedures comprised a bibliographic research, geographic database organization in a GIS environment, data tabulation, digital image processing and map production. Land use and land cover mapping was carried out by the vectorization method. Mapping accuracy encompassing global and Kappa index accuracies was above 90%. Mangrove area expansion by 1.8 km^2, agricultural class reduction and increase in dense Atlantic Rainforest remnants were noted at the Iguape Bay RESEX over the last 36 years (1986 to 2022). In this context, multitemporal land use and land cover analyses become paramount, as they allow for furthering knowledge on targets exposed to the probable impacts of rising mean sea levels, contributing to REEX coastal planning and management and the formulation of public policies aimed at local fishing communities.

Keywords: Conservation unit; Mangrove; Environmental impacts.

Resumo: O presente trabalho teve como objetivo analisar a dinâmica de uso e cobertura da terra na Reserva Extrativista Marinha da Baía do Iguape, utilizando imagens do Landsat de 1986, 1994, 2003, 2017 e 2022. A RESEX Baía do Iguape, abrange os municípios de Cachoeira, São Félix e Maragogipe, localizada no Recôncavo Baiano. Os procedimentos metodológicos englobaram pesquisa bibliográfica, organização de um banco de dados geográficos em ambiente SIG, tabulação de dados, processamento digital de imagens e confecção de mapas. Para a realização dos mapeamentos de uso e cobertura da terra optou-se pelo método de vetorização. A acurácia dos mapeamentos para os índices exatidão global e de Kappa foi acima de 90%. Na RESEX Baía do Iguape, nos últimos 36 anos (1986 a 2022), houve expansão da área de manguezal de 1,8 Km^2, redução da classe agropecuária e aumento dos remanescentes de floresta ombrófila densa da Mata Atlântica. Nesse contexto, considera-se fundamental as análises multitemporais de uso e cobertura da terra, que permitem conhecer os alvos expostos aos prováveis impactos da elevação do nível médio do mar, contribuindo para o planejamento e gerenciamento costeiro da reserva e na formulação de políticas públicas voltadas para as comunidades pesqueiras que ali se encontram.

Palavras-chave: Unidade de conservação; Manguezal; Impactos ambientais.

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1. Introduction

Coastal zones worldwide undergo strong environmental pressures, subject to intense population concentrations and various socio-environmental impacts. In addition to anthropogenic impacts, these areas are also vulnerable to the risks of climate change, likely leading to increased relative mean sea levels (RMSL). The Intergovernmental Panel on Climate Change has, in fact, predicted an alarming scenario by 2100, where RMSL may exceed one meter, affecting numerous cities and coastal ecosystems (IPCC, 2022).

In this scenario, land use and land cover vulnerable to the RMLS impacts require identification, as this is considered an important environmental indicator, essential in understanding targets that will be affected by rising tides. Land use and land cover analyses are, thus, valuable tools for regional or local territorial planning (ARAÚJO FILHO; MENESES; SANO, 2009). Detecting spatial modifications is, thus, crucial, allowing for the analysis and understanding of geographic space changes, providing answers about land use typology distributions. They are also essential in understanding specific environmental issues in a given location, especially within a climate change context (IBGE, 2013).

It is important to note that information on this subject should describe not only current situations, but also recent transformations and the occupation history of the study area (SANTOS, 2004). Spatiotemporal studies are, therefore, paramount in this sense. Land use and land cover spatial change analysis are performed using geoprocessing tools, which refer to a larger set of applications that includes several geotechnologies used to collect, store and apply geographic data integrated with other analyses. These geotechnologies include Geographic Information Systems (GIS), Remote Sensing (RS), Digital Cartography (CD) and the Global Positioning System (GPS), among others (SOUZA FILHO; CRÓSTA, 2003). Among these, Remote Sensing plays an important role in detecting land changes, encompassing land change observations, monitoring and characterizations (ZHU; QIU; YE, 2022).

Several researchers from different countries are currently employing spatio-temporal land use and land cover analyses (SU; FENG; REM, 2023; MUCHE *et al*., 2023; ZHANG; LI, 2022), mainly to detect mangrove vegetation cover changes and the impacts resulting from the surroundings uses of these ecosystems (SELMY *et al.,* 2023; MOHAMED; ELHADI; JACKSON, 2023; NEDD; OYEDOTUN; SIMARD, 2023; NABABA *et al*., 2020).

For example, Mohamed, Elhadi and Jackson's (2023) carried out a multitemporal mangrove cover analysis from 1973 to 2020 at the Chwaka and Menai bays in Zanzibar, Tanzania, using Landsat satellite data and applying the maximum likelihood algorithm for image classification. Their data indicate a mangrove cover reduction of 48.5 hectares (ha) and 6.8 h, respectively, at Chwaka Bay and Menai Bay between 1973 and 2020. Illegal logging, firewood collection, charcoal burning, aquaculture, agricultural and urban expansion are the main causes of mangrove loss in Zanzibar.

In Brazil, some authors, such as Galina, Ilha and Pagatto (2022) and Leão, Araújo and Oliveira (2021) have carried out multitemporal analyses employing geotechnology tools to identify, map and analyze spatiotemporal land use and land cover evolution dynamics in conservation units (CUs), mainly in Extractive Reserves (RESEX). Land use and land cover mapping can be performed both applying visual image interpretations and digital image classifications. In the latter, information is extracted from images to recognize patterns and homogeneous objects and Remote Sensing is employed to map areas of the Earth's surface that correspond to the subjects of interest (INPE, 2002, n.p).

Most studies addressing land use and land cover employ the digital image classification method (SARTORIO *et al*., 2023; PAULA, ESCADA, ORTIZ, 2022; SILVA *et al*., 2021). However, some studies, sych as Souza *et al.* (2023); Souza (2023); Sousa *et al*. (2016) and Braz *et al*. (2017), chose to employ vectorization instead of semi-automatic or automatic classifications in their multitemporal mapping assessments. In this context, this study aims to analyze land use and land cover dynamics at the Iguape Bay RESEX, in the state of Bahia, Brazil, in 1986, 1994, 2003, 2017 and 2022.

2. Study area

Located in the Bahian Recôncavo region, the Iguape Bay RESEX covers the municipalities of Cachoeira, São Félix and Maragogipe (Figure 1), and is located about 110 km from Salvador, the capital of the state of Bahia. It encompasses 10,074 hectares (ha), the equivalent to 100.74 km^2, located in the lower course of the Paraguaçu River. The CU areas in the respective municipalities are as follows: São Félix 94.487 ha (0.94 km^2); Maragogipe 4,145 (41.45 km^2) and Cachoeira 5,833.66 ha (58.35 km^2). The Iguape Bay RESEX consists of 2,831.24 hectares of mangrove area and 5,286.29 hectares of internal Brazilian waters (MMA, 2010).

This RESEX was created on August 11, 2000 and is the first RESEX in the state of Bahia. This CU displays a 6,167 ha (61.37%) overlap with the Todos os Santos Bay Environmental Prptection Area. It was created by the Federal

Government due to the presence of predominantly artisanal fishing activities carried out by local traditional communities (CONSERVATION UNITS IN BRAZIL, 2023).

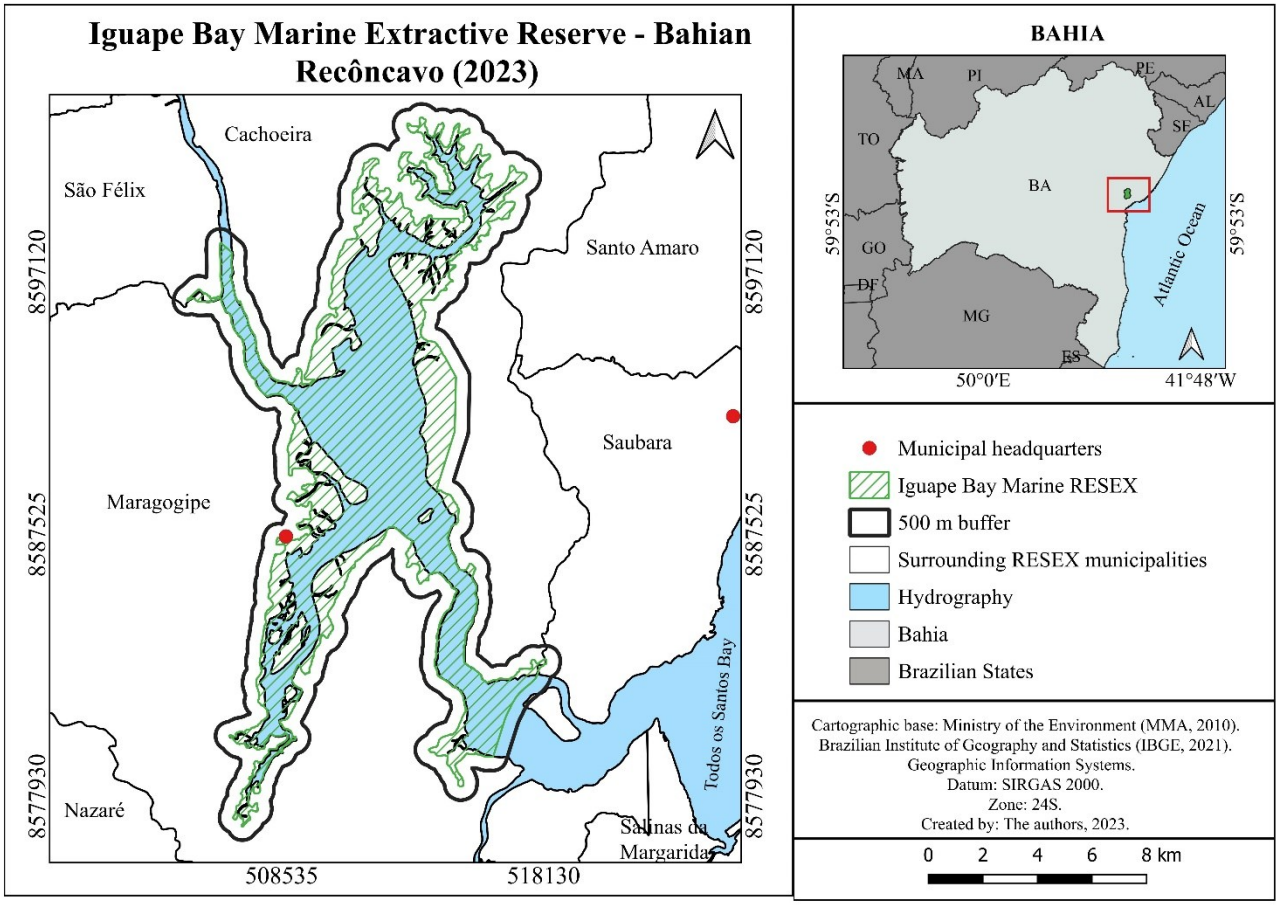


Figure 1 – Geographical location of the Iguape Bay Marine Extractive Reserve, in the Bahian Recôncavo region, Bahia, Brazil.
Source: Authors (2023).

Considering that the perception of territory for traditional communities is not always limited to legal demarcations, with local fishing community views on territory potentially differing from official boundaries, a 500 m buffer was created around the Iguape Bay Marine RESEX polygon. In this analysis, the surrounding area is considered important for land use and land cover assessments. In addition, surrounding mangrove forests are present beyond the legal boundaries of this RESEX.

The study area presents a hot and humid climate with a rainy autumn-winter period. The highest temperatures are noted from November to March and the lowest, from July and August (GENZ, 2007).

2.1 Methodological procedures

A Geographic Database (GDB) was structured containing spatial information, vector files (shapefiles - points, lines and polygons) and raster files (digital images generated by Remote Sensing). The data necessary for the GDB construction were obtained from federal and international agencies and institutions, namely the Brazilian National Institute for Space Research (INPE), Brazilian Institute of Geography and Statistics (IBGE) and United States Geological Survey (USGS). All files (vectors and rasters) were reprojected to the Universal Transverse Mercator (UTM) coordinate system applying the Geocentric Reference System for the Americas (SIRGAS 2000).

A 36-year space-time period (1986, 1995, 2003, 2017, and 2022) was defined to analyze land use and land cover dynamics, due to image availability. Image (period) selection was based on image quality (number of clouds, cloud shadows, and lowest number of noises or errors). The selected images are dated June 14, 1986, July 6, 1994, January 12, 2003, July 17, 2017, and June 17, 2022. All images correspond to autumn-winter, except for the January 12, 2003 image, (summer), chosen because no quality images were available for autumn-winter period for this year.

Landsat 5 and 7 images were obtained free of charge from INPE (2022), while the Landsat 8 and 9 Sensor images were obtained from USGS (2022). The processed images were georeferenced applying a Root Mean Square (RMS) of always less than one pixel. Only the Landsat 5 and 7 images were georeferenced, as the Landsat 8 and 9 images are available already corrected for distortions. Landsat 5 and 7 image corrections were performed based on the corrected Landsat 8 and 9 images. Applied processing techniques include band selection, georeferencing and study area clipping, in addition to the application of a 500 m buffer around the RESEX polygon. The spectral band considered for Landsat 5 and 7 images was R4G5B3, and the color composite used for Landsat 8 and 9 images was R5G6B2.

The Technical Land Use Manual (IBGE, 2013) is essential for land use and land cover mapping efforts. However, a local reality adaptation was required. Thus, the following land use classes were defined based on the obtained images: Mangroves, Agriculture, Rivers, Urban Area, Exposed Soil and Forest (Table 1).

Table 1 – Abstraction levels adopted in mapping land use and coverage at the Iguape Bay Marine RESEX, adapted from the Land Use Technical Manual.

Level 1	Level 2	Level 3
Water mirror	River, lake, pond and dam	River
Land surface	Natural area	Mangrove
		Dense Atlantic Rainforest
	Anthropogenic activity	Urbanization
		Exposed soil
		Agriculture

Source: Adapted from IBGE (2013).

The following basic interpretation elements were used to interpret the satellite images: hue/color, texture, size, shape, shadow, height, pattern, and location (FLORENZANO, 2007) and identify Iguape Bay RESEX land use and land cover classes (Figure 2).

The process of constructing the land use and land cover maps was then initiated. Targets were mapped manually, applying image screen vectorization, due to the need to discriminate the established land use and land cover classes in greater detail. In addition, a certain misperception between exposed soil, apicum area (the transition zone between the mangrove and the mainland), and urban area classes was observed. In this sense, when different types of land use with very similar patterns occur, and the classifier cannot distinguish between targets, the respective areas should be vectorized.

The validation phase was carried out using GPS points obtained in the field for all use and coverage classes. The Kappa and Global coefficient indices were used to complement the validation.

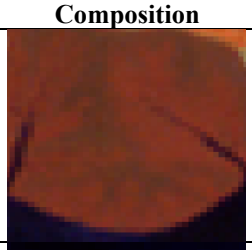
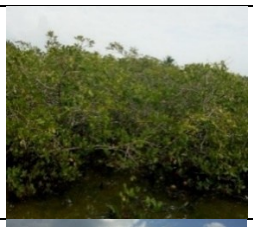
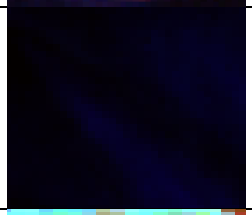
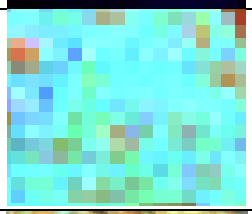
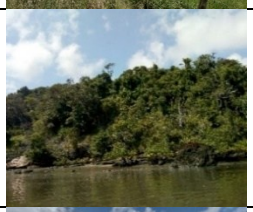
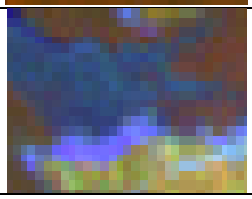
Class	Target/Image Composition	Field Image
Mangrove		
Water		
Urban area		
Agriculture		
Dense Ombrophilous Atlantic Rainorest vegetation		
Exposed Soil/Apicum		

Figure 2 – Interpretation keys for land use and land cover classes represented by a LANDSAT 9 image. Source: Authors (2023).

Information from all vectorized land use and coverage classes was cross-referenced with the classes observed in the reference images, alongside field data, to assess the employed accuracy indices. Random points were associated with the land use and coverage classes generated in the vectorization. Mapping accuracy for the two Global and Kappa indices in the vectorized years (1986, 1994, 2003, 2017 and 2022) was above 90%, falling within the “excellent” map quality classification, according to Landis and Koch (1977).

3. Results and discussion

Six land use and cover classes were identified at the Iguape Bay RESEX: urban, exposed soil, agriculture, forest, mangrove swamp and water or water mirror areas (Figure 3). Water mirrors are an extremely important area for traditional fishing communities that inhabit the surrounding RESEX areas, used as fishing grounds for shrimp (*Caridea* sp.), puffer fish (*Lagocephalus* sp.), jack (*Caranx* spp.), hake (*Cynoscion* ssp.), snook (*Centropomus* spp.), cobia (*Rachycentron canadum*) and ray (*Rajidae* sp.), among others. The water mirror class represents the largest area in all mapped years at the studied RESEX, followed by the mangrove class. In 1986, mangroves covered a total area of 26.6 km^2 (25.8%).

In 1994, a slight increase of 0.4 km^2 was noted, totaling 27 km^2 (26.8%). In 2003, a 26.2 km^2 (26%) area was mapped, representing a 0.8 km^2 decrease compared to 1994. In 2017, a 1.2 km^2 increase was observed, increasing further to 27.9 km^2 (27.8%, with a 0.5 km^2 area increase) in 2022. This quantification refers to the Iguape Bay RESEX polygon. When applying the 500 m buffer, some mangroves area were noted outside the RESEX limits, with a 33.2 km^2 area (19.8%) recorded in1986 mapping, increasing slightly to 33.8 km^2 (20.3%) in 1994, representing a 0.6 km^2 increase. In 2003, another slight increase was observed, totaling 34 km^2 (20.5%), a 0.2 km^2 increase compared to 1994. The mapping without applying the buffer, in the same year, however, indicated a reduced mangrove area.

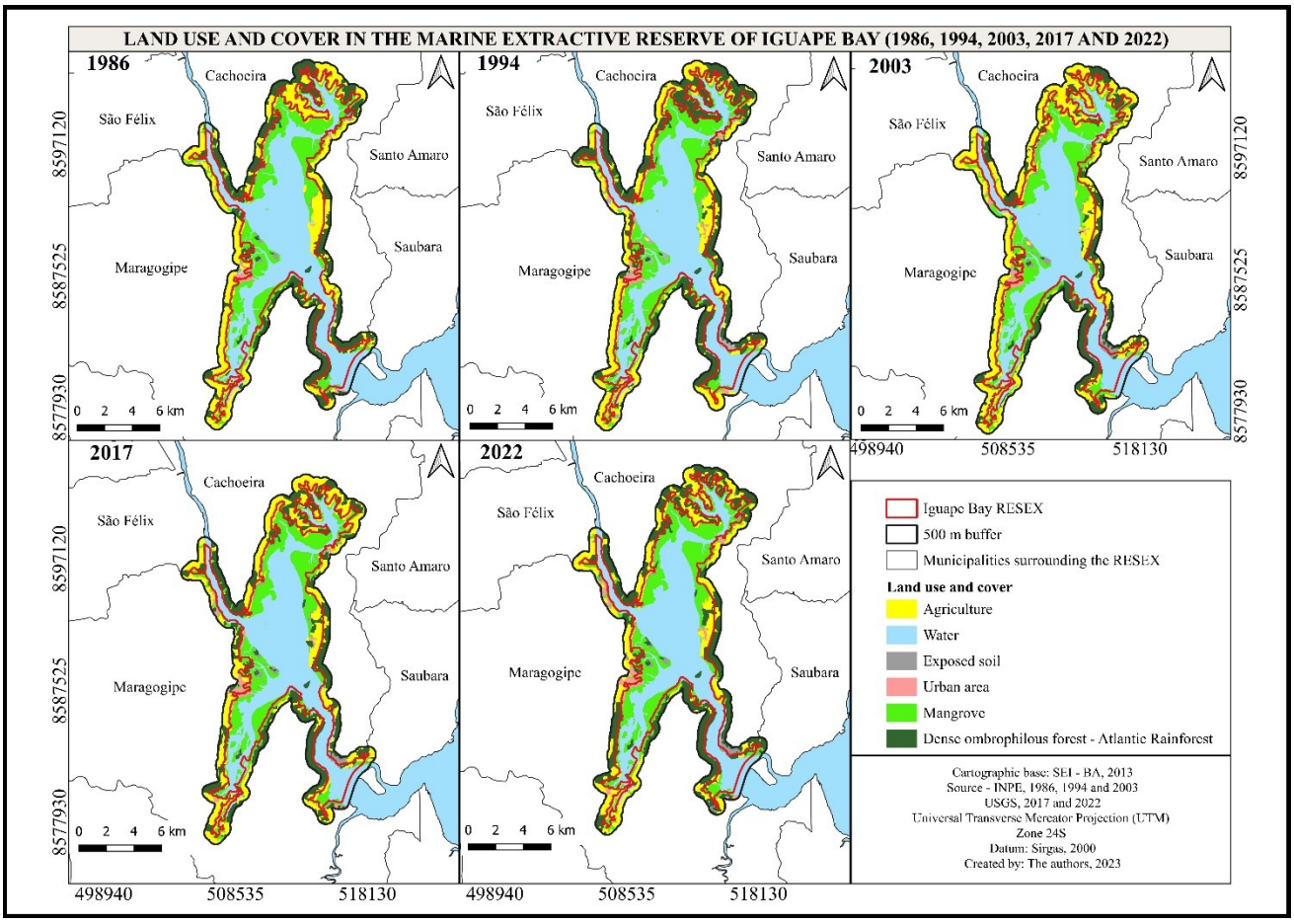


Figure 3 – Multitemporal land use and land cover mapping at the Iguape Bay RESEX/BA. Source: Authors (2023).

In 2017, a 34.3 km^2 (20.5%) area was mapped, encompassing a 0.3 km^2 increase compared to 2003. In 2022 another slight increase, of 0.7 km^2 was observed, totaling 34.7 km^2 (21%) (Table 2). Under this perspective, mangroves present within the legal RESEX limits declined only in 2003, while the mapping applying the 500 m buffer indicated an increase in all mapped years across the last 36 years.

Table 2 – Land use and land cover class quantifications at the Iguape Bay RESEX. Source: The authors (2023).

Land use and land cover classes at the Iguape Bay RESEX										
Land use	**1986**		**1994**		**2003**		**2017**		**2022**	
	km²	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
Agriculture	8.6	8.5	7.0	7.0	11.6	7.5	7.5	5.8	5.8	5.8
Forest	5.5	5.5	6.6	6.5	3.8	5.8	5.8	7.0	7.1	7.0
Mangrove	**26.6**	**26.5**	**27.0**	**26.8**	**26.2**	**26.0**	**27.2**	**27.0**	**27.9**	**27.8**
Urban Area	0.5	0.5	1.0	0.9	1.0	1.0	1.0	1.2	1.2	1.2
Water Surface	58.0	57.5	57.0	56.6	56.1	57.0	57.0	56.8	57.2	56.8
Exposed Soil	1.5	1.5	2.2	2.2	2.0	2.0	2.0	1.4	1.5	1.4
Total	100.7	100	100.7	100	100.7	100	100.7	100	100.7	100
Land use and land cover classes at the Iguape Bay RESEX applying the 500 m buffer										
Land use	**1986**		**1994**		**2003**		**2017**		**2022**	
	km²	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**	**km²**	**%**
Agriculture	36.5	21.8	32.5	19.5	45.0	27	32.5	19.5	28.3	17.0
Forest	30.2	18.3	32.6	19.5	21.3	12.9	32.5	19.5	35.5	21.2
Mangrove	**33.2**	**19.8**	**33.8**	**20.3**	**34.0**	**20.5**	**34.3**	**20.5**	**35.0**	**21.0**
Urban Area	1.5	0.8	2.0	1.2	2.0	1.2	2.5	1.5	3.3	2.0
Water Surface	63.0	37.8	62.2	37.3	61.6	36.6	61.6	37.0	61.8	37.0
Exposed Soil	2.5	1.5	3.8	2.2	3.0	1.8	3.3	2.0	3.0	1.8
Total	166.9	100	166.9	100	166.9	100	166.9	100	166.9	100

Source: Authors (2023).

Aguiar *e* Cançado (2020) indicated that the Iguape Bay RESEX is an important instrument from an environmental point of view, aimed at the conservation of natural environments and the livelihoods of its beneficiaries, while also promoting sustainability. In addition, most CUs in Brazil are under strong pressure from surrounding activities, such as livestock farming, dams, hydroelectric plants, agriculture, shrimp farming, and private enterprises, which put pressure on and impact RESEX-protected resources. This has been noted at several RESEX in Brazil, suc as Iguape Bay RESEX, BA (SOUZA, 2023), Canavieiras RESEX, BA (AGUIAR et al., 2022; AGUIAR, 2023), Acaú RESEX, Goiana, PE/PB (SILVA et al., 2020), São João da Ponta RESEX, PA (FERNANDES; PIMENTEL, 2019) and Mocapajuba RESEX, PA (CAVALCANTE; LIMA, 2019), RESEX Jaci-Paraná - RO (SANTANA; SILVA, 2019).

Some studies (SANTOS et al., 2022; GALINA; ILHA; PAGATTO, 2022; LEÃO; ARAÚJO; OLIVEIRA, 2021), detected local mangrove area increases when carrying out multitemporal analyses. This is not, however, usual in both national and international scenarios, as these ecosystems have suffered significant environmental problems, mainly caused by illegal shrimp farming and increased urbanization (SOUZA *et al.*, 2021; NABABA *et al*., 2020; SOUZA *et al*. 2019).

In this sense, some mangrove degradation vectors were detected at the Iguape Bay RESEX, namely urban expansion and sewage and solid waste pollution (Figure 4). These, alongside other factors such as the construction of the Pedra do Cavalo Hydroelectric Plant dam and the Enseada Paraguaçu Shipyard (EEP), have directly affected local fishing resources.

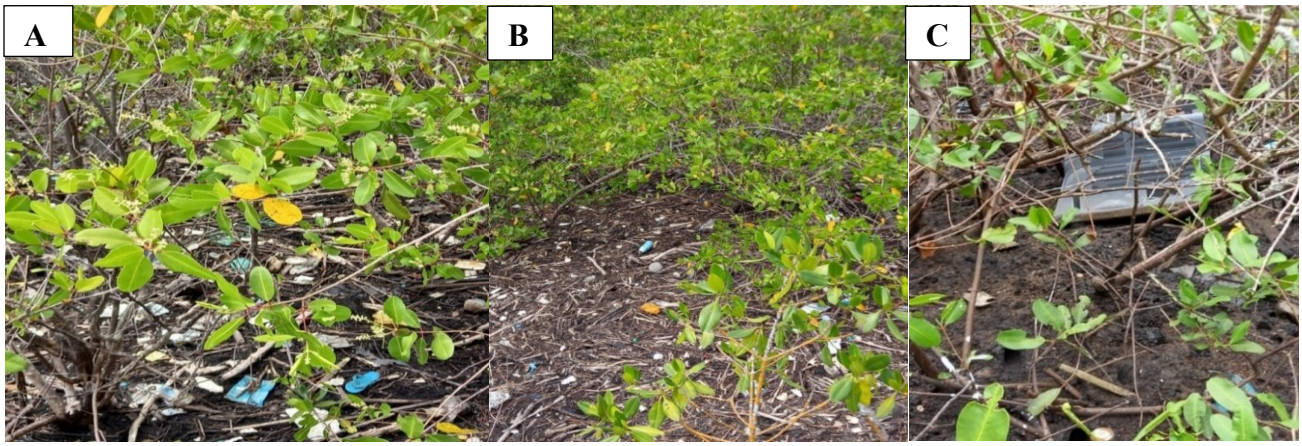


Figure 4 – Images A, B and C indicate the presence of solid waste in Iguape Bay RESEX mangrove areas, near the urban Maragogipe area.
Source: Fieldwork (2023).

Silva *et al.* (2020) and Leão, Araújo and Oliveira (2021) when assessing land use and land cover employing RESEX as a spatial cutout, noted that almost all of these areas suffer anthropic pressures from their surroundings. Regarding Iguape Bay, several apicum features are noted to the west of the RESEX, located near pastures. In addition, mangroves and fenced apicums are also verified, which makes it difficult for fishing populations to access mangrove areas. The local apicum areas are used specifically for livestock farming practices (Figure 5), in which cattle trampling causes soil compaction, making it difficult for mangrove propagules to develop.

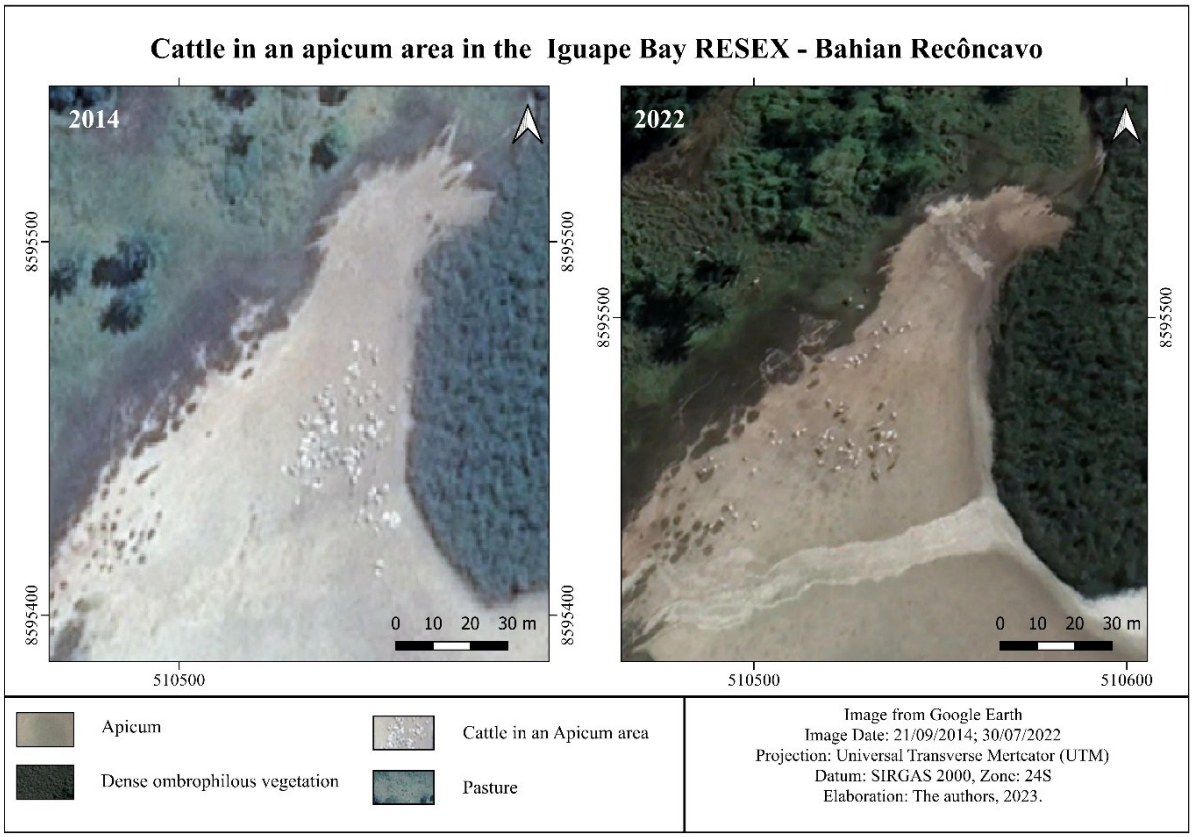


Figure 5 – Cattle grazing in an apicum area at the Iguape Bay RESEX, Cachoeira, BA. Source: Authors (2023).

Even amidst the anthropogenic pressures that take place near the Iguape Bay RESEX, local mangroves have remained resilient and expanded far from urban areas. The same has been verified at the Caeté-Taperaçu RESEX, in Bragança, Pará, (LEÃO; ARAÚJO; OLIVEIRA, 2021).

In the Iguape Bay RESEX mapping carried out herein, the exposed soil class corresponds to apicum areas and mangrove areas suppressed by anthropogenic activities. A degraded mangrove area was present in 1986, corresponding to 33.72 ha (0.33 km^2) northeast of Iguape lagoon, close to and upstream of the town of Santiago do Iguape, in the municipality of Cachoeira (Figure 6). The degraded area recovered after eight years, totaling 18.97 ha (0.18 km^2). Another degraded area corresponding to 29.71 ha (0.29 km^2) was also present in the same location, albeit close to the river channel. Nine years later (2003), this area was almost completely recovered, recovering further in 2017 and 2022, with an increased vegetation cover.

The greatest mangrove increase in the last 36 years, 1.1 km^2, was noted in the municipality of Cachoeira considering the the RESEX polygon plus the 500 m buffer. However, exposed soil areas not corresponding to mangrove vegetation are noted in the 2017 and 2022 mappings of mangrove area surroundings, which used to be occupied by dense Atlantic Rainforest or by the agricultural class. An increase was also observed in the municipality of Maragogipe, although to a lesser extent than in Cachoeira (0.7 km^2). Fluctuations in land use and land cover class quantifications were observed across the study years, with only the mangrove class demonstrating continuous growth. In fact, local mangroves exceed the legal limits of the RESEX in all mapped years.

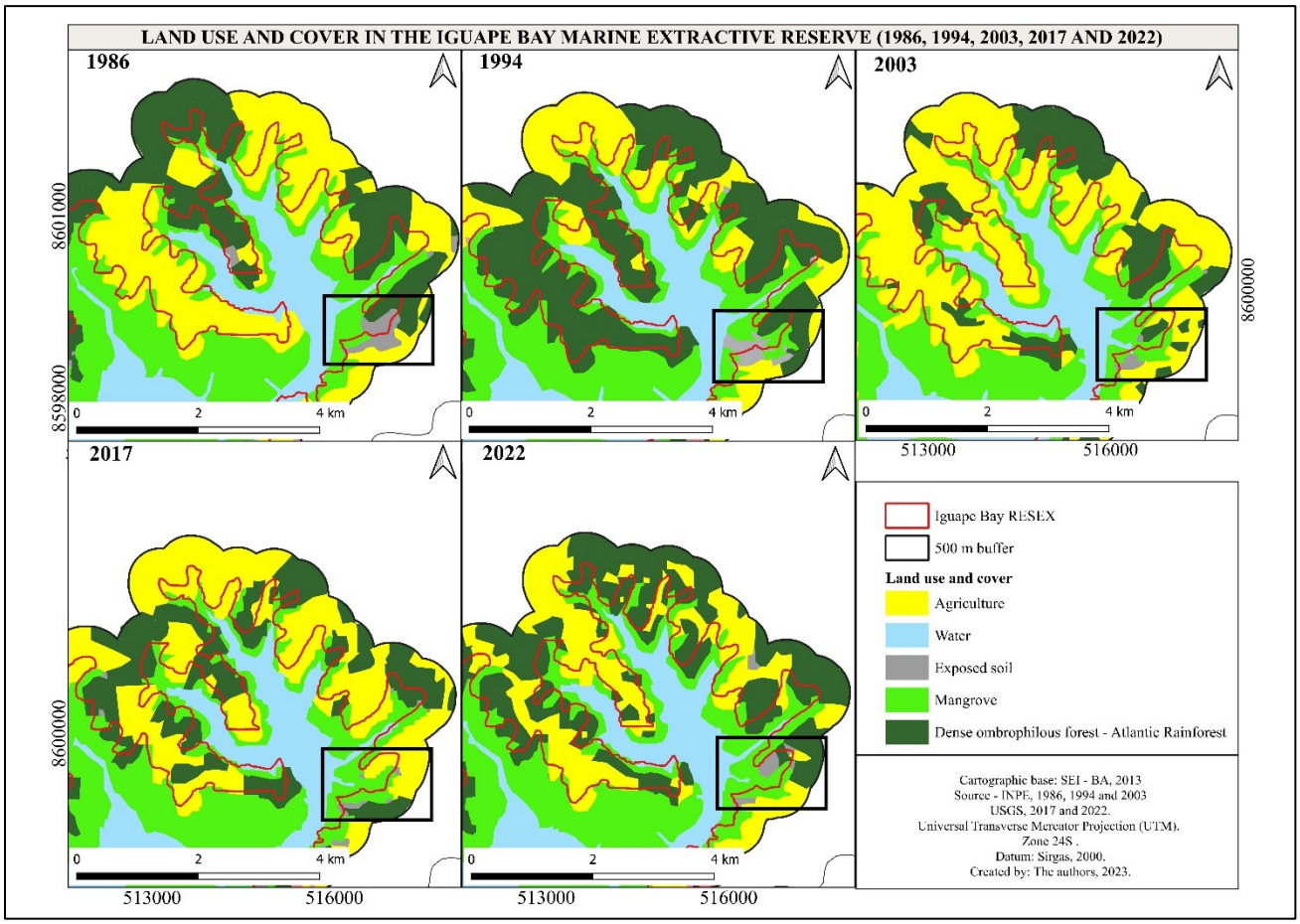


Figure 6 – Evolution of mangrove areas in the Iguape Bay RESEX, in Cachoeira, BA, Brazil. Source: Authors (2023).

Mangrove expansion is directly linked to increasing salinity values noted at Iguape Bay. Genz (2007); Genz, Lessa and Camargo (2008) and Silva et al. (2015) assessed the impacts of a dam and hydroelectric plant on the Paraguaçu River and Iguape Bay and reported that the dam interferes with the local freshwater flow and has increased salinity levels in the Iguape Bay estuary. This, in turn, altered estuarine dynamics, resulting in mangrove expansion.

Mangrove area preservation and expansion at the Iguape Bay RESEX are also due to environmental education actions carried out in surrounding RESEX municipalities, specifically Maragogipe, where the Vovó do Mangue Foundation is located, which carries out several mangrove preservation actions. In addition, monitoring actions of the Chico Mendes Institute for Biodiversity Conservation (ICMBio) and initiatives by traditional quilombola and fishing communities, which recognize the social importance of mangroves for their respective populations as a means of survival and income, are also noteworthy.

The agricultural class applie dherein encompasses both agriculture and livestock farming. Both are presente in RESEX municipalities, with a predominance of livestock pastures. Piassaba and oil palm extraction are also carried out near Iguape Bay. The agricultural class, considering the RESEX limits, encompassed 8.6 km^2 in 1986, decreasing 1.6 km^2, to 7 km^2, in 1994. In 2003, a 4.6 km^2 increase was observed compared to 1994, reducing again (4.1 km^2) in 2017. In the 2022 mapping, the area totaled 5.8 km^2, representing a further 1.7 km^2 reduction compared to 2017.

When applying the 500 m buffer, the agricultural class totaled 36.5 km^2 area in 1986, decreasing 4 km^2 in 1994, to 32.5 km^2. A 12.5 km^2 increase was observed in 2003, totaling 45 km^2. In 2017, however, a decrease in the same amount (12.5 km^2) was observed. In 2022, another decrease was noted, of 4.2 km^2, totaling 28.3 km^2. Several economic activities are carried out within 500 meters of the RESEX polygonal area, mainly eucalyptus plantations. The total reduction in

agricultural activities within the RESEX boundaries was of 2.8 km^2, the result of actions such as the recognition of quilombola lands, which consequently contributed to mangrove and dense Atlantic Rainforest class expansions.

Fernandes and Pimentel (2019) when assessing the São João da Ponta Marine Reserve, and Leão, Araújo and Oliveira (2021) when assessing the Caeté - Taperaçu Marine Reserve, Bragança, Pará, observed that both reserves are under strong pressure from their surroundings, *i.e.,* from livestock farming, mechanized agriculture and the construction of hydroelectric plants, specifically the Tabajara hydroelectric plant. Similar to the Iguape Bay Reserve, it is important to highlight livestock farming as an economic activity present near CUs.

The forest class corresponds to remaining dense Atlantic Rainforest areas. At the Iguape Bay RESEX, this class totaled 5.5 km^2 in 1986, In 1994, a 1.1 km^2 increase took place, totaling 6.6 km^2. In 2003, the forest area was reduced to 3.8 km^2. In 2017, a 5.8 km^2 increase was observed, followed by a further 1.3 km^2 increase in 2022. This king of vegetation preservation was also observed by Machado, Soares and Faria (2022) at the Cururupu Marine RESEX, MA employing 2014 and 2020 Landsat 8 images, land use classes defined based on visual interpretation, local region knowledge, and a supervised classification applying the Semi-Automatic Classification Plugin (SCP) QGIS 3.10.10 software plugin.

In turn, the forest class mapping applying the 500 m buffer in 1986 totaled 30.2 km^2. In 1994, the area increased slightly to 32.6 km^2, a 2.4 km^2 increase compared to 1986. In 2003, the mapped area reduced 11.3 km^2, to 21.3 km^2. In 2017, the local forest increased compared to 2003, totaling 32,5 km^2. In 2022, the forest area corresponded to 35.5 km^2, with a 3 km^2 increase compared to 2017. The remaining Atlantic Rainforest areas were the only class to significantly increase their coverage area (1.6 km^2) in the UC polygon.

The multitemporal RESEX landscape analysis applied herein indicates vegetation cover increases. The observed increase in the forest class took place due to some surrounding RESEX areas being recognized as quilombola territories, in the municipalities of Maragogipe (Salamina Putumuju, Dendê, Porto da Pedra, Guaí, Guerém, Giral Grande, Enseada do Paraguaçu, among others) and Cachoeira (São Francisco do Paraguaçu, Santiago do Iguape, Dendê, Kaonge, Engenho da Praia, Engenho da Ponte, etc.). These traditional communities comprise the only RESEX beneficiaries by law, extracting oil and piassaba palm from the forests, practicing fishing and shellfish gathering and engaging in subsistence agriculture (manioc, cassava, banana, corn, beans), and extensive cattle raising.

4. Final considerations

The mapping employed herein at the Iguape Bay RESEX detected six land use and land cover classes, namely mangroves, urbanized areas, agriculture, dense Atlantic Rainforest remnants, and exposed soils. The landscape at the RESEX reveals increases in mangrove vegetation cover over the past 36 years. Dense Atlantic Rainforest class increases and an agricultural class decrease were also noted. This study also confirmed that local Iguape Bay mangroves exceed legal RESEX limits.

In the last 36 years, a 1.2 km^2 increase for the RESEX cutout took place, increasing to 1.8 km^2 when applying the 500 m buffer. The municipality of Cachoeira underwent the greatest area gains, followed by Maragogipe. Mangrove area preservation and expansion are due to environmental CU education actions, ICMBio monitoring and traditional fishing communities.

This study also furthers knowledge on land uses and coverage exposed to the probable impacts of rising sea levels, thus contributing to coastal Iguape Bay RESEX planning and management and the formulation of public policies aimed at local fishing communities.

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