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Analysis of the dynamics of deforestation and regeneration of natural vegetation in the Itapecuru River Basin, Maranhão

Análise da dinâmica do desmatamento e regeneração da vegetação natural na Bacia Hidrográfica do Rio Itapecuru, Maranhão

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Abstract: Due to the various changes that occur in a Hydrographic Basin, such as deforestation, which triggers a range of environmental problems, the present study aims to evaluate the dynamics of land use and occupation, analyzing essential factors, such as deforestation rates and regeneration of deforested areas over a multitemporal series of the last 31 years (1988 to 2019) in the Itapecuru River Hydrographic Basin (BHRI), using geoprocessing tools through images available on the Mapbiomas collection 7.0 platform. Changes were verified in 9 classes for natural vegetation formation and 7 for anthropic vegetation formation. According to the data analysis in 1988, the BHRI had 4,950,21 ha of vegetation. Secondary vegetation increased between 1988 and 2019, from around 33,329 ha to 240,16 ha, allowing us to consider an increase in regeneration within the basin area over the years. The methodology using geoprocessing contributed positively to achieving the results presented, and even though there was an increase in regeneration rates, there is a need to invest in actions to protect natural resources, especially native vegetation.

Keywords: Land use; Environmental Impacts; Geoprocessing.

Resumo: Em razão das diversas modificações que ocorrem em uma Bacia Hidrográfica, como o desmatamento, que desencadeia uma gama de problemas ambientais, o presente estudo visa avaliar a dinâmica do uso e ocupação do solo, analisando fatores importantes, como índices de desmatamento e regeneração de áreas desmatadas ao longo de uma série multitemporal dos últimos 31 anos (1988 a 2019) na Bacia Hidrográfica do Rio Itapecuru (BHRI), utilizando ferramentas de geoprocessamento por meio de imagens disponíveis na plataforma Mapbiomas coleção 7.0. Foram verificadas as modificações em 9 classes para formação vegetal natural e 7 classes para formação vegetal antrópica. De acordo com a análise dos dados, no ano de 1988 a BHRI apresentou um total de 4.950.212 ha de vegetação em toda sua área. A vegetação secundária aumentou entre os anos de 1988 e 2019, que antes eram cerca de 33.329 ha, passou a ser 240.165 ha, permitindo considerar que houve um aumento na regeneração dentro da área da bacia ao longo dos anos. Verificou-se que a metodologia utilizando o geoprocessamento contribuiu positivamente para a realização dos resultados apresentados, e mesmo havendo um aumento dos índices de regeneração, existe a necessidade de investimento em ações de proteção dos recursos naturais e principalmente da vegetação nativa.

Palavras-chave: Análise; Impactos Ambientais; Geoprocessamento.

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1. Introduction

The intensification of deforestation in micro-watersheds for the installation of agricultural activities puts the conservation of natural resources and the provision of ecosystem services at risk (BARÃO et al., 2021). According to Brito et al. (2016), one of the main factors contributing to the intensification of deforestation processes is the expansion of agriculture in the country. The predatory use of natural resources without conscious management unconditionally affects natural ecosystems. This process is responsible for the rapid change in land cover, often carried out intensively and poorly planned, resulting in the environmental degradation of rural areas and micro-watersheds (LEANDRO and ROCHA, 2019).

For Facco et al. (2016), there is a need to apply data collection techniques that aim to provide data and perform analyses on the use of natural resources. The authors point to remote sensing technologies as practical monitoring tools, as they provide data processing quickly, with a reasonable degree of accuracy, and at a low cost. Mapping and assessing changes in land use and land cover has gained significant prominence in recent years due to the growing concern with the dynamics of global change and environmental preservation (ROSAN and ALCÂNTARA, 2016).

Information on the impacts associated with land use dynamics and trends in the occupation and use of geographic spaces constitutes an ongoing challenge in the management of river basins, as this can be useful for adequate planning of water resource use, for example. Remote sensing data and Geographic Information System techniques have helped collect this information, making it possible to understand the dynamics of land occupation (DUARTE et al., 2022). The intensification of land use has reduced forest cover and facilitated its conversion, promoting a decrease in biological productivity and loss of biodiversity and ecosystem services (VIEIRA and ALMEIDA, 2013).

For Barbosa et al. (2022), understanding environmental vulnerability is extremely important. Monitoring the environmental quality of an area and carrying out assessments is crucial to obtaining data on aspects that influence both negatively and positively. This highlights the intersection of multiple criteria, connecting with anthropic actions and degree of interference. These criteria are important to favor results that enable the determination of more conservation units within Hydrographic Basins.

Natural resources are of utmost importance for the balance of the environment. Unbridled use and inadequate management cause a range of environmental problems that can often be irreversible. Thus, this study aims to analyze deforestation and regeneration rates, contributing to the identification of vegetation loss due to deforestation rates and the possible occurrence of regeneration in areas affected by this environmental degradation in the Itapecuru River Basin in the state of Maranhão.

2. Methodology

2.1 Study area

Maranhão is one of the 27 federative units of Brazil, located in the Northeast Region. The state borders three states: Piauí (east), Tocantins (south and southwest), and Pará (west), in addition to the Atlantic Ocean (north). With an area of 331,937.450 km² and 217 municipalities, it is the second-largest state in the Northeast region and the eighth-largest in Brazil. The state has a population of 7,114,598 inhabitants (IBGE, 2021). The Itapecuru River Basin covers an area of approximately 52,972.1 km² (Figure 1), representing 16% of the territory of the state of Maranhão, Alcantâra (2004). The Itapecuru River rises in the foothills of the Crueira, Itapecuru, and Alpercatas mountain ranges at altitudes of approximately 500 m, with an extension of 1,050 km; its mouth goes to the Arraial Bay, in the south of the island of São Luís.

The Itapecuru hydrographic region comprises the Cerrado and Mata dos Cocais ecosystems, transitional vegetation between the Cerrado and the Amazon Rainforest. Both are currently undergoing degradation due to human action. Given their unique natural wealth and scenic beauty, these formations are essential for biological studies and "sustainable development" (SILVA and CONCEIÇÃO, 2011).

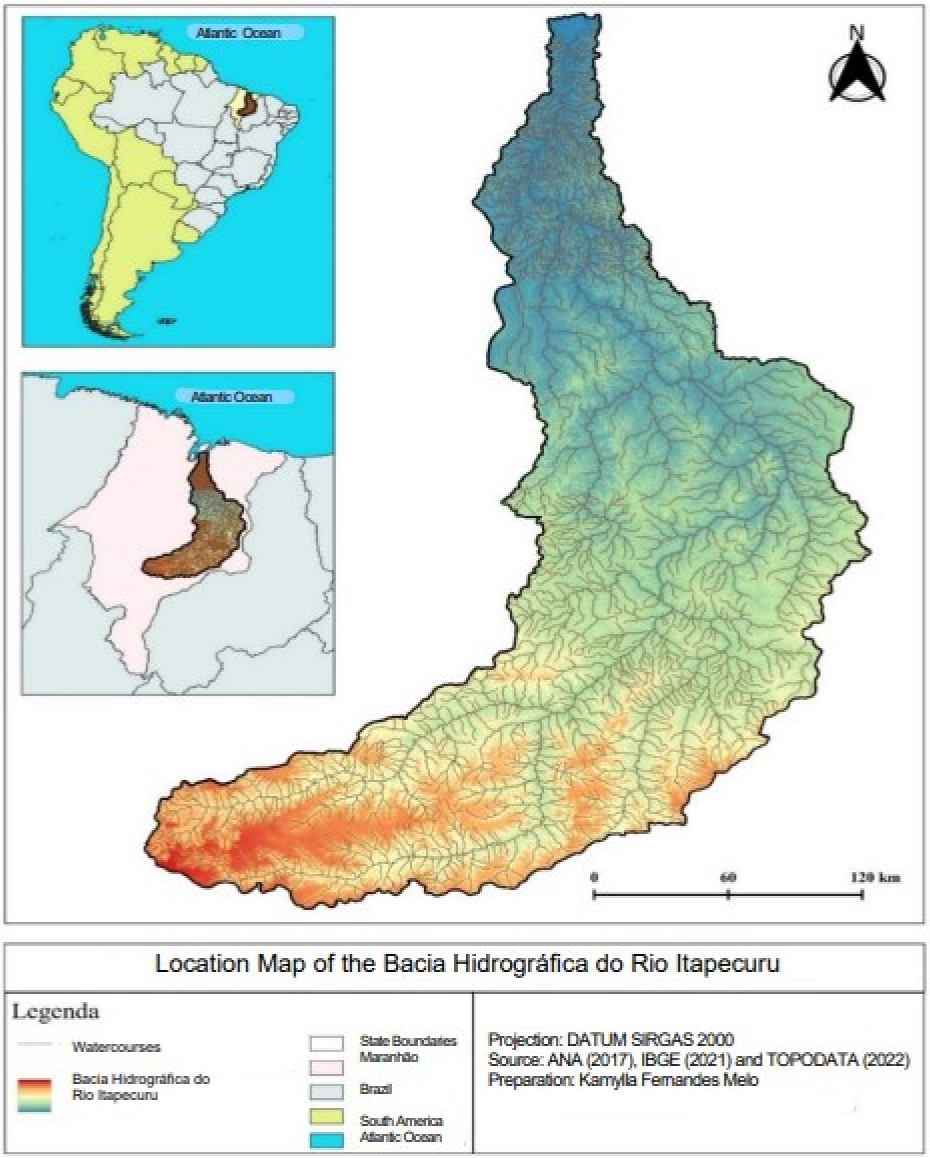

Figure 1 – Location Map of the Itapecuru River Basin – MA.
Source: Authors (2022).

2.2 Data acquisition, procedures, and tools used for research

The *land* use and land cover data acquired through the Mapbiomas collection 7.0 platform was used. The Mapbiomas project provides free downloads of annual land use and land cover maps from 1985 to 2021. Deforestation and Reforestation data were used, initially from 1988 to 2019, for the multitemporal analysis of the Itapecuru River Basin. The platform uses data from the Landsat 5-sensor TM satellites (images from 1988 to 2008) and Landsat 8-sensor OLI (image from 2019). These satellites have a spatial resolution of 30 m, corresponding to the spatial resolution of the data obtained. The platform data are already pre-processed and correspond to the area in hectares for each class. Its processing is obtained by multiplying the number of pixels by the spatial resolution of the image (900 m²) and by subtracting each year.

The data were classified into hectares and refined in the Excel program, which originated the quantitative graphs of the natural and anthropic classes found in the Basin. The GIS software Qgis version 3.22.1 was used to process the satellite images in Raster format. The classification was carried out according to the standard Mapbiomas color palette with each class; in this way, the BHRI layouts were prepared for the years 1988, 1995, 2000, 2010, and 2019, generating the representation of the multitemporal analysis in order to evaluate the dynamics of the use and coverage of the study area.

On the Mapbiomas platform, annual coverage can be checked by biome category, geographic division, hydrographic basins, conservation units, etc., according to the classification established by the platform, which uses hierarchical classification for use and coverage classes, according to the Food and Agriculture Organization (FAO), IBGE, and (MAPBIOMAS, 2022).

Table 1 shows the identity of each of the classes that address the issue of deforestation and reforestation identified in the Itapecuru River Basin and their reference subclasses.

Table 1 – Classes of land use and cover of natural and anthropogenic nature for the Itapecuru River Basin – MA.

Natural plant formation	Anthropic Plant Formation
Forestry Training	Agriculture
Savannah Formation	Forestry
Mangrove	Pasture
Wooded Sandbank	Agriculture
Flooded Field and Marshy Area	Temporary Farming
Countryside Formation	Perennial Crops
Apicum	Mosaic of Uses
Other Non-Forest Formations	
Herbaceous/Shrubby Restinga	

Source: Authors (2022).

3. Results and discussion

3.1 Native vegetation and its recovery

According to the results acquired through data from the Mapbiomas platform collection 7.0 (Figure 2), which correspond to the primary vegetation index for the time series from 1988 to 2019 of the Itapecuru River Basin, the primary vegetation presented a total of 4,950,212 hectares. This value is for the year 1988. The graph notes the reduction of this class of vegetation, which declined until the last year of the analysis, 2019.

In a study of the analysis of land use and occupation for the state of Maranhão, Santos et al. (2019) quantitatively evaluated the classes of vegetation types present in the state from 2000 to 2016 and found that the amount of native area in the initial period corresponded to the class of greatest occupation in the territory; however, in 2016, it also suffered a reduction throughout the state.

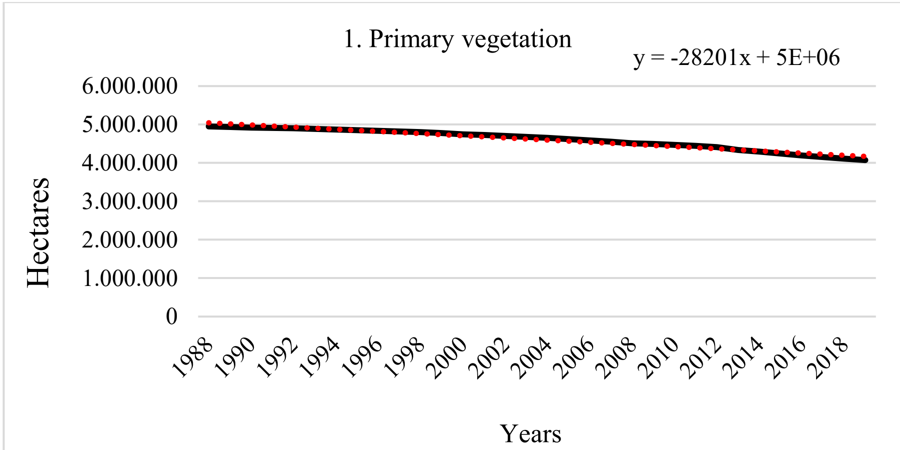

Figure 2 – Primary vegetation class index for the Itapecuru River Basin – MA.
Source: Authors (2022).

As seen in (Figure 3), there was a big jump in the increase in the secondary vegetation class; according to the trend line, the class that initially 1988 had around 33,329 ha at BHRI over the years increased to 240,165 ha in 2019. The peak increase in this type of vegetation may be related to the disappearance of areas of dense forests present in the primary vegetation class.

According to Morais (2022), when analyzing native vegetation by subclasses based on the type of vegetation for the Bacanga River Basin on São Luís Island, it was found that the natural class disappeared as activities such as logging, subsistence agriculture, and population expansion occurred in that space over the years, thus emphasizing anthropization as the main factor in the reduction of flora in the region analyzed.

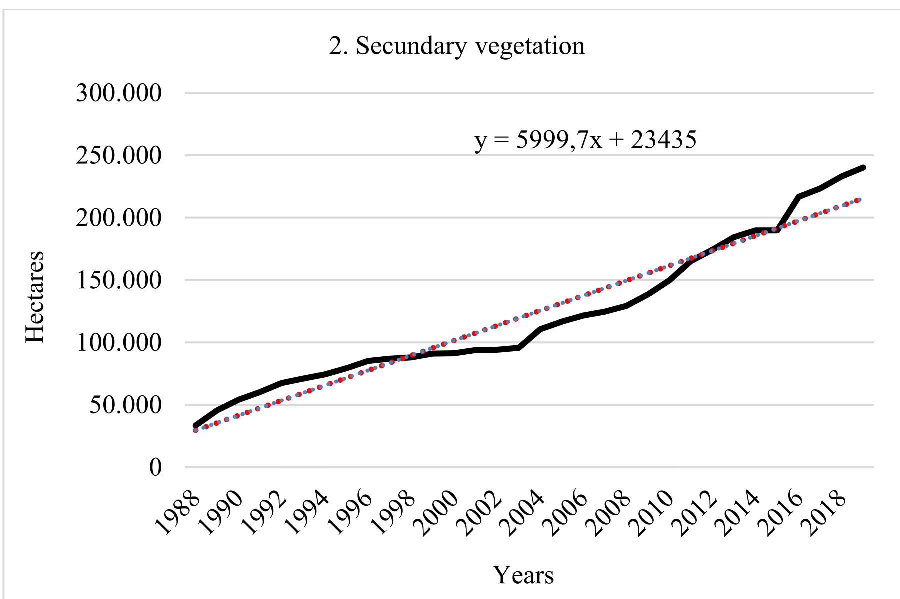

Figure 3 – Secondary vegetation class index for the Itapecuru River Basin – MA.
Source: Authors (2022).

Regarding the results generated in the study (Figure 4), the recovery rate of the disappearance of vegetation classes converted into recovery for secondary areas increased in 1988. The class presented a total of 11,820 hectares. This class, in turn, increased, with a positive peak of 20,156 ha in 2003. The highest peak in the series occurred in 2015 when the class reached 39,847 ha. However, even with the drop at this peak, the class remained high as the years passed. This class corresponds to mosaics of agricultural activities and is therefore characterized as an anthropic class.

According to Carneiro et al. (2008) and Jardim (2021), the expansion of agricultural practices in the state began in the 20th century. Thus, over the years, activities linked to soybean farming and agriculture began to be introduced throughout the state of Maranhão, contributing to the deforestation and modification of native vegetation for the new plant segment linked to the class of agricultural crops.

Lima et al. (2020) point out that a large part of the environmental impacts that occur in the state of Maranhão are related to anthropogenic events, such as demographic growth and the fragility of environmental management, which is undervalued in some municipalities in the state, often due to a lack of environmental inspection.

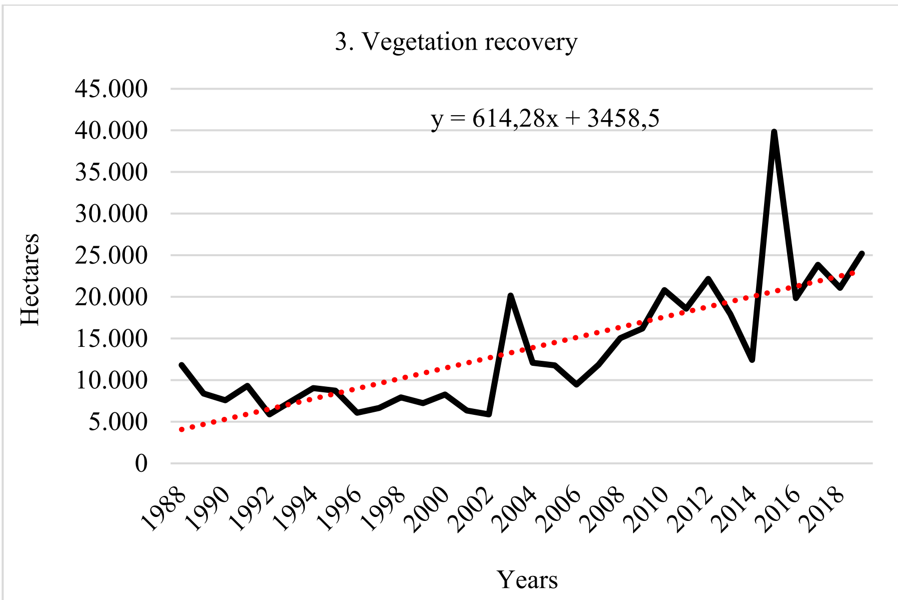

Figure 4 – Recovery class index for secondary for the Itapecuru River Basin – MA. Source: Authors (2022).

3.2 Deforestation of primary and secondary vegetation

The primary vegetation of the BHRI has suffered from deforestation in its densest natural vegetation class, which has been evident over the years (Figure 5). In 2000, there was a peak of 22,70 ha, the reduction of natural vegetation, which happened again in a higher way in 2013 with 67,77 ha; that is, the primary vegetation had a significant reduction in that year. Mendes et al. (2021) evaluated the deforestation of a micro-basin of the Pirarara River, Cacoal-Rondônia, with images from the years 1988, 1998, 2008, and 2018 from the Landsat 5 and Landsat satellites, carried out a multitemporal analysis of the vegetation of those years and discovered the deforestation suffered in the region based on land use and occupation, data like this demonstrate that the increase in deforestation occurred in other regions, corroborating the influence of factors such as population density and the advancement of agriculture throughout the country.

According to Campos (2019), the Maranhão cerrado has suffered from agricultural exploitation. There must be a strategy aimed at conserving native vegetation and preserving hydrographic basins since these regions encompass a range of ecosystems. Preserving these areas will stabilize environmental impacts and highlight the importance of defining a hydrographic basin as a management unit so that actions to preserve the natural environment can take place.

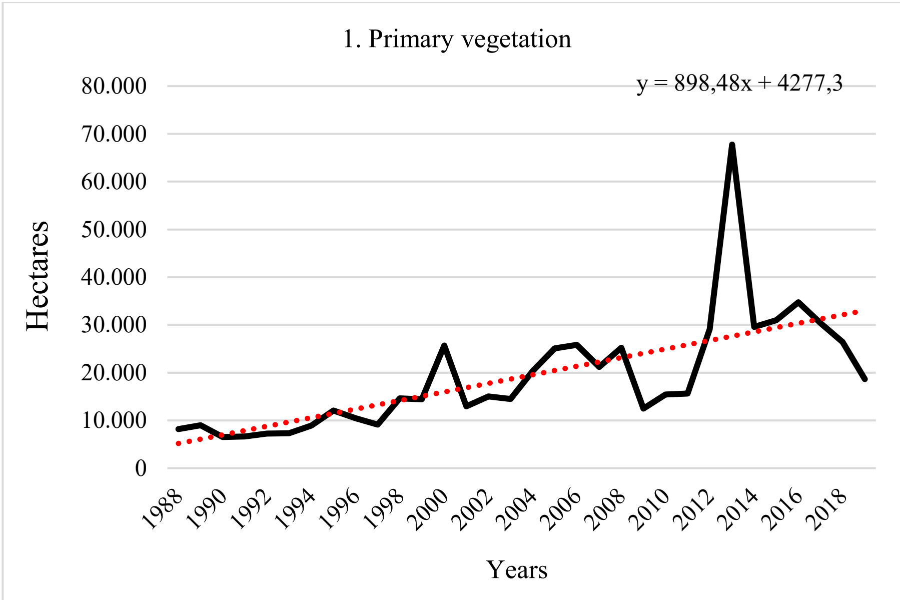

Figure 5 – Deforestation rate of primary vegetation for the Itapecuru River Basin – MA. Source: Authors (2022).

When analyzing the BHRI deforestation chart for the time series from 1988 to 2021 (Figure 6), it was noted that secondary vegetation suffered a reduction in the number of hectares over the years analyzed. This behavior may be related to agricultural activities in this period, classified as an increase in anthropic vegetation. According to Silva Junior et al. (2018), deforestation of cerrado areas, such as grassland and savanna formation, occurs through agricultural expansion. The authors also point out that deforestation resulting from fires is still considered relatively minor, even if it increases slightly in drier periods.

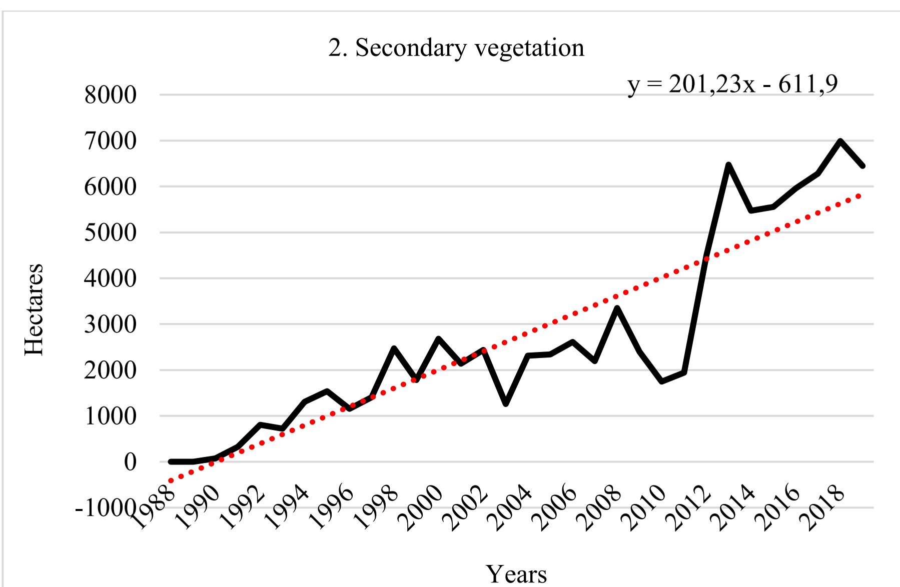

Figure 6 – Deforestation rate of primary vegetation for the Itapecuru River Basin – MA. Source: Authors (2022).

In 1988, most of the vegetation cover of the Itapecuru River Basin was composed of native flora, which was classified as primary vegetation (Figure 7 A). When highlighting areas of the basin in two situations, it is clear that section B has a part of the basin in excellent dynamics due to the anthropic class; this area still has natural vegetation. In section C, a part less modified by other anthropic classes can be observed, highlighting that in 1988, native vegetation predominated in this region.

For Ferreira et al. (2020), one of the main modulating agents of the environmental situation in the state of Maranhão is economic growth. This factor contributes to direct impacts on flora and fauna, thus causing profound changes in the sociocultural patterns of traditional populations. The increase in productivity in the agrarian space and the agricultural model, not to mention the direct actions that modify land use and management, negatively impact the area with natural vegetation.

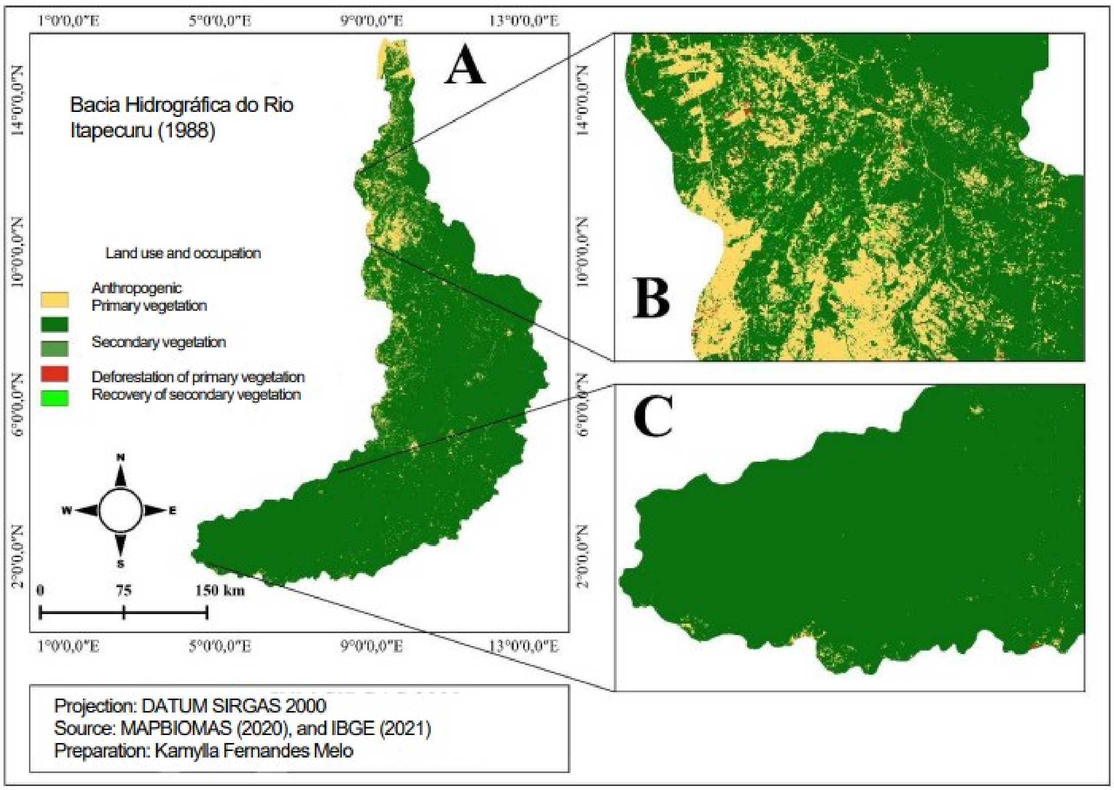

Figure 7 – Map of Deforestation and Regeneration of the Natural Vegetation of the Itapecuru River Basin - MA for the year 1988.
Source: Authors (2022).

In 1995, natural vegetation exhibited visual behavior similar to that of 1988 (Figure 8). Apparently, even over the years, very few visual changes were noted. However, there was still an increase in anthropized areas and deforestation.

Silva et al. (2021) emphasize that natural resource management bodies in the state of Maranhão need actions in partnership with society for environmental preservation and awareness, as they highlight the occurrence of actions that negatively impact natural resources, which are mostly left aside due to a lack of popular initiative, thus weakening the application of environmental management in socio-environmental terms.

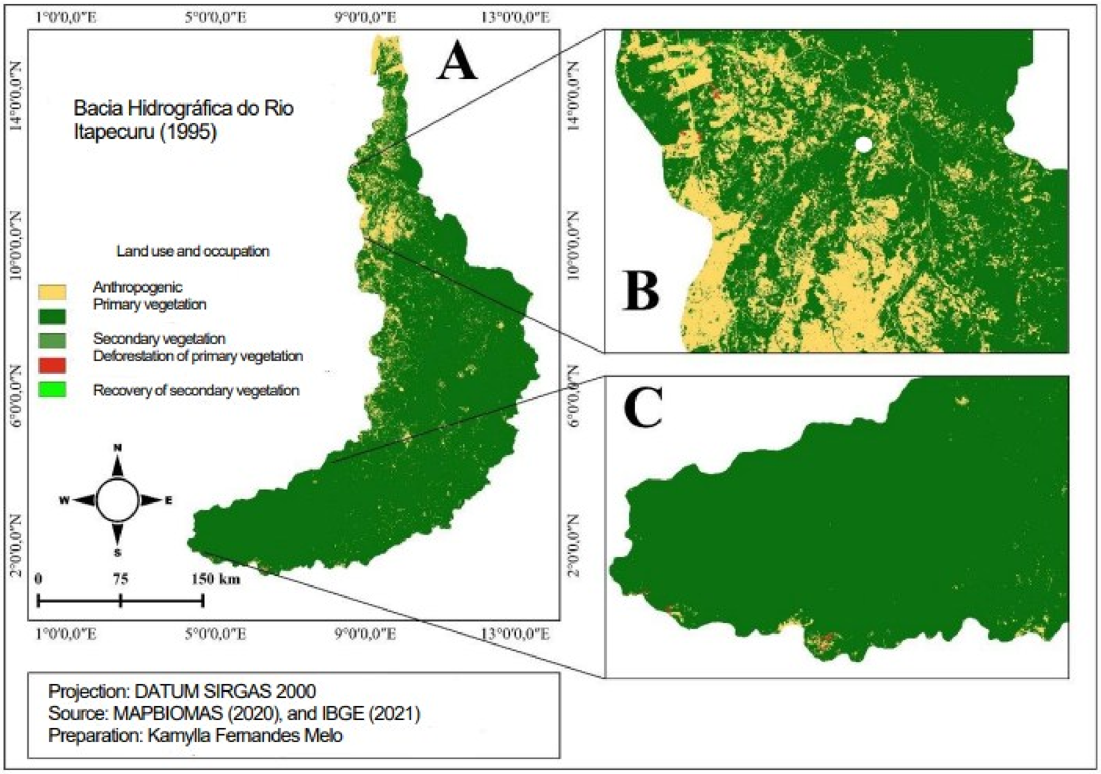

Figure 8 – Map of Deforestation and Regeneration of the Natural Vegetation of the Itapecuru River Basin - MA for the year 1995.
Source: Authors (2022).

The year 2000 was marked by the intensification of the anthropic class in section B (Figure 9). This class propagated widely, and the area of deforestation of primary vegetation corresponding to dense forests can also be observed in section C.

According to Silva et al. (2015), deforestation implies changes that range from the displacement of fauna to modifications in the soil and climate of the region that suffers from such a negative impact.

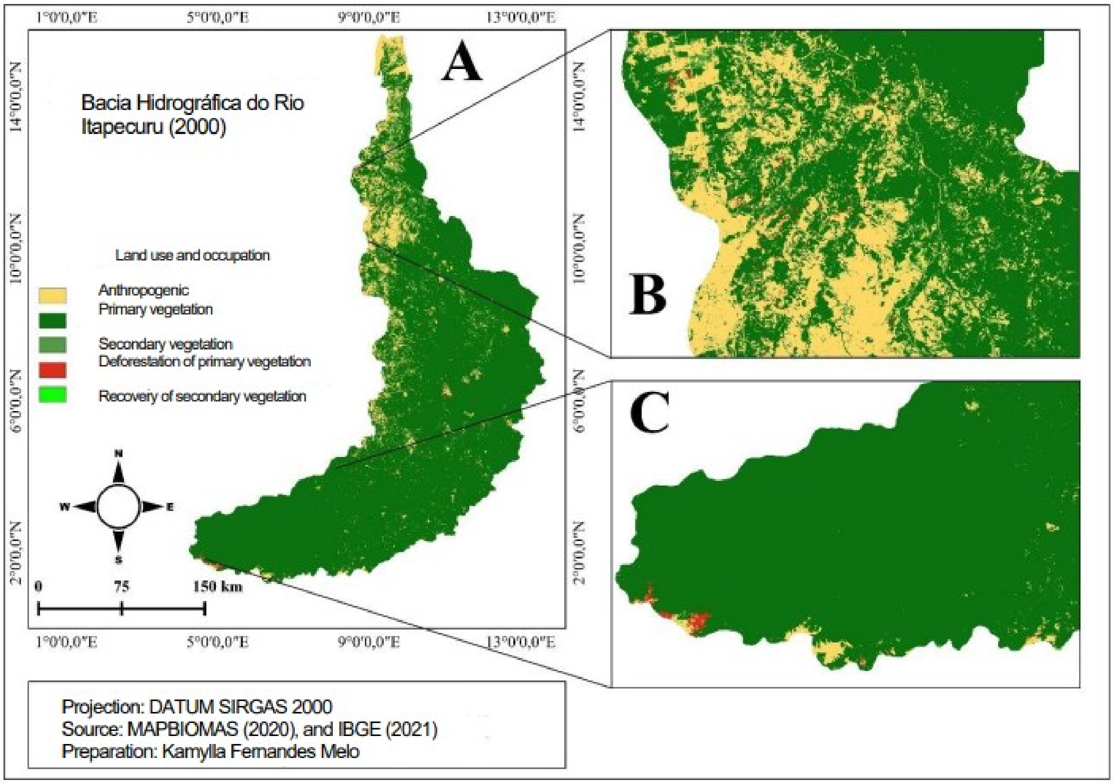

Figure 9 – Map of Deforestation and Regeneration of the Natural Vegetation of the Itapecuru River Basin - MA for the year 2000.
Source: Authors (2022).

When analyzing the use and occupation classes of the BHRI for 2010 (Figure 10), it was noted that section B continued to intensify with the anthropic class over the last few years. This is also observed in section C, where the vegetation previously impacted by deforestation was converted to another class, the anthropic class. Compared to the last 10 years, this class increased in the Basin, not only occupying the previously deforested class but also intensifying it in this region.

As proposed by Messias et al. (2020), deforestation and unbridled modifications of the natural environment must be resolved through monitoring programs aimed at environmental inspection for illegal and exorbitant deforestation practices. Such immediate action is believed to reduce such negative effects on the environment.

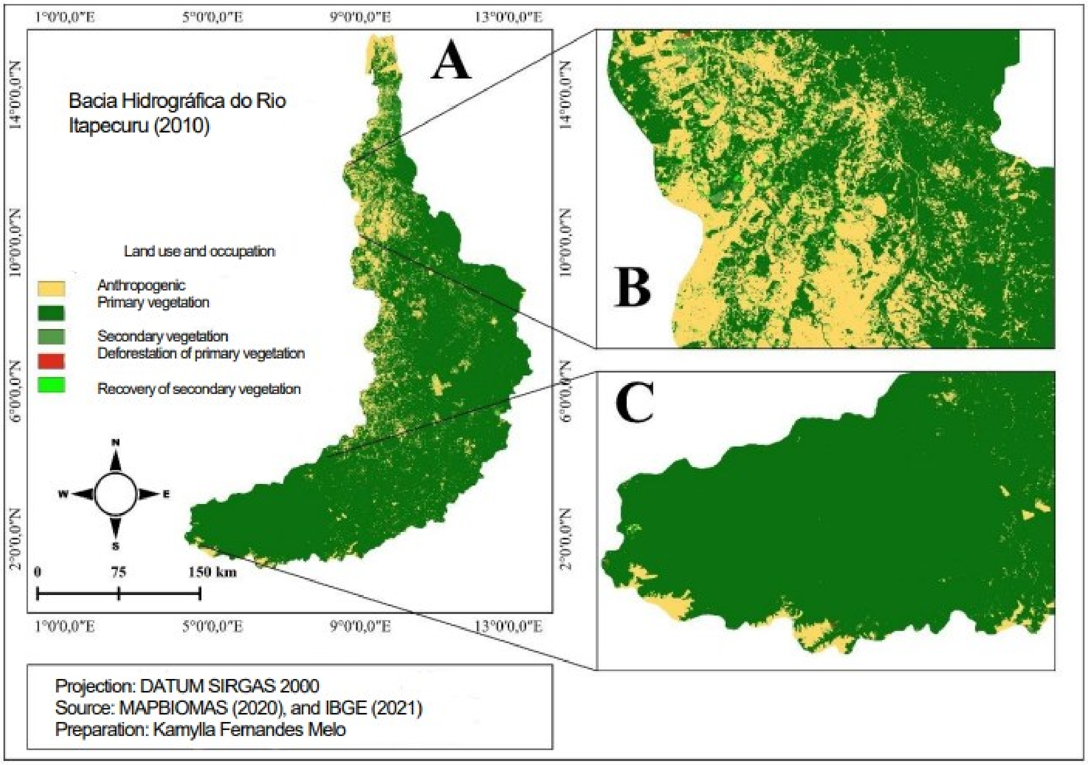

Figure 10 – Map of Deforestation and Regeneration of the Natural Vegetation of the Itapecuru River Basin - MA for the year 2010.
Source: Authors (2022).

2019 is the last year of analysis (Figure 11) in which the anthropic class was a very intense dynamic in section B. Thus, it is considered that agricultural activities have expanded and settled in this region of the BHRI. In section C, there is a more evident presence of what was previously considered a visually smaller area in this region of the Basin, thus noting land use activities in an area where native vegetation prevailed.

In a study by Barros et al. (2022), they found that in regions with major human interference, practices such as taking mitigating measures to create areas of environmental protection and preservation, ensure greater quantities of areas of environmental vulnerability, allow a greater balance for the existence of fauna and flora, and conserve the region's biodiversity are needed.

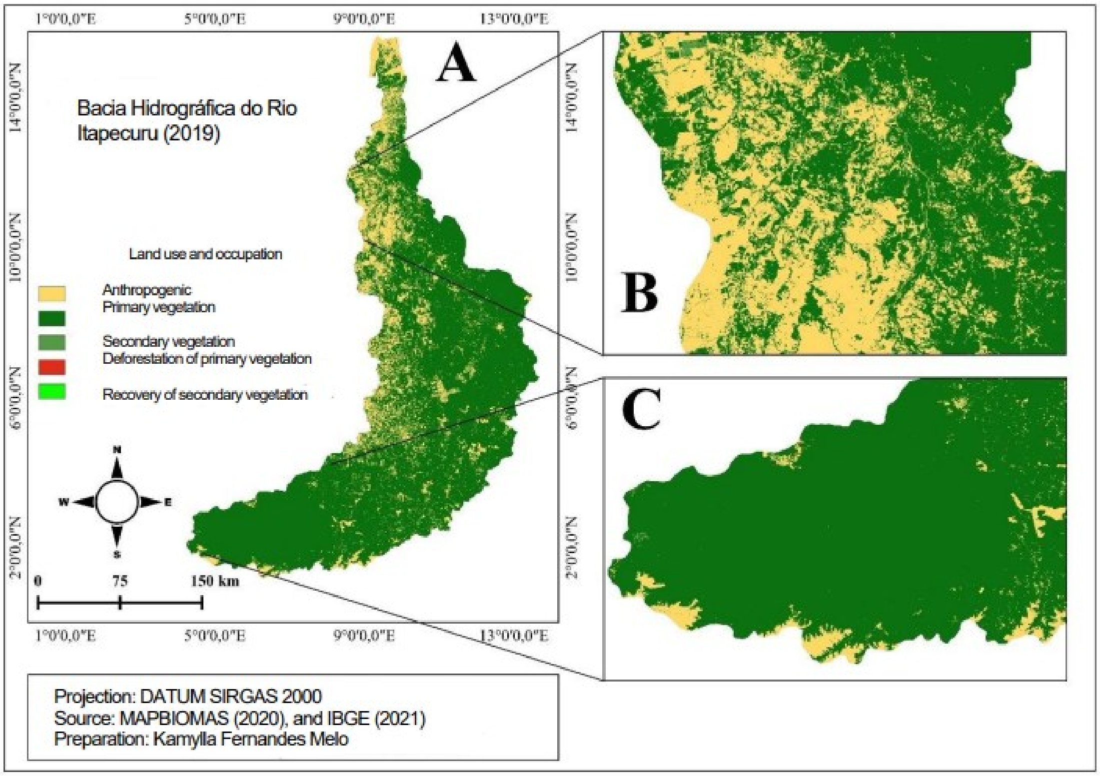

Figure 11 – Map of Deforestation and Regeneration of Natural Vegetation in the Itapecuru River Basin - MA for the year 2019.
Source: Authors (2022).

4. Final considerations

The methodology used proved efficient for investigating land use and land cover analysis. The Itapecuru River Basin has undergone changes over the years in its natural landscape. The period analyzed showed that much of its natural vegetation was lost, either through deforestation or adaptation for agricultural activities, with human interference. The highest level of primary vegetation deforestation in 2013 was 67,773 ha. Prominent secondary vegetation deforestation peaks were observed in 2013 and 2018, at 6,475 and 6,991 ha, respectively.

The BHRI region needs environmental management policies to protect natural vegetation and the fauna and flora of the regions near the riverbeds. A good alternative would be to implement more Environmental Conservation Units with the premise of generating, in addition to sustainability, greater environmental awareness in local society. The data generated serve as a reference for the formulation of conservation and sustainable management policies, in addition to supporting more comprehensive studies on local biodiversity and the effects of human interventions. Thus, this research is a valuable resource for researchers and environmental managers, promoting a better understanding of regional ecosystems.

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