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IMPLICATIONS OF LAND USE AND LAND COVER CHANGES IN THE WATER MANAGEMENT OF THE ARAGUAIA RIVER BASIN

Implicações das transformações no uso e cobertura da terra na gestão hídrica da bacia hidrografica do rio Araguaia

Implicaciones de las transformaciones en el uso y cobertura de la tierra en la gestión hídrica de la cuenca hidrográfica del río Araguaia

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ABSTRACT

This study investigates transformations in land use and cover in the Araguaia River basin between 1985 and 2022, highlighting the pressures resulting from agricultural expansion on the sub-basins. Using data from MapBiomas, the study offers a detailed analysis of environmental changes over nearly four decades, reflecting the intensification of human activities such as agriculture, livestock, and urbanization. The analysis revealed a significant reduction in natural vegetation cover, with a 44.21% decrease in Forest Formation, 41.53% in Savanna Formation, and 34.74% in Grassland Formation. These transformations demonstrate a shift towards intensified agriculture, with a significant increase in soybean cultivation and other temporary crops in previously uncultivated areas. The Rio das Mortes sub-basin stands out among the other sub-basins for having the highest rate of area conversion. Even after 26 years since the enactment of the Water Law, the Araguaia River basin still lacks committees which cover its entire territory. There are currently only seven basin committees, covering only 39.47% of the basin's total area. There are 23 among the 40 sub-basins which still do not have an established basin committee. This gap in water resource management underscores the urgent need for effective public policies for the conservation and sustainable use of the river basin.

Keywords: Araguaia River; Native Vegetation Conversion; Mapping; MapBiomas.

RESUMO

Este estudo investiga as transformações no uso e cobertura das terras na bacia hidrográfica do Rio Araguaia entre 1985 e 2022, destacando as pressões resultantes da expansão agropecuária sobre as sub-bacias hidrográficas. Utilizando dados do MapBiomas, o estudo oferece uma análise detalhada das mudanças ambientais ao longo de quase quatro décadas, refletindo a intensificação das atividades humanas, como agricultura, pecuária e urbanização. A análise revelou uma redução expressiva da cobertura vegetal natural, com uma diminuição de 44,21% na Formação Florestal, 41,53% na Formação Savânica e 34,74% na Formação Campestre. Tais transformações evidenciam um avanço em direção à intensificação da agricultura, com o aumento significativo do cultivo de soja e outras culturas temporárias em áreas anteriormente não cultivadas. Entre as sub-bacias, a do Rio das Mortes se destaca por ter sido a bacia com a maior taxa de conversão de áreas. Mesmo após 26 anos da promulgação da Lei das Águas de 1997, a bacia hidrográfica do Rio Araguaia ainda carece de comitês que abranjam todo o seu território. Atualmente, existem apenas sete comitês de bacia, que cobrem somente 39,47% da área total da bacia. Entre as 40 sub-bacias hidrográficas, 23 ainda não possuem nenhum comitê de bacia hidrográfica instituído. Esta lacuna na gestão dos recursos hídricos sublinha a necessidade urgente de políticas públicas eficazes para a conservação e o uso sustentável da bacia hidrográfica.

Palavras-chave: Rio Araguaia; Conversão da vegetação nativa; Mapeamento; Mapbiomas.

RESUMEN

Este estudio investiga las transformaciones en el uso y la cobertura de la tierra en la cuenca del Río Araguaia entre 1985 y 2022, destacando las presiones resultantes de la expansión agrícola en las subcuencas. Utilizando datos de MapBiomas, el estudio ofrece un análisis detallado de los cambios ambientales a lo largo de casi cuatro décadas, reflejando la intensificación de actividades humanas como la agricultura, la ganadería y la urbanización. El análisis reveló una reducción significativa en la cobertura de vegetación natural, con una disminución del 44.21% en la Formación Forestal, 41.53% en la Formación de Sabana y 34.74% en la Formación de Pastizales. Estas transformaciones demuestran un cambio hacia una agricultura intensificada, con un aumento significativo en el cultivo de soja y otros cultivos temporales en áreas previamente no cultivadas. Entre las subcuencas, la subcuenca del Río das Mortes se destaca por tener la mayor tasa de conversión de área. Aun después de 26 años desde la promulgación de la Ley del Agua, la cuenca del Río Araguaia aún carece de comités que cubran todo su territorio. Actualmente, solo hay siete comités de cuenca, cubriendo solo el 39.47% del área total de la cuenca. Entre las 40 subcuencas, 23 aún no tienen un comité de cuenca establecido. Esta brecha en la gestión de los recursos hídricos subraya la necesidad urgente de políticas públicas efectivas para la conservación y el uso sostenible de la cuenca.

Palabras clave: Río Araguaia; Conversión de Vegetación Nativa; Mapeo; MapBiomas.

1. INTRODUCTION

Public policy initiatives in Brazil aimed at the appropriation and occupation process of the Cerrado were based on the premise that it was necessary to occupy unexplored economic spaces in the country’s interior (PIRES, 2000). With this understanding, several economic activities were expanded since the 1930s, particularly with implementation of the

March to the West, promoted by Getúlio Vargas (BRASIL, 1974; Inocêncio, 2010; Inocêncio; Calaça, 2010; Chaveiro; Barreira, 2010; Silva, 2013).

Key events stand out among the public policies with the greatest impact on the occupation process of the Cerrado areas, such as founding the capital city of Goiânia in 1937; establishment of the Fundação Brasil Central in 1943 with the objective of exploring and colonizing regions located between the Araguaia and Xingu Rivers in Central and Western Brazil (FREITAS, 1979; PIRES, 2000); implementation of the "Goals Plan" ("*Plano de Metas*") during the administration of Juscelino Kubitschek (1956–1961), which included construction of the new federal capital, Brasília, in 1960; and reorientation of the Rio-São Paulo economic axis to more internal areas of the country, promoting expansion and intensification of the infrastructure and energy system necessary for the production flow (Inocêncio, 2010; Inocêncio; Calaça, 2010; Chaveiro; Barreira, 2010; Silva, 2013).

As the 1960s progressed, the Brazilian government's political initiatives intensified occupation incentives for the Central-West (Cerrado) and North (Amazon) regions. These initiatives were intensified in the 1970s with the First National Development Plan (1969–1974) and the subsequent implementation of the Second National Development Plan in 1974.

Within this framework, several programs were established to meet emerging needs, most notably the Cerrado Development Program (o Programa de Desenvolvimento dos Cerrados - POLOCENTRO), and later the Japanese-Brazilian Cooperation Program for the Development of the Cerrado (o Programa de Cooperação Nipo-brasileira para o Desenvolvimento dos Cerrados - PRODECER). These programs were responsible for increasing agricultural productivity and expanding the areas involved in the production process, aiming to meet the demands of the domestic and foreign markets (Pires, 2000; Inocêncio and Calaça, 2010; Chaveiro; Barreira, 2010; Silva; Anjos, 2010; Silva, 2013; Faria; Santos, 2016).

These incentives triggered rapid transformation in the use and coverage of Cerrado lands marked by intense deforestation, including practices such as the use of chains, burning and charcoal production (Castro, 2005). This process resulted in greater concentration and land appreciation, as well as increased social inequality, characterized by a predominance of temporary labor (Pires, 2000; Chaveiro; Barreira, 2010).

In this context, it is observed that the Cerrado has faced a rapid and intense process of change in its land use and coverage over the last few decades (Klink; Machado, 2005). Although it represents an important area for providing ecosystem services, this biome has already recorded the loss of approximately 880,000 km^2 (46%) of its native vegetation cover (Strassburg *et al*., 2017; Sano *et al*., 2019), with only 8.21% of its territory under legal protection (Brasil, 2019). The Cerrado suffered a reduction of approximately 23% of its native vegetation between 1985 and 2017, while there was a simultaneous significant increase of 51% in areas dedicated to agriculture (Silva, 2020). The dynamics of land use and occupation in this biome in recent decades have categorized it as "seriously threatened" (Silva, 2020), a situation mainly attributed to high deforestation rates and variations in burning patterns caused by human actions (Silva, 2020).

As a result of implementing multiple federal programs, such as the Integrated Development Program for the Araguaia-Tocantins Basin (*Programa de Desenvolvimento Integrado da Bacia do Araguaia-Tocantins - Prodiat*) established in the early 1980s (BRASIL, 2006), and the integration mechanism involving the North-South Railway and the Carajás Railway with the Araguaia, Tocantins and Das Mortes Rivers waterway, the Araguaia River basin (which is located in this scenario) has emerged as one of the main targets of the transformation process linked to the advancing agricultural frontier, as well as changes in the land use and occupation pattern in recent decades (Castro, 2005).

The Araguaia River basin has established itself as a strategic area for Brazil's economic development in recent decades. This region is expected to grow significantly in the coming decades, being driven by national and international demand for commodities (Bayer *et al*., 2020). These particularities resulting from their economic and environmental value have accelerated the land use and occupation process in the Araguaia River basin, resulting in a series of environmental impacts (Castro, 2005).

An acceleration of native vegetation deforestation and the impacts associated with expanded agricultural activities stand out among the adverse effects, which have caused problems such as habitat fragmentation and a significant loss of biodiversity (Faria; Castro, 2007; Faria, 2011; Siqueira, 2012; Carneiro, 2012; Faria; Santos, 2016; Gomes *et al*., 2022), water, energy and fertilizer consumption, contamination of surface and groundwater resources, introduction of invasive alien species, soil erosion (Latrubesse *et al*., 2009), impacts on climate regulation and air quality, in addition to changes in the hydrological regime (Albernaz, 2003; Mendes, 2005; Foley *et al*., 2005; Castro, 2005; Coe *et al*., 2011; Silva, 2020).

As a consequence of this dynamic of land use and occupation, the Araguaia River basin also faced an intense silting process in its river channels, mainly attributed to agricultural activities, such as soybean production and livestock farming (Castro, 2005;

Bayer *et al*., 2020; Gomes *et al*., 2022). This phenomenon resulted in an increase in the sediment amount in the river channels over the last few decades (Bayer, 2002; Latrubesse *et al*., 2009; Bayer, 2010; Bayer; Zancopé, 2014; Zancopé *et al*., 2015, BAYER *et al*., 2020; Suizu *et al*., 2022), negatively affecting the biodiversity linked to these ecosystems (Albernaz, 2003; Mendes, 2005).

The Araguaia River basin is located in an ecological transition zone between the two largest Brazilian biomes, the Cerrado and the Amazon, two phytogeographic areas which stand out for their rich biodiversity (Lopes; Franco; Costa, 2017). It faces constant pressure due to agricultural expansion. Such pressure not only threatens the conservation of the remaining natural area, but also the connectivity between these biomes.

Given its environmental, social and economic importance, this study aims to investigate changes in land use and land cover which occurred in the Araguaia River basin and sub-basins during the period from 1985 to 2022. This analysis aims to obtain a deep understanding of the transformation dynamics which marked the region. The lack of effective management and absence of committees or control bodies will also be examined, aiming to identify gaps in the governance of this river basin.

2. METHOD

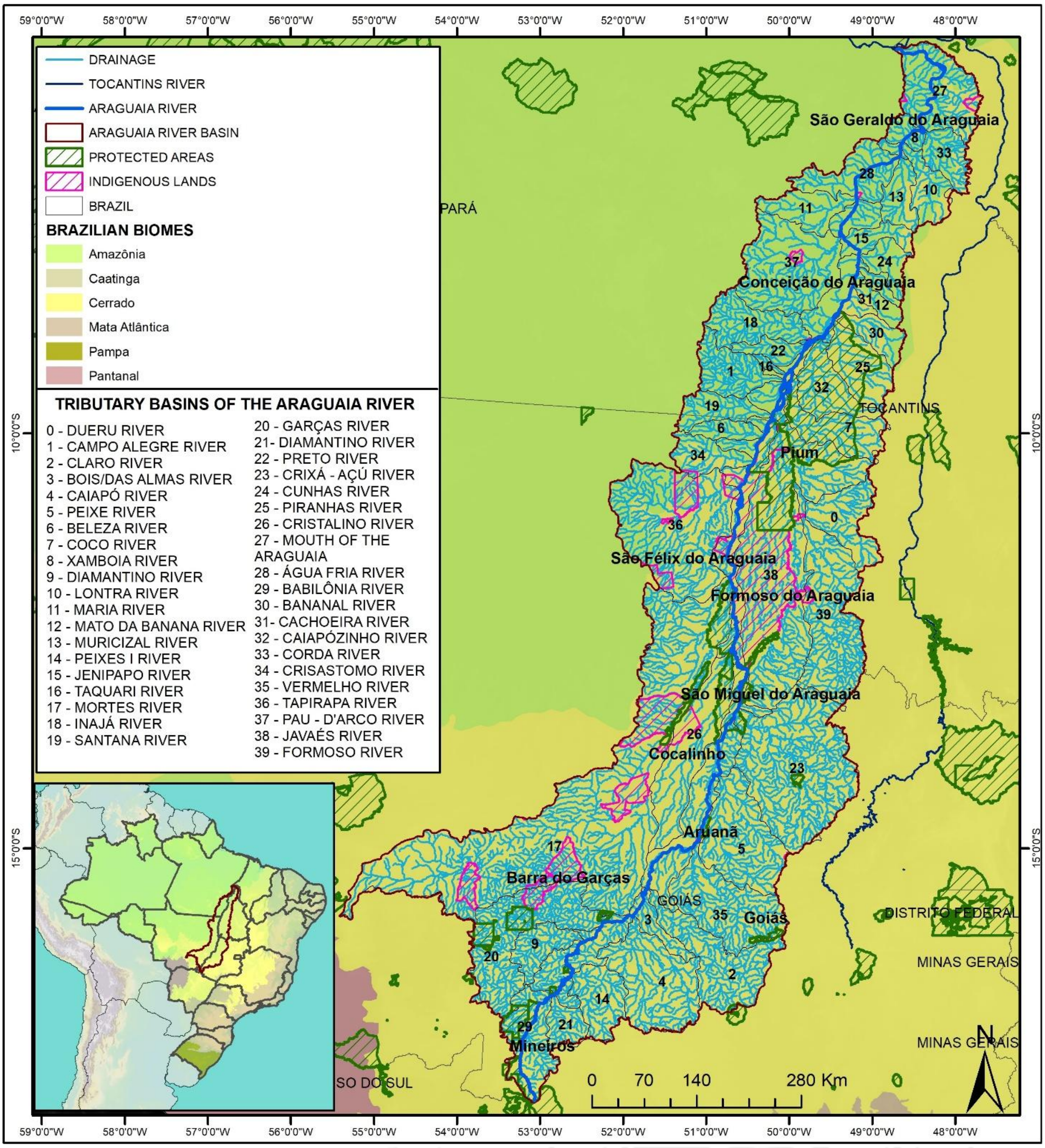
2.1 Study area

The Araguaia River basin extends across two Brazilian biomes, the Cerrado and the Amazon, occupying a territory of approximately 386,000 km^2 (ANA, 2015). This area covers 205 municipalities, distributed among the states of Goiás, Mato Grosso, Tocantins and Pará (Figure 01).

The Araguaia River basin is located in a tropical climate region, and is dominated by an Aw climate (tropical with dry winter, according to the Koppen climate classification). It is characterized by a rainy season from October to April and a dry season from May to September, with an average annual temperature ranging from 22 to 26°C. Annual precipitation in the basin ranges from 1300 to 2000 mm, with approximately 95% of the annual total concentrated during the rainy season (Irion *et al*., 2016; Lininger and Latrubesse, 2016).

This river is notable for being the only major river system in the Central and Northern regions of Brazil that remains undammed or impacted by other direct human interventions in its course (Latrubesse *et al*., 2009). Furthermore, it is recognized as one of the rare large free-flowing rivers in South America, sheltering vital areas for biodiversity conservation (Latrubesse *et al*., 2019; Martins *et al*., 2021).

Figure 01 – Location of the Araguaia River basin and its sub-basins



Source: Elaborated by the authors, 2024.

It is essential to highlight that the Araguaia River basin preserves important remnants of the natural vegetation of the Cerrado, in addition to having a complex floodplain that is recognized as one of the largest and most diverse floodplains in the world (the Bananal Plain, covering more than 100,000 km^2) (Dagosta and Pinna, 2017; Latrubesse *et al*., 2019). Notable geodiversity stands out in the Cerrado, including lakes and lake systems with varying connectivity levels, hosting a greater number of fish species than any other basin within this biome (Valente; Latrubesse; Ferreira, 2013; Latrubesse *et al*., 2019).

2.2 Methodological procedures

The data used in the land use and land cover analysis in the Araguaia River basin were acquired from MapBiomas Collection 8, released on August 31, 2022, for the years 1985 and 2022, using a scale of 1:100,000.

The MapBiomas Project is a collaborative initiative which brings together experts from different biomes, land use and land cover categories, remote sensing techniques, and cloud data processing methods, aiming to produce historical maps of land use and land cover in Brazil (MAPBIOMAS, 2024).

The procedure for obtaining data related to land use and land cover in the Araguaia River basin was conducted using the Google Earth Engine platform. Additionally, area statistics were generated on the aforementioned platform.

The data were manipulated using the Google Earth Engine plugin in QGIS, and the corresponding maps could be viewed and produced using the Python terminal. The land use and land cover categories examined included Forest Formation, Savannah Formation, Flooded Field and Wetlands, Silviculture, Grassland Formation, Pasture, Sugarcane, Other Temporary Crops, Urbanized Area, Mining, River/Lake, Agriculture and Pasture Mosaic, Soybean, Rice and Coffee. The specific RGB color palette for each class was applied to illustrate these categories on the maps, as designated by the MapBiomas Algorithm Theoretical Basis Document (ATBD) for the Collection 8.

Vectorization and improvement in the Araguaia River basin and sub-basin boundaries used data provided by the National Water Agency (Agência Nacional de Águas - ANA). This step was performed using ArcGIS software and with the support of complementary tools, including Google Earth for viewing and adjusting details, shapefile data for the drainage networks and the Digital Elevation Model (DEM) obtained from the Shuttle Radar Topography Mission (SRTM).

The data were conducted under the SIRGAS 2000 geodetic reference system using the ArcGIS and QGIS Geographic Information System (GIS) software, which enabled an accurate and detailed assessment of the land use and land cover evolution in the study area, covering both the Araguaia River basin and sub-basins.

3. RESULTS AND DISCUSSION

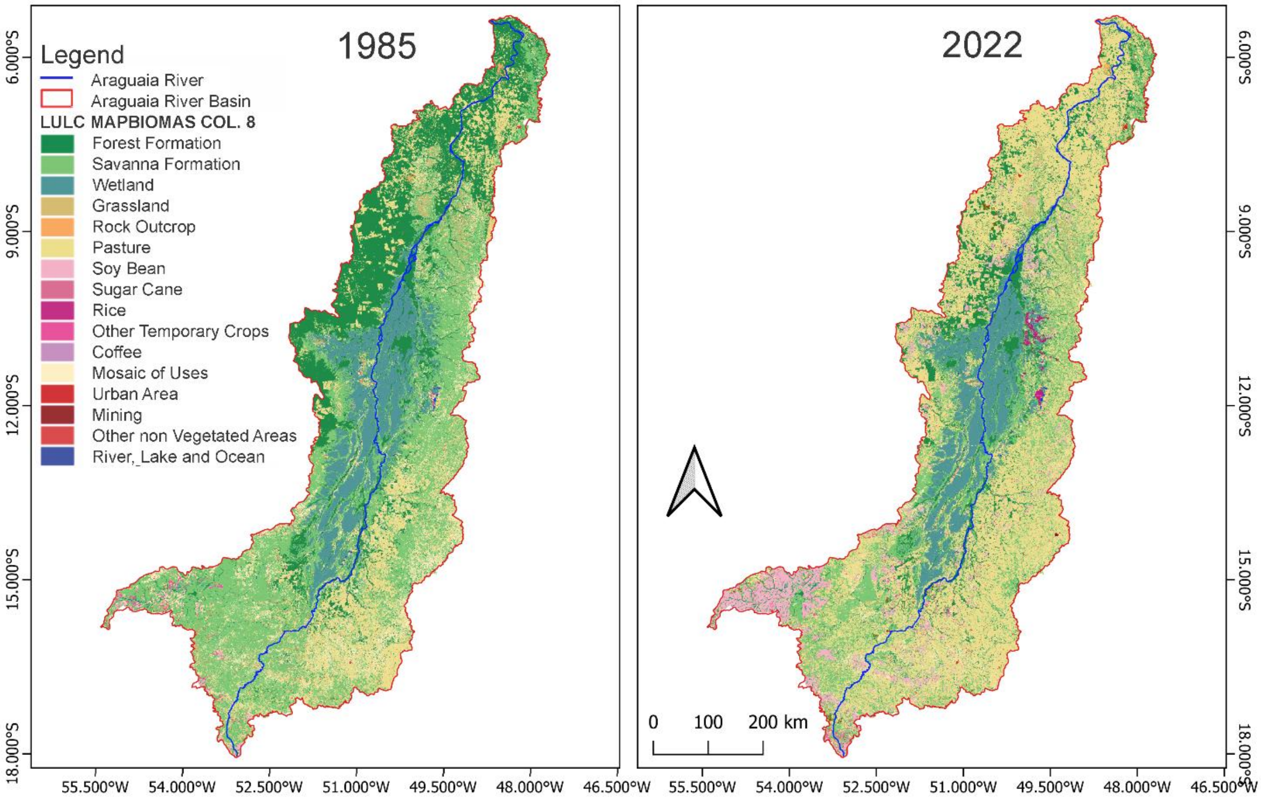
The results and discussion section address three central topics which highlight the main environmental dynamics in the Araguaia River Basin (*Bacia Hidrográfica do Rio Araguaia - BHRA*). The first topic addresses land use and occupation, examining the transformations in land use patterns over the decades, with a significant conversion of natural areas into territories destined for agriculture. The second topic analyzes the reduction in vegetation cover and its impacts on the 40 sub-basins of the region, evidencing replacement of native vegetation by anthropized areas. Finally, the management of water resources is discussed, emphasizing the challenges faced by the basin, the limited performance of basin committees and the prospects for more effective management in facing human pressures and the need for environmental conservation.

3.1 Land use and occupation in the *BHRA*

Mapping of changes in land use and land cover in the Araguaia River Basin (*BHRA*) between 1985 and 2022 reveals a scenario of intense environmental transformation, reflecting the complexity of land use dynamics and an interaction between natural factors and human interventions. A significant reduction in the area occupied by the Forest Formation was observed during the period from 1985 to 2022, with a decrease of 44.21%. In addition, the Savannah Formation also showed a reduction of 41.53%, while the Grassland Formation recorded a decrease of 34.74% (Figure 02).

Pasture areas in the *BHRA* almost tripled during this period, with a significant increase of 148.73%. A notable increase in the area dedicated to soybean cultivation is also observed, with a growth of 1581.19%, reflecting the intensive expansion of soybean farming and consequent transformation of the landscape to meet growing agricultural demands. This scenario also accompanied significant increases in sugarcane and rice production (Table 01).

Figure 02 – Changes in land use and occupation in the Araguaia River basin between 1985 and 2022



Source: Elaborated by the authors, 2024.

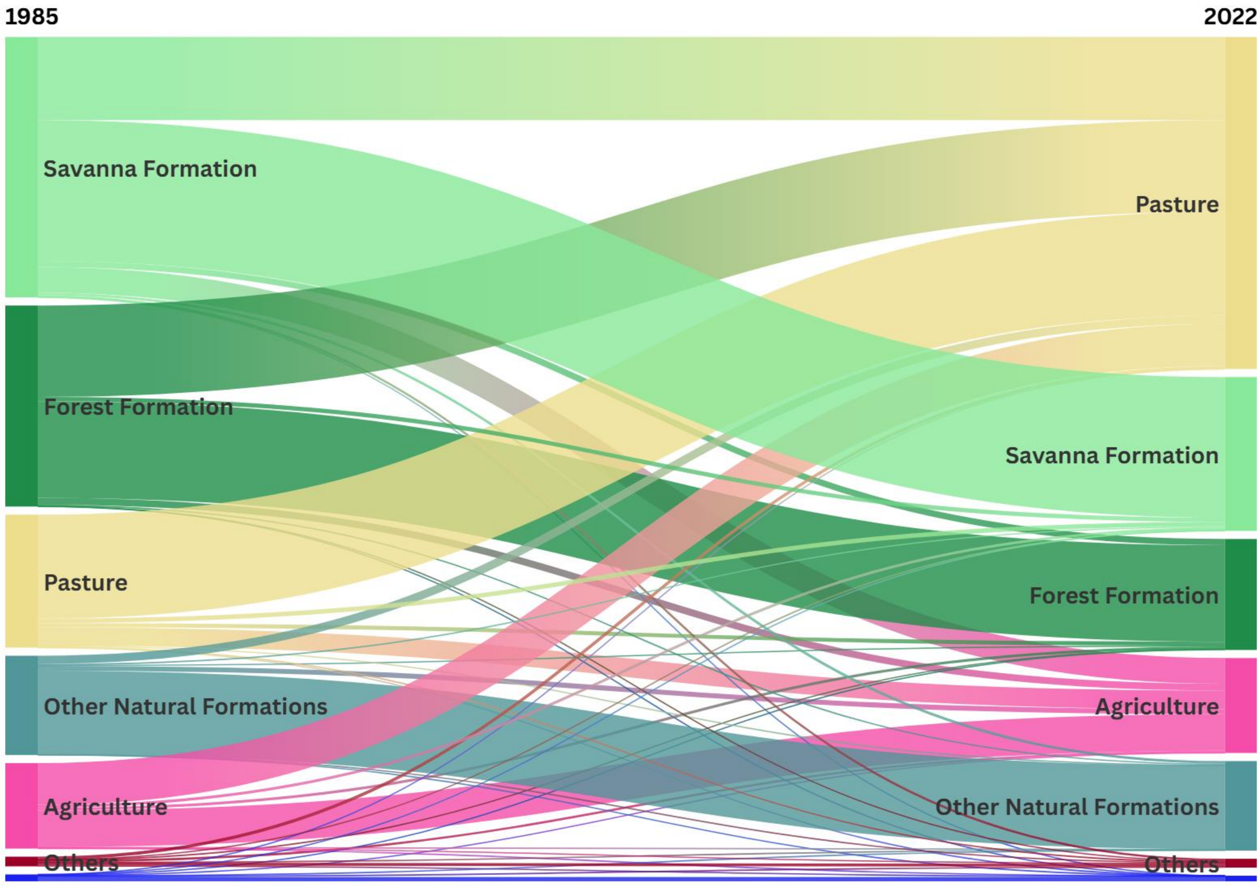
Table 01 – Changes in land use and land cover in the Araguaia River basin from 1985 to 2022

Land use and land cover classes	1985 (ha)	2022 (ha)	Variation %
Forest Formation	94,294.50	52,609.82	-44.21
Savanna Formation	121,520.05	71,051.96	-41.53
Flooded Field and Marshy Area	38,329.27	36,343.30	-5.18
Grassland Formation	7,613.61	4,968.73	-34.74
Rocky Outcrop	547.96	549.31	+0.25
Pasture	63,154.57	157,085.41	+148.73
Soybean	1,235.59	20,772.60	+1,581.19
Sugarcane	0.036	458.19	+1,277.19
Rice	54.18	939.48	+1,633.42
Other temporary crops	1,003.74	2,776.73	+176.65
Coffee	0.054	1.911	+3,440.74
Mosaic of uses	38,088.09	18,396.77	-51.69
Urbanized area	213.23	515.09	+141.63
Mining	2.46	70.37	+2,759.76
Other non-vegetated areas	3,786.65	3,014.28	-20.39

Source: Elaborated by the authors, 2024.

These trends not only reflect economic and social changes over time, but also raise crucial questions about the sustainability of land use and land cover changes, biodiversity conservation and ecosystem resilience, as there are notable transitions in natural formations over the years between pastures and agricultural areas (Figure 03).

Figure 03 – Changes in land use and occupation in the Araguaia River basin



Source: Elaborated by the authors, 2024.

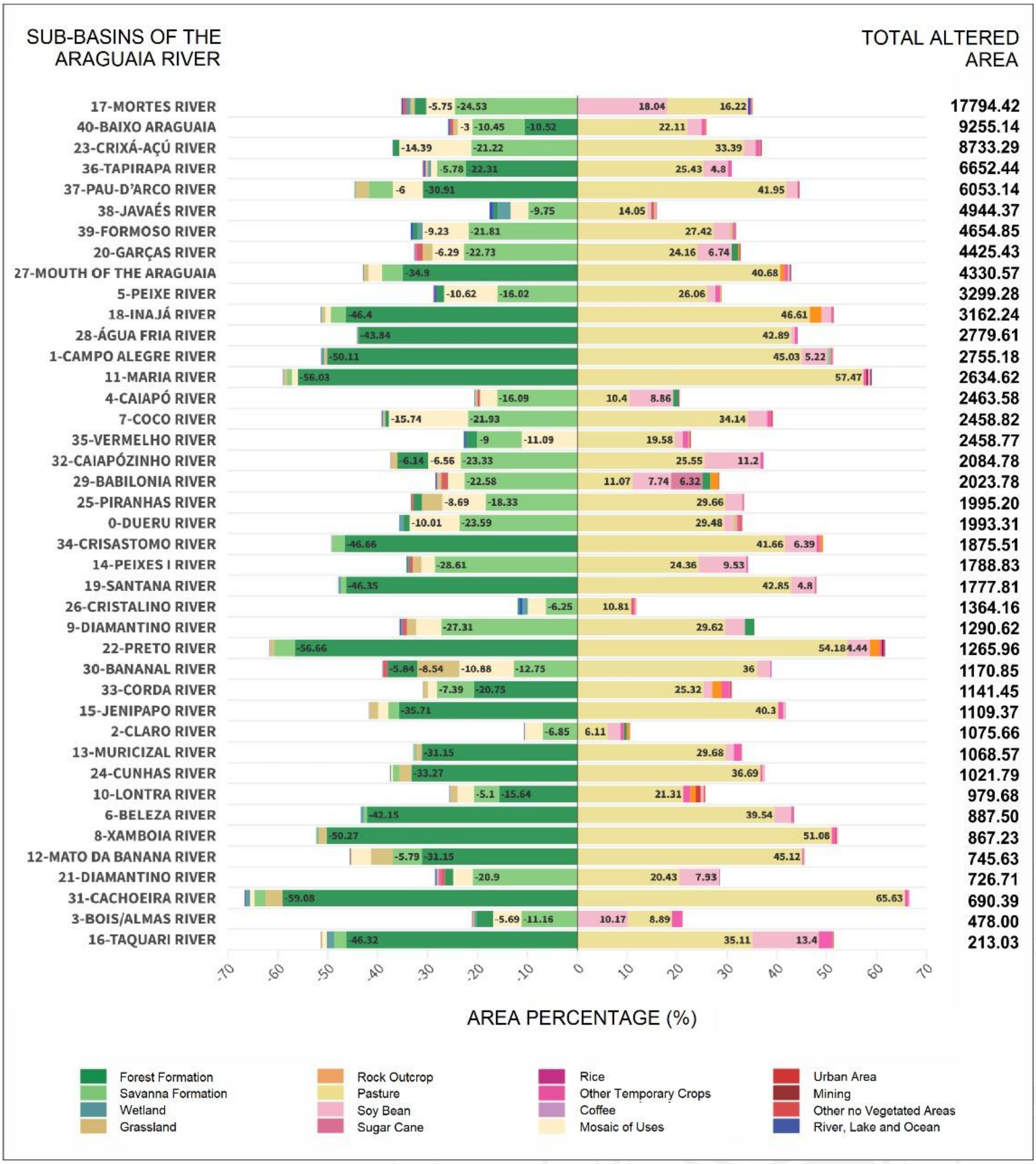
The data show a significant reduction in the Forest, Savannah and Grassland Formation areas, accompanied by a significant increase in the areas dedicated to agriculture, especially pastures and soybean cultivation.

These changes in the land use and occupation of the river basin are marked by expanded agricultural activities and reduced natural vegetation areas, which have caused and continue to cause significant environmental impacts. Among the most notable effects are habitat fragmentation, biodiversity loss, introduction of invasive species, advancing erosion processes and an increase in the amount of sediments contributed to the main channel, which have been observed since the early 2000s (Klink; Machado, 2005; Latrubesse *et al*., 2009).

3.2 Reduction of vegetation cover: impacts on sub-basins

A detailed analysis by hydrographic sub-basins highlights the variability of regional transformations, where agricultural and urban expansion stand out as the main change vectors (Figure 04).

Figure 04 – Land use and occupation in the Araguaia River sub-basins



Source: Elaborated by the authors, 2024.

According to the analysis of Figure 04, the Rio das Mortes basin stood out among the analyzed basins for having the most significant conversion of areas in terms of land use and coverage. However, it is worth noting that the Baixo Araguaia, Crixá-Açu, Tapirapé, Pau D'arco, Rio Javaés, Formoso, Rio das Garças, Foz Araguaia and Rio do Peixe basins also presented significant native vegetation conversion into anthropized areas, especially in "Pastures" and soybean production areas and urban areas. In addition to the reduction in the native vegetation classes, there were significant reductions in the "River and Lake" class in all basins.

These observations are corroborated by previous studies which detail the environmental transformations in specific sub-basins. Faria *et al*. (2012) indicated that the remaining fragments in the Rio Claro sub-basin were dispersed and isolated amidst a predominant use of anthropic activities. This sub-basin was highly degraded, with a low percentage of remaining vegetation and a predominance of small fragments, which are insufficient for maintaining biodiversity. On the other hand, there was a predominance of remaining vegetation in the Garças River basin.

Faria *et al*. (2012) also report that there were differences between the most representative phytophysiognomies in each sub-basin, with the Forest Formation in the Rio Claro sub-basin covering 7.56% of the area, and the Savannah Formation predominating in the Rio Garças sub-basin, covering 49.75% of the area. The Grassland Formation naturally occurs in a specific way, and is not very representative in both of the studied areas.

The analysis for 2022 points to a different scenario, namely a predominance of the Savannah Formation in the Claro and Garças sub-basins. The Forest Formation maintains a representation of approximately 7.56% of the total area in the Rio Claro basin, as indicated by Faria *et al*. (2012), while the Savannah Formation corresponds to approximately 10.66%. The Forest Formation occupies approximately 5.76% of the area in the Rio das Garças basin, while the Savannah Formation covers approximately 36.86% of the total area.

The comparison and analysis of differences in land use and land cover data between this study and that of Faria *et al*. (2012) are influenced by several methodological and scale issues. Faria *et al*. (2012) conducted their analysis of the two sub-basins using Landsat image interpretation, with the segmentation and classification technique in the SPRING software, operating at a scale of 1:150,000. In contrast, the data used in this study were obtained through MapBiomas, processed in the Google Earth Engine platform, adopting a scale of 1:100,000. These methodological and scale differences can significantly impact the results and conclusions of both studies. The platform choice (SPRING versus Google Earth

Engine) can affect the image interpretation accuracy. In addition, the difference in spatial scale (1:150,000 versus 1:100,000) can influence the data resolution and representativeness, especially in smaller or more detailed areas.

There is also a lack of studies that adopt a specific analytical approach in the context of the *BHRA* sub-basins. This research gap indicates that developing this approach is still in its early stages, making direct comparisons with more recently developed studies difficult.

Some studies developed in the last decade have addressed and demonstrated these changes in the *BHRA*. For example, as identified by Gomes *et al*. (2022), the Rio Claro basin has experienced high native vegetation degradation characterized by a predominance of pastures, increased fragmentation, and reduced Permanent Preservation Areas (PPAs) in recent years. Furthermore, the study highlights that human activities have a significant impact on the hydrological regime in this basin.

An ecological analysis of the landscape in the Rio dos Peixes basin conducted by Carneiro (2012) revealed significant changes over time. The area was mostly homogeneous and preserved in 1975, with few but large fragments. Then there was a significant increase in the pasture area from 1985 onwards, coinciding with a significant increase in the number of fragments, which exceeded 1000, representing an increase of 80%. Later, there was a considerable advance of agriculture in 1996 resulting in a new fragmentation, almost doubling the number of fragments to 2,078. New deforestation was observed from 1996 to 2009, accompanied by a reduction in the area designated for agriculture and a notable increase in the pasture area.

This environmental transformation pattern is not exclusive to the Rio Claro and Rio dos Peixes basins. The Rio das Mortes is recognized as the main tributary of the Araguaia River, followed by the Javaés River, and both play fundamental roles in the hydrographic basin (Aquino *et al*., 2009), and stand out as the main basins occupied by agriculture in 2022. This agricultural land distribution reflects the findings presented in the Irrigation Atlas (ANA, 2021), developed by the National Water and Sanitation Agency. By considering the analysis of the total irrigated area, as well as the occupation concentration and density, together with the potential and growth observed in the short and medium term, the document identifies 28 national hubs as priorities for efficient management of water resources destined for irrigated agriculture in the country.

In turn, three of the 28 National Irrigated Agriculture Hubs for irrigated agriculture water resource management on a national scale are located in the Araguaia River basin, namely: upper Araguaia (central pivot), upper Rio das Mortes (central pivot) and

Javaés/Formoso (flooded rice), and are considered emerging hubs with high expansion prospects (ANA, 2021). Within these hubs, the Upper Araguaia region covers a currently irrigated area of 24 thousand hectares, with an estimated annual water demand of 118 billion liters, with the municipalities of Jussara, Santa Fé de Goiás and Britânia standing out as the municipalities with the greatest irrigation activity (ANA, 2021).

The irrigated area in the upper Rio das Mortes basin reaches 72.3 thousand hectares, with an annual water requirement of 221 billion liters, with Primavera do Leste, Campo Verde, Poxoréu, Dom Aquino, Novo São Joaquim, General Carneiro and Santo Antônio do Leste being the main irrigating municipalities. The area under irrigation in the Javaés/Formoso basin region totals 113 thousand hectares, with an estimated annual water consumption of 664 billion liters, with municipalities such as Lagoa da Confusão, Formoso do Araguaia and Pium standing out as leaders in irrigation practices.

This expansion of irrigated agriculture, especially in key areas of the basin, highlights the urgency of sustainable water resource management, aiming to balance agricultural development with environmental preservation, especially in sensitive ecosystems such as flooded fields and marshy areas. It is crucial to consider that the analysis of the Flooded Field and Marshy Area class revealed a low conversion rate of these natural areas. This low change is largely due to the fact that these areas are almost entirely located within the floodplain (Bananal Plain, which extends over more than 100,000 km^2) (Dagosta; Pinna, 2017) and are protected by conservation units (CUs) of different categories (Assis *et al*., 2021).

Furthermore, these lowland areas, flooded fields and marshes present significant limitations for use and occupation, especially with regard to pasture and agriculture, as they correspond to environments with soils that are frequently saturated with water, low permeability and prolonged flooding periods, making them less suitable for cultivating traditional agricultural crops and limiting the mobility required for livestock farming and low forage production.

Therefore, maintaining biodiversity and ecosystem services, such as water regulation and shelter for various species, becomes a greater challenge in areas altered for agricultural or livestock purposes. In turn, conversion of these wetlands to land for pasture or agriculture is generally not profitable due to the high adaptation and maintenance cost, in addition to possible negative environmental impacts, including the loss of essential habitats and reduced water quality (Zedler; Kercher, 2005; Junk *et al*., 2013; Mitsch; Gosselink, 2015; Tiner, 2017). Thus, it is possible to argue that the CUs created in the river basin were mainly directed to this region, as this is exactly where the most significant CUs in terms of territorial extension (measured in hectares) within the *BHRA* are located (Assis *et al*., 2021).

However, a critical issue emerging from this study is the predominant concentration of CUs in the middle basin of the Araguaia River, which is in contrast to the evidence presented by Assis *et al*. (2021) who highlight an absence of CUs for the main tributary sources of the *BHRA* primarily located in the upper basin. This discrepancy suggests a significant gap in environmental conservation strategies, which may compromise the provision of ecosystem services in this river basin.

The analysis of the current scenario in the *BHRA* suggests that this unequal distribution of CUs, with an emphasis on the middle basin to the detriment of the upper basin, may be influenced by the natural dynamics and the potential for agricultural and livestock development, and consequently the increase in land value that is predominant in the upper basin. This region, as illustrated in Figure 02 and corroborated by the data, stands out as the area with the highest natural vegetation conversion rate, and an increase in areas occupied by agricultural activities.

3.3 Water resource management and basin committees: challenges and perspectives

In this context, the urgent need for effective environmental management and conservation policies becomes evident. From the perspective of the Water Law (Law No. 9,433/1997), the River Basin Committees (*Comitês de bacias hidrográficas - CBH*s) established by the National Water Resources Policy (*Política Nacional de Recursos Hídricos - PNRH*) emerge as one of the main mechanisms for improving the integrated administration of these areas. These committees play a crucial role in institutionalizing social participation and in formulating public policies for water management in river basins. The main responsibilities of the *CBH*s include promoting debate on issues related to water resources, managing conflicts involving these resources, and participating in the preparation, in addition to monitoring implementation of the basin's Water Resources Plan.

However, although the River Basin Committees (*CBH*s) represent an important tool for implementing integrated basin management from a participatory and decentralized perspective (Silva, 2018), Silva (2018) highlights that there are still significant difficulties in implementing these mechanisms even 20 years after the Water Law. This results in water management with limited democratic participation of society.

However, despite the progress that these committees can bring to environmental management, the Araguaia River basin faces significant challenges. Even 26 years after enacting the Water Law, the Araguaia River basin still does not have committees which cover its entire territory, with only seven committees covering approximately 150,000 km², which represents approximately 39.47% of the total area of the basin.

When considering the creation of the last basin committees, dated 2014, it is observed that there has been no significant progress in implementing these committees even after nine years. Examples such as the Rio Vermelho, Atributaries of Alto Araguaia, Atributaries of Goianos of Alto Araguaia and the Médio Araguaia *CBHs* were created, but their effective implementation has not yet been carried out (Table 02).

Table 02 – River Basin Committees (Comitês de bacias hidrográficas - CBH) in the *BHRA*

CBH	FU	Area (km²)	REFERENCE YEAR	SITUATION	SUB - BASINS
CBH Rio Vermelho	GO	11,020.303359	2011	Created but not installed	2, 5, 35
CBH dos Afluentes do Alto Araguaia	MT	23,287.524055	2013	Created but not installed	9, 17, 20, 29
CBH dos Ribeirões Sapé e Várzea Grande (COVAPÉ)	MT	630.943191	2003	In operation	17
CBH dos Rios Lontra e Corda	TO	7,985.647098	2013	With PNRH instruments	8, 10, 13, 27, 33
CBH do Rio Formoso do Araguaia	TO	20,500.628475	2011	With PNRH instruments	0, 23, 38, 39
CBH dos Afluentes Goianos do Alto Araguaia	GO	40,937.605569	2013	Created but not installed	29, 2, 3, 4, 14, 20, 21, 29, 35
CBH Médio Araguaia	GO	50,969.20068	2014	Created but not installed	5, 23, 35, 38, 39

Source: Elaborated by the authors, 2024.

The implementation analysis of the *CBH*s in the Araguaia River basin reveals a worrying situation regarding the coverage and effectiveness of these committees, as 23 of the 39 river basin sub-basins present in the region still do not have any established river basin committee (27, 28, 13, 11, 15, 24, 37, 31, 12, 30, 18, 25, 22, 16, 32, 1, 19, 7, 6, 34, 36, 26). This data is indicative of a significant gap in the integrated and participatory management of water resources, as recommended by the Water Law (Law No. 9,433/1997) (Figure 05).

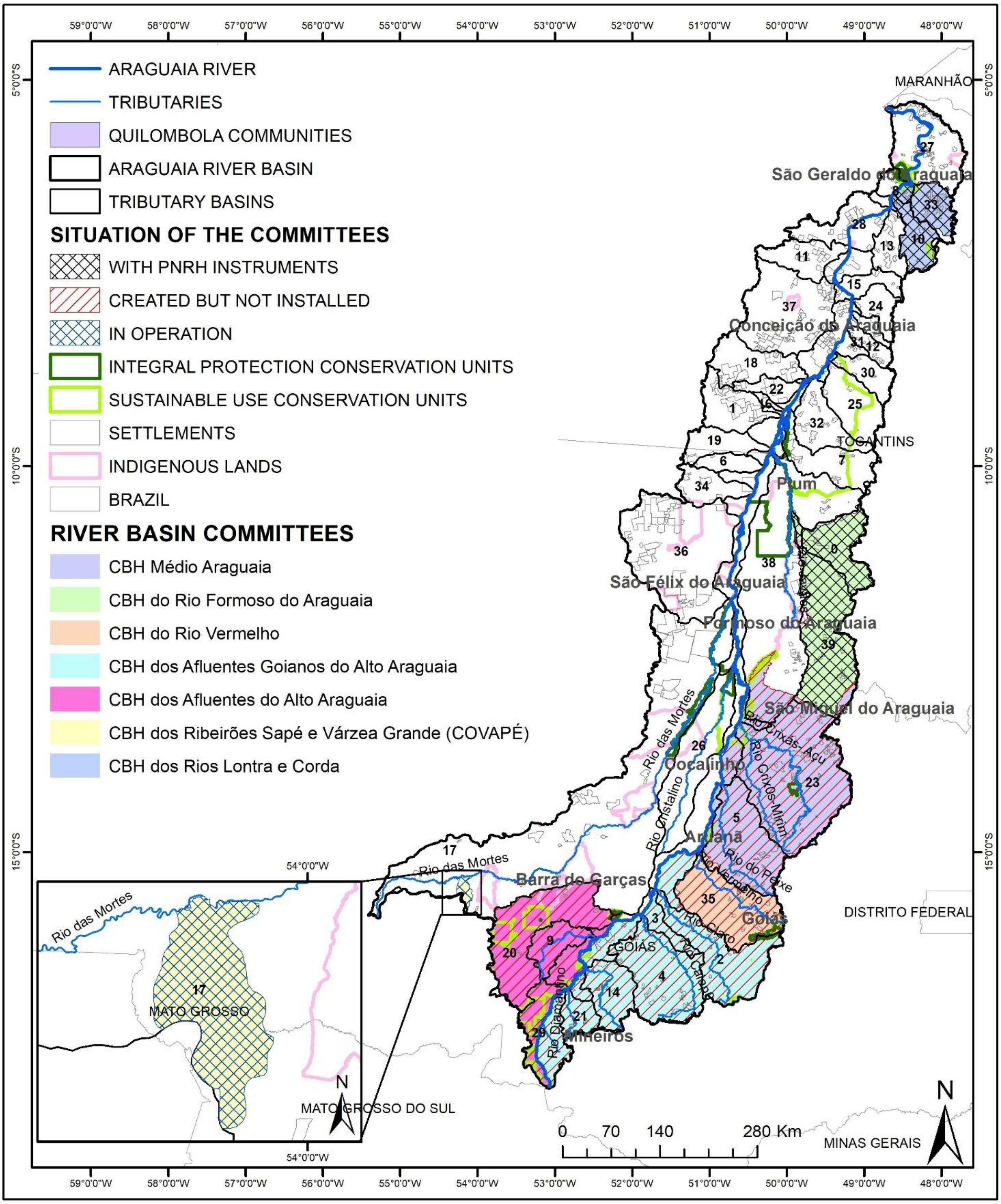
In the context of the analysis of land use and coverage in 2022, the Rio das Mortes and Javaés basins, which stand out as agricultural areas, face considerable challenges in relation to basin committees. For example, the Javaés River basin is not under the jurisdiction of any basin committee, while the Rio das Mortes basin has only 1.11% of its territory assisted by a basin committee, specifically the Sapé and Várzea Grande River Basin Committee (Comitê de Bacia Hidrográfica dos Ribeirões Sapé e Várzea Grande - COVAPÉ).

Settlements, indigenous territories and CUs are crucial elements for the effectiveness of river basin committees due to their essential role in the sustainable management of water resources and environmental preservation. The inclusion of these elements is essential to ensure an integrated and participatory approach to water resource management.

However, of the three *quilombola* communities in the *BHRA* (Buracão, Ilha de São Vicente and Cocalinho), only one is included in a basin committee, specifically in the Goianos Tributaries of the Upper Araguaia *CBH*. In addition, only 230 of the 606 settlements in the *BHRA* are included in a basin committee, resulting in 62% of the settlements not covered by any committee. Furthermore, only five of the 29 indigenous territories in the *BHRA* have some areas covered by basin committees: Karajá de Aruanã I, Karajá de Aruanã III, Krahô-Kanela, Merure, São Marcos and Taego Ãwa. Of these, only one territory (Karajá de Aruanã I) is fully covered by a basin committee.

The total area covered by CUs in the Araguaia River basin is 35,227.88 km^2. However, only 6,286.01 km^2 of this area is under the jurisdiction of a basin committee, which corresponds to approximately 17.84% of the total. The diversity of CU categories existing in the Araguaia River basin covering both full protection areas and sustainable use areas (ASSIS *et al*., 2022) brings to light an even more worrying situation. The coexistence of these different CU categories demands a more complex and integrated management of water resources, which accentuates the need for the presence of basin committees. These committees are essential to mediate conflicts and promote efficient and equitable management of water resources in these distinct environments (Figure 05).

Figure 05 – River basin committees in the Araguaia River basin



Source: ANA (2021) and Assis *et al*., (2021). Elaborated by the authors, 2024.

This lack of committees in more than half of the Araguaia River sub-basins compromises the effectiveness of public water resource management policies. Without the presence of *CBH*s, the ability to promote debates, manage conflicts and monitor implementation of water resource plans is severely limited. The lack of institutionalization of social participation prevents implementing decentralized and democratic water governance, resulting in management which does not adequately reflect local needs and challenges. Therefore, efforts must be intensified to create and implement *CBH*s in all sub-basins, ensuring more comprehensive and inclusive management of water resources in the Araguaia River basin.

4. CONCLUSION

Recent decades have seen significant native Cerrado vegetation losses in the Araguaia River basin. The observed transformations are a direct result of intensified human activities, especially agriculture, livestock farming and urbanization expansion. These processes have caused profound and significant changes in land use and land cover, evidencing a transition to more intensive agriculture. Agricultural expansion, combined with introducing irrigation and soil fertilization technologies, has driven these changes, resulting in notable environmental impacts, such as habitat fragmentation and biodiversity loss.

The analysis of land use and land cover changes in the Araguaia River basin and sub-basins (*BHRA*) over the period from 1985 to 2022 revealed significant dynamics, including a significant reduction in the Forest Formation, Savanna Formation and Grassland Formation categories, while pasture areas have almost tripled and soybean cultivation has increased exponentially.

The growth in the area dedicated to soybean cultivation and expansion of other temporary crops in previously unexplored regions highlight a movement towards intensified agricultural practice. This dynamic not only reconfigures the natural landscape, but also signals a change in land use and land cover management practices.

In addition, the fundamental roles of the Rio das Mortes and Rio Javaés in the *BHRA*, both recognized for their significance and agricultural occupation, emphasize the need for efficient water resource management. The experience with *CBH*s in Brazil, especially in the Araguaia River basin, underscores the need for more robust and coordinated actions to ensure effective participation by society in water resource management.

Despite the theoretical potential of committees to promote integrated and participatory water governance, practice has shown that the mere creation of *CBH*s is not enough. It is essential that there is renewed commitment from public authorities and civil society to overcome existing obstacles, ensuring full operationalization of the committees created. Only in this way will it be possible to achieve the National Water Resources Policy objectives, ensuring more democratic and effective water management which is capable of meeting contemporary demands and challenges.

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