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INFLUENCE OF LAND USE AND LAND COVER ON THE MAINTENANCE OF WATER BODIES IN THE PARAGUAÇU BASIN

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ABSTRACT

Given the current scenario of changes in land use and land cover and the negative environmental impacts resulting from these changes, mechanisms for the management of watersheds must be created and improved. The objective of the present study was to identify how changes in land use and land cover in the Paraguaçu River basin influence spatial/temporal changes in water availability. The Paraguaçu River watershed is located in the eastern center of the state of Bahia. Land use and land cover data were obtained from MapBiomas, in which information from the years 1985 to 2021 was used. The historical flow series were obtained from the fluviometric stations of the hydrometeorological network of the Hydrological Information System (Hidroweb) of ANA. Aiming at a better understanding of the phenomena that occurred in the study area, the basin was divided into contribution basins. Given the negative environmental impacts on natural resources resulting from anthropic activities, which affect their availability and quality, conducting research aimed at conserving the environment has become fundamental today. The management of resources, especially water resources, is characterized as a great challenge, due to the high demand by various sectors of society and inefficient management, which leads to their degradation. In this sense, based on the preliminary review of the literature, there was a

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lack of studies on the influence of land use and land cover on the maintenance of water bodies. Based on the results obtained, it was possible to identify a reduction in the flow values when analyzing data from the fluviometric stations of the Paraguaçu River basin. This reduction may be associated with changes in land use and land cover, signaling the need for interventions that ensure the adequate management of natural resources in the area of the aforementioned basin. The effective application of the river basin plan and the regulation of activities in the region of the Paraguaçu River basin are actions that help in the management of water resources.

Keywords: Geoprocessing. Mapbiomas. Water Resources.

INTRODUCTION

Given the current scenario of changes in land use and land cover and increasingly frequent and intense extreme weather events, mechanisms for the management of watersheds must be created and improved. Thus, to guarantee the right of access and the quantitative and qualitative control of water resources, the National Water Resources Policy (PNRH), Law No. 9,433 (1997), was enacted in 1997, which provides for the consolidation of water resources management in Brazil, to ensure the availability of water in adequate quality standards for present and future generations.

The creation of the aforementioned law was a great advance for the management of water resources in the country so that the National Water Resources Management System (SINGREH) was created, which began to consider the hydrographic basins as basic territorial units for planning and management of water resources and to recognize water as a finite good, of public use, vulnerable and endowed with economic value.

Effective watershed management requires multiple efforts ranging from knowledge of applied hydrology, exact and earth sciences to social and political sciences. Variables such as climate, geomorphological characteristics, and land cover can influence the hydrological behavior of watersheds. Changes in land use, especially for extractive purposes, in which they do not have adequate management, can compromise water availability (Rebouças, Braga & Tundisi, 1999; Latuf, 2007; Tucci, 2012; Souza, Silva, Ratke, Lisboa & Almeida, 2017).

In the face of global challenges to achieve environmental sustainability, the insertion of new technologies and the implementation of water resources management policies and plans are on the agenda of global policies and legislation. According to Alcântara *et al*. (2020), the major discussions on recent climate change show that its impacts are not only reflected in major disasters caused by extreme events but also in the socioeconomic context.

In addition, the effects and consequences of the occupation process on ecosystems need to be understood through the analysis of historical mapping of land use and occupation. The use of technologies allows integrated analysis of environmental and spatial aspects so that the focus of the study is understood as a whole (Pires, Silva, Izippato & Mirandola, 2012). Several technological tools can help collect data and generate spatial information, such as vegetation cover, hydrographic network, road network, relief and altimetry, area delimitations, and georeferenced location of agricultural activities with the potential to cause environmental degradation, enabling diagnoses and prognoses that facilitate the monitoring and management of watersheds, as the factors that trigger the degradation of the natural environment can be identified to make decision-making more efficient (Leite & Ferreira, 2013).

According to Aquino, Almeida, and Oliveira (2012), the methods of collecting data regarding land use and the evolution of vegetation cover, since the 1970s, rely on the use of remote sensing techniques, which enable the study of geographic spaces of significant dimensions and in a temporal way. In this sense, a nationwide initiative is the Annual Mapping Project of Land Cover and Use in Brazil - MapBiomas, which has developed and published a database with annual information on land use and land cover since 1985, through remote sensing techniques and digital processing of images in the cloud, on the Google Earth Engine platform, with quality in the maps produced and freely accessible information (Annual Mapping of Land Use and Cover in Brazil [MAPBIOMAS], 2021).

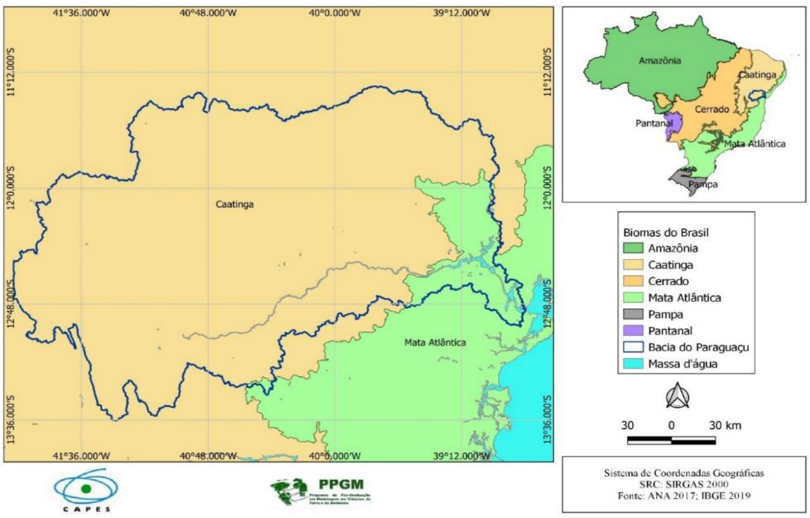
To mitigate environmental impacts due to anthropogenic activities, the agenda for sustainable development proposed by the United Nations (UN) in 2015, including the 2030 Agenda, aims to combat climate change and its impacts, strengthen and implement sustainable production and consumption patterns (United Nations [UN], 2015).

Given the above, this research sought to identify how changes in land use and land cover in the Paraguaçu basin can generate spatial/temporal changes in water availability between 1985-2021.

FIELD OF STUDY

The hydrographic basin of the Paraguaçu River (ottobasin 754) is located in the eastern center of the state of Bahia, between the parallels 11º17' and 13º36' and between the meridians 38º50' and 42º01' (Figure 1).

Figure 1. Location of the study area



Source: Author (2022)

The basin is composed of more than 150 rivers, which nourish 86 municipalities in Bahia. The area bathed by it is 54,877 square kilometers (km²) (Institute of the Environment and Water Resources [INEMA], 2022), about 10% of the state's territory. The Paraguaçu River rises at an altitude of approximately 1,200 m, in the Municipality of Barra da Estiva and runs for about 500 kilometers (km) to its mouth in the Bay of All Saints (Sousa, Macedo, Guedes & Silva, 2016). This basin is the most important in the state, being responsible for supplying 60% of the population of the metropolitan region of Salvador, which is currently the fourth largest city in Brazil (Genz, Tanajura, Araújo, 2012; Conservation International Brazil [CIB], 2020).

Due to its large extension, the Paraguaçu River is divided into three parts: Alto Paraguaçu, a stretch upstream of the confluence of the Santo Antônio River; Middle Paraguaçu, between the mouth of the Santo Antônio and the Pedra do Cavalo dam; and Baixo Paraguaçu, a downstream stretch of this dam (National Water and Basic Sanitation Agency [ANA], 2010). Despite its economic relevance, this hydrographic basin is located in the semi-arid region of Bahia, which is a critical region in terms of water resources management, and being highly vulnerable to droughts (Silva, 2012).

According to the Köppen classification, the Paraguaçu river basin has three types of climate: semi-arid climate (BSh), predominant in the central part of the basin; subhumid to dry climate (Aw), in the upper part of the basin, in the Chapada Diamantina region; and humid to subhumid climate (Af), in the lower third of the Paraguaçu river basin (GENZ *et al*., 2012). The rainy season is concentrated between November and January and the annual rainfall varies from 400 mm to 1600 mm.

The biomes present in the basin range from the transition between the caatinga and the Atlantic Forest to the caatinga with patches of seasonal forest (Carelli & Santo, 2016). The vegetation cover is seasonal forests and rupestrian fields and a geological substrate composed of magmatic and metamorphic rocks (INEMA, 2021). According to the Brazilian Agricultural Research Corporation - EMBRAPA, the main soils present in the area are: oxisols (37%) and planosols (33%) (Brazilian Agricultural Research Corporation [EMBRAPA], 2011).

It is worth mentioning the agricultural suitability of the basin, and the Chapada Diamantina region stands out in this sense. In the basin, the low to medium and medium to high agricultural suitability classes are recorded, in which there is a slightly higher precipitation rate than in the other regions of the basin, where there is a predominance of semi-humid to humid climate (Santos, 2013). According to the same author, the union of these elements makes the region a pole of attraction for agribusiness.

OBTAINING LAND USE AND LAND COVER DATA

MapBiomas is composed of a collaborative network formed by NGOs, universities, and technology companies whose objective is to generate annual maps of land use and cover. The maps are produced from images from the Landsat satellite, which has a spatial resolution of 30 m. Classification is carried out pixel by pixel and all processing is in the cloud, performed through the Google Earth Engine - GEE platform (MAPBIOMAS, 2021).

From pre-defined scripts, developed by the code editor of the GEE platform, temporal mosaics, spectral mixing modeling, and land cover classification are generated, thus generating an efficient database to analyze the modifications and transitions of land use and occupation, as well as to observe the variations in time for the Paraguaçu River basin.

Land use and land cover data were obtained from the Annual Mapping Project of Land Use and Land Cover in Brazil (MAPBIOMAS, 2021). Information from the years 1985 to 2021 was used, which corresponds to the data in Collection 7. With this, it becomes possible to generate maps to study changes in land use and occupation and analyze temporal variations in the study area. For the export of the data, the following code was used in the GEE with:
<https://code.earthengine.google.com/7bcdf070022cc0430859a673433fc45b>

ANALYSIS OF LAND USE TRANSITIONS

To understand the changes in land use and land cover, a reclassification of the MapBiomas maps was carried out to unite similar classes, as shown in Chart 1.

Table 1. Reclassification of land cover classes based on collection 7 of the MAPBIOMAS project.

MAPBIOMAS CLASSIFICATION	RECLASSIFICATION	DESCRIPTION
Forestry Training	Forest	Vegetation types with predominance of continuous canopy - Forested Steppe Savannah, Seasonal Semi-Deciduous and Deciduous Forest
Savannah Formation		Vegetation types with a predominance of semi-continuous canopy species - Wooded Steppic Savannah, Wooded Savannah.
Countryside Training	Non-Forest Natural Formation	Vegetation types with a predominance of herbaceous species (Savannah-Steppe Park, Savannah-Steppe Woody-Woody Savannah, Savanna Park, Grassy-Woody Savannah) + (Floodable areas with a network of interconnected ponds, located along watercourses and in areas of depressions that accumulate water, predominantly herbaceous to shrubby vegetation).

<table>
<tr><td>Rocky outcrop</td><td></td><td>Rocks naturally exposed on the earth's surface without soil cover, often with partial presence of rupicolous vegetation and high slope.</td></tr>
<tr><td>Pasture</td><td rowspan="2">Pasture</td><td>Pasture area, predominantly planted, linked to agricultural activity. Natural pasture areas are predominantly classified as grassland formations that may or may not be grazed.</td></tr>
<tr><td>Mosaic of Uses</td><td>Areas of agricultural use where it was not possible to distinguish between pasture and agriculture.</td></tr>
<tr><td>Temporary Farming</td><td rowspan="3">Agriculture</td><td>Areas occupied with short or medium-term crops, usually with a vegetative cycle of less than one year, which after harvest need new planting to produce.</td></tr>
<tr><td>Coffee</td><td>Areas cultivated with coffee cultivation.</td></tr>
<tr><td>Perennial Agriculture</td><td>Areas occupied with crops with a long vegetative cycle (more than one year), which allow successive harvests, without the need for new planting. In this version, the map covers mostly areas of cashew on the coast of the northeast and oil palm in the northeast region of Pará, but without distinction between them.</td></tr>
<tr><td>Urbanized Area</td><td>Urbanized Area</td><td>Areas with significant density of buildings and roads, including areas free of buildings and infrastructure.</td></tr>
<tr><td>Water Body</td><td>Water Body</td><td>Rivers, lakes, dams, reservoirs and other bodies of water.</td></tr>
<tr><td>Non-Vegetated Areas</td><td>Non-Vegetated Areas</td><td>Areas of non-permeable surfaces (infrastructure, urban sprawl, or mining) not mapped in their classes.</td></tr>
</table>

Source: Adapted from MapBiomas (2021)

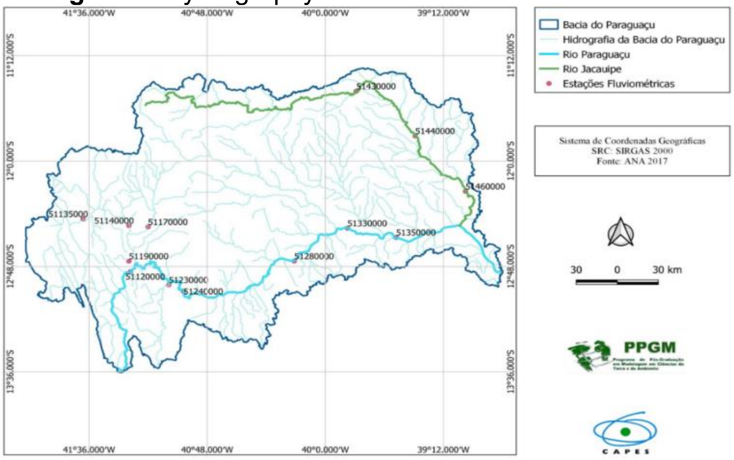
This junction between the classes was made to identify the transitions that took place and which were the most significant changes between the areas of natural formation and other uses during the period of analysis, making it possible to obtain the areas that changed between the years 1985 and 2021.

OBTAINING THE HISTORICAL HYDROLOGICAL SERIES

The historical flow series were obtained from the fluviometric stations of the hydrometeorological network of ANA's Hydrological Information System (Hidroweb), selected according to data availability (ANA, 2021).

The stations that are distributed in the Paraguaçu Basin, analyzing 13 fluviometric stations that had a current data series and are more than 30 years old, as illustrated in Figure 2.0

Figure 2. Hydrography and main fluviometric stations.



Source: Author (2022)

Aiming at a better understanding of the phenomena that occurred in the study area and a relationship between the dynamics of changes in land use and land cover on water resources, the contribution basin of each of the 13 fluviometric monitoring stations was generated, using the Digital Elevation Model (DEM), available on the EMBRAPA platform, and through the QGIS 3.16 'Hannover' software. It should be noted that for the processing and elaboration of the maps, the Datum SIRGAS - 2000 was adopted.

RESULTS

DYNAMICS OF LAND USE AND LAND COVER THE CATCHMENTS

In general, the Paraguaçu river basin showed losses in the forest areas of the contribution basins analyzed, except basin 51230000, located in the municipality of Itaeté, which showed an increase in the forest class.

Regarding the forest class, it was also possible to verify that the greatest loss of forest area was recorded in the contribution basin 51170000, in Utinga, in the Alto Paraguaçu region, presenting a loss of 33.85 hectares (ha) between the years 1985 and 2021, which corresponds to about 12% of forest suppression.

A decrease in the areas of non-natural forest formation was observed in almost all contribution basins, with emphasis on basin 51120000 (Andaraí), with about 5.5% reduction between the years 1985 and 2021.

Regarding the Non-Forest Natural Formation class, it was found that 77% of the analyzed contribution basins showed a reduction for the non-forest natural formation class.

Analyzing the pasture class, the numbers showed that only one of the thirteen contribution basins showed a decrease. Basin 51120000 (Andaraí) had a reduction in the percentage of pasture areas of around 6.8%. The opposite could be observed for the basins 51170000 (Utinga) and 51330000 (Rafael Jambeiro), which showed a significant increase in the pasture area. The data obtained in basins 51170000 and 51330000 showed an increase of 12.38% and 9.88%, respectively, a fact that may be related to the reduction of the forest area.

For the urbanized area class, there was a general increase in the contribution basins, with emphasis on the 51440000 basin (Riachão do Jacuípe) which in 1985 had 507 ha of urbanized area and in 2021 this urbanization rate reached 2,704 ha. The opposite could be observed for the data referring to the contribution basin 51230000, since it presented the lowest variation for this class, being, among all the basins analyzed, the one with the lowest urbanization rate.

Based on the data of the non-vegetated area, it is possible to verify that all the basins, except 51440000 (Riachão do Jacuípe) and 51120000 (Andaraí), showed a reduction in the non-vegetated area. Considering the agriculture class, there was an increase in all the contribution basins. There is a significant growth, in terms of area with agricultural suitability, in basins 51120000 (Andaraí), with 52,223 ha; 51240000 (Itaeté), with 58,994 ha; 51280000 (Iaçu), with 59,798 ha; 51330000 and 51350000 (both in Rafael Jambeiro), with 60,710 and 60,712 ha, respectively.

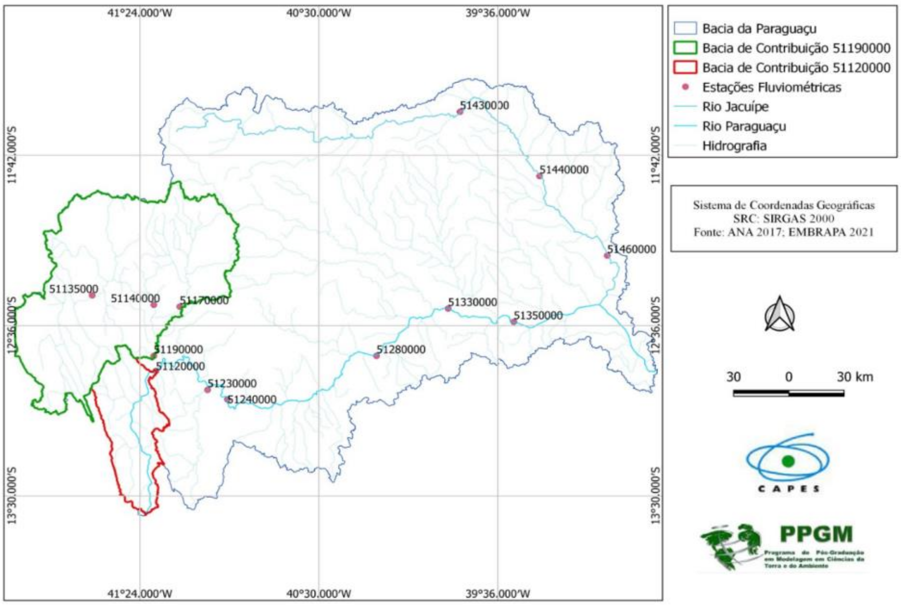
These data reflect the agricultural potential verified in some regions of the Paraguaçu River basin, which, due to the availability of water, enables high production through irrigated agriculture. Such indices analyzed may also be related to the reduction of the forest area. As for the area destined for agriculture, between the years 1985 and 2021, there was a significant increase in the contribution basin 51430000 (Gavião), with a variation of approximately 136%, which doubled the area of agricultural exploitation.

For the water class, only basins 51120000 (Andaraí), 51280000 (Iaçu) and 51440000 (Riachão do Jacuípe) did not have a reduction in the water mirror, which may be linked to the presence of dams at various points in the Paraguaçu basin. The reduction of the water mirror in the other contribution basins may be linked to the increase in pasture areas, agriculture, urbanized area and forest reduction.

CHOICE OF CATCHMENTS

Based on the analysis of the dynamics of land use and land cover in each contribution basin, 2 contribution basins were selected, 51120000 (Andaraí) and 51190000 (Andaraí) (Figure 3), which, although very close, have different scenarios regarding the dynamics of land use and occupation. The selection of such basins can help in understanding how the temporal evolution of land use and land cover (1985 - 2021) can influence the maintenance of water bodies.

Figure 3. Catchments chosen for analysis.

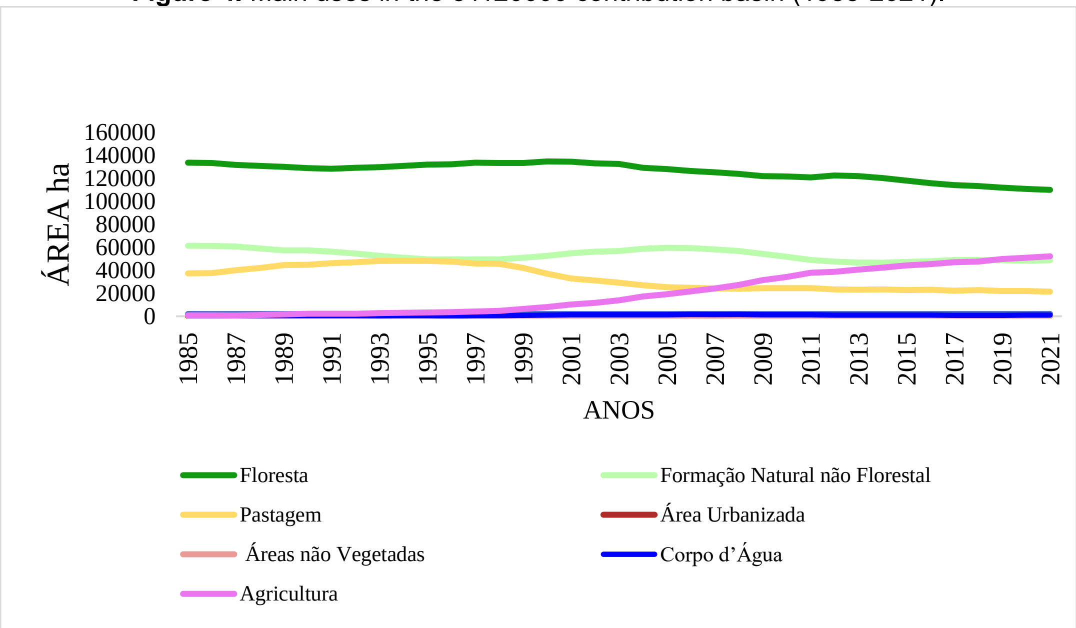


Source: Author (2022)

DYNAMICS OF USE AND COVERAGE IN THE CONTRIBUTION BASINS

Among the main land uses in the 51120000 (Andaraí) basin (Figure 4), an increase in the agriculture class and a decrease in the forest class stand out.

Figure 4. Main uses in the 51120000 contribution basin (1985-2021).



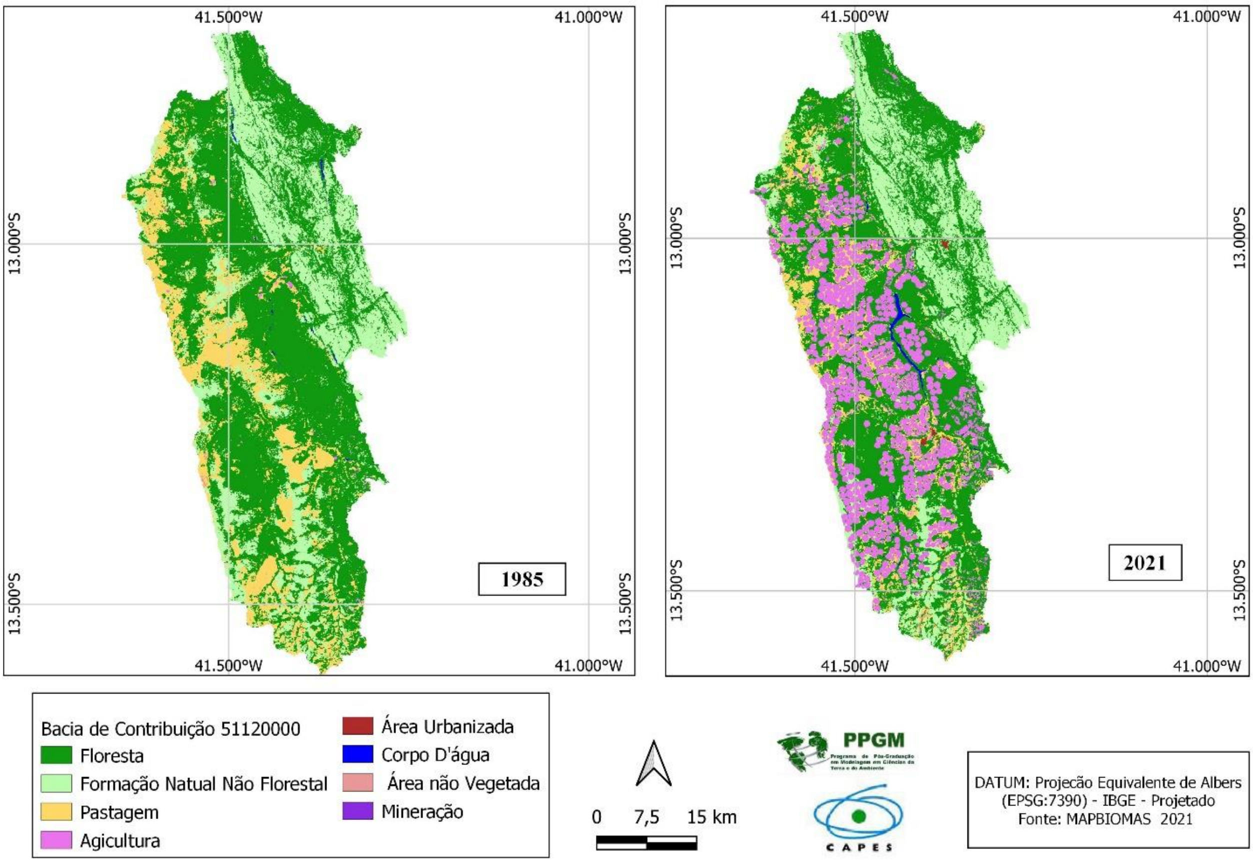
Source: Author (2022)

In 1985, the region had practically no agricultural activity, however, data from 2021 show that more than 22% of its area was in use with agriculture, including developed through irrigation systems with center pivots.

According to Sarmento-Soares, Santos & Martins-Pinheiro (2021), in the Alto Paraguaçu region, where sub-basins with mouths equal to 1,000 meters (m) or above are concentrated, there is a large number of dams for water abstraction, which characterizes the suitability of this area for agricultural use.

According to the same authors, between the 1980s and 1990s, there was a great suppression of the area of Campos Gerais, a characteristic vegetation of the region, for the implementation of mechanized agricultural activity, marked mainly by the use of central pivots; Agriculture, since then, has become one of the bases of the local economy. Figure 5 illustrates the land uses and land cover in the 51120000 contribution basin for the year 1985 and 2021, with emphasis on the advance of agriculture in the region.

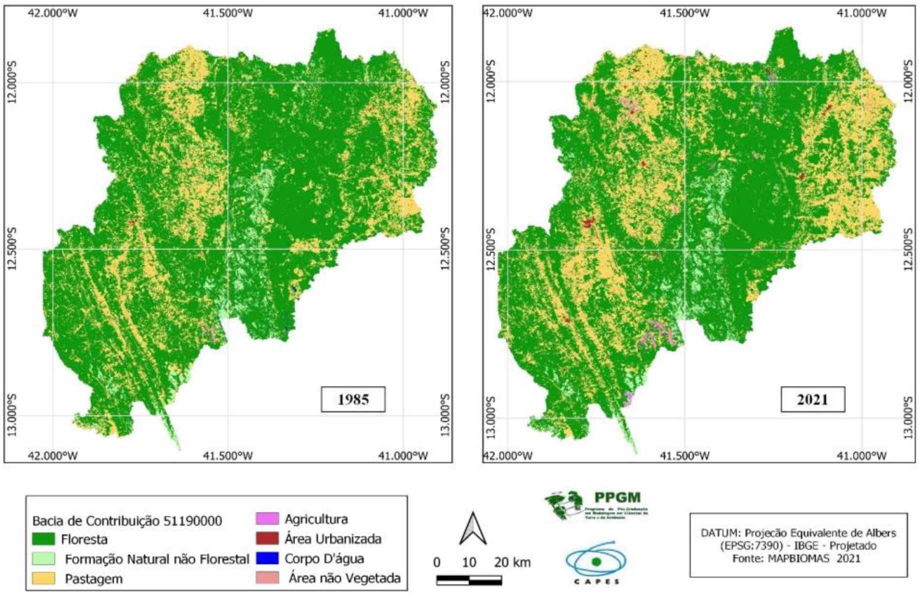
Figure 5. Main uses in the 51120000 contribution basin (Andaraí) (1985-2021).



Source: Author (2022)

For the contribution basin 51120000 (Andaraí) there was a reduction of approximately 15,862.5 ha of pasture area. However, for basin 51190000 (Andaraí) there was a significant increase of about 58,922 ha in the pasture class, as illustrated in Figure 6.

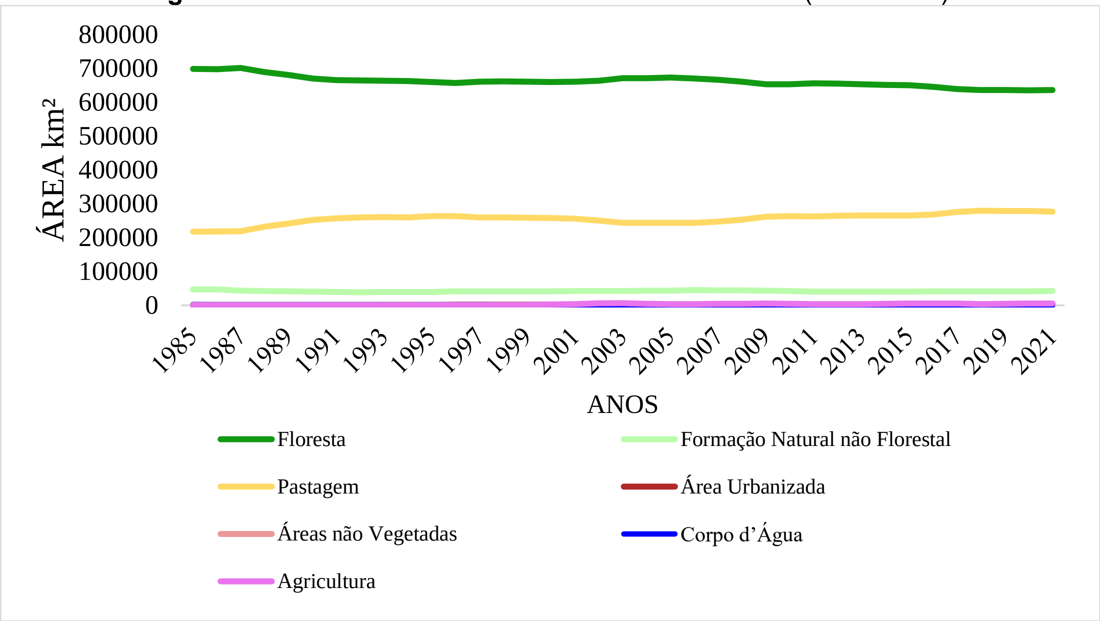
Figure 6. Main uses in the 51190000 contribution basin (Andaraí) (1985-2021).



Source: Author (2022)

Basin 51190000 (Andaraí) has a very different use dynamic (Figure 7) about basin 51120000 (Andaraí). In 2021, basin 51190000 showed an increase of 4,927 ha in the area used for agriculture and a reduction of 388 ha in the water surface mapped in MapBiomas.

Figure 7. Main uses in the 51190000 contribution basin (1985-2021).



Source: Author (2022)

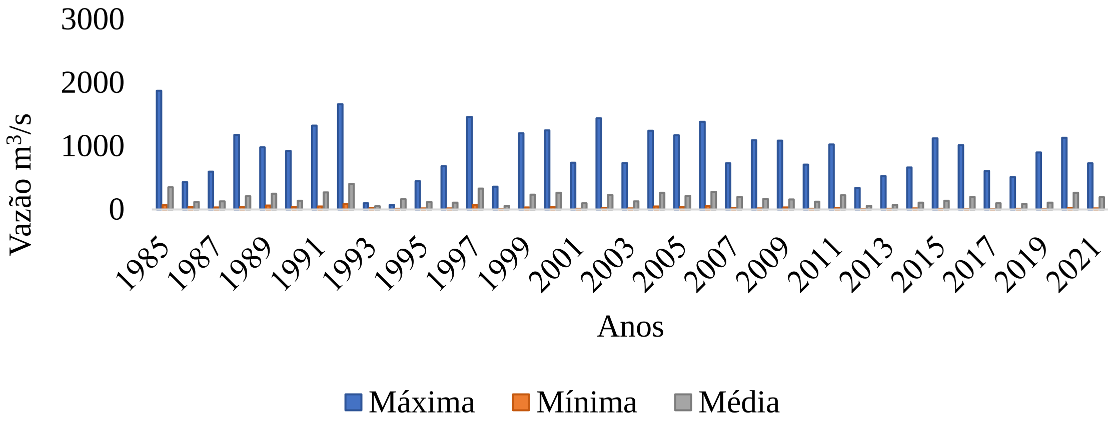
The decrease in the water surface observed in the 51190000 contribution basin may be related to the significant increase in the area used for activities such as agriculture and livestock, since the intense development of agricultural and livestock areas is strictly linked to the availability and quality of natural resources (Mendoza, Granados, Geneletti, Pérez-

Salicrup & Salinas, 2011). These activities can lead to biodiversity loss, reduced soil fertility, increased erosive processes, and decreased water resources (Vanzela, Hernandez, & Franco, 2010).

FLOW IN THE CATCHMENT BASINS

Based on ANA flow data, the maximum, minimum and average flows for each contribution basin were calculated, between the years 1985 and 2021. For the year 1985, the flow in the contribution basin 51120000 (located in the municipality of Andaraí) presented maximum, minimum and average values of, respectively, 1872 m3/s; 65 m3/s and 351 m3/s (Figure 8). In 2021, the maximum and average flow values fell by 40 and 55%, in that order, and the minimum reduced by about 30%.

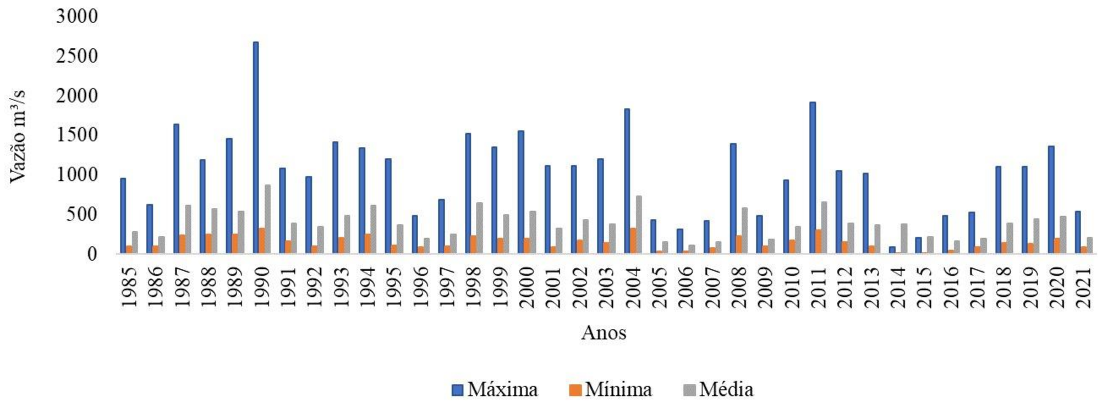
Figure 8. Representative graph of flow in the 51120000 contribution basin.



Source: Adapted from ANA (2021)

Figure 9 illustrates the flow values recorded for basin 51190000 (Andaraí) between the years 1985 and 2021. For the year 1985, the maximum, minimum and average flow in the referred contribution basin was, respectively, 954 m3/s; 102 m3/s and 280 m3/s. In 2021, there was a drop in these values about the first records of the historical series, with a maximum, minimum and average flow of 531 m3/s; 89 m3/s and 205 m3/s, in that order. In 2021, the maximum and average flow values fell by 45% and 26.79%, in that order, and the minimum reduced by about 12.75%.

Figure 9. Representative graph of flow in the 51190000 contribution basin.



Source: Adapted from ANA (2021)

According to the flow data obtained, it was observed that in the first 20 years (1985 to 2005) the average average flow for basins 51120000 and 51190000 was 946 m3/s and 1,229.38 m3/s, respectively. In the last 10 years, the average average flow values for these basins were 778 m3/s (51120000) and 852.72 m3/s (51190000), which means an 18% drop in the average flow in the 51120000 basin, where there was a large increase in the irrigated agricultural area and the water mirror with the implementation of the Perto reservoir. In basin 51190000 the drop was 31%. In this basin there was an increase in the pasture area and the urban area.

DISCUSSION

Irrigated agriculture is expanding throughout Brazil. In quantitative terms, most of the watersheds that have compromised water availability have irrigation as the most significant activity; in 2019 alone, this activity was responsible for 49.8% of raw water withdrawal from water bodies in Brazil (ANA, 2021).

According to Souza, Silva, Ratke, Lisboa & Almeida (2017), in the state of Bahia, the Paraguaçu basin, as it has several other dams along the main course of the river, which meet numerous demands of the most diverse uses, is pointed out as the most important in the state.

Throughout the present study, it was found that the 51120000 contribution basin is also one of the few where it was possible to observe an increase in water surface cover, from 417 ha in 1985 to 1,040 ha in 2021, mainly due to the construction of the Perto reservoir. Completed in the late 1990s and located in the upper part of the Paraguaçu basin, in the vicinity of the Chapada Diamantina National Park, the Aperture dam is one of the factors that contribute to the agricultural development of the region (Silva, Palma, Guedes & Polkeing, 2020).

Regarding issues related to conflicts related to water use, the Paraguaçu River basin, especially in the upper stretch, is the one that most lacks water resources management actions, given the great demand for water abstraction to meet the advanced irrigated agriculture present in the region (Souza, 2017).

Although the Estreito dam in the Paraguaçu basin has a capacity of 108 hm³, a water mirror about 23 km long and a hydraulic area of 13.56 km2 and a regularized flow of 7.6 m³/s (Companhia de Engenharia Hídrica e de Saneamento da Bahia [CERB], 2022; Pereira & Johnsson 2005), it is necessary to implement management plans aimed at better management of water resources, to sustain irrigated agriculture activities, the supply of the population and, above all, to ensure the conservation of water bodies in the region.

Regarding the conservation and protection of water resources, the National Water Resources Policy, instituted by Law 9.433 of 1997, establishes the creation of river basin committees as bodies responsible for the management of water resources in these areas. According to the same law, acting as collegiate bodies, the committees perform advisory and deliberative functions, being hierarchically characterized as the most important instance of participation and integration in the water management of the watersheds, since the decisions made by them directly impact the lives of users.

Thus, aiming at a better management of water resources in the study area, it was instituted, through Decree No. 9,938, of March 22, 2006, the creation of the Paraguaçu River Basin Committee - CBHP. This Water Planning and Management Region (RPGA) is fully integrated by 40 municipalities, including Rafael Jambeiro, Utinga, Gavião, Riachão do Jacuípe, Itaeté and Andaraí. Due to the impacts of the anthropogenic activities developed in the basin, in 2018 the strategic action plan for the management of water resources in the hydrographic basins of the Paraguaçu River and the northern recôncavo and Inhambupe was prepared. However, the state water resources plan is undergoing a broad review, which takes into account the changes in land use and occupation that have occurred in recent years, to meet the need for broader participation by the government, water users, and communities (INEMA, 2018).

Regarding the consequences of the increase in agricultural activities and their effects on the environment, it was evidenced in the study carried out by Silva, Vidal, Barros & Freita (2018) that the process of environmental degradation in the Northeast is also associated with the mode of agricultural production, causing negative environmental impacts such as the loss of biodiversity and soil degradation.

In a study conducted by Vanzela *et al*. (2010), on the influence of land use and occupation on the water resources of the Três Barras Stream, in Marinópolis - SP, showed that the areas occupied by forests favor the increase of the specific flow due to the greater coverage, stability and infiltration of water in the soil, in addition to promoting a reduction in the intensity of surface runoff, also contributing to the improvement of water quality. In general, inhabited and cultivated areas and degraded forests contribute to the reduction of specific flow and water quality due to the change in the intensity of surface runoff.

The expansion of irrigated agriculture in the upper Paraguaçu and urban growth without adequate investment in sanitation throughout the basin have been major threats to the availability of clean and abundant water in the region. In the two basins chosen, there was a significant increase in the urbanized area. In the 51120000 basin there was practically no urban area in 1985 and increased to 328 ha, while in the 51190000 basin the urban area went from 536 ha to 2,573 ha, which represents an increase of 2,037 ha of urbanized area.

Given the size and importance of the Paraguaçu basin for the state of Bahia, it is noted that more strategies are needed to conserve the natural resources present in the region. According to the State Department of the Environment in the Paraguaçu River basin, eight conservation units are legally constituted, among them are: Chapada Diamantina National Park, which includes the municipalities of Palmeiras, Mucugê, Andaraí, Lençóis, Ibicoara and Itaeté; Area of Relevant Ecological Interest Serra do Orobó, in the municipalities of Itaberaba and Rui Barbosa; Marimbus/Iraquara Environmental Protection Area that covers the municipalities of Andaraí, Palmeiras, Lençóis, Iraquara and Seabra; Lago de Pedra do Cavalo Environmental Protection Area, between the municipalities of Feira de Santana, Santo Estevão, Antônio Cardoso, Cabeceiras do Paraguaçu, Muritiba, Governador Mangabeira, São Félix, Cachoeira, Conceição de Feira and São Gonçalo dos Campos.

For the Forest class, there was a reduction in area in the two contribution basins analyzed, with a decrease of more than 10% in 51120000 and more than 6.43% in basin 51190000. With the removal of the natural vegetation cover, the soil becomes more exposed to the action of rain, favoring the formation of surface sealing and consequent difficulty in infiltration of water into the soil, or even soil erosion and degradation (Oliveira, Santos & Araújo*,* 2018).

Given the flow data made available by ANA, and the calculations carried out to determine the maximum, average and minimum flows for the selected contribution basins, between the years 1985 and 2021, it was found that there was a significant reduction. In

2021, in basin 51120000, the maximum, average, and minimum flow values fell by 40%, 55%, and 30%, respectively, compared to the beginning of the time series, in 1985. For the 51190000 contribution basin, a reduction in the flow values was also observed, since the maximum, minimum and average were respectively 44.66%, 12.77% and 26.79% lower than the first records of the historical series, in 1985.

This drop in the flow values, recorded in the historical series of the two basins analyzed, demonstrates the effect of growing urbanization and the pressure of anthropogenic activities in the region. The expansion of irrigated agriculture, the increase in pasture areas and the decrease in forests may be directly related to the depletion of water resources in the region. In a study carried out by Calijuri, Castro & Costa (2015) in the Alto Paraguaçu basin, it was possible to detect that changes in land use/cover influenced the variation in precipitation and also in the availability of water.

Another factor that may be related to the decrease in flow values is the presence of wells for the capture and use of groundwater sources in the Paraguaçu River basin. According to CERB data, a total of 2,165 wells were registered in the basin (of which 68 in the municipality of Andaraí) are distributed in a very heterogeneous way, depending on local demands and availability (INEMA, 2018). Due to the precariousness of data, the absence of monitoring programs and studies aimed at this purpose, the quantitative evaluation of groundwater reserves in the Paraguaçu River basin is difficult; it is necessary to expand the knowledge of these reserves through specific studies on groundwater sources and their interaction with surface water resources, as well as control and monitoring actions for the use of these sources (INEMA, 2018).

Changes in land use and occupation tend to promote changes in the hydrological regime of the hydrographic basin (Santos, Griebeler & Oliveira, 2010). Another relevant factor is the management of agricultural soil and the type of crop implanted, because if the infiltration conditions are affected, there is an increase in surface runoff with risks of erosion and soil loss, and a reduction in aquifer feeding, which reflects on flows (Tucci, 2002). Due to the current conditions of environmental degradation of the basin, it is urgent to implement actions aimed at recovering its environmental quality, especially in the most critical areas for water production, with a focus on the areas of interception, recharge, springs and riparian forests. However, the reversal of the current scenario will not be possible without the engagement, participation and commitment of all segments of society, and specific studies must take place that help in the assessment of environmental losses and the awareness and guidance of the population and, above all, of managers in the decision-making process (Oliveira *et al*., 2018).

CONCLUSION

Based on the study carried out in the Paraguaçu watershed, it was observed that the use and occupation of the land, since 1985, the beginning of records by MapBiomas, has generated significant changes in the contribution basins analyzed. The increase in the urbanized area, reduction in the forest area and the expansion of agricultural activities observed in the selected basins have a direct impact on the region's water availability, a fact that can be attested by the data from the fluviometric stations, since they show a tendency to decrease the flows, especially the minimum flows.

The contribution basin of monitoring point 51120000 has shown a large expansion of agricultural use in the last 20 years, including intensive use of water in irrigation pivots. and showed a smaller reduction in average flow in the last 10 years than the 51190000 contribution sub-basin, which had much smaller changes in use and cover.

As both basins are neighboring and suffer similar climatic and rainfall conditions, this difference may be related to the construction of the Estreito reservoir and the opening of many artesian wells, with at least 2,165 registered.

The reduction in the minimum flow values is a fact that requires a lot of attention, as it can be an indication of water deficit in these basins, considering that this is the flow level that ensures the quality and quantity of water necessary to minimally maintain the components, functions and processes of aquatic ecosystems. This highlights the need for interventions that ensure the proper management of these basins to avoid a water crisis in the region.

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