A TEMPORAL ANALYSIS OF LAND USE AND COVER IN THE PARÁ RIVER BASIN AFTER THE IMPLEMENTATION OF 1988'S FEDERAL CONSTITUTION OF BRAZIL.

Uma análise temporal do uso e cobertura do solo da Bacia do Rio Pará após a vigência da Constituição Federal do Brasil de 1988.

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ABSTRACT

The present research aimed to analyze the land use and cover of the Pará River Basin territory, located in Minas Gerais, Brazil, between the years 1990 and 2020, considering the period after the enactment of the 1988's Federal Constitution, which imposed on the Public Power and the community the duty to defend and preserve the environment for present and future generations. In this sense, we assessed whether the constitutional command that recognizes that everyone has the right to an ecologically balanced environment has been observed. To this end, changes in land use and land cover (LULC) were quantified, using as database classified images provided by the MapBiomas Project. These analyzes were performed through the application of landscape metrics and the Land Change Modeler (LCM) tool, to determine the spatial pattern assumed by the LULC classes and define the contributions of each class to the landscape changes. The temporal analyzes reveal that the vegetation cover has been explored without the concern of replacing the native vegetation and demonstrate that the environmental constitutional commands haven't had a positive impact on an ecologically balanced environment in the study area.

Keywords: Federal Constitution; Environment; Temporal Analysis; Territory; environmental imbalance.

RESUMO

A presente pesquisa teve como objetivo analisar o uso e cobertura do solo do território da Bacia Hidrográfica do Rio Pará, localizada em Minas Gerais, Brasil, entre os anos de 1990 e 2020, considerando o período após a promulgação da Constituição Federal de 1988, que impôs ao Poder Público e à coletividade o dever de defender e preservar o meio ambiente para as presentes e futuras gerações. Neste sentido, buscou-se avaliar se o comando constitucional que reconhece que todos têm o direito ao meio ambiente ecologicamente equilibrado vem sendo observado. Para tal, foram quantificadas as alterações nos usos e coberturas do solo (LULC), utilizando como base de dados imagens classificadas pelo projeto MapBiomas. Estas análises foram feitas através da aplicação de métricas da paisagem e da ferramenta Land Change Modeler (LCM), para determinar o padrão espacial assumido pelas classes de LULC e definir as alterações e contribuições de cada classe para as mudanças na paisagem. As análises temporais revelam que a cobertura vegetal vem sendo explorada sem a preocupação de reposição da vegetação nativa e demonstram que os comandos constitucionais ambientais não vêm impactando positivamente para um meio ambiente ecologicamente equilibrado no território da área de estudo.

Palavras-chave: Constituição Federal; Meio Ambiente; Análise Temporal; Território; Desequilíbrio Ambiental.

1 INTRODUCTION

The Federal Constitution of 1988 (BRASIL, 1988) brought a specific chapter dedicated to the environment and was the first Brazilian Constitution to do so, demonstrating the importance of the matter. In this chapter, it was recognized that everyone has the right to an ecologically balanced environment. To this end, it imposed on the Public Power and the community the duty to defend and preserve the environment, in the name and for the sake of present and future generations.

According to Brasil (1988), in obedience to the environmental constitutional commands, it was incumbent upon the Public Power, among others, to define territorial spaces to be protected in all units of the federation and the duty to demand previous environmental impact studies for the installation of work or activity with the potential to cause significant degradation to the environment.

Previous environmental impact studies are required so that the Public Power can have sufficient subsidies to assess and weigh the positive and negative environmental impacts of an activity, considering mitigating/compensatory measures, in order to make economic and social development compatible with environmental protection, assuring an ecologically balanced environment for all. However, the assessment of environmental impacts has been carried out in a fragmented way. The enterprises are analyzed considering, as a rule, the area of possession and/or property of the entrepreneur that requires environmental licensing, which may not guarantee the environmental balance of the territory.

However, the procedure is different for the analysis of water resources use requests, and what is take into account is the availability of water considering the conditions of the hydrographic basin and not the water available in the applicant's area.

The hydrographic basins, pursuant to Law no. 9,433, of 1997 (BRASIL, 1997), are planning units for the management of water resources, as was also the case with the Agricultural Policy, Law no. 8171, of 1991 (BRASIL, 1991), which established the hydrographic basin as the basic unit for use, conservation and recovery of natural resources planning.

The suppression of native vegetation for soil sealing and for agricultural activities, among other activities, affects the quality and availability of water resources, so it is not reasonable that the environmental impact assessment, due to the installation and operation of an enterprise, should be dissociated from the territory of the hydrographic basin, as it has been applied.

The negative environmental impact can be different according to the soil type, available nutrients and sediment transport, among others, which can modify the physical-chemical and biological processes of natural spaces, as explained by Menezes et al (2016). And all of this can also be mitigated by monitoring land use and land cover using spatial-temporal information of landscape changes (COELHO et al., 2014).

The management and monitoring of land use and occupation through Geographic Information Systems (GIS) has been gaining ground as an auxiliary tool for understanding the rapid changes in the landscape, since it allows obtaining information for the construction of scenarios and environmental indicators, that can be used as practical subsidies in the assessment of environmental support capacity (OLIVEIRA-ANDREOLI et al, 2021).

Therefore, the objective of this research is to analyze the land use and cover of the Pará River Basin, after the promulgation of the Federal Constitution of 1988, considering the years 1990 and 2020, in order to analyze whether the current model for evaluating environmental impacts has contributed to the environmental balance, which everyone is entitled to. Thus, this is an exploratory and descriptive research, embodied in a quantitative approach, allowing to identify, quantify, analyze and evaluate the land use and cover, considering the constitutional principles and guidelines of environmental protection, with the aid of geotechnologies, as a contribution to the improvement of environmental management with a focus on the territory.

2 METHODOLOGY

2.1 Study area

The Pará River watershed occupies 5.22% of the territory of São Francisco River Watershed, being located in the southwest of the Minas Gerais State, with an extension of 12,233.06 km² (Figure 1). This basin covers 34 municipalities, 89.7% of which are urban and 10.3% rural (IGAM, 2021; IBGE, 2021).

The predominant original vegetation cover in the São Francisco River Basin belongs to the Cerrado biome, along with semideciduous seasonal forest formations, belonging to the Atlantic Forest biome (IGAM, 2008).

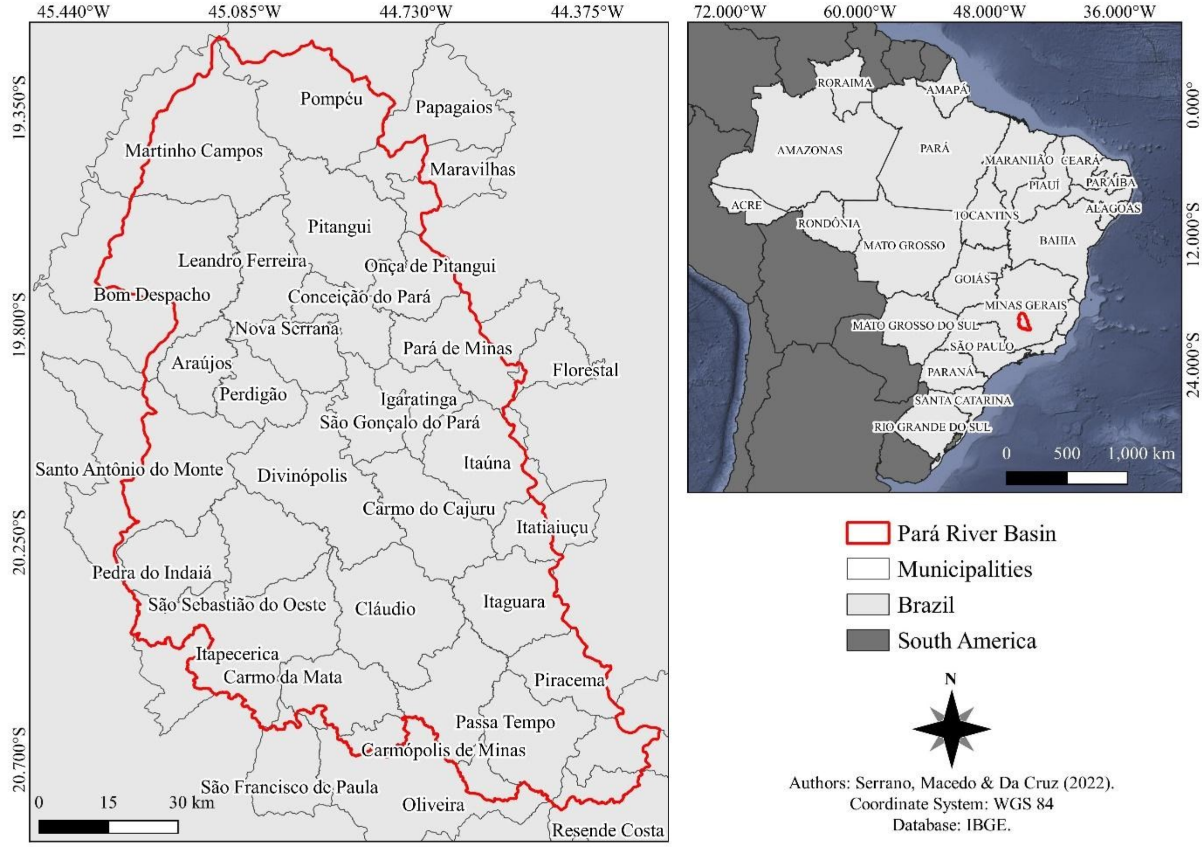

Figure 1: Location of the Pará River Basin.

According to IGAM (2008), the Pará River is born with the name of Ribeirão Cajuru, on the slopes of the Galga and Cebola mountains, at an altitude of 1,180 meters, flowing into the São Francisco River, close to the reservoir Três Marias, on the border of the municipalities of Pompéu and Martinho Campos – MG. In addition, the main streams of the Pará River are the São João and Peixe rivers on the right bank and the Itapecerica, Lambari and Picão rivers on the left bank.

The Pará River Basin Water Resources Planning and Management Unit comprises the São Francisco River administrative unit, called SF2, and has 10 sub-basins, governed by the CERH/MG Normative Deliberation No. 06, of 2002 (IGAM, 2002). The region of this hydrographic basin has its Master Plan, which aims to establish strategic goals and management instruments with a view to the sustainable development of the region, contributing to the improvement of the living conditions of the local populations.

2.2 Database

Aiming to identify the Pará River Basin limits, we use the set of vector data from the hydrographic regions of Brazil, available by the National Agency for Water and Basic Sanitation (ANA, 2022).

For the purpose of evaluating land use and land cover, we used classified images provided free of charge by the MapBiomas Project, Collection #6, referring to the years 1990 and 2020 (MAPBIOMAS, 2022a). The adopted method by this project is the pixel-by-pixel classification, whose process is carried out entirely through the Google Earth Engine platform and the input images come from Landsat satellites, with a spatial resolution of 30 m (MAPBIOMAS, 2022b).

In order to improve the process of change analysis in land use and cover, we used scenes from the Digital Elevation Model (DEM), with a spatial resolution of 30 m, obtained from the Shuttle Radar Topography Mission (SRTM) project, made available free of charge through the United States Geological Survey's Earth Explorer portal (USGS, 2022).

2.3 Data Processing

The processing of geographic data was carried out, initially, through the free software QGIS version 3.20 (QGIS, 2022), where the extraction of the polygon referring to the territorial limits of the Pará River Basin was carried out in the images of use and land cover. Then, these images were reclassified, in order to facilitate the following steps of analysis and following the levels proposed by the MapBiomas Project, such as: Forest, Forest Plantation, Non Forest Natural Formation, Farming, Non Vegetated Area, Mining and Water.

After preparing the database, the image analysis was performed, so that it was possible to quantify the changes in LULC of the Pará River Basin, from 1990 to 2020. To that point, first we obtained a description of the landscape structure, using the LecoS v.3 extension of QGIS. This tool is based on quantitative parameters, known as metrics, to generate statistics about the spatial patterns of elements in the landscape (JUNG, 2016). For the present study, the following metrics were determined: Number of Patches (NP); Mean Euclidean Nearest Neighbor Distance (ENN MN) and Landscape Proportion (LP).

Finally, the land use and land cover images, along with the MDE, were submitted to the TerrSet software to perform the Land Change Modeler (LCM) tool, in order to quantify the contribution of each class to changes in the landscape, in addition to obtain the gains and losses that they have presented over the years (LCM, 2022).

3 RESULTS AND DISCUSSION

The maps of land use and occupation, referring to the years 1990 and 2020, can be seen in Figure 2, as well as the percentage of changes observed in the proportion of the landscape composed by each class for the evaluated period.

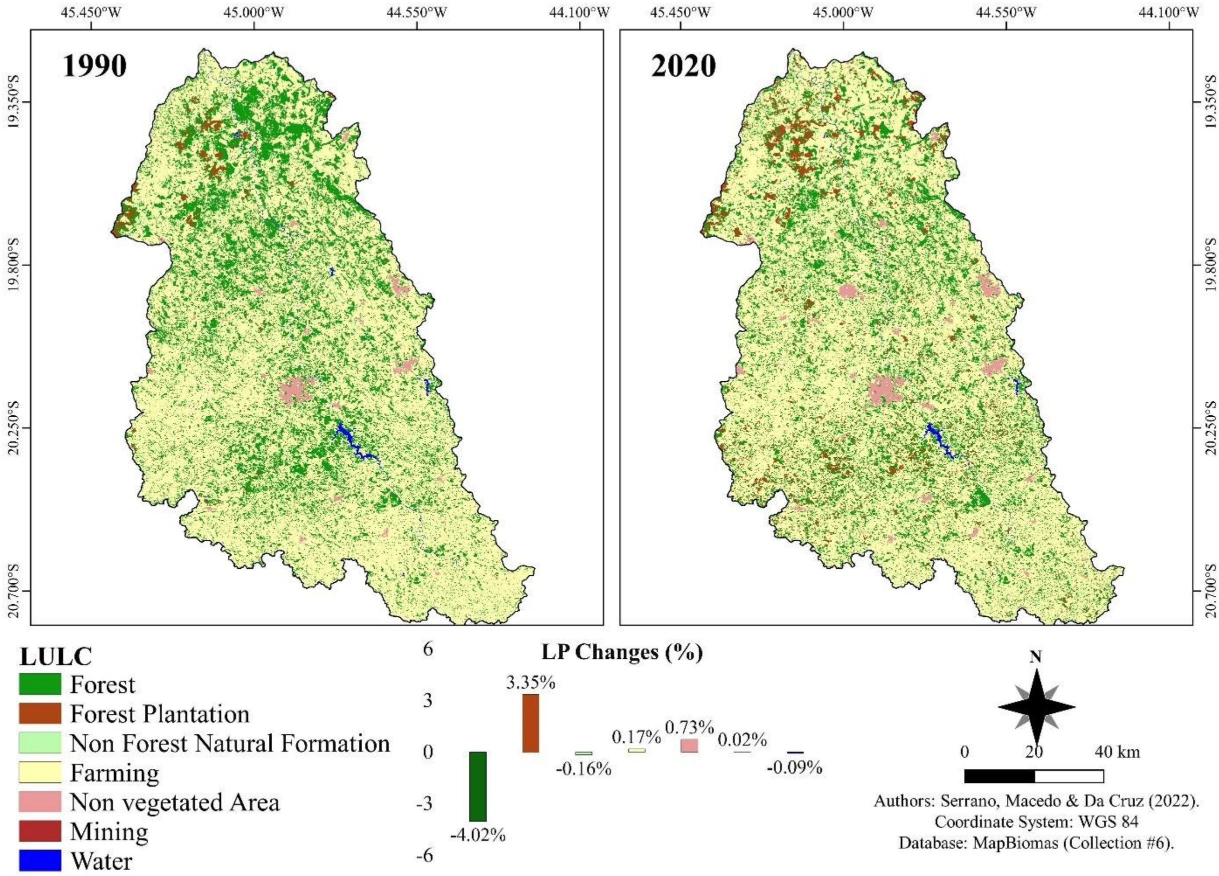

Figure 2: Land use and cover (LULC) of the Pará River basin and changes in the landscape proportion (LP %), between the years 1990 and 2020.

In 1990, most of the landscape was used for agriculture, which covered about 71% of the basin's territory. For the year 2020, this value decreased by 0.2%, indicating a low variation for this class within the 30-year period. The same cannot be said about the classes of natural forest and silviculture, which showed higher percentages of changes in the values of landscape proportion (LP).

The area that was initially covered by natural forest represented about 25.50% of the basin's territory, however, this value dropped to 21.48% in 2020, that is, a decrease of 4.02% in its original coverage. In the opposite direction, there was an almost proportional increase for areas destined to forestry (+3.35%), which went from 0.81% to 4.16%.

Other classes that also had increases in their landscape proportion were mining (+0.02%) and non-vegetated area (+.0.73%) – which is the macro class that includes the urbanization subclass.

From an environmental point of view, this loss in extension of natural forest areas can be harmful, especially for the water regime of the basin, since the absence of vegetation cover reduces the flow of water bodies, following the concepts discussed in Cecílio et al. (2019) and Saddique et al. (2020), in addition to allowing the carrying of particles, resulting in the silting of rivers, soil degradation (CURVELLO et al., 2008; VIEIRA et al., 2016) and decreased of water quality (BROGNA et al., 2018; DE MELLO et al., 2018).

As an example, Rodrigues et al. (2015) conceived different forest cover scenarios in the Pará River Basin and, through the SWAT model, also recently used by Das et al. (2022), Lin et al., (2022) e Oliveira Serrão et al., (2022), they evaluated the demand for water resources by native vegetation and planted forest. As a result, the authors verified that the reforestation scenarios presented the highest values of water deficit, varying according to the age of the vegetation, while the native forest scenario presented the highest average daily value of flowrate.

The area close to the downstream of the Pará River watershed, as shown in Figure 3 below, revealed more expressive changes in the forested area.

The municipalities that quantified the greatest losses in forest cover were Pompéu (-14590 ha), Martinho Campos (-6270 ha) and Pitangui (-5581 ha), which together represent a decrease of almost 8% of the original area of native forest in the basin. The Cerrado biome is predominant in these municipalities and, despite being considered a global biodiversity hotspot, it suffers an exceptional loss of habitat, especially due to the installation and development of agricultural activities (BRASIL, 2022).

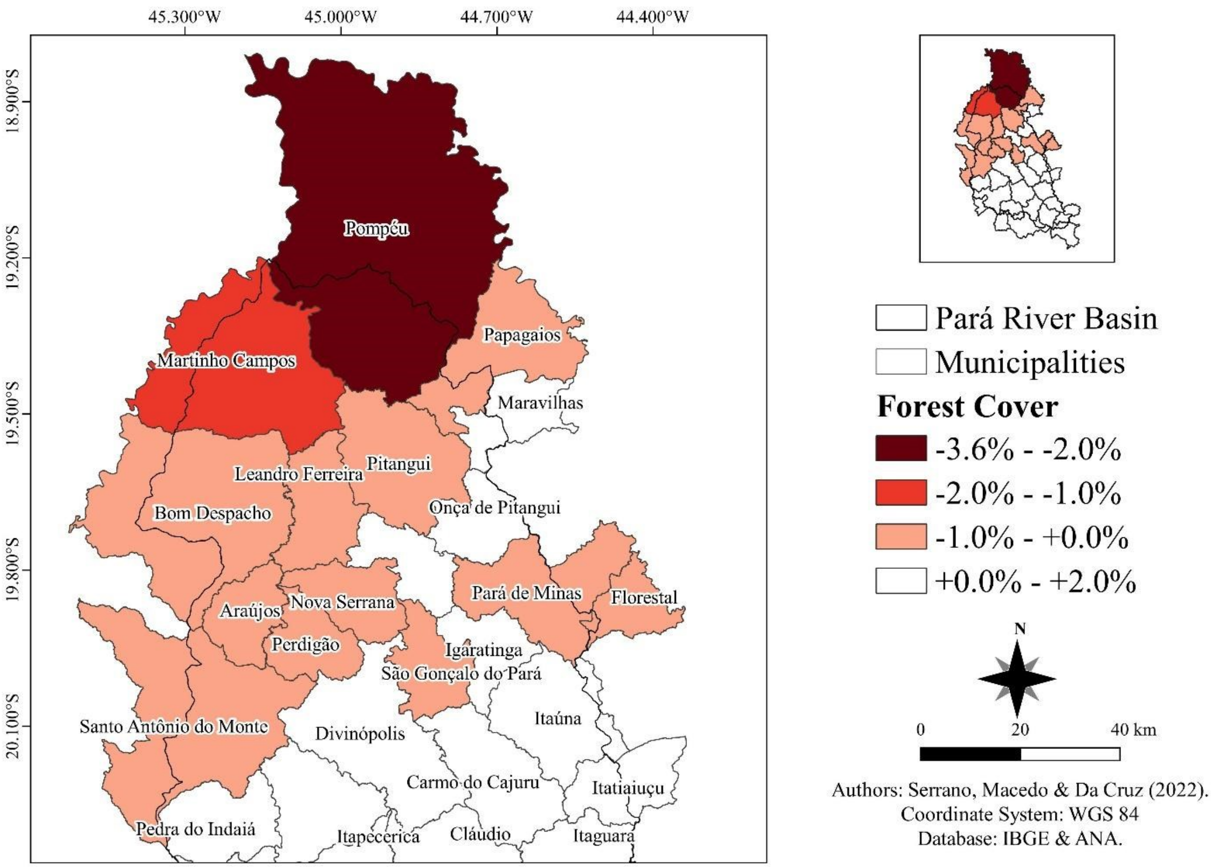

Figure 3: Changes in forest cover (%) observed in each municipality that makes up the Pará River basin, for the period between 1990 and 2020.

It is worth mentioning that, in its Master Plan, it is stated that 4 of the 10 Pará River sub-basins are not suitable for silviculture: the Peixe River, Picão River, Lower Pará River and Lambari River sub-basins, which, in turn, cover the aforementioned municipalities. Furthermore, the Peixe River sub-basin, followed by the Lower Pará River and Picão River sub-basins, have the lowest number of springs in the entire basin, which reveals a certain disregard for the preservation of areas hydrologically sensitives.

In the opposite direction, positive values were observed in the region near to the upstream portion of the basin, where areas of natural forest were regenerated. In fact, forests located in higher regions of a watershed play an important role in its water supply, influencing the quantity, form and quality of water that will be transported to the rest of the watershed (TAMBOSI et al, 2015).

The numbers obtained from the landscape metrics, shown in Figure 4, indicate that such losses in forest area also affect the continuity of these habitats.

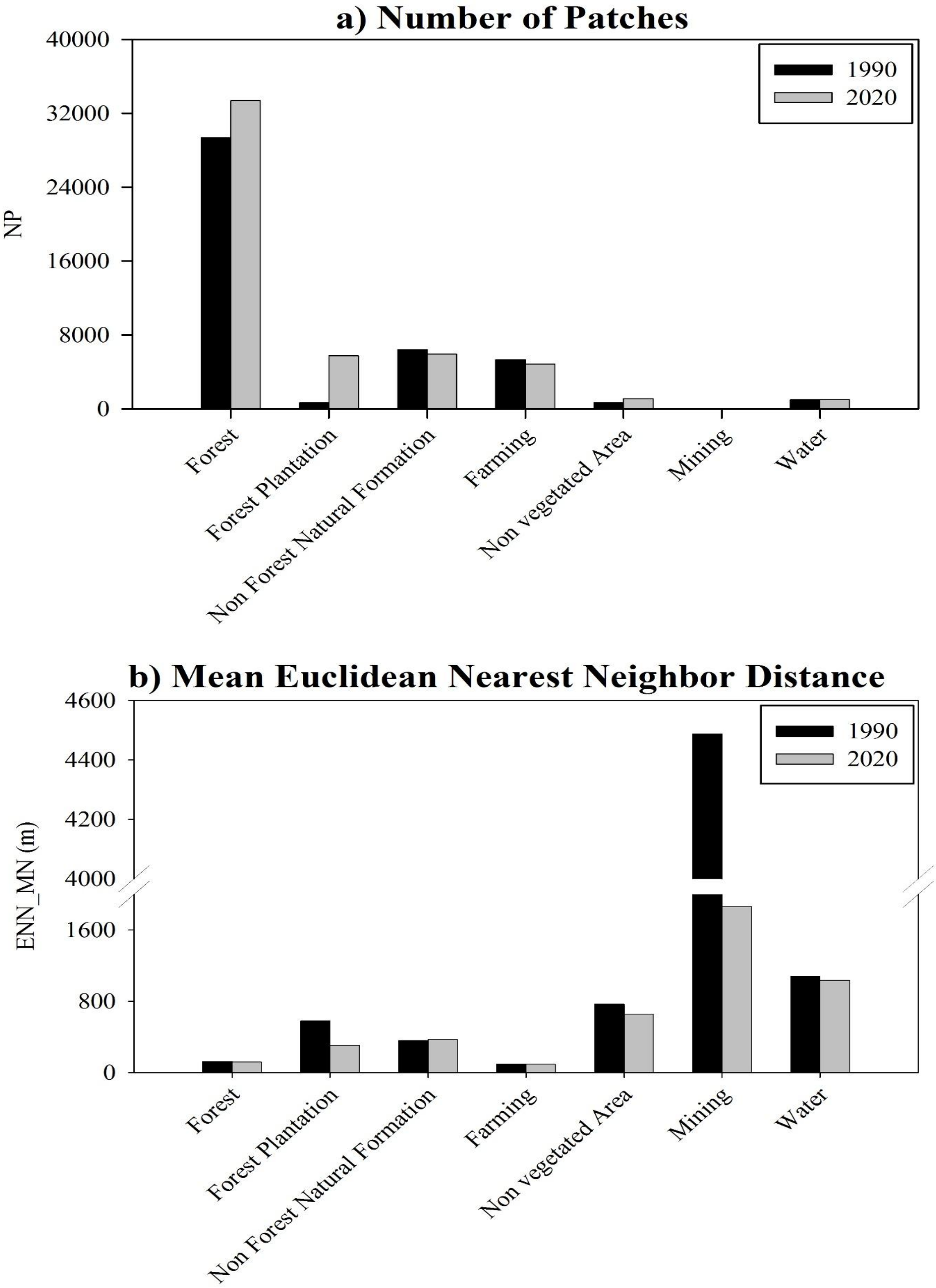

Figure 4: Metrics for describing the landscape of the Pará River basin, for the period between 1990 and 2020: a) Number of Patches per class; b) Mean Euclidean Nearest Neighbor Distance of each class (m). Chart prepared by the authors.

For the year 2020, about 3300 new forest fragments were observed in the landscape (Figure 4a), giving a growth of more than 100% in relation to 1990. This result points to a subdivision pattern of natural areas, which can result in great damage to the fauna and flora of the region (DOS SANTOS et al., 2016; GRAÇA; SOMAVILLA, 2019; LIU et al., 2019).

Another class that also showed an increase for this metric was forestry, with more than 5000 new patches for 2020, a number 9 times greater than the one observed in 1990. These results corroborate to the period of growth of forest production in the state of Minas Gerais, which in recent years has shown a significant expansion of the sector, generating great financial returns for the region (RIBEIRO et al., 2018; TEIXEIRA; RODRIGUES, 2021).

The metric of mean distance between patches (ENN_MN) of each class in the landscape can determine how connected these areas are to each other (MCGARIGAL; MARKS, 1995). Thus, for the Pará River Basin, the classes that showed the most significant decreases for this parameter were: Mining (-2625.65 m), Forest Plantation (-274.79 m) and Non Vegetated Area (-108.98 m) (Figure 4b).

This result indicates that these classes are becoming closer in the landscape, mainly due to the increase in extension already reported, in addition to being associated with economic and urban expansion resulting from the growth of forestry and steel production in the state (TEIXEIRA; RODRIGUES, 2018).

Observing the land use and land cover classes from a punctual perspective, it is possible to identify that the greatest changes in the landscape of the Pará River Basin during the analyzed years were in Forest and Farming classes, which had large fluctuations in losses and gains in area (Figure 5a). However, considering the net values of changes (Figure 5b), it is noted that the Farming class obtained a positive area balance, but inexpressive compared to the other classes.

The gains in natural forest, on the other hand, did not compensate for the losses and their balance was negative at the end of the evaluated period, as indicated in the previous results. Therefore, it is important to assess the main classes that contributed to the advance of forest fragmentation in the basin.

Figure 5: Changes observed in land use and cover classes in the Pará River basin, for the period between 1990 and 2020: a) Losses and Gains (ha); b) Net Changes (ha). Chart prepared by the authors.

In this sense, Figure 6 shows the spatial and categorical results about forest losses in the Pará River Basin.

Forest production was responsible for the reduction of approximately 12,500 ha of natural forest, with a higher incidence in the downstream portion of the basin, where the highest LP deficits were reported for this class. On the other hand, the growth of agricultural areas generated a deficit of more than 36,500 ha of forest, which is the class that most negatively affected the forest cover of the Pará River basin, mainly because its occurrence is wider within the territory, including the central-south region, where this loss was compensated.

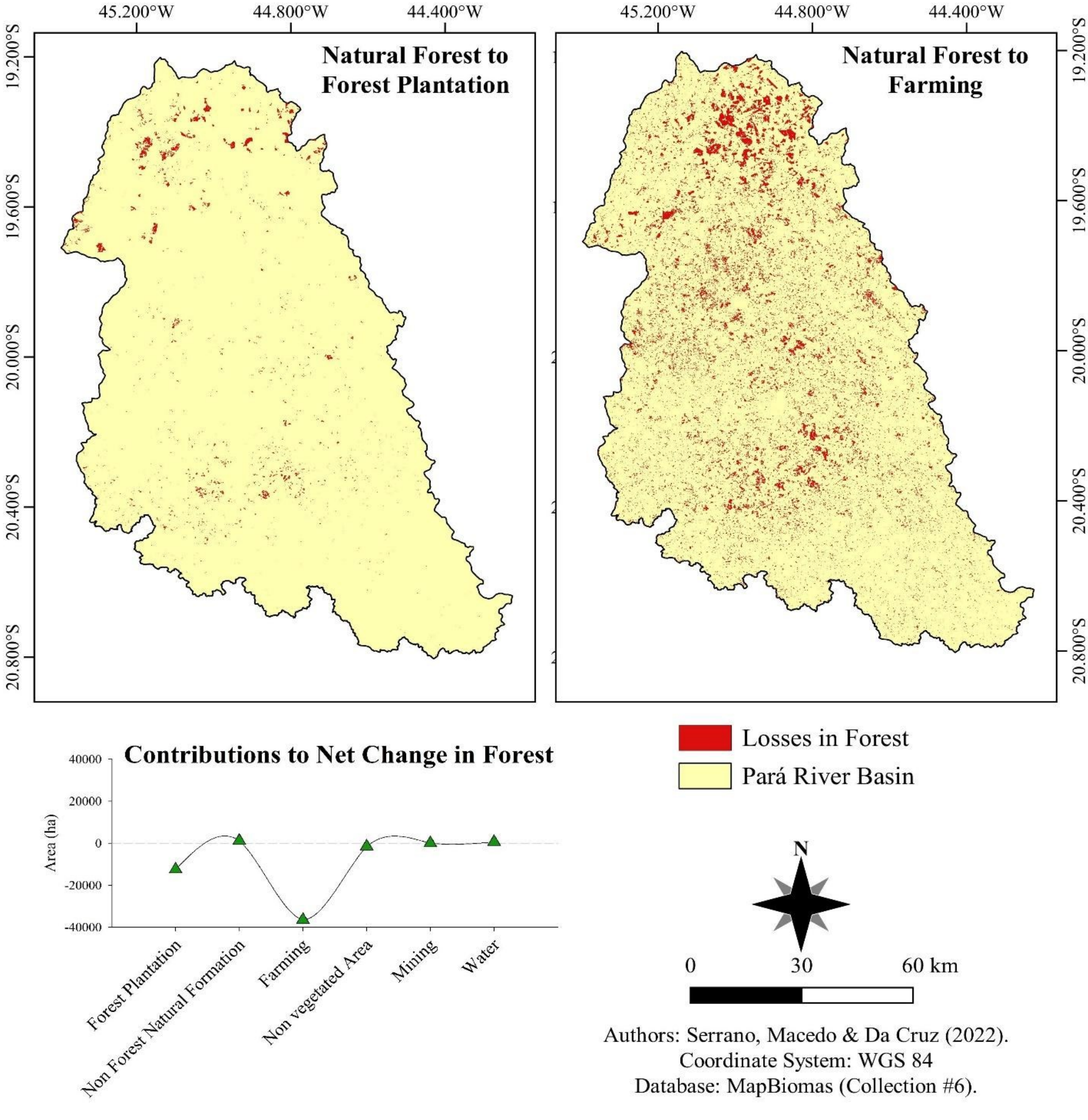

Figure 6: Contributions in area (ha) of land use and land cover classes for changes in the Natural Forest class of the Pará River basin, for the period between 1990 and 2020.

The result obtained in this study demonstrates the advance of agricultural cultivation, combined with the fragmentation and exploitation of the native vegetation remaining in the Pará River Basin territory, without concern for the environment.

This imbalance between the exploration and the preservation, or recovery of degraded areas, can also be related to an inefficient management of the Public Power – either in the environmental licensing, without observing the impacts and define the mitigating/compensatory measures, or due to illegal interventions that are neglected by the absence of the State in monitoring and controlling the territory of the area under study.

The obligations for those who explore the native vegetation of the Brazilian territory are related to forest replacement obligations and environmental compensation, when applied.

Environmental compensation, according to Gouveia et. al (2020), is one of the main instruments to guarantee the conservation and preservation of the natural environment and should be observed by all those who explore special areas or vegetation for the implementation of their economic activity.

Forest replacement is an obligation that all individuals or legal entities are subject to when exploring native vegetation in Brazilian territory, with the aim of preserving native species and supplying the demand for forest raw materials, maintaining stock for the present and future generations (SERRANO, 2019).

In 1965, the obligation of forest replacement was instituted, which took place with the first Brazilian Forest Code and is part of the current Forest Code in force, Law no. 12,651, of 2012 (BRAZIL, 2012). This norm determines that "Individuals or legal entities that use forest raw material originating from the suppression of native vegetation, or that hold authorization for the suppression of native vegetation, are obliged to restore forests".

As found in this research, the alteration of the landscape with the alternative use of the soil for the implementation of silviculture and agriculture activities took place in 49,000ha, however, there was no forest replacement in the same proportion, with the recovery of degraded areas, for example.

From the images obtained from the MapBiomas Project, the landscape of the year 1990, compared to the images of 2020, also registers an advance of interventions in Permanent Preservation Areas (APPS), notably in the marginal strips of watercourses, which deserves studies to quantify the losses in these special areas and whether they come from illegal interventions or authorized by the Government.

APPs are areas covered or not by native vegetation and thus legally recognized, with the environmental function of preserving water resources, biodiversity, landscape, geological stability; protect the soil; and, facilitate the migration of fauna and flora, ensuring the well-being of human populations (BRASIL, 2012).

Legal Reserves (RLs), in turn, are delimited by the government and must be conserved with the aim of ensuring the sustainable economic use of the natural resources of the rural property, contributing to the conservation and rehabilitation of ecological processes and promoting the conservation of biodiversity. In the area under study, the RLs must comply with a minimum of 20% of the rural property (BRASIL, 2012).

APPs and RLs are specially protected spaces and, in principle, should not undergo interventions for alternative land use, as they are areas that must be preserved and conserved, respectively.

A recent survey carried out in the city of São Carlos, in the São Paulo State, demonstrates that much of the loss of native vegetation in that municipality is related to illegal interventions, as recorded by Nunes de Sousa and Maran De Oliveira (2021):

> Most damage to flora was related to “suppression or damage to native vegetation”, with 34% of occurrences, followed by “damage to Permanent Preservation Areas – APPs” (32%), “suppression or damage to vegetation” (17%) and damages referring to the “Legal Reserve - RL” (12%).
> Similarly, Cintra et al. (2006), when consulting 385 inquiries from the State Public Ministry (from 1991 to 2000), to assess the environmental damage that occurred in São Carlos/SP, identified deforestation as the predominant damage, with infractions referring to the suppression and/or impediment to the vegetation regeneration, as well as damage to APPs, APAs and RLs.

In addition to the possible illegal interventions in permanent preservation areas and legal reserves within the territory of the Pará River Basin, the obligation of forest replacement by suppressed native vegetation has not been fulfilled, generating a large environmental liability in the territory.

Another finding verified in this research is the implementation of activity in areas that do not have the ability to do so, which is the case of the implementation of forestry activity in the municipalities of Pompéu, Martinho and Pitangui, which are located in the sub-basins of the Peixe River, of Picão River, Lower Pará River and Lambari River.

Soil studies in the region were carried out by Embrapa (2004) and it was found that the soil is not suitable for silviculture. And this is not the only problem, because the sub-basins of Peixe River, of Picão River, Lower Pará River and Lambari River have the lowest number of springs in the entire basin, demonstrating that the study area has been explored without the concern of forest replacement, with the aggravating factor that the soil has been used for the cultivation of eucalyptus despite not being suitable for that.

In addition to the implementation of activities that are not contributing to the conservation of the soil and the environment, it is very likely that the alteration of the landscape in the Pará River Basin may also have been due to illegal interventions, which may explain the alternative use of the soil without the fulfillment of forest replacement, but it would be a topic for another research.

From all that was seen and analyzed in this study, it is important to note that the territory of the Pará River Basin has been economically exploited without observing the minimum criteria for preservation and conservation of the environment, failing to comply with the obligation of forest replacement and using the soil for the development of activities in which he is not adept.

The disregard for the environment by those who use natural resources for economic exploitation is unacceptable and it should also be considered that the Public Power has not been acting to inhibit actions, such as those addressed in this study.

Changing the natural landscape without worrying about comply with the forest replacement and implementing an activity that does not suit the soil's capacity, is to disregard the normative commands for protecting the environment and despise everyone's right to an ecologically balanced environment.

4 CONCLUSIONS

By analyzing the use and coverage of the Pará River Basin territory, it was shown that after the enactment of the Federal Constitution of 1988 (BRASIL, 1988), the study area underwent changes aimed at increasing economic and social development, without concern with environmental issues, demonstrating the symbolic value of protective commands.

It can also be said that the normative commands provided in the Agricultural Policy, related to the environment and approved by the Federal Constitution of 1988 (BRASIL, 1988), are also symbolic commands. For despite the aforementioned norm recognizing that watersheds are units planning for the use, conservation and recovery of natural resources, it was shown that they are not considered from this perspective for the installation of agricultural enterprises; and that the use of vegetation cover is not proportional to the conservation and recovery of areas essential to the maintenance of environmental balance.

It is still possible determinate that the management model adopted in Minas Gerais, especially in the study region of this research, has not been guaranteeing an ecologically balanced environment, since the territory has not been observed for the analysis of environmental licenses requests, allowing ventures, such as forestry, to be installed in areas that are unsuitable for doing so.

Thus, it is possible to conclude that, despite the evolution of Environmental Constitutional Law and geotechnologies, this hasn't had a positive impact on better management of natural resources.

Finally, it is worth mentioning that the use of products available for free and accessible to the most diverse users, such as free satellite images (Landsat and others) and open geoprocessing programs (such as QGIS), has provided great democratization of information, been applied, including, in the field of legal reports and expertise. Furthermore, the improvement of the spatial resolution of these products, which are being continuously made available, has collaborated more and more in this sense, providing results with great precision. Still, it is important to have professionals with good technical skills and compatible with the area of geotechnologies (Engineers Cartographers and Surveyors, Geographers, for example), to improve the GIS analysis and produce quality researches.

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