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LAND USE AND LAND COVER DYNAMICS AND POTENTIAL CONSEQUENCES ON THE ECOSYSTEM SERVICES IN MARAPANIM RIVER WATERSHED, PARÁ, BRAZIL

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Resumo

Dinâmica do uso e cobertura do solo e possíveis consequências na prestação de serviços ecossistêmicos na bacia do rio Marapanim, Pará, Brasil. Alterações na dinâmica do uso e cobertura do solo podem mudar significativamente os padrões e processos dos ecossistemas, resultando em mudanças na oferta de seus serviços ecossistêmicos. Na Amazônia, tem-se entre as áreas mais afetadas por essas alterações estão as bacias hidrográficas florestadas, que carregam consigo uma enorme variabilidade de serviços ecossistêmicos que auxiliam no bem-estar humano e animal. Diante do exposto, o presente estudo tem por objetivo analisar a dinâmica de desmatamento e alterações das classes de uso e cobertura do solo na bacia do Rio Marapanim, no nordeste paraense, de forma a identificar possíveis consequências nas prestações de serviços ecossistêmicos. Como metodologia, propõe-se mapear e quantificar o desmatamento e as alterações no uso do solo utilizando dados dos projetos PRODES e MapBiomas, identificando seus impactos através das estimativas de perda de serviços ecossistêmicos hídricos e analisando consequências desse processo. Os resultados revelaram que o desmatamento acumulado na bacia do Rio Marapanim entre os anos de 1988 e 2019 foi de 1.614,72 km², cerca de 74,84% da área da bacia, alterando boa parte da formação florestal para pastagem e áreas urbanas. Tal situação trouxe efeitos sobre os serviços ecossistêmicos hídricos e derivados, principalmente nos serviços do tipo de regulação, afetando a umidade da floresta e do solo, a evapotranspiração, o sequestro de carbono e o aumento da temperatura. Por fim, constatou-se que a ocupação humana próximo a áreas de cabeceira tem contribuído para a poluição dos rios da bacia, inviabilizando o uso destes para o consumo humano.
Palavras-chave: Balanço Hídrico. Desmatamento. Formação Florestal. Pastagem. Poluição.

Abstract

Changes in the dynamics of land use and land cover may significantly alter ecosystem models and processes, leading to changes in the delivery of their ecosystem services. In the Amazon, among the areas most affected by these changes are the forested watersheds, which involve a huge variety of ecosystem services that support human and animal well-being. Given the above, this study aims to analyse the dynamics of deforestation and changes in land use and land cover classes in the Marapanim River watershed, located in the northeast of Pará, to identify the possible consequences in the provision of ecosystem services. The methodology used in this study consists of quantifying and mapping deforestation and land use change using PRODES and MapBiomas data, identifying their impacts through estimates of loss of water-related ecosystem services and analysing the consequences of this process. The results revealed that the accumulated deforestation in the Marapanim River watershed between the years 1988 and 2019 was 1,614.72 km², about 74.84% of its area, resulting from forest conversion for pasture and urban areas in the most cases. In addition, it is concluded that this situation has had effects on water-related ecosystem services, especially regards to regulating services, affecting forest and soil moisture, evapotranspiration, carbon sequestration and temperature increase. Finally, it was found that human occupation close to head watershed areas has contributed to the pollution of its rivers, by preventing their use for human consumption.
Keywords: Water Balance. Deforestation. Forestry Formation. Pasture. Pollution.

INTRODUCTION

Changes in land use and land cover have significantly transformed ecosystem processes at different stages, leading to changes in the provision of ecosystem services (ES). As a result, the estimation of responses of various ES to land use changes to establish a sustainable balance between the various uses of different ES has emerged as a new field of research (WU *et al*., 2018). In the Brazilian Amazon, this scenario is represented by the conversion of the forest to other uses to meet the needs of economic activities such as agriculture, livestock, and slash-and-burn agriculture, with the impact of significant changes in the region's climate. More worrying is when the deforestation process occurs over forest watershed which support a large variety of ES including purification facilities and preservation of water in nature, maintenance of habitat for aquatic species and terrestrial, landscape protection, flood control, human and animal well-being, among others (AGUILAR; OBENG; CAI, 2018; USFS, 2021).

This context has been observed in the northeast of Pará state, one of the areas in which the occupation of the Brazilian Amazon began, bringing with it major economic projects for the state, with an occupation process intensified at the end of the 20th century with the construction of the Belém-Bragança Railroad. Such development pathway consolidated agriculture and extensive livestock farming as one of the variables in the region's economic matrix, leading to major changes in the local landscape and watersheds, creating serious risks to the maintenance of biodiversity and the livelihoods of local populations (VALE; BORDALO; FONSECA, 2015).

Policies to control illegal forest activities have been implemented in Brazilian Amazon and monitoring programs that use remote sensing data have played an important role such as the Brazilian Program for Monitoring Deforestation in the Amazon (PRODES) which has been under operation since 1988. The contribution of the MapBiomas project, created in 2015 to identify and quantify land use and land cover in the country's different biomes, has been also relevant (INPE, 2021; MAPBIOMAS, 2021). Through their methodologies, it is possible to observe the dynamics of deforestation and its consequences on land use and land cover in a given zone of the Amazon biome.

Based on the foregoing, this study aims to analyse the dynamics of deforestation and changes in land use and land cover classes in the Marapanim River watershed (MRW), located in the northeast of Pará state, to identify the possible consequences on the provision of ecosystem services. This watershed has similar characteristics to others located in the Brazilian Amazon and which has suffered from human pressures arising from the expansion of various economic activities in the region.

Among the specific objectives are (a) to use PRODES and MapBiomas data to study the quantification and spatialization of forest suppression and land use classes, through the development of thematic maps specific to the study; (b) to identify the possible limitations presented by them in the preparation of studies involving deforestation and the dynamics of land use and cover; and (c) to assess, using scientific literature, the possible effects of land use and land cover dynamics on ecosystem services in forested watersheds in general and the watershed under consideration (MRW).

MATERIAL AND METHODS

Study area

MRW is situated in the northeastern part of the state of Pará and comprises an area of 2,157.52 km², with its territory distributed in 11 municipalities, namely: Castanhal, Curuçá, Terra Alta, São Francisco, Igarapé-Açu, Maracanã, Magalhães Barata, Santo Antônio do Tauá, São Caetano, Vigia de Nazaré and Marapanim. Figure 1 depicts the delimitation of this watershed.

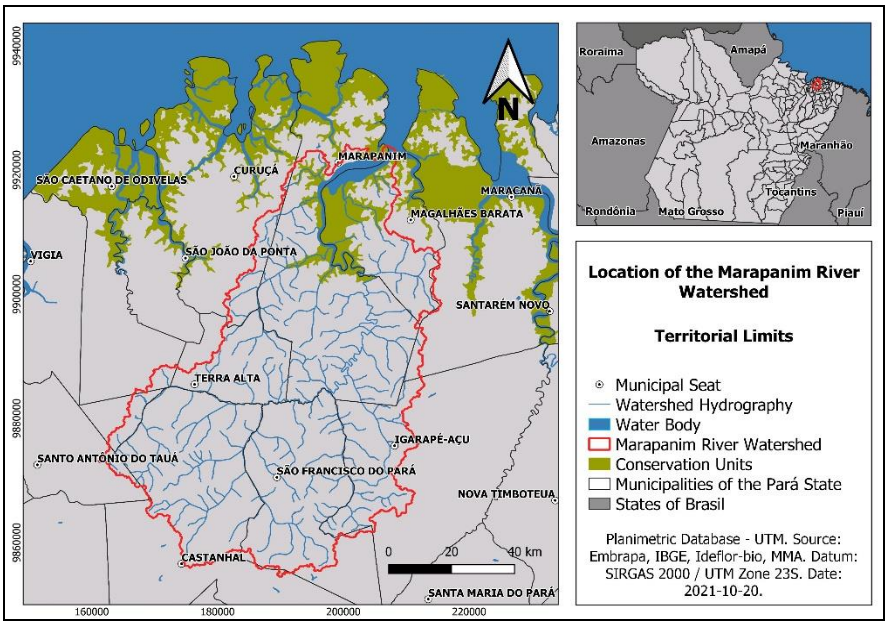

Figure 1. Location map of the Marapanim river watershed.
Figura 1. Mapa de localização da bacia hidrográfica do rio Marapanim.

Annual rainfall in the region is greater than 2000 mm, with the season of greatest rainfall covering the months of December to May, with March having the highest rainfall; while the period with less rainfall covers the other months of the year, with greater drought in September and October. The watershed original vegetation is of the dense ombrophilous lowland forest type, with a predominance of well-drained soils and of low natural fertility, mostly of the Dystrophic Yellow Latosol type (ALBUQUERQUE *et al*., 2010; ANDRADE *et al*., 2020).

There are 270 channels in the watershed, with a total drainage length of 905.06 km, with 89.56 km of the main channel alone, which extends from the municipality of São Francisco do Pará to the municipality of Marapanim. In this watershed there are two federal conservation units for sustainable use in which the exploration and direct economic use of natural resources in a planned and regulated manner is allowed: the marine extractive reserves (known as RESEX) of Mestre Lucindo, in the municipality of Marapanim, and Cuinarana, in the municipality of Magalhães Barata (SANTOS *et al*., 2020).

Both reserves are made up of mangrove environments, "restinga" vegetation, dunes, floodplains, flooded fields, rivers, estuaries and river islands, created in 2014 with the purpose of protecting these environments and ensuring the sustainable use of natural resources besides protecting livelihoods and culture of local traditional extractive communities (BRASIL, 2014).

Research characterization and design

This study used a descriptive, quantitative research approach to understand the possible consequences of deforestation driven by other anthropogenic land uses on the supply of ecosystem services in the Marapanin River watershed (MRW). To enable this analysis, PRODES and MapBiomas data were used. The choice of these Brazilian monitoring projects for analysis came from studies that showed the accuracy and reliability of their results produced. According to Parente *et al*. (2021), the accuracy of the PRODES mapping is 93.17% (±0.89%), while Neves *et al*. (2020) indicate an agreement of 92% of the MapBiomas classification, still in its classes 2 and 3, for the Amazon biome.

Using the National Spatial Data Infrastructure platform, two groups of vector files referring to deforestation in the Legal Amazon were downloaded in accordance with the two phases of the PRODES methodology. The first group refers to the shapefile file referring to the accumulated deforestation calculated by PRODES between the years 1988 to 2007, while the second group is related to the vector files of the annual deforestation polygons for the years 2005 to 2019. For each data group, vector data clipping for the study area was performed.

From this, the total deforested area was quantified, enabling the sum resulting from deforestation incremented during the time interval of each PRODES data group. The areas of the deforestation polygons were obtained from the information table of each vector file, where the occurrence of the non-inclusion of duplicate data and the presence of residues in the calculations was verified which, according to Guerra, Mura and Freitas (2010), correspond to errors of omission of deforestation by PRODES. Complementarily, maps of increased deforestation were prepared to visually identify the distribution of deforestation in each of these periods.

The MapBiomas land use and occupation maps were acquired on the project's own digital platform for the Amazon biome, making a subsequent cut for the study area. A multitemporal land use and cover map was carried out, as well as the quantification of the area of each land use class and its percentage in relation to the total area of the watershed, enabling the understanding of the change dynamics (growth or degrowth) of use of the soil of the Marapanim River watershed. The reference years for the MapBiomas land use and land cover maps were: 1990, 2000, 2010 and 2019. In addition, it was decided to elaborate transition matrices through the Semi-Automatic Classification Plugin, a complement to the QGis software 3.16.

After the technical analysis, we moved into the last stage which depicted national and international literature research to discuss how changes in land use and land cover, within a forest watershed, affect the provision of ecosystem services.

RESULTS

Deforestation data from PRODES applied for the study area demonstrate that the deforestation process has been going on for many years as shown in the accumulated deforestation area from 1988 to 2007 period. The total deforested within this period was approximately 1,614.72 km², corresponding to about 74.84% of the study area.

When assessing deforestation that occurred between 2008 and 2019, a reduction of about 29.17 km² in forest cover in the watershed was observed. As such, the total modified area in MRW was 1,643.89 km², or 76.19% of its area.

Figure 2 illustrates the spatial distribution of areas within the basin that have already undergone previous deforestation processes, considering the two data periods obtained from the PRODES project for the region of interest: 1988 to 2007 and 2008 to 2019.

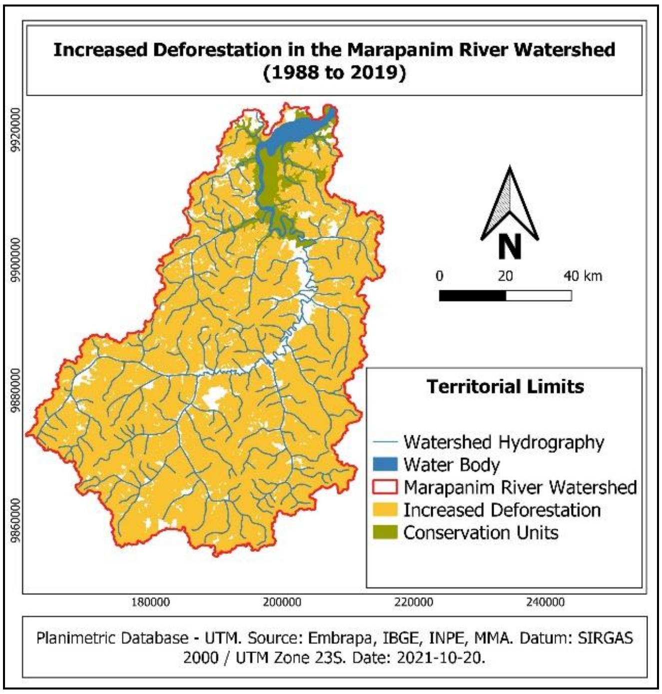

Figure 2. Spatial distribution of accumulated deforestation within the Marapanim River watershed (1988-2019).
Figura 2. Distribuição espacial do desmatamento incrementado no interior da bacia do Rio Marapanim (1988-2019).

The available PRODES data on deforestation for the period 1988 to 2004 lack information on annual deforestation, making it impossible to construct a historical series that would allow to visualize what periods deforestation has reached its peaks, as well as its behaviour. This analysis could only be conducted from 2005 to 2019, as shown in Figure 3, which represents the sum of deforested areas per year in the watershed.

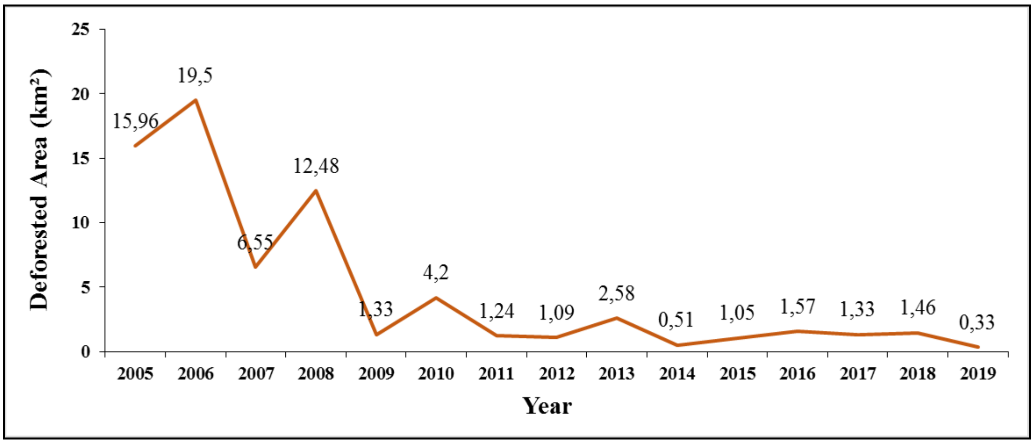

Figure 3. Evolution of deforestation in the Marapanim River watershed from 2005 to 2019.
Figura 3. Evolução do desmatamento na bacia do Rio Marapanim de 2005 para 2019.

The presence of conservation units in the basin is noteworthy because the history of landscape transformations is different. Mestre Lucindo RESEX within the study area presented, until 2013, approximately 3.64 km² of the cumulative deforested area. Between 2014 and 2015, that is, after its creation in 2014, only 0.25 km² of deforestation were recorded. For the Cuinarana RESEX, an amount of approximately 9.36 km² of the cumulative deforested areas in the watershed was recorded during the analysis period (1988-2019), with no deforestation after 2010.

The impact of deforestation on MRW can be observed in the dynamics of land use and land cover. The excerpts from the MapBiomas project identified ten types of classes among the 1990, 2000, 2010 and 2019 maps, with the following classes: forest formation; mangrove; planted forest (identified exclusively on the 2019 map); field training; pasture; urban infrastructure; other non-vegetated areas; apicum; river, lake and ocean; and other temporary crops. The multitemporal land use and cover map (Figure 4) illustrates the spatial distribution of each of these classes for each reference year, while Table 1 contains the quantification of their areas and percentage in relation to the size of the basin. For a better reading of the tables, the land use and cover classes were rewritten in acronyms, as follows: FF = forest formation; M = mangrove; FP = forest plantation; GF = grassland formation; P = pasture; UI = urban infrastructure; ONVA = other non-vegetated areas; SF = salt flat; RLO = river, lake and ocean, and; OTC = other temporary crops.

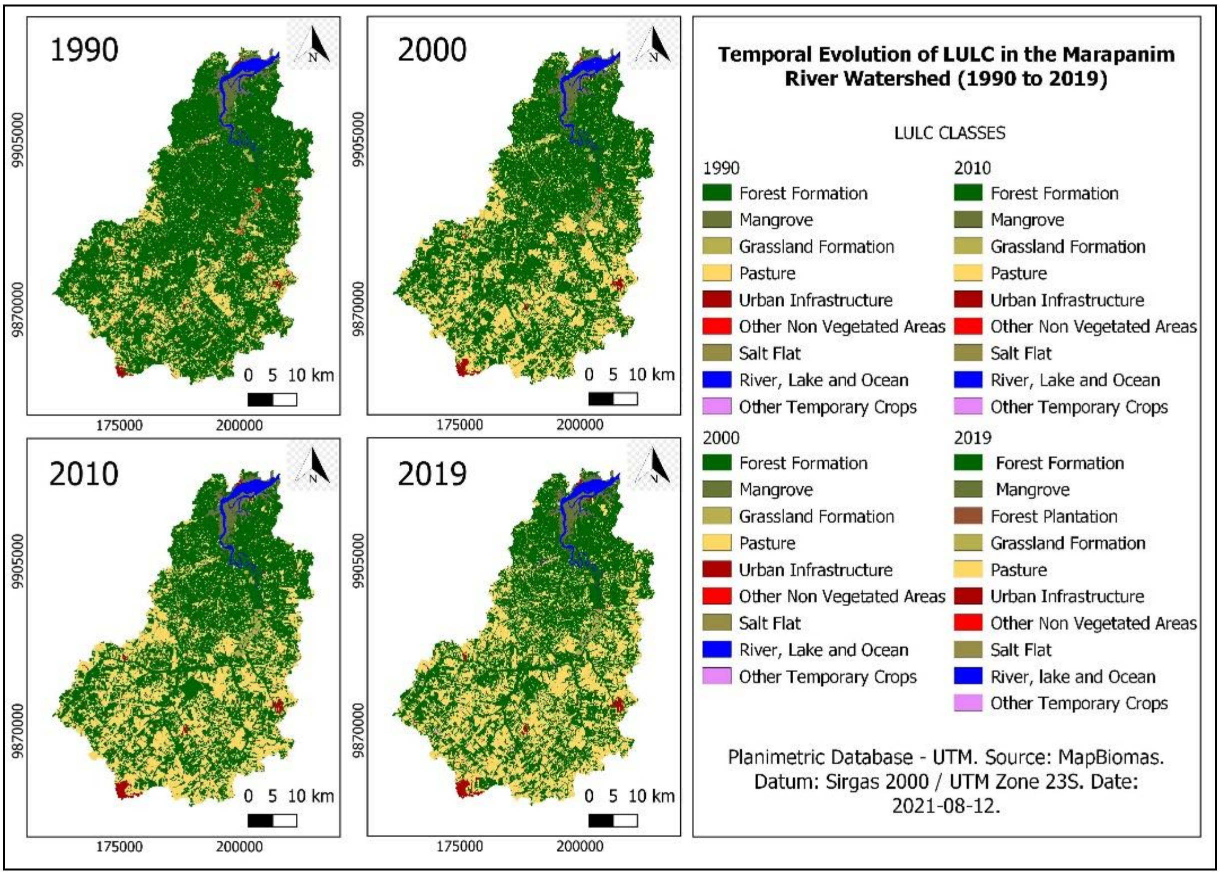

Figure 4. The evolution of LULC classes in BHRM (1990-2019).
Figura 4. Evolução das classes de UCS na BHRM (1990-2019).

Table 1. The **e**volution of land use and land cover classes in the MRW.
Tabela 1. Evolução das classes de uso e cobertura do solo na BHRM.

CLASS	1990		2000		2010		2019	
	AREA (km²)	**(%)**	**AREA (km²)**	**(%)**	**AREA (km²)**	**(%)**	**AREA (km²)**	**(%)**
FF	1627.28	75.43	1370.78	63.54	1245.94	57.75	1181.97	54.78
M	51.87	2.40	52.32	2.42	50.88	2.35	49.58	2.29
FP	-	-	-	-	-	-	0.13	0.006
GF	16.29	0.75	19.24	0.89	20.56	0.95	17.59	0.81
P	406.51	18.83	662.13	30.68	783.6	36.31	844.61	39.15
UI	7.48	0.34	13.01	0.60	17.11	0.79	19.91	0.92
ONVA	9.88	0.45	1.33	0.06	0.22	0.01	0.22	0.01
SF	0.03	0.001	0.004	0.0002	0.006	0.0002	0.008	0.0003
RLO	37.54	1.73	37.99	1.75	38.49	1.78	40.68	1.88
OTC	0.6	0.0279	0.69	0.03	0.69	0.03	2.79	0.12

Overall, MRW's forest cover decreased by around 445.31 km² between 1990 and 2019. On the other hand, the growth of pasture areas within the territory can be noted as the main driver of forest degradation, with an incorporation of 438.10 km², corresponding to 98.41% of the forest decrease

Another class of land use and land cover that showed a notable growth, however not as significant in relation to the size of the watershed, was the urban infrastructure class, ranging from 7.48 km² in 1990 to 19.91 km² in 2019, following the population growth of the municipalities that make up the MRW.

The transition matrices are represented in tables 2 to 4, illustrating how land use and land cover classes transacted with each other during the chosen year intervals. The rows represent the classes analysed in the first reference year and the columns the last year. The intersections between them show how much area in square kilometres a previous class lost to another class in the later mapping.

Table 2. Transition matrix of areas of LULC classes in BHRM, between 1990 and 2000, in km^2.
Tabela 2. Matriz de transição das áreas das classes de UCS na BHRM, entre 1990 e 2000, em km^2.

	FF	M	GF	P	UI	ONVA	SF	RLO	OTC	1990
FF	1246.18	2.49	3.74	370.72	2.5	0.11	0	0.93	0.57	1627.28
M	1.75	49.47	0.0008	0.006	0	0	0	0.64	0	51.87
GF	1.58	0.005	13.25	0.5	0.02	0.61	0	0.25	0.05	16.29
P	118.66	0.02	0.3	284.3	2.99	0.08	0	0.11	0.02	406.51
UI	0.002	0	0.0008	0.003	7.47	0	0	0	0	7.48
ONVA	1.34	0.005	1.7	6.02	0.005	0.52	0	0.23	0.03	9.88
SF	0.001	0	0.02	0.0008	0.0008	0	0.004	0.004	0	0.03
RLO	0.85	0.31	0.21	0.36	0.001	0	0	35.8	0	37.54
OTC	0.39	0	0	0.2	0	0	0	0	0	0.6
2010	1370.78	52.32	19.24	662.13	13.01	1.33	0.004	37.99	0.69	2157.52

Table 3. Transition matrix of areas of LULC classes in MRW, between 2000 and 2010, in km^2.
Tabela 3. Matriz de transição das áreas das classes de UCS na BHRM, entre 2000 e 2010, em km^2.

	FF	M	GF	P	UI	ONVA	SF	RLO	OTC	2000
FF	1087.26	1.18	1.93	278.17	0.78	0.07	0	1.06	0.28	1370.78
M	2.25	49.51	0.001	0.0008	0.0008	0	0	0.55	0	52.32
GF	1.8	0.0008	16.64	0.48	0.01	0.01	0.006	0.14	0.12	19.24
P	153.65	0.006	0.49	504.11	3.3	0.07	0	0.2	0.28	662.13
UI	0.003	0	0.001	0.005	12.99	0	0	0.001	0	13.01
ONVA	0.03	0	1.09	0.14	0	0.05	0	0	0.0008	1.33
SF	0	0	0.004	0	0	0	0	0	0	0.004
RLO	0.86	0.17	0.28	0.13	0.002	0	0	36.52	0.001	37.99
OTC	0.05	0	0.1	0.53	0	0	0	0	0	0.69
2010	1245.94	50.88	20.56	783.6	17.11	0.22	0.006	38.49	0.69	2157.52

Table 4. Transition matrix of areas of LULC classes in MRW, between 2010 and 2019, in km^2.
Tabela 4. Matriz de transição das áreas das classes de UCS na BHRM, entre 2010 e 2019, em km^2.

	FF	M	FP	GF	P	UI	ONVA	SF	RLO	OTC	2010
FF	1015.59	1.44	0.06	1.53	224.07	0.31	0.03	0	1.34	1.53	1245.94
M	2.61	47.86	0	0	0	0	0	0	0.39	0	50.88
GF	3.63	0.001	0	15.35	0.32	0	0.15	0.008	1	0.08	20.56
P	159.41	0.005	0.07	0.43	619.51	2.5	0.008	0	0.48	1.15	783.6
UI	0.01	0	0	0	0.01	17.07	0	0	0	0	17.11
ONVA	0.008	0	0	0.04	0.13	0.007	0.02	0	0	0	0.22
SF	0	0	0	0	0	0	0	0	0.006	0	0.006
RLO	0.59	0.26	0	0.07	0.11	0.003	0.008	0	37.43	0	38.49
OTC	0.09	0	0	0.13	0.44	0.001	0	0	0	0.013	0.69
2019	1181.97	49.58	0.13	17.59	844.61	19.91	0.22	0.008	40.68	2.79	2157.52

From what was analysed through the transition matrices, the dynamics of land use and land cover at MRW works within a system of area gains and losses between the identified classes, occurring as a consequence of anthropic or natural actions. The growth of a class occurs when, within this system of gains and losses, it aggregates to itself more areas from other classes than the area losses registered in the period, the opposite being the representative of the decrease in its area.

Therefore, it was observed that the greatest reduction of forest formation in the study area occurred in the interval between 1990 and 2000. During this period, about 256.50 km² of forest formation was lost. Relating to the pasture area, the forest formation lost 370.72 km² of area, however, 118.66 km² of pastures were converted to the forest formation. Over the same period, the urban infrastructure class saw the highest growth from areas that were previously registered as pastures and forest formation.

The mangrove areas, which correspond to the territories where the extractive RESEX of Mestre Lucindo and Cuinarana are located, also showed a decrease. However, the transition matrices pointed out that most of the mangrove areas considered lost were actually interpreted as forest formation in later years' analyses, as they were not converted, as expected, into other classes such as pasture.

DISCUSSION

With regards to the main drivers of land use and cover changes, MRW is in the same context as the world scenario, that is, replacing tropical forests into areas for agriculture, grazing and urbanisation. Pasture is the main anthropogenic land use in Brazil, which is the second largest producer and exporter of beef in the world. In the Northeast region of Pará, where the MRW is located, the main cause of deforestation lies in traditional activities such as shifting agriculture, intensification of extractive activities and cattle raising, which constitute the source of most of the gross domestic product of the municipalities in the watershed (IGAWA; MACIEL, 2018).

Areas converted to pasture, subsistence agriculture or other farming practices are periodically abandoned, resulting in a process of regeneration and secondary vegetation formation. As a consequence, the forest areas within the watershed is formed by vegetation at different levels of ecological succession, which can be used again for productive activities, through the slash and burn techniques practiced in the region (ANDRADE *et al*., 2019; SANTOS *et al*., 2020).

It can be seen from the spatial distribution of deforestation in the MRW that vegetation cover has already been removed in most of its territory. As framed by Andrade *et al*. (2020), the exception is only applied in some regions around the main rivers and in some areas in its northern portion that still have preserved forest fragments, inferring the importance of Brazilian legislation such as the Forest Code and the establishment of conservation units to preserve such areas. An example of this is the deforestation observed in the territory of conservation units within the MRW.

Previous studies that used PRODES to quantify deforestation in the same study area showed that in 2017, approximately 80% of the watershed has been deforested, highlighting the municipalities of Marapanim, Castanhal, São Francisco do Pará and Igarapé-Açu as being the ones which contributed the most, meaning that they represented approximately 79% of this deforestation (HOMMA *et al*., 2020).

In the graph in Figure 3, a decrease in annual deforestation rates can be seen. Santos *et al*. (2018) explain that this has occurred since 2004, in accordance with the trend of the historical series of PRODES for the Legal Amazon. These reductions were consequence of public policies actions such as the Action Plan for Prevention and Control of Deforestation in the Legal Amazon (PPCDAM) and the implementation of the Real Time Deforestation Detection System (DETER), projects whose main objectives are to help combat deforestation in the Amazon.

It should be noted that in the forest formation class of the MapBiomas data there is no difference between primary and secondary vegetation, disguising the real impact of deforestation on MRW. In the study by Andrade *et al*. (2020), a mapping of land use and land cover was carried out using the Maximum Similarity Algorithm (MaxVer) with Landsat 8 data for the same area, for the year 2017, with an overall accuracy of 0.85. Through this methodology, the authors identified that the secondary vegetation corresponded to 906.92 km² for that year. If this amount remained unchanged until 2019, we could assume that secondary vegetation in MRW would represent approximately 77% of the forest formation class.

The pasture areas in the northeast of Pará are explained by the production model adopted, based on extensive cattle raising, demanding the opening of large areas. Although technological increment, such as genetic improvement, has registered an increase in productivity, rudimentary production practices still predominate, thus requiring large areas for production (COELHO *et al*., 2018).

Except for the municipality of Marapanim, which the administrative centre is located downstream of the MRW, those municipalities developed close to the watershed drainage areas that flow through these urbanized areas. São Francisco do Pará is the only municipality with a more interiorized administrative centre, while the others are located on the border of the headwaters of MRW, resulting in an adverse condition for the watershed (FARIAS; LIMA; SILVA JÚNIOR, 2020).

Within the approach of forested watersheds, MRW works, in general, like any other tropical forest ecosystem, providing important ES. As explained by Brandon (2014), in relation to climate and meteorological patterns (especially precipitation and temperature), the services provided by these ecosystems are: water candy, natural disaster control, maintenance of biodiversity, nutrient cycling and food provision, among others. The same author also emphasizes that tropical deforestation affects the climate, mainly due to the reduction in the passage of moisture from the oceans and rain, making temperatures warmer and storms more intense.

Changes in land use and land cover patterns were recognized as the main factor in water quality degradation. The conversion of forests to pastures and soil compaction have negative effects, such as increased runoff, nutrients and sediments into rivers. This scenario, in turn, contributes to eutrophication, loss of aquatic biodiversity and toxic algae bloom, increase in water temperature and decrease in dissolved oxygen (MELLO *et al*., 2018).

The provision of services offered directly by water resources is also hampered by the various economic activities added to the practices in land use and land cover in the territory, as the quality and quantity of water flowing through a protected forest can be better than flowing water through an unprotected forest due to differences in the way these forests are managed (HANNA; RAUDSEPP-HEARNE; BENNET, 2020).

Deforested areas cause changes such as a greater surface albedo than preserved areas, a drop in moisture storage capacity, an increase in sensible heat and in the emission of greenhouse gases. Furthermore, the removal of forest cover affects total evapotranspiration and increases soil evaporation, making it drier (USFS, 2021). Another concern is the maintenance of biodiversity, since their habitats are degraded along with the forests, contributing to the extinction of species and a reduction in genetic variability.

Within this framework, it can be inferred that the ES supply (mainly supporting and regulating services) has declined in the MRW over the period analysed in this study, since most of these variables (humidity storage, sensitive heat regulation, release of greenhouse gases, total evapotranspiration and soil moisture) are dependent on forest formation. This leads to the need to apply quantitative methods to assess ES in order to more accurately estimate the impact on the supply of these services, besides contributing to the development of public policies that encourage the adoption of more sustainable methods in MRW´s agricultural activities.

It is noteworthy that the degradation of regulating and supporting services also affects the forest resistance and resilience, since the Amazonian primary forests are adapted to abundant water and it is their leafy crowns that keep soil and air humidity in high levels, which makes this ecosystem naturally resistant to fire (COPERTINO *et al*., 2018).

The problem presented by Farias, Lima and Silva Júnior (2020) is configured in the pollution of the analysed headwater springs, classified with water quality ranging from very bad to bad, with the causes presented being urbanization and the developed economic activities. The authors report that the occurrence of sediments in these waters was perceived by the population due to the removal of vegetation cover, the presence of erosive features and the mortality of aquatic life.

Headwater streams are sensitive to land conversion, and despite their small size, their flows make up about 80% of the channel in flow networks and can therefore have large cumulative effects on downstream ecosystems. Such situations directly affect the supply of provision services offered by water bodies, affecting the quality of water supply and food provision (JANKOWSKI *et al*., 2021).

At this point, it is important to note that the growth of pasture areas took place in a south-north direction, being close to the main federal highways that connect the mesoregion of northeast Pará with the rest of the country. In addition, the southern portion of the MRW, where the largest number of pastures is concentrated, also corresponds to the upstream zone of the watershed, raising the possibility of water bodies receiving the aforementioned impacts from the pasture areas and these same impacts being transported to the regions located downstream.

CONCLUSION

- The deforestation in MRW is a historically common practice in the region due to agricultural economic activities carried out.
- Between from 1988 to 2019, the watershed has already suffered an accumulated deforestation of about 76.77 % of its area.

- Since 2005, the annual deforestation rates have been decreasing, and this is due to public environmental management policies that include command and control actions such as monitoring and inspection of illegal deforestation activities, the creation of environmental protection reserves.
- Regarding the dynamics of land use and land cover in the region, the deforestation caused the conversion of forest formation ecosystems first to pasture areas and then to urbanized areas.
- The maps of the MapBiomas Project in the study region do not separate the primary vegetation class from the secondary vegetation class, camouflaging the real impact of economic activities on land use in MRW.
- According to the references obtained to analyse the possible impacts of these environmental pressures on the provision of SE in the basin, the main categories of SE affected are the regulation and provision services.
- Among the services affected are the forest and soil moisture, evapotranspiration, area temperature, carbon sequestration, flood protection, human supply and food provision.

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