DOI: 10.46551/rc24482692202412

Revista Cerrados ISSN: 2448-2692

https://www.periodicos.unimontes.br/index.php/cerrados

Temporal analysis of land use in Guajará, Amazonas, Brazil

Análise temporal do uso da terra em Guajará-Amazonas

Análisis temporal del uso del suelo en Guajará-Amazonas, Brasil

Kelyan Lago dos Anjos
Federal University of Amazonas – UFAM, Manaus, AM, Brazil
kelyanlagoanjos@gmail.com

Luciomar da Silva Almeida Filho
Federal University of Amazonas – UFAM, Manaus, AM, Brazil
luciomar.almeida13@gmail.com

Abstract

Environmental degradation in the Amazon is a recurring theme in environmental management and geography studies, especially when the focus is turned to analyzing agricultural production and its continuous association with deforestation. The purpose of this study is to analyze land use and land cover in the municipality of Guajará, Amazonas between 1985 and 2022, in order to verify the growth dynamics of the area used for anthropogenic purposes using data from the 1995-1996 and 2006 IBGE agricultural censuses and the MAPBIOMAS project. The methodology is based on the theoretical framework and consists of processing and mapping the MAPBIOMAS use classes and statistical processing of the agricultural census data. The result shows a significant increase in the area of the pasture class, in two axes of growth to the southern portion of the municipality, due to its strong economic relationship with the state of Acre.

Keywords: Land use. Land cover. Temporal analysis. Guajará. Amazon rainforest.

Resumo

A degradação ambiental na Amazônia é tema recorrente em estudos de gestão ambiental e geografia, principalmente quando se voltam as lentes para análises a partir da produção agropecuária e a constante associação desta com o desmatamento. Este trabalho tem o objetivo de analisar o uso e a cobertura da terra no município de Guajará, Amazonas entre 1985 e 2022, para verificar a dinâmica de crescimento da área destinada a usos antrópicos a partir de dados dos censos agropecuários de 1995-1996 e 2006 do IBGE e do projeto MAPBIOMAS. A metodologia parte do referencial teórico e consiste no mapeamento das classes de uso do MAPBIOMAS e tratamento estatístico dos dados dos censos agropecuários. O resultado demonstra um aumento significativo

CC BY NC SA

da área da classe de pastagem, em dois eixos de crescimento ao sul do município devido à forte relação econômica com o estado do Acre.

Palavras-chave: Uso do solo. Cobertura da terra. Análise temporal. Guajará. Amazônia.

Resumen

La degradación ambiental en la Amazonia es un tema recurrente en los estudios de gestión ambiental y geografía, especialmente cuando el lente se vuelve hacia los análisis basados en la producción agropecuaria y su constante asociación con la deforestación. El objetivo de este trabajo es analizar el uso y la cobertura del suelo en el municipio de Guajará, Amazonas entre 1985 y 2022, con el fin de verificar la dinámica de crecimiento del área destinada a usos antrópicos utilizando datos de los censos agropecuarios de 1995-1996 y 2006 del IBGE y del proyecto MAPBIOMAS. La metodología se basa en el marco teórico y consiste en el procesamiento y mapeo de las clases de uso del MAPBIOMAS y el procesamiento estadístico de los datos del censo agropecuario. El resultado muestra un aumento significativo de la superficie de la clase pastos, en dos ejes de crecimiento al sur del municipio debido a la fuerte relación económica con el estado de Acre.

Palabras-clave: Uso del suelo. Cubierta terrestre. Análisis temporal. Guajará. Amazonía.

Introduction

The analysis of the landscape structure makes it possible to obtain information that is able to support policies and decision-making processes that are based on information on the different uses that make up the dynamics of society and which leave their own characteristics on the coverage of the Earth's surface (Pimenta, et al., 2018).

Land use is a term that refers to the way in which human beings manage and take advantage of a certain portion of the territory. Land cover can be defined as the distribution of biophysical elements in the geographic space. The study of these variables is crucial in environmental analysis, as it allows the verification of the different pressures and impacts on the natural elements in the landscape (Seabra, et al., 2014).

The pattern of the cover classes is the result of the spatial variation in viability, quality, and suitability related to land productivity. Furthermore, landscapes may vary at the spatial and temporal level, with human activities having impacts on ecosystem services, with subsequent repercussions on socioeconomic development (Hasan, et al., 2020).

The cause and result of the conversion of forests into pastures or agricultural areas is a key factor to be considered in management, particularly in the Amazon region, which is subject to pressures ranging from agricultural expansion to urbanization, resulting in the loss of biodiversity and ecosystem services (Pimenta, 2018).

Currently, the main resource for this type of study is the use of products from remote sensing. The use of geotechnologies represents a tool that has gained prominence y enabling the visualization of large areas in a broader way and by making it possible to understand issues related to environmental changes in space (Rosa, 2005).

Alves (2001) argues that, traditionally, mapping of deforested areas has been carried out using images from the Landsat Program, a tool used mainly due to its temporal scope and applicability. Thus, the purpose of this study is to analyze land use and land cover in the municipality of Guajará, in the state of Amazonas (AM) in the period 1985-2022, with the aim of verifying the dynamics of growth in the area designated for human use and the decrease in the area of forests based on data from the agricultural census carried out by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE) and the MAPBIOMAS project.

The municipality of Guajará is located in the far southwest of Amazonas, close to an area that has been attracting the attention of environmentalists and entrepreneurs in the agricultural sector, which has been referred to as the deforestation arc. Although it is not yet considered a continuously present municipality on the list of those that make up the arc, the advance of livestock farming as the main economic activity of the municipality has already been observed.

The study area is located in a region with its own dynamics and which, according to Becker (2005), requires a reflection on its policies for land use planning, based on what is experienced in the region and from its stakeholders. Guajará is located in an area considered by the author to be a resistance front against the destruction of the forest, as most of the primary green area is still preserved.

The impact of the deforestation arc involves not only deforestation, but also demographic, economic and social aspects (Miragaya, 2013). Based on a diagnosis of the situation in the municipality, it is crucial to reconcile the interests involved and mitigate the environmental impacts and, above all, the socioeconomic impacts resulting from the expansion of agricultural and pastoral activities. Thus, when necessary

preventive measures are not taken, compensatory measures should be applied as a minimum.

In the 1970s, mapping of deforested areas already made it possible to detect the configuration of the regions of most intense occupation in the Amazon region. An estimate made in the 1990s showed a concentration of higher rates in municipalities close to the road network in the eastern, southern and southwestern portions of the Amazon. The development axes that offer easy access to the country's South and Center-West region concentrate most of the deforestation (Alves, 2001).

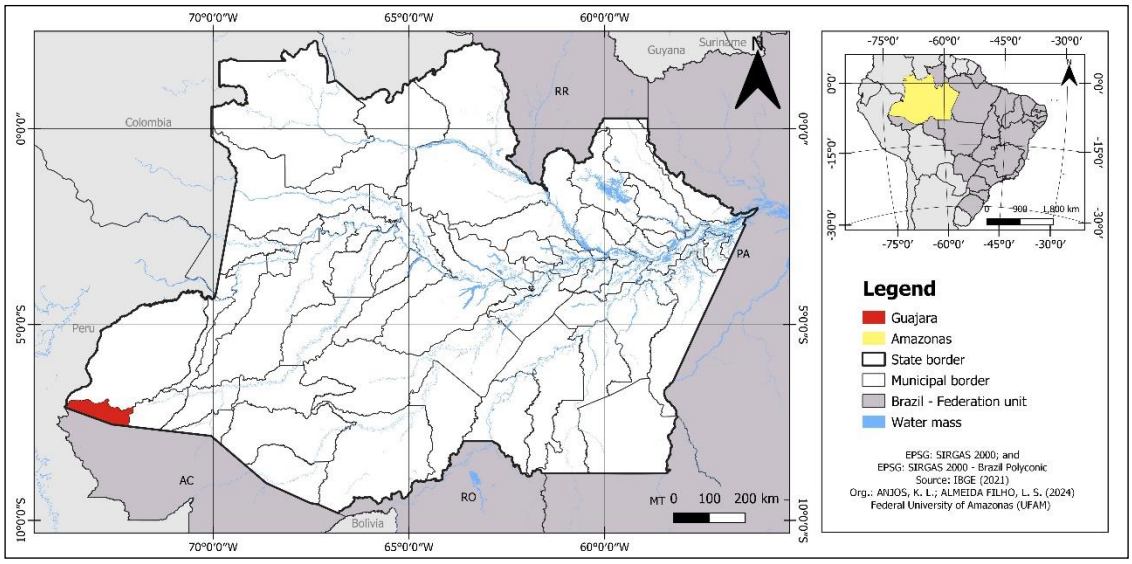
Studies that conduct a land cover analysis include those by Souza, et al., (2017); Pimenta, et al. (2018); Ferreira, et al. (2022); Paula, et al. (2022); Azevedo and Matis (2023); and Vasconcelos, et al. (2024), whose main tool uses land cover data from the MAPBIOMAS project in order to understand the dynamics of occupation and deforestation in municipalities in Brazil and allows a comparison with the present study with other areas analyzed in the Amazon, contributing to the understanding and quantification of the advance of polygons of human intervention over the forest.

The data from the MAPBIOMAS project offer good coverage of land use and land cover mapping for the entire Brazilian territory and, by standardizing the spatial scale, enables a comparison with other regions or areas in the same state. The project's work, despite being conservative for the biome, as noted by Maurano and Escada (2019), allows for a comprehensive analysis, as the algorithm details a greater number of classes on a time scale of almost 40 years.

Study area

The municipality of Guajará is located in the far southwest of the state of Amazonas (Figure **1**), in the intermediate region of Tefé, the immediate region of Eirunepé, and the rural region of the Sub-Regional Center of Cruzeiro do Sul, occupying an area of 7,583.70 square kilometers. According to the latest IBGE demographic census (2022), the municipality's population is 13,815 inhabitants, and as of 2010, the urban population accounted for 53.15% of the inhabitants, while 46.86% lived in rural areas (IBGE, 2010).

Figure 1 – Location of the municipality of Guajará, AM



Source: IBGE, 2021.

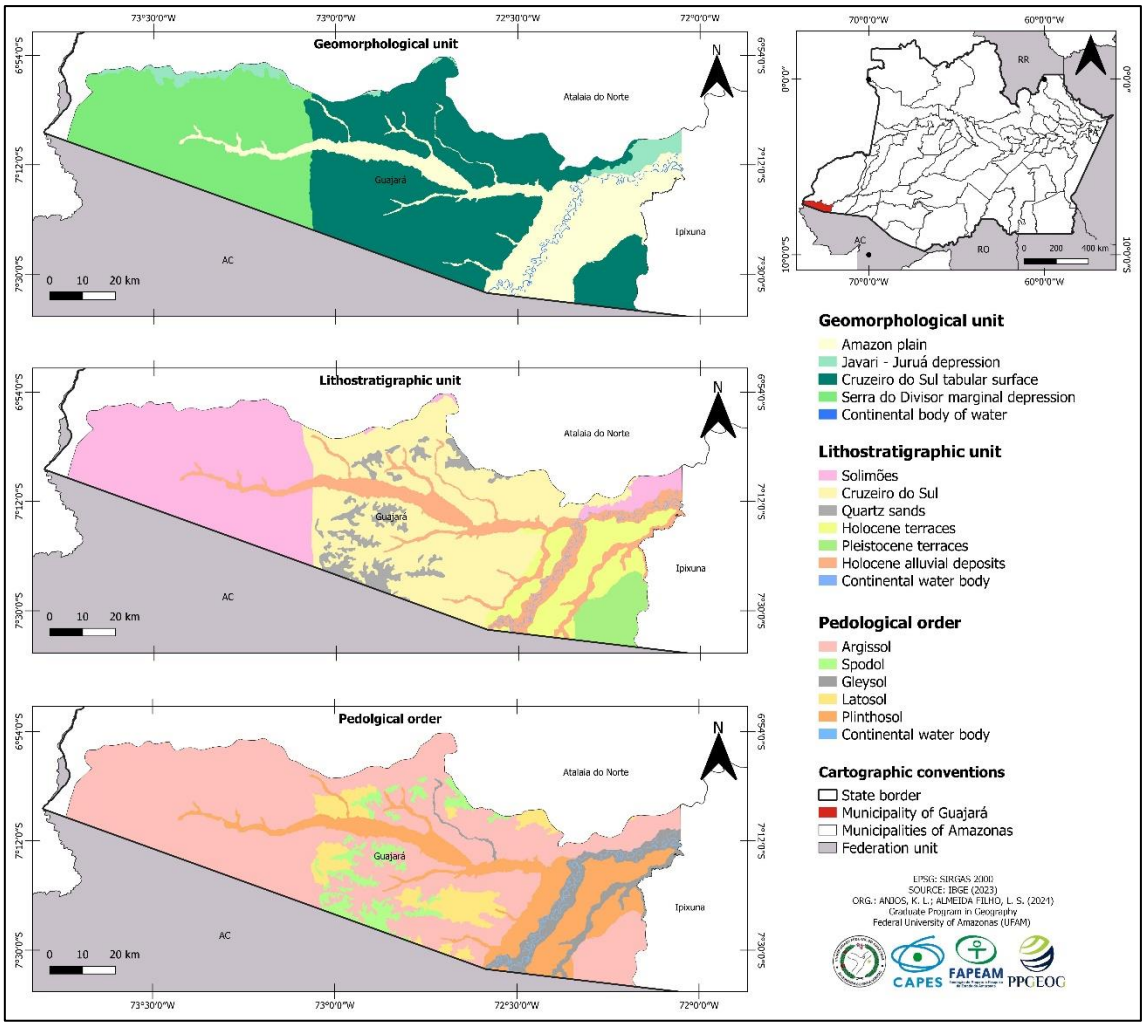
The main rivers in the region are Juruá, whose spring located on the left bank, and the Ipixuna River, which cuts through the municipality in a west-east direction. The area of the municipality is based on the Solimões formation and the Cruzeiro do Sul formation, and it has a geology composed of Holocene alluvium, Holocene and Pleistocene terraces, and areas of quartz sands. Regarding the soils in the region, it includes dystrophic yellow latosol, dystrophic red-yellow argisol, and alytic in the highest areas of the municipality. Further, hydromorphic ferrihydric spodosol, eutrophic haplic gleysol on the banks of the Juruá River, and dystrophic argiluvic plinthosol are found mainly on the banks of the Ipixuna River (IBGE, 2010).

The vegetation is mainly characterized by being mostly of the open alluvial and lowland ombrophilous type. There are also dense alluvial ombrophilous forests, lowland submontane and forested and grassy-woody campinarana vegetation, and finally, secondary vegetation and vegetation resulting from agricultural activities (IBGE, 2010).

As for geomorphology, the municipality has the characteristic relief forms of the Amazon plain, the Juruá-Iaco depression, the depression marginal to Serra do Divisor, and the tabular surface of Cruzeiro do Sul under the morpho-structural domain of the Phanerozoic basins and sedimentary covers. The relief has flat areas resulting from river accumulation and subject to flooding, low-lying areas with convergent planes, areas of river dissection with strong structural control with hills and tabular interfluves, well-

defined valleys and slopes of varying gradients, carved by furrows and first-order drainage headwaters, as well as shallow valleys with slopes of small and medium gradient, as shown in Figure 2 (IBGE, 2010).

Figure 2 – Physical aspects of Guajará, AM



Source: IBGE, 2023.

Guajará is located 1,470 kilometers from Manaus, with an economy that is strongly connected to the neighboring state of Acre, thanks to its proximity and easy access by highway, being based mainly on agricultural and extraction activities (IDAM, 2011).

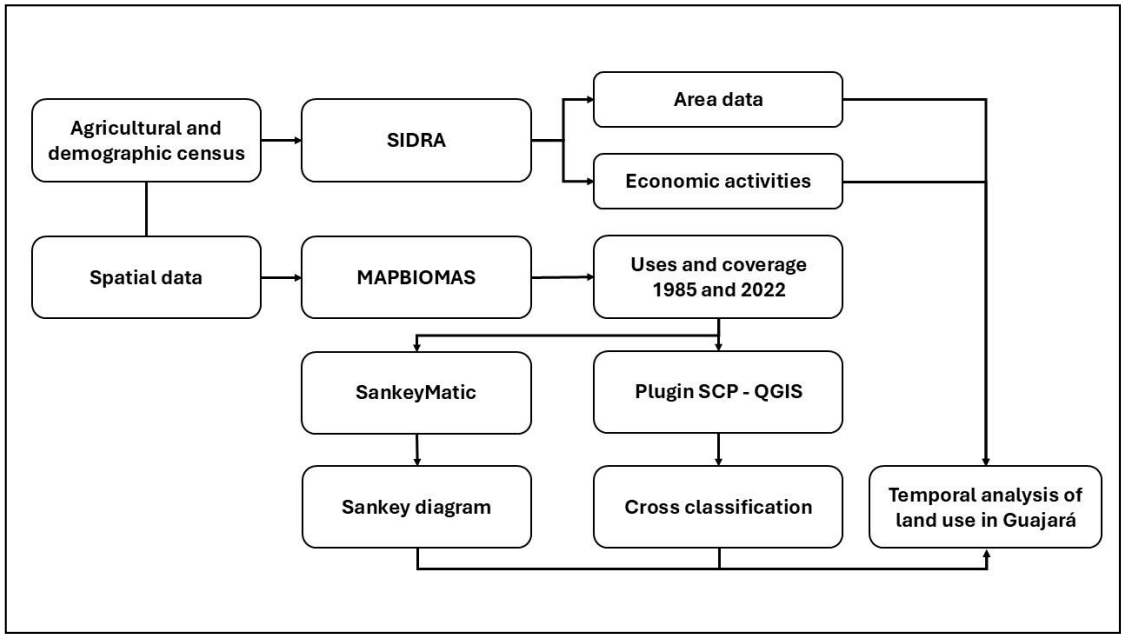
The municipality is marked by very low social indicators, such as the proportion of employed inhabitants, which reaches the mark of 4.05%. Households with monthly incomes of up to 0.5 minimum wages account for 52.9% (IBGE, 2021). The municipal

Human Development Index (HDI) of Guajará according to the Development Atlas was 0.532 in 2010, below the HDI of Amazonas and the North Region, which are 0.700 and 0.702, respectively. According to the Amazonas State Secretariat for Social Assistance (*Estado de Assistência Social do Amazonas* – SEAS), in 2021, approximately 11,000 people lived in extreme poverty, which is visible by the high proportion of people registered in the county's Federal Welfare Registry (*Cadastro Único*).

Methodology

The methodological approach of the study includes a literature review on the journal portal of the Coordinator's Office for the Improvement of Higher Education Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* – CAPES), as it offers better quality search filters and allows access to articles from paid journals when they appear, with the goal of situating the article within the scope of the topic in Brazil, which, through a simple search by subject, sought articles based on the terms "Land use and coverage" and the subsequent steps to systematize the data obtained, as shown in Figure .

Figure 3 – Methodological approach



Source: Authors' own work, 2024.

The second stage of the methodology consists of collecting data from the agricultural and demographic censuses of the municipality of Guajará in the IBGE Automatic Recovery System (*Sistema IBGE de Recuperação Automática* – SIDRA), in which data on area, groups of economic activities and land use were retrieved.

To prepare the coverage dynamics maps, the study used products from collection 8 of the MAPBIOMAS project, which maps land cover and land use using Landsat satellite images, with a temporal coverage since 1985. The data are produced through pixel-by-pixel classification and machine learning of Landsat images, with a spatial resolution of 30 meters. The entire process is carried out in the cloud on the Google Earth Engine platform. Metrics are extracted from each pixel, in each band of each satellite image, thereby creating mosaics for each year for the whole of Brazil. The mosaics are used for the algorithm to classify the images and as a source of parameters (MAPBIOMAS, 2023).

The temporal analysis of land cover aims to verify the changes that occurred in the period 1985-2022. Initially, the raster data were weighted using the QGIS table reclassification tool. This application in the program reclassifies a raster band by assigning new class values based on the intervals specified in a fixed table (Table **1**). For this study, the goal was to differentiate the MAPBIOMAS classes by generalizing what would comprise the classes of natural cover (Class 1), anthropic use (Class 2), and water (Class 3).

Table 1 – Weighting of land cover classes for cross-classification

MAPBIOMAS legend	MAPBIOMAS ID	Weighted class
Forest, savanna, flooded forest, flooded field, and grassland formation	3, 4, 6, 11, and 12	1
Pasture, urban area, and temporary crop	15, 24, and 41	2
Water	33	3

Source: Authors' own work, 2024.

Subsequently, cross-classification was performed in the QGIS Semi-Automatic Classification plugin, in which the pixel values of a raster layer (land cover in 2022) are compared with the pixel values of a reference raster (land cover in 1985). This allows checking the area for combining classes, in which one was converted to another based on the assimilation presented in Table **2**.

Table 2 – Cross-classification of MAPBIOMAS classes between 1985 and 2022 for Guajará

USE 1985	USE 2022	CLASS
1	1	Preserved
2	1	Regenerated
3	1	Regenerated
1	2	Deforested
2	2	Deforested
3	2	Deforested
1	3	Water
2	3	Water
3	3	Water

Source: Authors' own work, 2024.

The Sankey diagram was created to compare the contribution of each class to the total amount mapped in each year from 1985 onwards and compare it with the years 2000, 2010 and 2022 in Guajará. The MAPBIOMAS data were organized in a TXT file, compatible with the format accepted by the SankeyMATIC tool[1], which is available online for creating flow diagrams. This tool was developed by Bogart (2014).

The diagram is used to reproduce flows through which each direction is represented by a line or arrow whose thickness indicates the proportion of contribution of the class or variable in the process. Thus, the thicker the line, the greater the participation of the class in the system, while the thinner the line, the smaller the contribution (Esquerdo, et al., 2018). This form of diagramming was initially conceived by Riall Sankey over 100 years ago, an Irish engineer who used it to analyze thermal efficiency in steam engines, and which has since been used for a multitude of representations of complex systems (Schmidt, 2008).

Results and discussion

In 1985, natural vegetation coverage accounted for 98.36% of the total area of the municipality. This group includes the classes of savanna formation, flooded field, grassland formation, flooded forests, and forest formation. The classes of anthropic use made up 1.09% of the area of the municipality, including, in this group, the mapped classes of pasture and urban area.

[1] Available at: https://sankeymatic.com/build/.

As of 2022, the area covered by natural vegetation represented 93.02% of the municipality's coverage, a 5% reduction that was added to the area designated for mapped anthropic uses, resulting in a percentage of 6.41%, now including the class of temporary crops.

Considering the data from the years of the series analyzed in this work, a reduction in the forest cover of around 40,500 hectares can be observed. This area represents the total conversion of natural cover by agricultural activities. The urban area of Guajará showed an increase of 132 hectares from 1985 to 2022.

What can be seen in Guajará is the advancement of the conversion of forest areas into pasture areas. This occupation occurs mainly in areas of firm land, close to roads through which access is possible. The data of areas of the classes mapped in Guajará (Table **3**) allow us to verify the increase in the characteristic classes of polygons of human intervention, such as pasture and urban areas and the gradual decrease in the area of the forest class (MAPBIOMAS, 2022).

Table 3 – Area in hectares of land cover classes in Guajará from 1985 to 2022

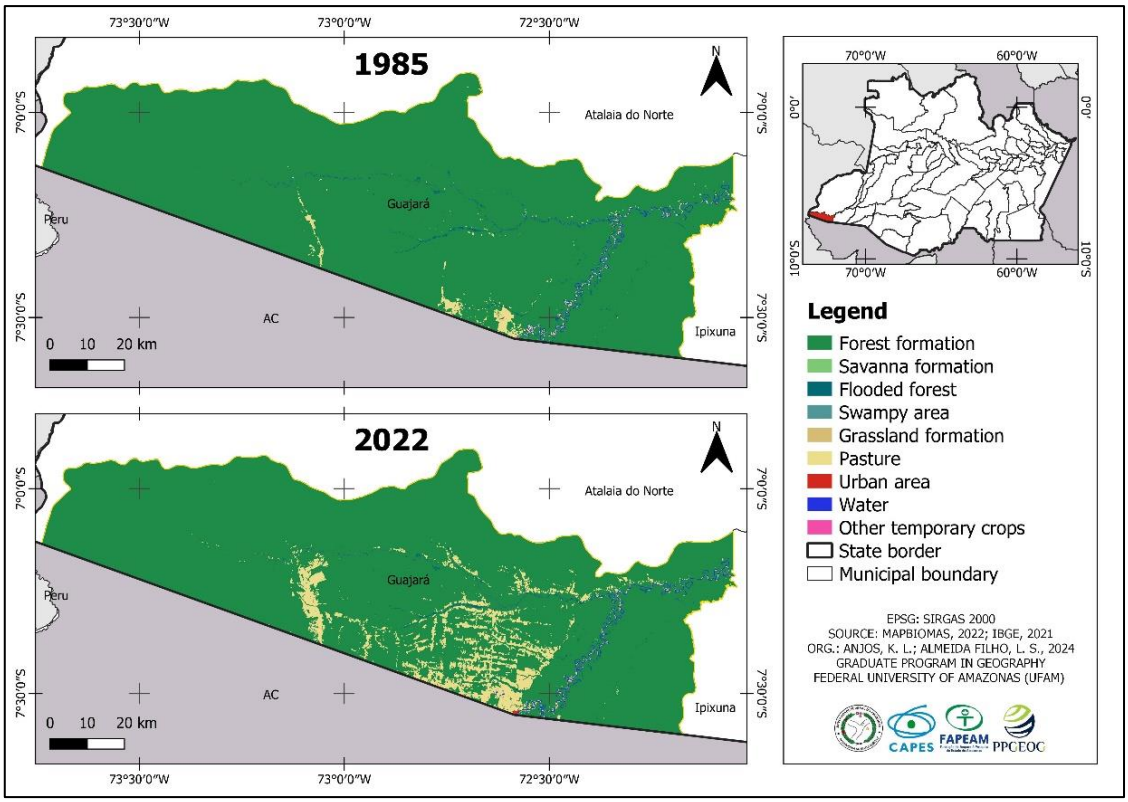
MAPBIOMAS ID	Class	1985	2000	2010	2022
3	Forest formation	741,585	726,554	715,674	700,412
4	Savanna formation	5	-	-	1
6	Flooded forest	3,219	3,153	3,332	3,250
11	Flooded field	531	463	631	498
12	Grassland formation	568	293	582	1,249
15	Pasture	8,277	23,113	34,125	48,489
24	Urbanized area	13	78	116	145
33	Water	4,136	4,679	3,874	4,288
41	Temporary crop	-	-	-	1

Source: MAPBIOMAS, 2023.

It is worth highlighting the increase in the grassland formation class, which, despite being mapped as a natural formation, may be an indication of areas of vegetation succession that were previously degraded to make way for pasture. Based on the land use and coverage map (Figure 4) organized with the matrix data from the MAPBIOMAS project, it is possible to see two axes of advancement – one that occurs mainly due to the location of the headquarters located to the southeast of the

municipality and the growth axis to the east of the urban area due to the presence of federal highway BR-307.

Figure 4 – Land use and use land cover according to the MAPBIOMAS methodology, in 1995 and 2022

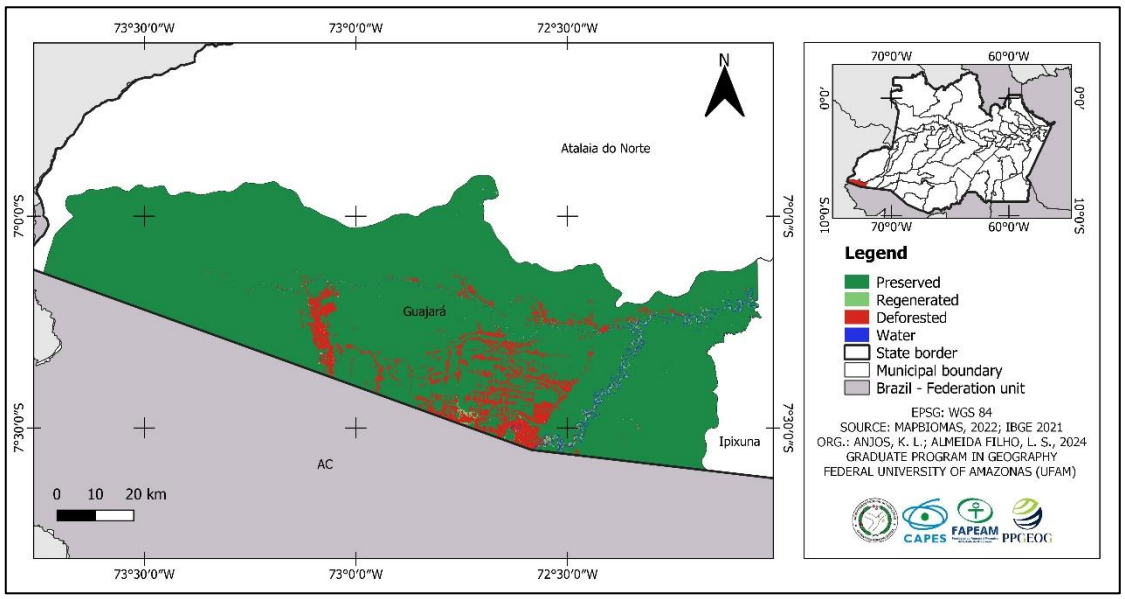


Source: MAPBIOMAS, 2023.

The dynamics of land cover in the period 1985-2022 shows that 48,000 hectares of natural vegetation were deforested, while another 40.8 hectares were regenerated, which is partly explained by the natural change in the course of the Juruá River.

Figure 5 shows the changes that are evident.

Figure 5 – Land cover dynamics in Guajará between 1995 and 2022



Source: MAPBIOMAS, 2023.

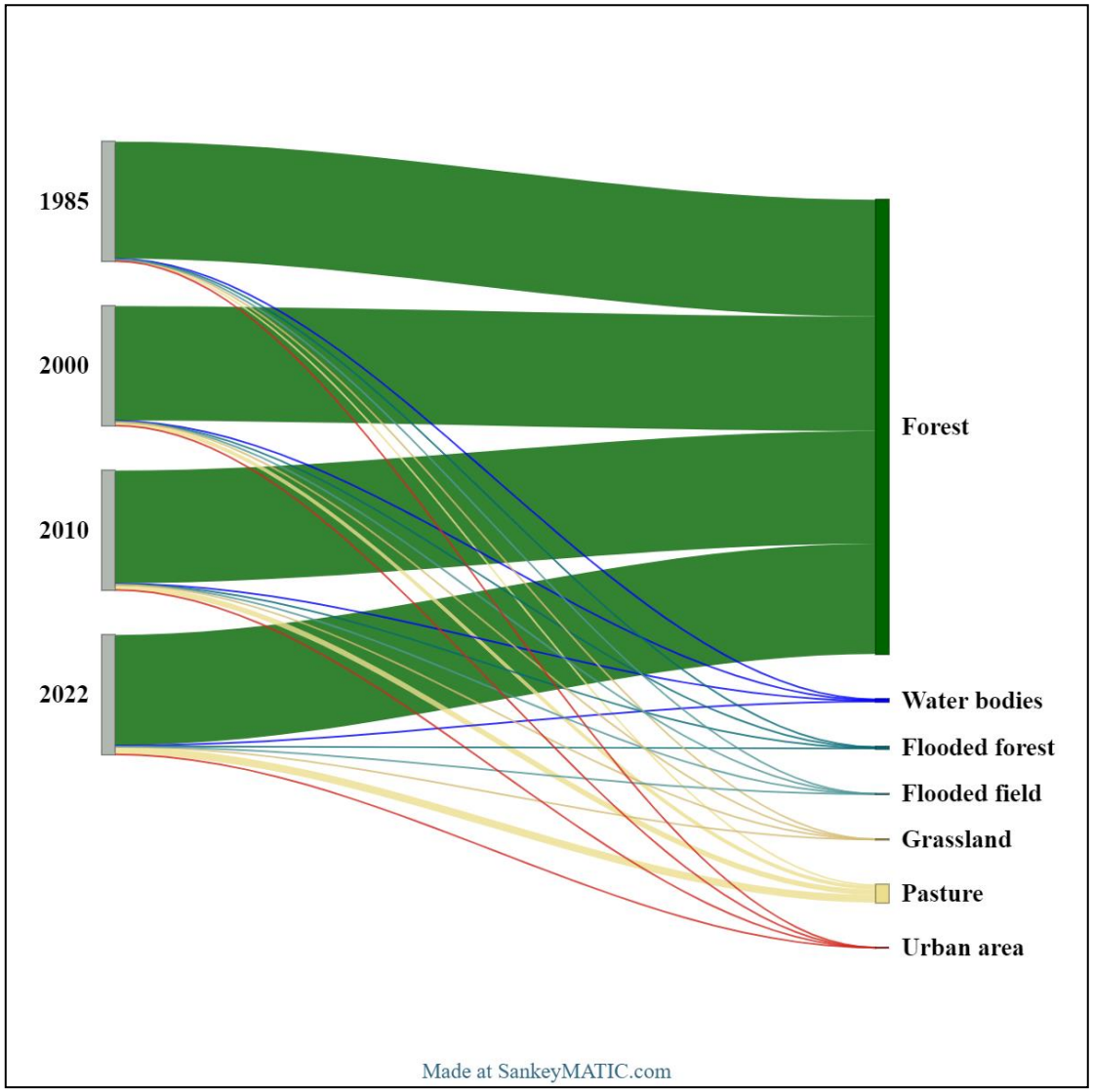
Based on the data analysis, it can be stated that there was an increase in the area designated for agricultural activities in the municipality of Guajará. Conversely, there was a decrease in forest cover. In the case of data from the MAPBIOMAS project, there was also an increase in the grassland vegetation class, which may indicate grass pastures intended for cattle raising.

The Sankey diagram allows the representation of land use and land cover transitions based on the mappings carried out. The largest flows of change from natural vegetation to pasture occurred in the years 2010 and 2022, and this was the class that proportionally increased the most in area compared to the urban area (Figure).

A number of studies have investigated the relationship between land cover changes and environmental changes, such as those by Alves and Alvarado (2019); Cruz and Cruz (2021); Pimenta, et al. (2018); Ferreira, et al. (2022); Paula, et al. (2022); Ferreira, Lima, and Gomes (2023); Santana, França, and Avelar (2023); Martins, Silva, and Castro (2023); and Fernandes, et al. (2023). The impacts of these changes can be seen in variables that have relationships between the Earth's surface and the

atmosphere, which have repercussions on climate, hydrology, and ecology. They also affect pollution indicators, acting as a source, storage or conductor of the processes (Feng et al., 2023).

Figure 6 – Land cover transition by period in Guajará from 1985 to 2022



Source: MAPBIOMAS, 2022; SANKEYMATIC, 2024.

Deforestation is driven by forces that vary according to the region and time. Most deforestation occurs through the actions of large and medium-sized farmers, and the actions of small farmers may have a significant potential where they are concentrated. In the Amazon region, the advance of the frontier shows peaks of

intensity, marking a movement that is linked to economic changes and decision-making processes (Fearnside, 2006).

Agricultural census

In 1995, the variety of agricultural production in permanent crops in Guajará consisted of avocado, banana, coffee, coconut, guarana, jackfruit, orange, mango, papaya, and tangerine, which are produced in 33 establishments. The production of temporary crops included pineapple, pumpkin, cotton, rice, sugarcane, beans, tobacco, yam, cassava, watermelon, corn, and tomatoes, in 745 establishments. In 1995, livestock farming had a total of over 53,000 head of livestock, including cattle (24,180), swine (4,083), and poultry (23,874), while other categories of animals were raised in 76 agricultural establishments. In 2006, permanent crops totaled 16 establishments, where mainly bananas were produced. Temporary crops included 489 establishments, where mainly sugarcane, beans, cassava and corn were produced. As regards livestock farming, the 164 establishments recorded produced cattle, swine, and poultry, among other animals, with the cattle herd estimated at 31,986 head. The swine herd totaled 5,158 pigs, while poultry totaled 14,270.

In 2017, the main crops produced on permanent farms included avocado, banana, cocoa, coffee, cashew, cupuaçu, guava, soursop, orange, mango, papaya, and pupunha, on 25 agricultural establishments. In turn, on temporary farms, on 635 establishments, the following crops were produced: sugarcane, beans, cassava, corn, pineapple, pumpkin, peanuts, rice, and watermelon (IBGE, 2017).

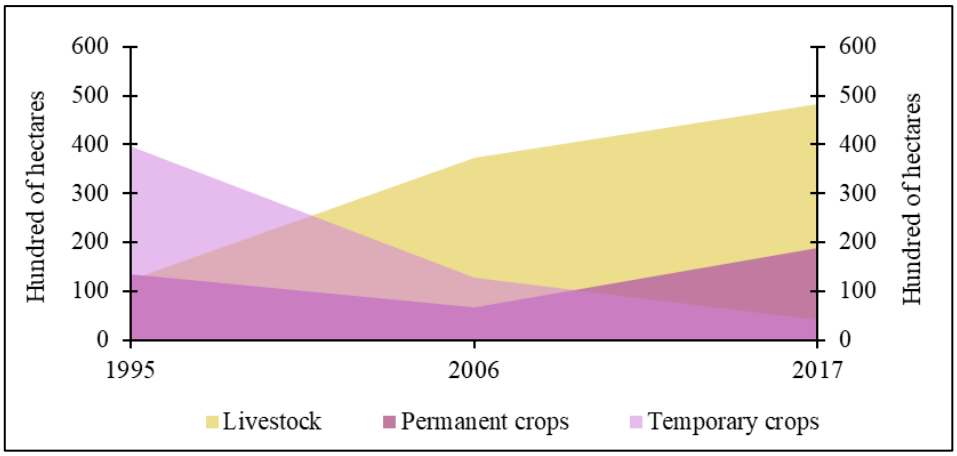
In livestock farming, cattle are mainly raised, with 28,027 head; as regards swine, 1,200 head were recorded; and the poultry herd comprised a total of 26,508,000 head of hens, roosters, chickens, pullets, chicks, and other species of animals, raised in 237 establishments.

It is important to note that a single agricultural establishment may perform more than one productive activity, which contributes to significant numbers in the totals

in units of the establishments. The total area of the establishments varied as shown in

Figure 7, where it is possible to verify the decrease in agricultural activity in permanent crops, contrary to what occurs in temporary crops and in livestock.

Figure 7 – Area of agricultural establishments by activity groups – Guajará – 1995 to 2017

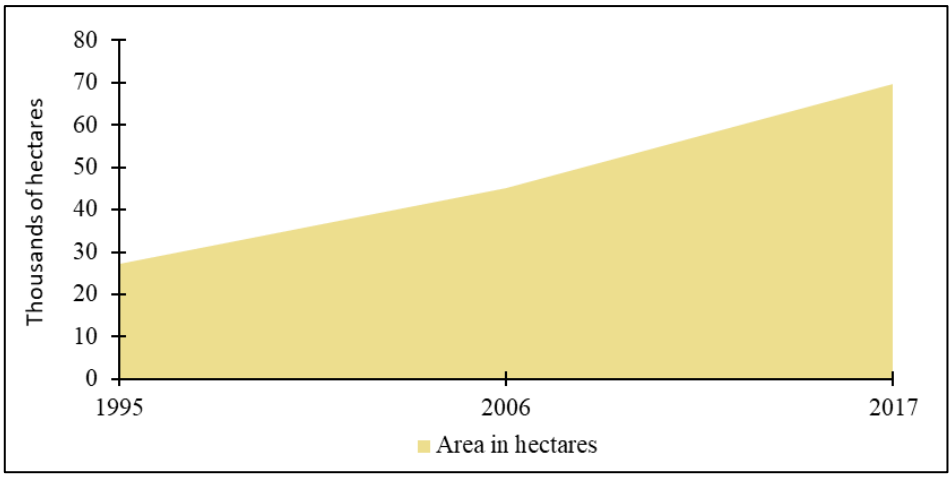


Source: IBGE, 2011; 2018.

The data from the agricultural census help to understand the increase in the area occupied by agricultural use, according to the IBGE in the years analyzed, the area of agricultural establishments jumped from 27,142 hectares in 1995 to over 45,000 hectares in the year in 2006, an increase of 60% in the area occupied by establishments.

The last agricultural census carried out in 2017 indicated that the area occupied by agricultural establishments was 69,580 hectares, accounting for 9.2% of the municipality's area of 7,583.53 square kilometers. The sequence of increase can be seen in Figure (IBGE, 2021).

Figure 8 – Area of agricultural establishments in the municipality of Guajará, AM



Source: IBGE, 2011; 2018.

Coutinho and Cecílio (2010), based on data from the 2006 and 2017 agricultural censuses, argue that Brazil's North region ranked third in terms of rural territorial extension, ahead only of the South region, which represents an increase from 17% to 19% of hectares related to rural establishments. The 2017 census also indicated a predominance of properties with less than 100 hectares, accounting for 90%, with the Central-West region having the lowest absolute number of properties due to the concentration of large estates in this region due to the prevalence of commercial monoculture.

The same occurs in Guajará, where 84.92% of rural properties have areas of less than 100 hectares in area, which according to the National Rural Registry System (*Sistema Nacional de Cadastro Rural* – SNCR) is the measurement of a fiscal module unit for the municipality.

The increase in the area of economic activities in Guajará can be observed both in the mapping carried out by MAPBIOMAS and in the data from the agricultural census. Even though the area values do not coincide, it is crucial to highlight the limitations of both the mapping that uses the pixel-by-pixel classification of raster images and the methodology used in the agricultural census, as well as the difference that may be related to the time lapse between the last census (2017) and the mapped year considered (2022).

In general, the census information allows us to understand the economic dynamics that explain the progress observed in the classes drawn in the mapping and

converge to situate the studied area in the context of the advance of the agricultural frontier over the western and central Amazon.

It is important to highlight the need to update agricultural and rural production statistics, as the gaps that exist mainly in state databases favor a context that hinders the advancement of studies and policies based on evidence.

Final remarks

In recent years, the municipality of Guajará has experienced an increase in its population, as well as in the area designated for agricultural activities. Consequently, there has been an increase in the diversity of the municipality's landscape, manifested in the land cover, with recent years being marked by a trend towards an increase in the number of land use classes.

Nevertheless, the results of this study point to the need to consider the impacts of the expansion of agriculture and livestock farming on the natural and socioeconomic environment, putting the impacts into perspective, as economic growth cannot be neglected when it can be converted into social well-being. It is necessary to consider policies that resolve problems in terms of spatial continuity and/or spatial discontinuity.

Even for the municipality of Guajará, which is considered a smaller city, the expansion of the forest is significant, imposed mainly by a recent dynamic that has made the forest a commodity in terms of natural capital.

The results also reveal that the increase in economic activities does not necessarily imply an improvement in the quality of life of the population, as the social indicators of the municipality studied are low. Guajará has characteristics that differentiate it from most cities in Amazonas, as it is connected by roads, with dynamics are directed towards the state of Acre thanks to its proximity.

The association of census information with mapping data is able to offer possibilities for relevant analyses for cities in the interior of Amazonas, particularly with regard to the gap in studies related to this topic.

Therefore, the use of tools from remote sensing is increasingly efficient for a broader-scale view, in addition to offering support for decision making. Despite the limitations of the methodologies, imposed by natural issues that are intrinsic to the

Amazon, the result achieved was satisfactory and allowed us to highlight the change that occurred in Guajará in the time series analyzed.

References

ALVES, D. B.; ALVARADO, S. T. Variação espaço-temporal da ocorrência do fogo nos biomas brasileiros com base na análise de produtos de sensoriamento remoto. **Geografia**, [S./l.], v. 44, n. 2, p. 321–345, 2019.

AMAZONAS. **Boletim informativo socioeconômico - Guajará**. SEAS, 2021. Disponível em: https://www.seas.am.gov.br/. Acesso em: 28 abr. 2024.

ARRAIS, S. C. S.; PRAT, B. V.; CAMBRAIA, R. P. Análise dos Censos Agropecuários brasileiros dos anos de 2006 e 2017 para identificação de características da população agrícola. **Revista Cerrados**, Montes Claros, v. 17, n. 02, p. 228–246, 2019. Disponível em: https://www.periodicos.unimontes.br/index.php/cerrados/article/view/118. Acesso em: 27 abr. 2024.

AZEVEDO, T.; MATIAS, L. F. Dinâmica da alteração do uso e ocupação agrícola na amazônia maranhense: uma análise a partir de dados do MAPBIOMAS. *In*: PPGEO UNICAMP, 20., 2023, Campinas. **Anais** [...], v. 1, n. 1, p. 89–103, 2023.

BECKER, B. K. Geopolítica da Amazônia. **Estudos avançados**, São Paulo, v. 53, n. 19, p. 71-86, 2005. Disponível em: https://www.revistas.usp.br/eav/article/view/10047. Acesso em: 15 abr. 2023.

BOGART, S. **SankeyMATIC**. 2014. Disponível em: https://sankeymatic.com/build/. Acesso em: 25 mar. 2024.

COUTINHO, L. M.; CECÍLIO, R. A. Análise de dados agropecuários por geoprocessamento: o caso da região sul do estado do Espírito Santo. **Geografares**, [S./l.], n. 8, p. 1-25, 2010. Disponível em: https://periodicos.ufes.br/geografares/article/view/1294. Acesso em: 1 maio 2024.

CRUZ, C. L. Z.; CRUZ, C. B. M. Avaliação da exatidão temática da cobertura e uso da terra representada através do MAPBIOMAS no Rio de Janeiro. **GEOgraphia**, [S./l.], v. 23, n. 50, 2021. Disponível em: https://periodicos.uff.br/geographia/article/view/47001. Acesso em: 11 jul. 2024.

DUPIN, Mariana G. V.; ESPÍRITO-SANTO, Mário M.; LEITE, Marcos E.; *et al.* Land use policies and deforestation in Brazilian tropical dry forests between 2000 and 2015. **Environmental Research Letters**, [S./l.], v. 13, n. 3, p. 1-12, 2018. Disponível em: https://doi.org/10.1088/1748-9326/aaadea. Acesso em: 27 abr. 2024.

ESQUERDO, J. C. D. M.; ANTUNES, J. F. G.; COUTINHO, A. C.; SANTOS, J. L.; PARAZZI, T. N. T.; BERTOLO, L. S. Avaliação da dinâmica de uso e cobertura da terra em municípios da BAP a partir da plataforma Web dos dados TerraClass

Amazônia. *In*: SIMPÓSIO DE GEOTECNOLOGIAS NO PANTANAL, 7., 2018, São José dos Campos. **Anais** [...]. São José dos Campos: INPE, 2018. Disponível em: http://www.alice.cnptia.embrapa.br/handle/doc/1099262. Acesso em: 6 jul. 2024.

FEARNSIDE, P. M. Desmatamento na Amazônia: dinâmica, impactos e controle. **Acta Amazônica**, [S./l.], v. 36, p. 395–400, 2006. Disponível em: https://doi.org/10.1590/S0044-59672006000300018. Acesso em: 27 abr. 2024.

FENG, H.; WANG, S.; ZOU, B.; NIE, Y.; YE, S.; DING, Y.; ZHU, S. Land use and cover change (LUCC) impacts on Earth's eco-environments: Research progress and prospects. **Advances in Space Research**, [S./l.], v. 71, n. 3, p. 1418–1435, 2023. Disponível em: https://doi-org.ez87.periodicos.capes.gov.br/10.1016/j.asr.2022.09.054. Acesso em: 27 abr. 2024.

FERNANDES, A. P. S.; MARTINS, Q. O.; PINHO, B. C. P.; PENA, G. A.; TROVÃO, A. A. F. Análise do uso e cobertura do solo na APA Triunfo do Xingu – PA. **Revista Contemporânea**, [S./l.], v. 3, n. 12, p. 25104–25127, 2023.
FERREIRA, M. S.; COSTA, N. C.; VIDAL, B. S.; SILVA NETO, J. C. A. Análise temporal do uso da terra no município de Anamã-AM. **Revista GeoAmazônia**, [S./l.], v. 10, n. 20, p. 23–43, 2022. Disponível: https://periodicos.ufpa.br/index.php/geoamazonia/article/view/13657. Acesso em: 27 abr. 2024.

FERREIRA, N. S.; LIMA, A. M. M.; GOMES, D. J. C. Vulnerabilidade das áreas úmidas e influência sazonal da precipitação pluviométrica na Amazônia Oriental. **GEOFRONTER**, [S./l.], v. 9, p. 1-23, 2023. Disponível em: https://periodicosonline.uems.br/index.php/GEOF/article/view/7366. Acesso em: 11 jul. 2024.

HASAN, S. S.; ZHEN, L.; MIAH, G.; AHAMED, T.; SAMIE, A. Impact of land use change on ecosystem services: A review. **Environmental Development**, [S./l.], v. 34, p. 1-14, 2020. Disponível em: https://doi.org/10.1016/j.envdev.2020.100527. Acesso em: 27 abr. 2024.

IBGE. **@cidades**. v. 4, Rio de Janeiro: IBGE, 2021. Disponível em: https://cidades.ibge.gov.br/brasil/am/coari/panorama. Acesso em: 16 out. 2023.

IBGE. **Censo agropecuário 1995-1996**. Sidra: sistema IBGE de recuperação automática. Rio de Janeiro: IBGE, 2011. Disponível em: https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2006/segunda-apuracao. Acesso em: 30 de mar. 2023.

IBGE. **Censo agropecuário 2006**. Sidra: sistema IBGE de recuperação automática. Rio de Janeiro, 2011. Disponível em: https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2006/segunda-apuracao. Acesso em: 30 mar. 2023.

IBGE. **Censo agropecuário 2017**. Sidra: sistema IBGE de recuperação automática. Rio de Janeiro, 2018. Disponível em: https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2017. Acesso em: 30 mar. 2023.

IBGE. **Censo demográfico de 2010**. Rio de Janeiro: IBGE, 2010. Disponível em: https://memoria.ibge.gov.br/sinteses-historicas/historicos-dos-censos/censos-demograficos.html. Acesso em: 16 out. 2023.

IBGE. **Geologia Brasil**. 2010. Rio de Janeiro: IBGE, 2010. Disponível em: https://www.ibge.gov.br/geociencias/informacoes-ambientais/vegetacao/22460-vegetacao-por-estado.html?=&t=downloads. Acesso em: 16 out. 2023.

IBGE. **Geomorfologia por estado**. 2010. Rio de Janeiro: IBGE, , 2010. Disponível em: https://www.ibge.gov.br/geociencias/informacoes-ambientais/geomorfologia/16028-geomorfologia-do-estado-de-ro-rr-to-ac-am-ma-mt-e-pa.html?=&t=downloads.

IBGE. **Mapa de clima do Brasil**. Rio de Janeiro: IBGE, 2002. Escala 1:5 000 000. Disponível em: http://mapas.ibge.gov.br/tematicos.html. Acesso em: 16 out. 2023.

IBGE. **Vegetação por estado**. 2010. Rio de Janeiro: IBGE, 2010. Disponível em: https://www.ibge.gov.br/geociencias/informacoes-ambientais/vegetacao/22460-vegetacao-por-estado.html?=&t=downloads. Acesso em: 16 out. 2020.

INCRA. **Índices Básicos dos municípios**. Disponível em: https://www.gov.br/pt-br/servicos/consultar-indices-basicos. Acesso em: 2 maio 2024.

INPE. **TOPODATA: banco de dados geomorfométricos do Brasil**. Variáveis geomorfométricas locais. São José dos Campos, 2008. Disponível em: http://www.webmapit.com.br/inpe/topodata/. Acesso em: 31 mar. 2022.

MAPBIOMAS. **General Handbook Algorithm Theoretical Basis Document (ATBD): Collection 8.** MAPBIOMAS, 2023. Disponível em: https://brasil.mapbiomas.org/download-dos-atbds-com-metodo-detalhado/. Acesso em: 5 jul. 2024.

MARINHO, T. P.; SCHOR, T. Nos interflúvios do rural e do urbano: o caso de Codajás - AM, Brasil. **Acta Geográfica**, [S./l.], v. 6, n. 11, p. 69–81, 2012.

MARTINS, A. M. M.; LOURENÇO, P. M. S.; SILVA, D. V. S.; CRUZ, C. B. M. Mapeamento do uso e cobertura do solo do município de Saboeiro (CE) através de processamento na nuvem no GEE. **Revista Continentes**, [S./l.], n. 22, p. 66, 2023.

MARTINS, W. R.; SILVA, A. A.; CASTRO, J. D. B. Desafios ambientais na bacia do rio Passa-Três: Impactos das mudanças no uso da terra nos recursos hídricos. **Revista Equador**, [S./l.], v. 12, n. 2, p. 119–140, 2023.

MAURANO, L. E. P.; ESCADA, M. I. S. Comparação dos dados produzidos pelo PRODES versus dados do MAPBIOMAS para o bioma Amazônia. *In*: SIMPÓSIO BRASILEIRO DE SENSORIAMENTO REMOTO, 19., 2019, São José dos Campos. **Anais [...].** São José dos Campos: INPE, 2019.

MIRAGAYA, J. F. G. **Transformações no Arco do Desmatamento:** a expansão da pecuária bovina na Amazônia, pressões sobre o ambiente e o papel das políticas públicas na contenção do desmatamento (1990/2010). 2013. 253 f. Tese (Doutorado em

Desenvolvimento sustentável) – Universidade de Brasília, Brasília, 2013. Disponível em: https://repositorio.unb.br/handle/10482/15401. Acesso em: 15 abr. 2022.

PAIXÃO, A. N.; OLIVEIRA, N. M.; MENDONÇA, M. V.; *et al.* Desenvolvimento rural dos municípios do estado do Pará: desigualdade e espacialidade. **Redes**, [S./l.] v. 25, p. 1504–1527, 2020.

PAULA, D. S.; ESCADA, M. I. S.; ORTIZ, J. O. Análise multitemporal do uso e cobertura da terra na Amazônia: A expansão da Agricultura de Larga Escala na Bacia do Rio Curuá-Una. **Revista Brasileira de Cartografia**, [S./l.], v. 74, n. 2, p. 379–398, 2022.

PIMENTA, L.; BELTRÃO, N.; GEMAQUE, A.; PONTES, A. Dinâmica do uso e cobertura da terra em municípios prioritários: uma análise no município de Moju, Pará no período de 2008 a 2014. **Revista de Geografia e ordenamento do território**, Coimbra, n. 14, p. 267-281, 2018. Disponível em: https://cegot.org/ojs/index.php/GOT/article/view/2018.14.011/pdf. Acesso em: 15 abr. 2023.
ROSA, M. Geotecnologias na geografia aplicada. **Revista do departamento de Geografia**, São Paulo, n. 16, p. 81-89, 2005. Disponível em: https://www.revistas.usp.br/rdg/article/view/47288. Acesso em: 15 abr. 2023.

SANKEYMATIC. Build a Sankey Diagram. **SankeyMATIC.com**, 2024. Disponível: https://sankeymatic.com/build/. Acesso em: 28 abr. 2024.

SANTANA, R. G.; FRANÇA, D. V. B.; AVELAR, C. M. C. Dinâmica do uso e cobertura da terra entre os anos 1985 e 2021 na bacia hidrográfica do rio Preguiças – MA, Brasil. **Geofronter**, [S./l.], v. 9, p. 1-23, 2023. Disponível em: https://periodicosonline.uems.br/index.php/GEOF/article/view/7645. Acesso em: 11 jul. 2024.

SCHMIDT, M. The Sankey Diagram in Energy and Material Flow Management. **Journal of Industrial Ecology**, [S./l.], v. 12, n. 1, p. 82–94, 2008. Disponível em: https://doi.org/10.1111/j.1530-9290.2008.00004.x. Acesso em: 6 jul. 2024.

SEABRA, V. S.; XAVIER, R. A.; DAMASCENO, J.; DORNELLAS, P. C. Mapeamento do uso e cobertura do solo da bacia do rio Taperoá: região semiárida do estado da Paraíba. **Revista Caminhos de Geografia**, [S./l.], v. 15, n. 50, p. 127-137, 2014. Disponível em: http://www.seer.ufu.br/index.php/caminhosdegeografia/. Acesso em: 25 mar. 2023.

SOUZA, A. R.; ESCADA, M. I. S; MONTEIRO, A. M. V. Padrão da paisagem associado ao uso e cobertura da terra em comunidades ribeirinhas e de terra firme situadas no sudoeste do Pará. **Revista Geografia**, Rio Claro, v. 42, n. 2, p. 135-164, 2017. Disponível em: https://www.periodicos.rc.biblioteca.unesp.br/index.php/ageteo/article/view/13076. Acesso em: 15 abr. 2023.

VASCONCELOS, B. R.; LIMA, M. T. V.; PARANHOS FILHO, A. C. Detecção de mudanças no uso e ocupação do solo no estado do amazonas baseada nas classificações do projeto MAPBIOMAS. **Geofronter**, [S./l.], v. 10, e7773, p. 1-21, 2024.

Authors

Kelyan Lago dos Anjos – He holds a Bachelor's degree in Geography from the Federal University of Amazonas (*Universidade Federal do Amazonas* – UFAM). He is currently pursuing a Master's degree in Geography from the Federal University of Amazonas (UFAM).

Address: UFAM University Campus: Av. General Rodrigo Octavio Jordão Ramos, 1200 – Coroado I, Manaus – AM, CEP: 69.067-005.

Luciomar da Silva Almeida Filho – He holds a Bachelor's degree in Geography from the Federal University of Amazonas (UFAM) with a specialization in Environmental Management from the Federal Institute of Education, Science and Technology of Amazonas (*Instituto Federal de Educação, Ciência e Tecnologia do Amazonas* – IFAM). He is currently pursuing a Master's degree in Geography from the Federal University of Amazonas (UFAM).

Address: UFAM University Campus: Av. General Rodrigo Octavio Jordão Ramos, 1200 – Coroado I, Manaus – AM, CEP: 69.067-005.

Article received at: May 02, 2024.

Article accepted at: June 10, 2024.

Article published on: June 15, 2024.