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Impacts of Agricultural Activities in the Legal Amazon Area: Spatio-Temporal Analysis of Land Cover Changes Between 1985 and 2022

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ABSTRACT

The Brazilian Forest Code stipulates the conservation of 80% of forested areas on rural properties as legal reserves. However, in recent decades, the expansion of agricultural areas has resulted in significant alterations to land use and cover. The objective of this investigation is to analyze the changes and transformations that have occurred in land use and coverage in the city of Sinop-MT, which is derived from the occupation of the Brazilian Legal Amazon. The spatio-temporal change between the years 1985 and 2022 was investigated. The methodology employed to obtain the maps was through the MapBiomas Platform. Socioeconomic reports were collected from the Brazilian Institute of Geography and Statistics (IBGE) database. The results indicated that agriculture in the region advanced significantly between 1995 and 2005, corresponding to the economic boom under the Real Plan. This period saw a surge in territorial expansion in the northern region of Mato Grosso, which was encouraged by the federal government. This expansion led to high rates of deforestation. Nevertheless, in 2004, monitoring programs were initiated with the objective of containing deforestation in the Legal Amazon. This resulted in the cessation of agricultural expansion between the years 2005 and 2022.

KEYWORDS: Anthropogenic changes; Ground cover; Environment.

1 INTRODUCTION

The region of Mato Grosso, located in the Center-West of Brazil, has the third largest territorial extension in the country with 903,208.361 km², and a population of 3,658,649 people (IBGE, 2022). Its territory is made up of three biomes, the Amazon being the largest, with 480,215 km². It is protected by the Brazilian Forest Code (Federal Law No. 4.771/1965 and amended by Provisional Measure No. 2.166-67/2001), which stipulates the conservation of 80% of forested areas on rural properties as a legal reserve and 35% in savannahs.

The Legal Amazon, the largest continuous tropical forest in the world, occupies 60% of Brazil's territory. Its contribution to the hydrological cycle has been widely evidenced in scientific studies (Nobre, 2014; Marengo *et al*., 2018). While precipitation originating in the Amazon provides irrigation and sustains the main metropolitan and agricultural areas of Mercosur, the persistence of deforestation and fires in the region has a negative global impact. This is because the Amazon holds the largest reservoir of forest carbon in the world, estimated at approximately 49 billion tons of carbon.

In this sense, one of the most significant environmental problems facing Brazil is deforestation, which is the result of various factors, such as the conversion of forests for livestock or agriculture and for illegal logging (Fearnside, 2010). Consequently, land cover change results in biodiversity loss, soil degradation, climate change and alterations to the hydrological regime (Huang *et al*., 2022; Ridwan *et al*., 2021). With climate change on the global agenda, several studies have demonstrated the relationship between land use change and its impact on the climate (Dos Reis *et al*., 2021; Malhi *et al.*, 2008).

According to Brum *et al*. (2021), the increase in exploitation in the northern region of Mato Grosso is due to the political project to encourage expansion in the 1970s, with a view to settlement. While Brazil grew by 225.4% between 1950 and 2000, the Midwest grew by 657.8% (Girardi, 2008). In the northern region of Mato Grosso, Sinop is the second city with the highest gross domestic product (GDP), behind Sorriso (IBGE, 2021). Due to its predominantly flat terrain, it is a very favorable region for agriculture. In addition, it is the most populous city (196,067

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inhabitants) and had the largest population increase in a short period in the region, with a growth of 73.36% between 2010 and 2022. Consequently, the jungle landscape has undergone significant changes as a result of the accelerated anthropogenic activity in the region.

The city of Sinop is classified as a planned city, with recent settlement (1974), illustrated by Fig. 1, developing from a nucleus of new occupation, with an urban layout with wide streets and avenues. Coy *et al*. (2020) describes that in the first few years the urban boundaries drawn up by the colonizing company were exceeded, and the development of the city shifted to the occupation of the area known as the "green belt", which was overlaid by areas of residential allotments.

Figure 1 - Aerial view of Sinop 1974.

Source: Collection Luiz Erardi.

The conversion of rural areas into urban areas was only possible when municipal legislation became more flexible, with the real estate sector acting directly (Silva, 2014). As legislation became more flexible, new allotments were created in peri-urban areas, which were not always regular. However, in 2006, Sinop's master plan was instituted, contributing to the orderly growth of the municipality.

Based on this context, this investigation will address the influence of the accentuated migration and, consequently, urbanization of Sinop on the transformation of land use and land cover, from a space-time perspective between 1985 and 2022. It will then address the necessary mitigation actions for the problems encountered.

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2 OBJECTIVE

To analyze the transformations that have occurred in the use and coverage of the land in the city of Sinop-MT as a result of anthropic actions, evaluating the time-space between 1985 and 2022. The mitigation actions needed to mitigate the environmental consequences caused by man will be evaluated.

3 METHODOLOGICAL PROCEDURES

Spatio-temporal evaluation is often used to carry out research that assesses changes in vegetation cover (Pessoa *et al*., 2013). To this end, the material used was satellite images (rasters) of land use in the city of Sinop-MT, running the Google Earth Engine script within the MAPBIOMAS Platform. After selecting the study area, we generated qualitative and quantitative data on land use and land cover between 1985 and 2022, extracting the images every 10 years to compare and evaluate the evolution of changes in land use and land cover.

In addition, quantitative data from the population census of the last 4 decades and the temporal variation of the urbanized area, forestry, agriculture and water bodies of the municipality of Sinop-MT were consulted on the website of the Brazilian Institute of Geography and Statistics (IBGE).

4 RESULTS

4.1 Evolution of deforestation in Sinop-MT

It is necessary to understand how the dynamics of deforestation are related to the production scenario and the interference it exerts on the environment. According to Carvalho and Fantin (2021), there has been strong pressure on the environment in recent years due to the opening up of new areas for growing corn, soybeans and cotton, as well as livestock to supply the domestic and foreign markets.

Fig. 2 shows the sharp increase in the rate of deforestation, taken from the Project for Monitoring Deforestation in the Legal Amazon by Satellite (PRODES), which makes it possible to monitor the evolution of deforestation. Between 2001 and 2004, deforestation in Mato Grosso hit a record high, increasing by almost 60% and reaching the second highest level in the PRODES historical series. As a result, the state of Mato Grosso maintains an average annual deforestation rate of over 1,100 km².

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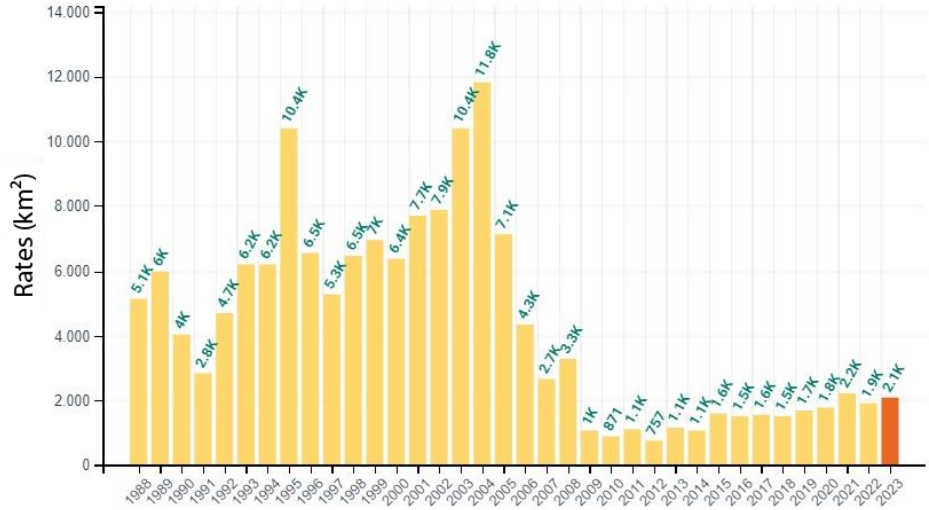
Figure 2 - Deforestation rate in Mato Grosso from the PRODES Amazon program - 1988 to 2023 (km²).



Source: INPE, 2023.

With the imminent problem of deforestation in the Legal Amazon, the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) was implemented in 2004, with the aim of reducing deforestation through a set of integrated actions, bringing together municipal, state and federal bodies, the private sector and civil society (Brasil, 2004). This led to the creation of the Real-Time Deforestation Detection System (DETER), which warns daily of changes in forest cover, contributing to effective enforcement (Deter, 2020). Another factor that influenced the reduction in deforestation was the granting of credits by the Central Bank of Brazil only to agricultural producers with no outstanding issues for illegal deforestation, in addition to the Conduct Adjustment Agreement (TAC) for meat issued by the Federal Public Prosecutor's Office (MPF), where meatpackers could not buy meat from deforested areas (Fearnside, 2020; Macedo *et al.*, 2012).

4.2 Socio-economic information about Sinop-MT

According to the 2022 IBGE census, Sinop has a population of 196,067 inhabitants, a significant increase of 580% in population density compared to 1985 (Fig. 3).

Figure 3 - Population of the municipalities of Mato Grosso - IBGE - 1985.

Santo Antônio do Leverger	10 552
São Félix do Araguaia	15 039
São José do Rio Claro	10 907
São José dos Quatro Marcos	27 446
Sinop	33 486
Tangará da Serra	47 186
Tesouro	2 619
Torixoreu	8 809

Source: IBGE.

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In terms of basic infrastructure, around 80% of urban households in Sinop have treated water, with the remaining 20% using water from semi-artesian wells or cisterns. More than 85% have garbage collection and approximately 60% have sewage disposal, with the remaining 40% mostly using rudimentary cesspits. Almost all urban roads have asphalt paving and public lighting (SNIS, 2021). Fig. 4 shows the population density between 1985 (Fig. 4a) and 2024 (Fig. 4b).

Figure 4 - Top view of the city of Sinop in 1985 (A) and 2024 (B).

Source: Google Earth Pro. Adapted by the authors.

4.3 Analysis of land cover changes

The materials initially generated were the maps of land use and cover, as shown in Fig. 5, showing the graphical evolution in the transformation of areas mostly made up of forests in 1985, by farming in the following years. The most aggressive transformation occurred between 1995 and 2005, from 74.49% forest areas to 44.33%. Coincidentally, this is the period identified with the highest rates of deforestation in Mato Grosso, according to the PRODES Amazônia program. In Fig. 5, the areas corresponding to forests and agriculture are identified in green and pink, respectively.

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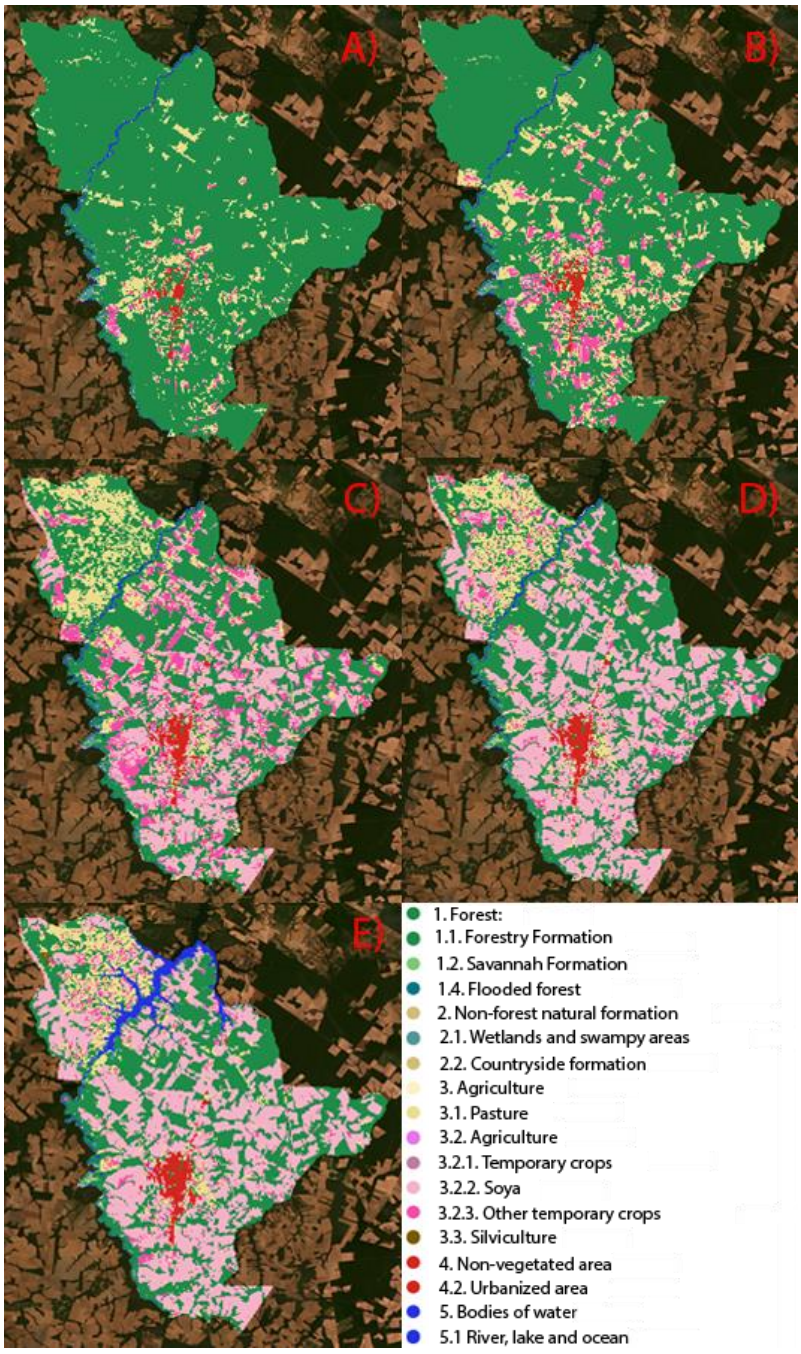
Figure 5 - Territorial development of Sinop in 1985 (A), 1995 (B), 2005 (C), 2015 (D) and 2022 (E).



Source: MapBiomas. Adapted by the authors.

From Fig. 5, quantitative data was extracted from Mapbiomas and Table 1 was developed. This table shows the evolution of farming in the Sinop region. Between 1985 and 1995 there was an increase of only 12.08% in the area used for farming, with a quantitative jump of almost 30% between 1995 and 2005. From 2005 onwards, the areas used for farming increased by only 4%, while the areas used for forests fell by approximately 8%. The non-vegetated area (in red in Fig. 5) is associated with urbanization activities, being only 0.84% in 1985 and 2.17% in 2022.

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In 1988, the beginning of the PRODES series recorded an estimated deforestation rate of 21,050 km². From 1989 onwards, there was a downward trend in annual deforestation rates, as illustrated in Figure 2 and corroborated by Table 1. This decrease can be attributed to the hyperinflation and economic recession that prevailed during the period, limiting the capital available for investment in agricultural activities. According to Moran *et al*. (2008) and Fearnside (2005), the sensitivity of owners of large estates to economic fluctuations, particularly inflation rates and land prices, contributed significantly to the reduction in deforestation between the second half of the 1980s and the early 1990s. Although inflation had a positive impact on the reduction of deforestation between the late 1980s and early 1990s, there was also a restriction on agricultural subsidies and a reduction in the implementation of new settlement and highway projects by the federal government, slowing the expansion of deforestation (Alencar *et al.*, 2004).

Table 1 - Coverage percentages by Class between 1985 and 2022 - Sinop-MT.

	Sinop 1985	Sinop 1995	Sinop 2005	Sinop 2015	Sinop 2022
Forest	86.95%	74.49%	44.33%	41.09%	36.74%
Agriculture	10.85%	22.93%	52.86%	55.86%	56.92%
Non-vegetated forest	0.84%	1.32%	1.61%	1.96%	2.17%
Non-forest natural formation	0.61%	0.43%	-	-	1.15%
Body of water	0.75%	0.83%	0.75%	0.72%	3.02%

Source: MAPBIOMAS, 2024.

With the implementation of the Real Plan and the reduction in inflation, deforestation peaked in 1995, lasting until 2004 with the increased incentive to expand the production of agricultural commodities (Fearnside, 2005). As mentioned above, the PPCDAm in 2004 played a fundamental role in forest conservation, along with other public policies implemented by the federal government, such as the TAC.

5 CONCLUSIONS

It is extremely important to understand the dynamics of deforestation and its relationship with the production scenario, as well as the interference exerted on the environment. Only in this way will we be able to improve the climate emergency scenario we find ourselves in.

Despite the growth in urbanized areas, agriculture is the class of land cover with the most significant increase. Between 1995 and 2005, there was an advance in agriculture in the region, related to the economic boom of the Real Plan, and encouraged by the federal government for territorial expansion in the northern region of the state of Mato Grosso. However, in 2004, monitoring programs were created to contain deforestation in the Legal Amazon, putting the brakes on agricultural expansion between 2005 and 2022.

We conclude by highlighting the importance of the Brazilian Forest Code, which determines that 80% of forested areas on rural properties must be conserved as a legal reserve, functioning as a legal mechanism for protecting natural heritage, given that the Amazon Forest,

considering its relation to biodiversity, the size of the river basin, among other riches, is defined as the world's greatest natural heritage.

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