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# Analysis of Agricultural Expansion and Deforestation in the Legal Amazon: A Spatio-Temporal Perspective (1985-2023) in Lucas do Rio Verde-MT

**Érica Lemos Gulinelli**
Professora Doutora, UNIVAG, Brasil
erica.gulinelli@univag.edu.br
https://orcid.org/0000-0002-6003-3504

**Jessica Seabra**
Professora Doutora, UNIVAG, Brasil
jessica.seabra@univag.edu.br
https://orcid.org/0000-0002-5890-5676

**Rosana Lia Ravache**
Professora Doutora, UNIVAG, Brasil
rosana@univag.edu.br
https://orcid.org/0000-0003-2900-8850

**Nátali de Paula**
Mestranda, UNIVAG, Brasil
arquitetanatalidepaula@gmail.com
https://orcid.org/0009-0006-1569-6268

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# Análise da Expansão Agrícola e Desflorestamento na Amazônia Legal: Uma Perspectiva Espaço-Temporal (1985-2023) em Lucas do Rio Verde-MT

**RESUMO**

Nas últimas quatro décadas, o avanço exponencial das atividades agrícolas em Mato Grosso vem ocasionando grandes mudanças no uso e cobertura do solo. Embora legislações ambientais estivessem em vigor, apenas em 2004 foram implementados instrumentos regulatórios mais eficazes para frear o desmatamento na Amazônia Legal. Este estudo visou realizar uma análise espaço-temporal do município de Lucas do Rio Verde – MT, considerando o impacto das políticas de ocupação da Amazônia Legal Brasileira sobre as dinâmicas de uso do solo. O recorte temporal abrange o período de 1985 a 2023, com dados coletados via plataforma MapBiomas e relatórios socioeconômicos do Instituto Brasileiro de Geografia e Estatística (IBGE). Os resultados indicam um avanço expressivo da agricultura e o consequente desmatamento, especialmente entre 1985 e 1995, motivado pelos incentivos governamentais que promoviam a migração para o interior de Mato Grosso desde a década de 1970, oferecendo financiamento e benefícios para estimular o plantio de culturas e a pecuária bovina. A análise evidencia como o uso agrícola na Amazônia Legal não apenas alterou a cobertura vegetal, mas também gerou novos embates legislativos sobre o uso sustentável das florestas. Conclui-se, portanto, que as atividades agrícolas na região exigem um monitoramento contínuo e políticas mais robustas para assegurar a preservação ambiental, além de uma gestão integrada que alie o desenvolvimento econômico à sustentabilidade da cobertura florestal e à regulação climática global.

**PALAVRAS-CHAVE**: Mudanças antrópicas. Cobertura do solo. Preservação ambiental.

# Analysis of Agricultural Expansion and Deforestation in the Legal Amazon: A Spatio-Temporal Perspective (1985-2023) in Lucas do Rio Verde-MT

**ABSTRACT**

Over the past four decades, the exponential growth of agricultural activities in Mato Grosso has led to major changes in land use and land cover. Although environmental legislation was in force, it was only in 2004 that more effective regulatory instruments were implemented to curb deforestation in the Legal Amazon. This study aimed to conduct a spatial-temporal analysis of the municipality of Lucas do Rio Verde, Mato Grosso, considering the impact of land use policies in the Brazilian Legal Amazon on land use dynamics. The time frame covers the period from 1985 to 2023, with data collected via the MapBiomas platform and socioeconomic reports from the Brazilian Institute of Geography and Statistics (IBGE). The results indicate a significant advance in agriculture and the consequent deforestation, especially between 1985 and 1995 motivated by government incentives that promoted migration to the interior of Mato Grosso since the 1970s, offering financing and benefits to stimulate the planting of crops and cattle ranching. The analysis highlights how agricultural use in the Legal Amazon has not only altered the vegetation cover, but has also generated new legislative conflicts over the sustainable use of forests. It is therefore concluded that agricultural activities in the region require continuous monitoring and more robust policies to ensure environmental preservation, in addition to integrated management that combines economic development with the sustainability of forest cover and global climate regulation.

**KEYWORDS:** Anthropogenic changes. Land cover. Environmental preservation.

# Análisis de la expansión agrícola y la deforestación en la Amazonía legal: una perspectiva espacio-temporal (1985-2023) en Lucas do Rio Verde-MT

**RESUMEN**

Durante las últimas cuatro décadas, el avance exponencial de las actividades agrícolas en Mato Grosso ha provocado importantes cambios en el uso y la cobertura del suelo. Si bien la legislación ambiental estaba vigente, no fue hasta 2004 que se implementaron instrumentos regulatorios más efectivos para frenar la deforestación en la Amazonía Legal. Este estudio tuvo como objetivo realizar un análisis espacio-temporal del municipio de Lucas do Rio Verde –

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MT, considerando el impacto de las políticas de ocupación en la Amazonía Legal brasileña en la dinámica de uso del suelo. El horizonte temporal abarca el período de 1985 a 2023, con datos recopilados a través de la plataforma MapBiomas e informes socioeconómicos del Instituto Brasileño de Geografía y Estadística (IBGE). Los resultados indican un avance significativo de la agricultura y la consecuente deforestación, especialmente entre 1985 y 1995, motivado por incentivos gubernamentales que promovieron la migración hacia el interior de Mato Grosso desde la década de 1970, ofreciendo financiamiento y beneficios para incentivar la siembra de cultivos y la ganadería. El análisis destaca cómo el uso agrícola en la Amazonía Legal no solo cambió la cobertura vegetal, sino que también generó nuevos conflictos legislativos sobre el uso sostenible de los bosques. Se concluye, por tanto, que las actividades agrícolas en la región requieren un seguimiento continuo y políticas más robustas para asegurar la preservación ambiental, además de una gestión integrada que combine el desarrollo económico con la sostenibilidad de la cubierta forestal y la regulación climática global.

**PALABRAS CLAVE:** Cambios antropogénicos. Cobertura del suelo. Preservación del medio ambiente.

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## 1 INTRODUCTION

In the Brazilian Midwest, the State of Mato Grosso encompasses the third-largest territorial area in the country, with approximately 900,000 km², a population of 3,836,399 people, and a population density of 4.05 inhabitants/km² (IBGE, 2022). The territory of Mato Grosso comprises three biomes: the Cerrado, the Pantanal, and, the most extensive, the Amazon, which spans over 480,000 km². The Amazon biome has been protected by federal law since 1965, requiring rural properties to preserve 35% of savanna areas and 80% of forests.

The Legal Amazon covers most of Brazil's territory and is the largest contiguous tropical rainforest in the world. Furthermore, various studies have highlighted its contribution to the hydrological cycle, evapotranspiration, and carbon storage (Nobre, 2014; Marengo et al., 2018). However, increasing deforestation and fires have been impacting biodiversity, water resources, and public health.

In the northern region of Mato Grosso, environmental problems resulting from deforestation are occurring. These issues stem from various factors, particularly the conversion of forest areas into agricultural or livestock lands and the illegal logging of timber (Fearnside, 2010). This significant change in land use and cover has led to biodiversity loss, soil degradation, and, above all, climate change. Multiple studies show that the climate is closely linked to land use (Dos Reis et al., 2021; Malhi et al., 2008).

To populate northern Mato Grosso, political projects were created in the 1970s to encourage migration (Brum et al., 2021). This is evidenced by the demographic increase between 1950 and 2000, during which the population growth in the Midwest was 657.8%, compared to Brazil's overall growth of 225.4% (Girardi, 2008). According to Cunha (2002, p. 11), Mato Grosso embodies “the complexity of the relationship between productive structures and demographic occupation.” Agricultural activity has benefited from the predominantly flat terrain in this region, which facilitated the conversion of forested areas for planting soybeans, corn, and cotton, as well as cattle farming.

With the opening of the BR-163 Highway in the 1970s, the municipality of Lucas do Rio Verde received its first settlers. Through the PROTERRA (Program for Land Redistribution and Agro-Industrial Stimulation in the North and Northeast), families were financed to purchase 25-hectare plots for farming. Only in 1986 was the urban nucleus of Lucas do Rio Verde elevated to a district of Diamantino, and in 1988, it gained political-administrative autonomy as a municipality with 5,500 inhabitants (Lacerda et al., 2020). Currently, according to the 2022 IBGE census, the municipality has a population of 83,798 inhabitants (IBGE, 2022). The notable demographic and urban dynamism is directly linked to the expansion of soybean production in the municipality, alongside other agricultural activities (Caparroz, 2010). Rapid population growth resulted in a series of municipal laws to expand the urban perimeter and public roads, culminating in the Urban Planning Master Plan for reordering the urban network between 2005 and 2007.

This study aims to investigate the influence of migration in Lucas do Rio Verde – MT on land use and cover by presenting a spatiotemporal analysis from 1985 to 2023 and discussing its impacts. To this end, the article’s findings are structured into four parts. The first part examines

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the evolution of deforestation in Mato Grosso, exploring how agricultural expansion and economic activities have affected the state's forest cover. The second part focuses on land cover changes in Lucas do Rio Verde, a municipality exemplifying the rapid process of converting natural areas into agricultural use. The third part discusses the importance of the Amazon Rainforest for climate regulation in Brazil, highlighting its crucial role in hydrological cycles and carbon sequestration. Finally, the fourth part addresses legislative disputes surrounding forest laws, emphasizing the conflicts between the agricultural sector and environmental preservation regulations, and highlighting the interests and political pressures on the Forest Code.

## 2 OBJECTIVES

This article aims to investigate the migration process in Lucas do Rio Verde – MT and its influence on land use and cover through a study that analyzes the spatiotemporal context from 1985 to 2023 and discusses its impacts. Additionally, it seeks to examine the role of public policies in this process.

## 3 METHODOLOGICAL PROCEDURES

According to Pessoa et al. (2013), spatiotemporal analysis is often used to assess changes in vegetation cover over time. For this study, satellite images (rasters) were collected from the MapBiomas platform to analyze land use and cover within the municipal perimeter of Lucas do Rio Verde – MT. Quantitative and qualitative data were extracted and evaluated for the years between 1985 and 2023, with a temporal interval of 10 years for comparative analysis. The interpretation of these images allowed for the assessment of agricultural expansion and the identification of patterns in the conversion of native vegetation into agricultural production areas.

In parallel, the research included a brief literature review on the Amazon as a critical element for climate regulation, as well as readings on federal forest legislation, particularly the Forest Code, and the disputes surrounding this legislation. This was complemented by a critical analysis of the relationship between deforestation, agricultural development, and environmental sustainability.

## 4 RESULTS

### 4.1 Evolution of Deforestation in Mato Grosso

To analyze the role of agribusiness in land use and cover in the municipality of Lucas do Rio Verde, it is essential to understand the dynamics of deforestation over recent decades in Mato Grosso and, specifically, in the Legal Amazon region. For monitoring deforestation, the Federal Government implements the Project for Monitoring Deforestation in the Legal Amazon by Satellite (PRODES). According to data obtained between 1988 and 2023, a sharp increase in

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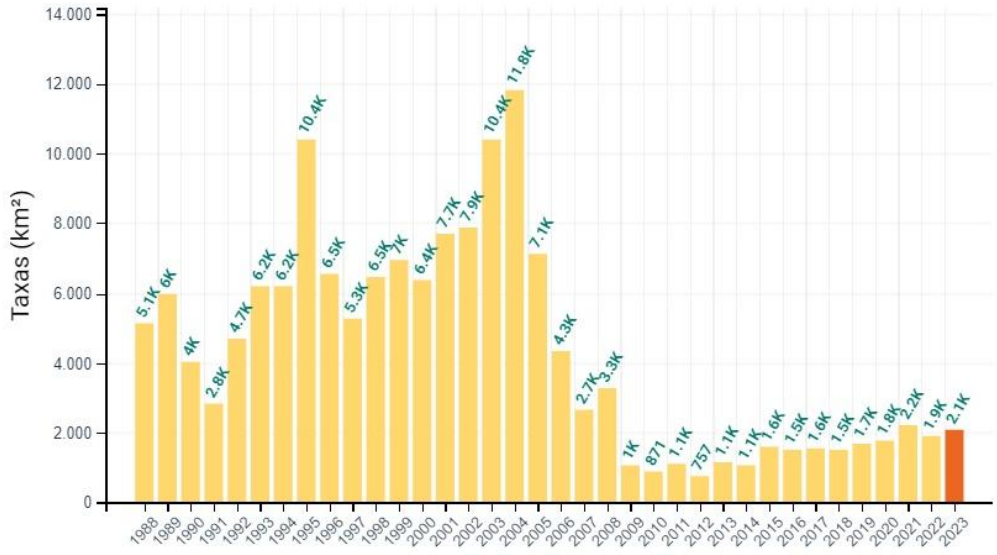
deforestation is evident between 1988 and 2004, followed by a decline starting in 2005 (Figure 1). The annual average deforestation rate since 1988 has been 1,100 km².

Figure 1 – PRODES – 1988 to 2023. Deforestation in Mato Grosso




Source: INPE (2023).

The decline in deforestation in Mato Grosso occurred following the implementation of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) in 2004. This plan was based on integrated actions involving federal, state, and municipal agencies, as well as civil society and the private sector (Brasil, 2004). As a result of this initiative, DETER[1] was created to monitor changes in forest cover in real time, enabling greater efficiency for enforcement agencies (DETER, 2020). Additionally, the reduction was influenced by changes in credit allocation policies by the Central Bank of Brazil, which began providing loans only to rural producers with no records of illegal deforestation. Furthermore, a new policy by the Federal Public Prosecutor's Office (MPF) required slaughterhouses to purchase meat only from non-deforested areas, formalized through a Term of Adjustment of Conduct (TAC) for implementing this measure (Fearnside, 2020; Macedo et al., 2012).

### 4.2 Analysis of Land Cover Transformations in Lucas do Rio Verde

According to the 2022 IBGE census, Lucas do Rio Verde has a population of 83,798 inhabitants and a population density of 22.80 inhabitants/km², representing a significant twelvefold increase compared to the 1991 demographic census. Figure 2 illustrates urban

[1] DETER is a rapid survey of alerts for evidence of changes in forest cover in the Amazon, conducted by the National Institute for Space Research (INPE). This system was created to support the monitoring and control of deforestation and forest degradation, providing essential data to the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) and other responsible environmental agencies.Cf.: http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/deter/deter

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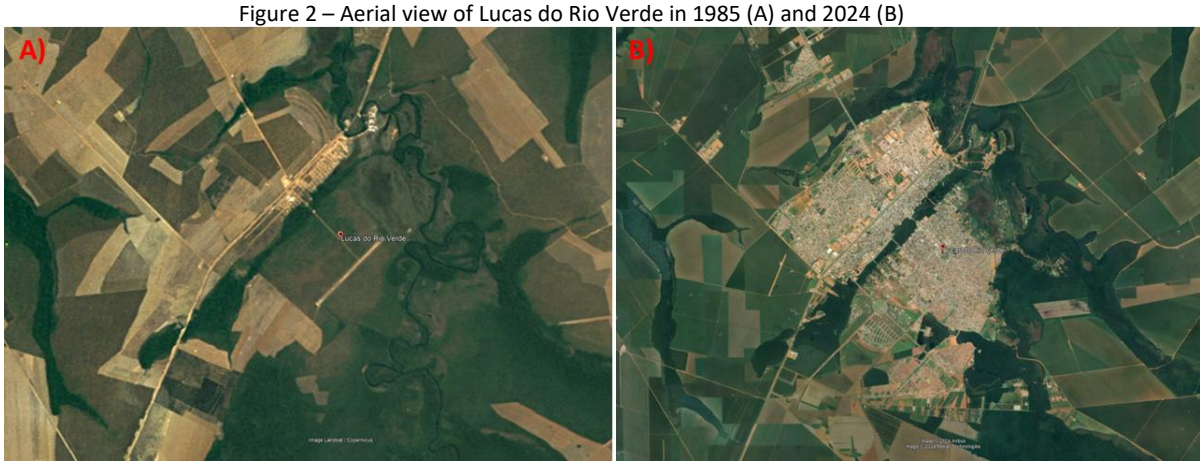
expansion from 1985 to 2024.

Figure 2 – Aerial view of Lucas do Rio Verde in 1985 (A) and 2024 (B)




Source: Google Earth Pro. Adapted by the authors.

The materials initially generated for the research were land use and cover maps, as shown in Figure 3, illustrating the graphical evolution of areas predominantly composed of forests in 1985, transitioning to agriculture and livestock in subsequent years. The most aggressive transformation occurred between 1995 and 2005, with forest areas decreasing from 74.49% to 44.33%. Coincidentally, this period corresponds to the highest deforestation rates recorded in Mato Grosso, according to the PRODES Amazon program[2]. In Figure 3, forest and agricultural areas are represented in green and pink, respectively.

Based on data extracted from MapBiomas, it was possible to analyze the percentages of land use and cover conversion, as shown in Table 1. Between 1985 and 1995, the most significant increase in areas allocated to agriculture and livestock occurred, rising from 40.91% to 55.87%, impacting forest percentages, which decreased from 53.52% to 41.19% by 1995. Between 1995 and 2005, deforestation and agricultural expansion continued at a rapid pace, reducing forest cover to 30.05% and increasing agricultural areas to 67.85% by 2005. However, after 2005, a slowdown in agricultural expansion was observed. The non-vegetated area (red in Fig. 3) increased from 0.79% to 1.24% by 2023, corresponding to urbanized areas, as expected with demographic growth, which gained momentum in 2008 with the establishment of BRF/Sadia in the municipality. In comparison, a study conducted by Souza et al. (2024) in Sinop-MT showed a reduction in forest cover from 86.95% in 1985 to 36.74% in 2022, while agricultural areas increased from 10.85% to 56.92% during the same period, demonstrating that the northern region of Mato Grosso has faced drastic changes in land use and cover over the past decades.

Figure 3 –Territorial development of Lucas do Rio Verde in 1985 (A), 1995 (B), 2005 (C), 2015 (D), and 2023 (E).

[2] PRODES Program: The PRODES project monitors deforestation by clear-cutting in the Brazilian Legal Amazon through satellite imagery and has been producing annual deforestation rates since 1988. These rates are used by the Brazilian government for establishing public policies. (See: http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes)

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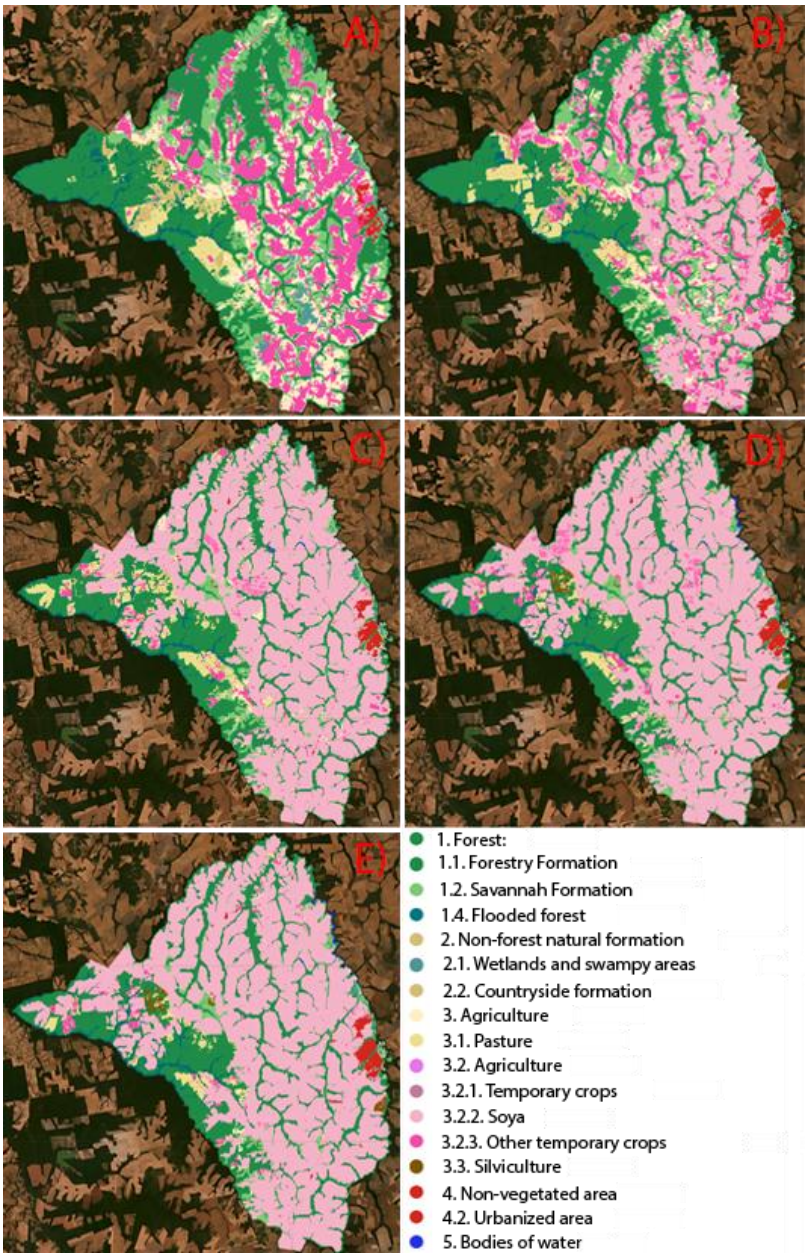


Source: MapBiomas. Adapted by the authors.

Table 1: Percentages of coverage by class between 1985 and 2023 – Lucas do Rio Verde - MT.

| | 1985 | 1995 | 2005 | 2015 | 2023 |
|---|---|---|---|---|---|
| Forest | 53.52% | 41.19% | 30.04% | 28.27% | 27.75% |
| Agriculture and livestock | 40.91% | 55.87% | 67.85% | 69.74% | 70.21% |
| Shrub and Herbaceous Vegetation | 4.64% | 1.78% | 0.86% | 0.60% | 0.51% |
| Non-vegetated area | 0.79% | 0.99% | 1.04% | 1.11% | 1.24% |
| Waterbody | 0.14% | 0.17% | 0.21% | 0.28% | 0.29% |

Source: MapBiomas (2024).

The implementation of the Real Plan and the consequent reduction of inflation coincided with the peak of deforestation in 1995, persisting until 2004, driven by incentives for

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expanding agricultural commodity production (Fearnside, 2005). The PPCDAm, launched in 2004, played a crucial role in forest preservation, supported by other federal public policies, such as those mentioned in the TAC.

However, the modest growth rates of deforestation and agricultural expansion should not be interpreted as a substantial improvement or mitigation of environmental risks. Federal government data reveal that the average deforestation rate in monitored municipalities decreased from 6,847 km²/year between 2002 and 2008 to 1,049 km²/year from 2009 to 2016, representing an 85% reduction. Additionally, less than 2% of soybean crop expansion during this period occurred in deforested areas. Of the 4.5 million hectares cultivated in the 2016/2017 harvest, only 47,365 hectares were non-compliant with the commitments of the Soy Moratorium. (BRASIL, 2018).

Nevertheless, the Soy Moratorium Report[3] on the 2022/2023 harvest highlighted the increase in deforestation rates by state in the Amazon between 2009 and 2022, showing that the 2022 rate was the highest in the 14-year historical series, tripling compared to 2012, the lowest rate in the series. In Mato Grosso, deforestation in 2022 reached 198,246 hectares, compared to 74,932 hectares in 2012 (Soy Moratorium Report, 2024, p. 11). In the case of Lucas do Rio Verde, which is part of the present research, the study reported 1,780 hectares deforested between 2022 and 2023, of which 352 hectares were converted for soybean cultivation, representing 19.7% of local production from deforested areas (Soy Moratorium Report, 2024, p. 16).

### 4.3 Importance of the Amazon in Climate Regulation

The Amazon rainforest in Brazil remained largely preserved until the "modern" era of deforestation, which began with the inauguration of the Transamazonian Highway in 1970, facilitating access to the region (Fearnside, 2005). In this context, deforestation rates in Mato Grosso have been rising since the late 1980s, as shown in Figure 1, progressing at varying rates.

More recently, the state of Mato Grosso has undergone significant transformations over the past two decades: from a land considered hostile, it became Brazil's major agricultural hub. The region's agricultural development model, primarily focused on livestock and monocultures such as soy, aims to maximize production for export. Large farms, often controlled by conglomerates and international investors, dominate vast forested areas that are cleared to meet global commodity demands. Additionally, the expansion of agribusiness contributes to land concentration, intensifying land conflicts and pressuring traditional riverine and Indigenous communities to leave their lands.

The Amazon plays an essential role in climate regulation in Brazil and across South

[3] The Soy Moratorium is an agreement aimed at preventing the commercialization and financing of soy produced in areas deforested in the Amazon after July 22, 2008, aligning with the restrictions imposed by the Forest Code. This commitment arose due to pressure from civil society and the international market and was led by Abiove (Brazilian Association of Vegetable Oil Industries) and ANEC (National Association of Cereal Exporters), two key representative entities contributing to the regulatory compliance of the grain production chain. Currently, the Soy Working Group (GTS), responsible for coordinating and monitoring the moratorium, includes organizations such as Abiove, ANEC, Greenpeace, WWF, Conservation International, MMA, Banco do Brasil, and INPE, along with representatives from producers, buyers, civil society, and the government.

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America. Among the most critical phenomena generated by the forest are the so-called "flying rivers"—water vapor currents transported through the atmosphere that originate over the Amazon. These currents mainly stem from moisture brought by oceanic winds to northern Brazil. Upon entering the forest, this moisture is absorbed by the soil and trees, which release it in large quantities as vapor through evapotranspiration. This vapor forms moisture clouds that are carried westward by winds until they meet the Andes Mountains. Part of this moisture precipitates on the eastern slopes of the mountain range, feeding the headwaters of Amazonian rivers, while the rest is diverted southward. Thus, the flying rivers travel toward Brazil's Midwest, Southeast, and South regions, as well as neighboring countries. This cycle is crucial for maintaining water balance and ensuring regular rainfall, which is vital for agriculture, water supply, and the preservation of entire ecosystems (Silva and Rezende, 2022).

According to meteorologist Bruno Takeshi Tanaka Portela, a climate and environment expert at the National Institute for Amazonian Research (INPA), deforestation over the years has weakened this phenomenon, as it depends on the forests in the Northern Region to occur. Therefore, advancing deforestation in the Amazon directly threatens this regulatory function. With the loss of trees, the amount of water vapor released into the atmosphere decreases, weakening the "flying rivers" and reducing rainfall in regions that rely on this phenomenon for their economic activities and biodiversity maintenance.

The degradation of the forest to make way for agribusiness begins with logging, which facilitates fires on the ground. Deforestation releases large amounts of carbon stored in trees, increasing greenhouse gas emissions into the atmosphere. By reducing carbon storage capacity and increasing greenhouse gas emissions, deforestation exacerbates global warming, directly impacting global and regional climates. This climate imbalance intensifies extreme events such as prolonged droughts and floods, affecting ecosystems, communities, and economic sectors across South America.

Thus, preserving the Amazon is vital for maintaining biodiversity, local communities, and mitigating the climate crisis while ensuring the continent's water balance. Implementing conservation policies and strict deforestation control, supported by rigorous monitoring, is an urgent necessity to ensure that the Amazon continues to perform its role as a climate regulator, essential for Brazil's and the world's environmental and socio-economic well-being.

### 4.4 Disputes Over Forest Legislation

Since the arrival of colonizers in Brazil, nature has been viewed by some groups as an inexhaustible resource and, in the case of the Amazon Rainforest, as an "obstacle" to development. This predatory perspective still persists in certain regions of the country, where many consider it economically more advantageous to clear or burn new areas than to invest in sustainable land management and increased productivity. This exploitation model is reinforced by legislative initiatives that disregard sustainability and favor agricultural expansion, contradicting decades of development in Brazilian environmental legislation, particularly concerning the Forest Code.

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The history of the Forest Code reflects Brazil's trajectory of exploration and occupation, marked by a constant clash between sustainability and agricultural expansion. Since the first Forest Code was created in 1934 during the Getúlio Vargas administration, Brazil has sought to regulate the use of its forests. In 1965, a new version of the Code, sanctioned by President Castello Branco, set clear limits for preserving native vegetation on properties, including the creation of Permanent Preservation Areas (APPs), aiming to balance environmental conservation with territorial occupation.

With worsening deforestation in the Amazon, new measures were adopted. Provisional Measure 1.511 of 1996, during the Fernando Henrique Cardoso administration, increased the legal reserve requirement for forested areas in the Amazon region to 80%. However, in recent decades, the Forest Code has faced intense pressure from the agricultural sector, which, rather than adapting to environmental requirements, seeks to relax the legislation. The most recent revision of the Code, initiated in 2009 and culminating in Federal Law No. 12.651/2012, was influenced by the rural caucus, which aimed to reduce preservation obligations for short-term profits.

The 2012 Forest Code, still in effect, defines in Article 3, Item III:

> Legal Reserve: an area located within a rural property or possession (...) with the function of ensuring the sustainable economic use of natural resources, assisting in the conservation and rehabilitation of ecological processes, and promoting biodiversity conservation, as well as the shelter and protection of wildlife and native flora." (BRASIL, 2012).

Regarding legal reserve percentages on rural properties, the new Forest Code maintained the directives of MP 1.511/1996. For the Legal Amazon, Law No. 12.651/2012 establishes that 80% of forested areas on properties must be preserved, while in cerrado areas, 35% must be preserved, and in grassland areas, 20%. Despite these measures, some rural caucus members propose removing Mato Grosso from the Legal Amazon framework to apply the same federal law established for the cerrado.

Complementing federal legislation, Mato Grosso enforces stricter measures, such as State Law No. 11.861/2022, requiring 60% preservation in cerrado and grassland areas within the Pantanal.

Thus, in contrast to these efforts, Law No. 12,709/2024 was recently enacted, penalizing companies participating in the Soy Moratorium, an initiative that commits to not buying soy from areas deforested in the Amazon after 2008. This time limit is in accordance with the provision of article 67 of the Forest Code, which establishes that, for rural properties holding areas with up to four fiscal modules and native vegetation until July 22, 2022, in percentages lower than those provided for in article 12 of this regulation, the Legal Reserve would be constituted by the area occupied by native vegetation and all new conversions to alternative land use would be prohibited.

Thus, the new Law No. 12,709/2024, proposed by state deputy Gilberto Cattani, directly challenges these data. The law restricts tax incentives for companies that have signed the pact, discouraging commitments to zero deforestation. It represents the political strength of

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some members of the “ruralist bloc” and a setback in environmental conservation, discouraging voluntary practices by the private sector that seek to go beyond the requirements of the Forest Code and promote sustainable exploitation of the Amazon.

In addition to this law, there are several other projects that attempt to weaken the Forest Code, proposing changes that, in essence, seek to distort environmental legislation, rather than improve it. Political pressure to relax the legislation and the influence of sectors that prioritize immediate profits highlight the conflict between an unsustainable economic growth model and the need to protect the Amazon biome.

## 5. CONCLUSION

The study revealed the transformative impact of agriculture on vegetation cover in Lucas do Rio Verde, MT, between 1985 and 2023, providing a spatiotemporal analysis of changes driven by the expansion of agribusiness in the Legal Amazon. The results highlight that agricultural expansion significantly contributed to deforestation, especially between 1985 and 2004, a period marked by government incentives for agricultural and livestock development and the opening of forested areas for cultivation and ranching. This process was further stimulated by economic incentive policies associated with the Plano Real, which bolstered the production of agricultural commodities in the region, increasing the conversion of natural areas into productive lands.

The implementation of monitoring and conservation measures from 2004 onward, particularly the PPCDAm, combined with satellite technology through the PRODES system and the establishment of DETER, played a decisive role in reducing deforestation rates. These initiatives, alongside policies such as the TAC, established to regulate the trade of agricultural products and curb the circulation of goods from non-preserved areas, contributed to more effective control of agricultural and livestock exploitation.

In summary, the study underscores the importance of consistent public policies and measures to ensure compliance with the Forest Code to preserve the Amazon, which mandates maintaining 80% of forest cover on rural properties. The Amazon’s fundamental role as a natural heritage and a vital climate regulator for Brazil and South America was emphasized, demonstrating its indispensable role in regulating rainfall and mitigating global warming.

The research concludes that, beyond sustainable management strategies, it is urgent to implement strict measures to curb deforestation. In the face of the global climate crisis, only assertive policies and intensive oversight can preserve the Amazon and its ecosystem services, which are essential for water balance, biodiversity, and the climate of all South America.

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## DECLARATIONS

### AUTHOR CONTRIBUTIONS

The participation of each author in the manuscript is described using the following criteria:

- Study Conception and Design: Érica Lemos Gulinelli, Jessica Seabra, and Rosana Lia Ravache
- Data Curation: Érica Lemos Gulinelli, Jessica Seabra, and Rosana Lia Ravache
- Formal Analysis: Érica Lemos Gulinelli and Jessica Seabra
- Funding Acquisition: No funding was received
- Investigation: Érica Lemos Gulinelli, Jessica Seabra, and Rosana Lia Ravache
- Methodology: Érica Lemos Gulinelli and Jessica Seabra
- Writing - Initial Draft: Érica Lemos Gulinelli, Jessica Seabra, and Nátali de Paula
- Writing - Critical Review: Érica Lemos Gulinelli, Jessica Seabra, and Rosana Lia Ravache
- Final Review and Editing: Érica Lemos Gulinelli
- Supervision: Érica Lemos Gulinelli and Jessica Seabra

### CONFLICT OF INTEREST STATEMENT

We, Érica Lemos Gulinelli, Jessica Seabra, Rosana Lia Ravache, and Natali de Paula, hereby declare that the manuscript titled *"Analysis of Agricultural Expansion and Deforestation in the Legal Amazon: A Spatial-Temporal Perspective (1985-2023) in Lucas do Rio Verde-MT"* adheres to the following:

1. Financial Links: There are no financial ties that could influence the results or interpretation of the work.
2. Professional Relationships: There are no professional relationships that could impact the analysis, interpretation, or presentation of the results.
3. Personal Conflicts: There are no personal conflicts of interest related to the content of the manuscript.