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SPATIO-TEMPORAL ANALYSIS OF LAND USE AND COVERAGE IN THE MUNICIPALITY OF GUIA LOPES DA LAGUNA - MS

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RESUMEN. El estudio se centra en el municipio de Guia Lopes da Laguna (MS), utilizando datos de Mapbiomas (1985-2020) para investigar la dinámica del uso y cobertura del suelo, identificando procesos de expansión, conversión y contracción agrícola. El análisis reveló una reducción gradual de las áreas de vegetación natural, un aumento inicial de los pastos, seguido de una disminución después de 2015, y una reciente expansión de las áreas agrícolas, principalmente para el cultivo de soja y maíz. El artículo también analiza el impacto de estos cambios en la economía local, basada en la agricultura, y la intensificación agrícola observada en los últimos años. Se concluye que, si bien hay una disminución de la presión por nuevas áreas agrícolas, la diversificación e intensificación de cultivos requieren más estudios para promover el desarrollo sostenible.

Palabras-clave: Detección remota; Geoprocesamiento; Desarrollo Rural; Sostenibilidad.

RESUMO. O estudo foca no município de Guia Lopes da Laguna (MS), utilizando dados do Mapbiomas (1985-2020) para investigar a dinâmica de uso e cobertura da terra, identificando processos de expansão, conversão e retração agrícola. A análise revelou uma redução gradual das áreas de vegetação natural, um aumento inicial das pastagens, seguido por uma diminuição após 2015, e uma recente expansão de áreas agrícolas, principalmente para o cultivo de soja e milho. O artigo também discute o impacto dessas mudanças na economia local, baseada na agropecuária, e a intensificação agrícola observada nos últimos anos. Conclui-se que, embora haja uma diminuição na pressão por novas áreas agrícolas, a diversificação e intensificação das culturas requerem mais estudos para promover um desenvolvimento sustentável.

Palavras-chave: Sensoriamento Remoto; Geoprocessamento; Desenvolvimento Rural; Sustentabilidade.

ABSTRACT. The study focuses on the municipality of Guia Lopes da Laguna (MS), using data from Mapbiomas (1985-2020) to investigate the dynamics of land use and coverage, identifying processes of agricultural expansion, conversion, and contraction. The analysis revealed a gradual reduction in areas of natural vegetation, an initial increase in pastures, followed by a decrease after 2015, and a recent expansion of agricultural areas, mainly for the cultivation of soybeans and corn. The article also discusses the impact of these changes on the local economy, based on agriculture, and the agricultural intensification observed in recent years. It concludes that, although there is a decrease in pressure for new agricultural areas, the diversification and intensification of crops require more studies to promote sustainable development.

Keywords: Remote Sensing; Geoprocessing; Rural Development; Sustainability.

1. INTRODUCTION

Information on land use and cover is important in research fields involving urban planning, climate monitoring, food security, and ecosystem protection (Lin *et al.*, 2018; Zhang; Liu; Henebry, 2019). Remote sensing products, such as satellite images, are sources of information for the production of cartographic products, including land use and land cover maps (Alshari; Gawali, 2021).

Initially, maps derived from remote sensing techniques contributed to identifying environmental problems and implementing public policies. More recently, interest has expanded to applications in controlling and evaluating these policies, with the main products derived from remote sensing being Earth observation (Räsanen; Virtanen, 2019). Some multi-institutional initiatives have produced detailed, regular, and high-precision mappings for monitoring the use and coverage of Brazilian territory, such as the projects "TerraClass" (Almeida *et al.*, 2016), "Monitoring the Coverage and Use of Land in Brazil" (IBGE, 2022), and "Annual Mapping of Land Use and Coverage in Brazil" (MapBiomas, 2023). For example, the products derived from these initiatives can be employed in secondary analyses, such as agricultural dynamics.

In recent centuries, there has been a significant increase in land cover dynamics, primarily due to activities such as agriculture, forestry, and urban expansion (Lambin and Geist, 2006). These changes have become major components of global environmental transformation and represent the impact of human activity on biodiversity conservation (Falcucci; Maiorano; Boitani, 2007), water quality (Yesuph, 2019), the availability of ecosystem services (Lawler *et al.*, 2014), and carbon stock in ecosystems (Legesse; Degefa; Soromessa; Bloor, 2024), among others. Such changes also impact the spatial pattern of the landscape, as they modify ecological processes at local, regional, and global levels (Allen *et al.*, 2014). Therefore, understanding these changes is crucial for a more accurate analysis of regional agricultural dynamics, providing information to support strategic decisions by local public agents and other stakeholders involved in rural areas, toward the sustainable development of these regions.

This work aims to investigate the dynamics of land use and cover in the municipality of Guia Lopes da Laguna (MS), which is one of the Agrotechnological Districts (DAT) studied by the Scientific Centre for Development in Digital Agriculture, CCD-AD/SemeAr (Embrapa-Fapesp, 2023), using data produced by the Mapbiomas Project (2023), between 1985 and 2020, and to identify processes of expansion, conversion and retraction that characterize the agricultural dynamics in the municipality's landscape.

2. MATERIAL AND METHODS

2.1 Study area

Guia Lopes da Laguna (GLL) is a municipality in the southwest mesoregion of the state of Mato Grosso do Sul, with an area of 122,543 ha and a population of 9,940 people (IBGE, 2023). The region's climate is tropical with dry winters and rainy summers, type Aw in the Köppen classification, and the average annual rainfall over the last 24 years was 1,442 mm according to data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). The municipality has predominantly flat and gently undulating terrain, with some areas of strongly undulating terrain to the south (Figure 1).

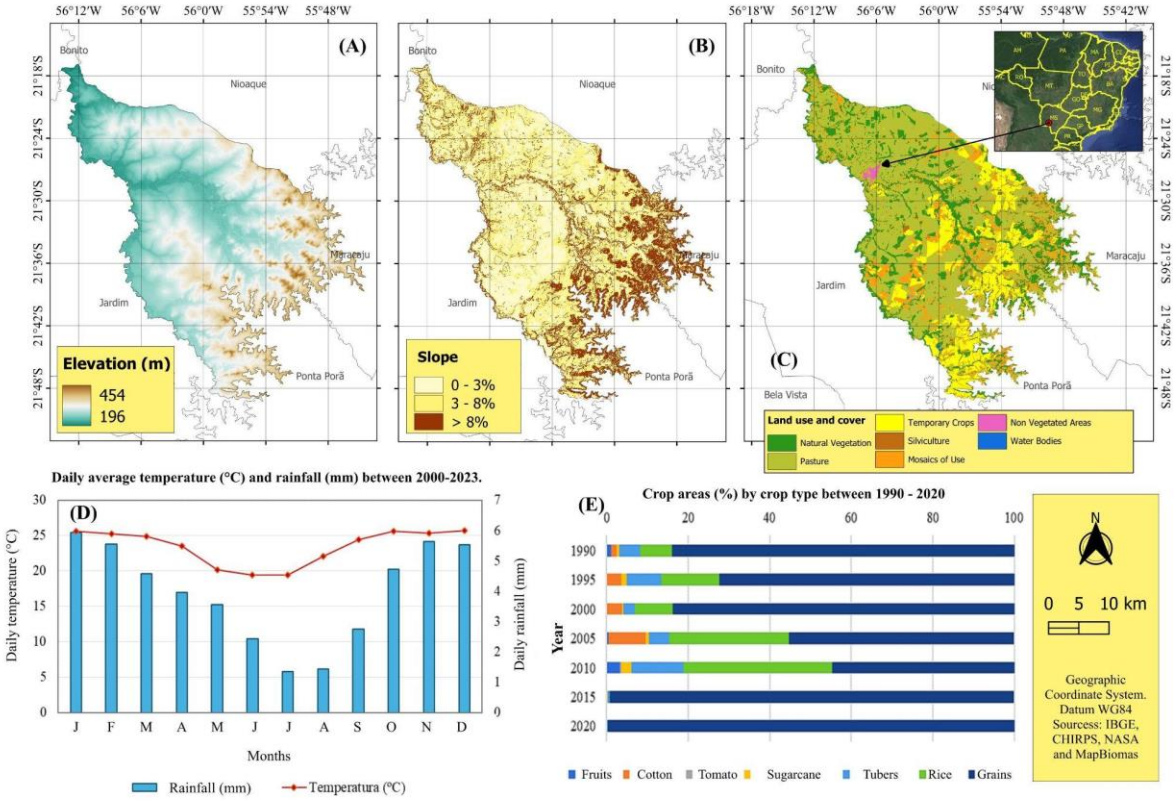

Figure 1. Characterization of the municipality of Guia Lopes da Laguna, MS. In which: (A) elevation map (m) and (B) slope map (%); (C) location map and main land use and cover classes; (D) average daily temperature (°C) and precipitation (mm) in January to December, between 2020 and 2023; (E) proportion (%) of agricultural areas according to crop types, between 1990 and 2020. Sources: Copernicus GLO-30 Digital Elevation Model, Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), *Mapbiomas* (2023) e Municipal Agricultural Production (PAM) of the Brazilian Institute of Geography and Statistics (IBGE).

2.2 Analysis of transitions and processes of agricultural expansion, conversion and retraction

The first step in generating the transition maps and agricultural dynamics processes involved acquiring data from the 8th collection of the MapBiomas Project (2023) via Google Earth Engine (GEE) for the municipality of Guia Lopes da Laguna (MS) for the years 1985, 1990, 1995, 2000, 2005, 2010, 2015 and 2020. The legend of the use and cover maps was then reclassified into eight classes: areas of natural vegetation (ANV), pastures (PAS), temporary

crops (TC), perennial crops (PC), forestry (FOR), use mosaics (MOS), non-vegetated areas (NVA) and bodies of water (WB). The MOS class refers to locations where agriculture and pasture predominantly occur, typically smaller fields where the classifications do not differentiate between these land uses. Table 1 illustrates the unified classes used for reclassifying the legend.

MapBiomas legend codes	Final classes (ID)
3, 4, 5, 49, 11, 12, 32, 29, 50, 13	Areas of natural vegetation (1)
15	Pastures (2)
19, 39, 20, 40, 62, 41	Temporary crops (3)
36, 46, 47, 48, 35	Perennial crops (4)
9	Forestry (5)
21	Mosaics of use (6)
23, 24, 30, 25	Non-vegetated areas (7)
26, 33, 31	Water bodies (8)

Table 1. MapBiomas original and reclassified land use and land cover class codes.
*The legend of the eighth collection of the MapBiomas Project can be viewed at: https://brasil.mapbiomas.org/wp-content/uploads/sites/4/2023/08/Legenda-Colecao-8-LEGEND-CODE.pdf

In the next step, the reclassified files were used to create transition maps of use and cover classes every five years (1985-1990, ..., 2015-2020). For the output pixels to identify the initial and final year class, the initial class value was multiplied by 10 and added to the final class value. Thus, pixels with values of 12 and 34, for example, indicate transitions from natural vegetation (1) to pasture (2) and from temporary crops (3) to perennial crops (4), respectively. Finally, the transition maps were reclassified to identify the expansion, conversion, and retraction of agricultural areas every five years. The processes of agricultural dynamics were identified using a transition matrix drawn up as follows: a) expansion: transitions from non-agricultural targets (natural vegetation, non-vegetated areas, and bodies of water) to agricultural targets (pasture, temporary and perennial crops, forestry, and mosaics of use); b) retraction, inverse transitions to those of expansion; and c) conversion, which represents transitions between agricultural classes.

The steps of reclassifying the original maps and generating transition maps and maps of dynamic processes were carried out using the Google Collaboratory environment, in Python language, and the resources of the rasterio and numPy libraries. The transitions were also analyzed using a Sankey diagram, a useful tool for detecting changes in land use and cover using comparative flows between categories from one moment to the next (Cuba, 2015), generated in the R environment. To complement the analysis of the dynamics processes, we also used temporal data from the Normalized Difference Vegetation Index (NDVI), extracted from the https://www.satveg.cnptia.embrapa.br/platform.

3. RESULTS AND DISCUSSION

3.1. Dynamics of land use and cover

The land use and cover dynamic analysis revealed a gradual decrease in natural vegetation areas from 38.5 thousand ha in 1985 to 24.1 thousand ha in 2020. After years of expansion and consolidation as the predominant land use and cover class, pasture areas started to decline from 2015 onwards. In 1985 it totaled 52.1 thousand ha, reaching a peak of 76 thousand ha in 2005 and falling to 579 thousand ha in 2020. Between 1985 and 2010, mosaic areas dropped from

30.3 to 16.1 thousand ha. However, between 2015 and 2020, these areas increased again, reaching 22.7 thousand ha, generated mainly from conversion processes (pasture → mosaic), and some expansion over native vegetation. Up until 2010, areas of pasture and mosaic expanded over areas of natural vegetation, in addition to conversion processes between them (Figure 2). Guia Lopes da Laguna's economy is based on agriculture and livestock, and its area is occupied by pastures, as shown in Figure 1. However, in 2022, the municipality produced 42,6 thousand ha of annual crops, mainly soybeans and corn, and only 10 ha of perennial crops (IBGE, 2023). Since 2010, the municipality has been losing out on agricultural diversity, with grain production predominating.

Since 1960, the Midwest has emerged as one of the primary regions experiencing significant growth in cattle farming within the country (Teixeira & Hespanhol, 2014). This dynamic was reflected most significantly in the state of Mato Grosso do Sul, with repercussions in Guia Lopes da Laguna, where pastures occupied an average of 65,900 ha throughout the analysis period (1985-2020), i.e. around 54% of the municipality's entire area. This is more than double the area considered suitable for pasture, according to Agroclimatic Zoning (Zaroni *et al*, 2009), which was 24,900 ha. According to the authors of the study, this is due to a few main factors: i) the location of the region in the center region of the country, which favors links with large consumer markets located in other areas of Brazil, especially in the Southeast; ii) the introduction of planted pastures, mainly of the Brachiaria genus; and iii) the relocation of cattle slaughtering units from the South and Southeast to the Midwest.

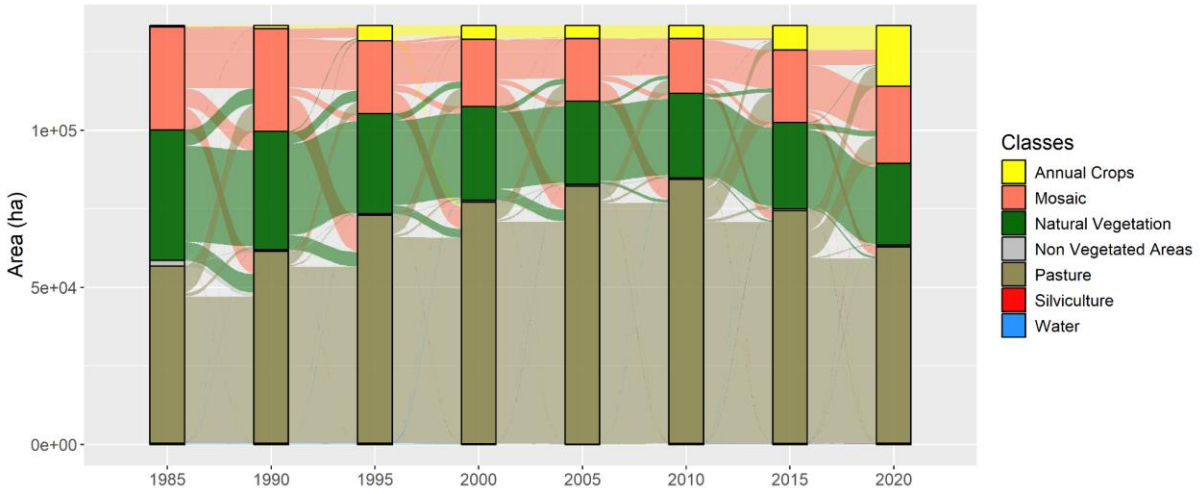

Figure 2. Sankey diagram representing land use and cover dynamics in Guia Lopes da Laguna, Mato Grosso do Sul, between 1985 and 2020.
Source: generated from MapBiomas data (2023).

On the one hand, these factors contributed to the expansion of the pasture area until 2010, when the municipality reached a peak of 77.9 thousand ha. On the other hand, the failure to adopt management programs for livestock farming may explain the high presence of degraded pastures in the municipality. The Pasture Atlas (Lapig, 2024) revealed that, in 2020, around 53% (31,500 ha) of all pastures of Guia Lopes da Laguna showed some degree of degradation, intermediate or severe, an increase of 22% for the period. This trend was the opposite of what was observed in the Midwest region, which recorded a reduction of around 7% in degraded pastures (Lapig, 2024). The country has also seen a drop in pasture areas, mainly due to the

adoption of planted pastures, which has increased livestock productivity, as well as conversion processes to make new areas available for the production of temporary crops, mainly grains (Martha Jr. *et al.*, 2012; Dias-Filho, 2014; Meyer; Rodrigues, 2014).

Since 2010, there has been a decrease in the expansion of pasture areas in the municipality. IBGE data (2023) indicates a reduction in the number of cattle since 2010, from 150,000 to 100,000 head in 2020. The drop in pasture areas can be partially attributed to conversion for higher-yielding activities per unit area, such as grain and eucalyptus cultivation (Bueno, 2015), as depicted in Figure 2. For 20 years, the area dedicated to temporary crops increased from 0.4 thousand hectares to 7.2 thousand hectares between 1985 and 2015. Subsequently, between 2015 and 2020 alone, this total expanded to 17.8 thousand hectares. This dynamic can be explained by the conversion of pasture areas and mosaics of use, with more than 10,000 ha converted to annual crops. The process of agricultural intensification can be observed in the region, primarily through the adoption of a double cropping system, which involves the soybean-maize cycle. An example of this is shown in Figure 3, which displays the areas of occurrence of the five main transition processes in the municipality between 2015-2020, highlighting processes of conversion from pasture and mosaics of use to annual crops, as well as illustrating the temporal profile of the NDVI of two converted areas between 2015 and 2020, revealing the occurrence of two annual crops in the same area.

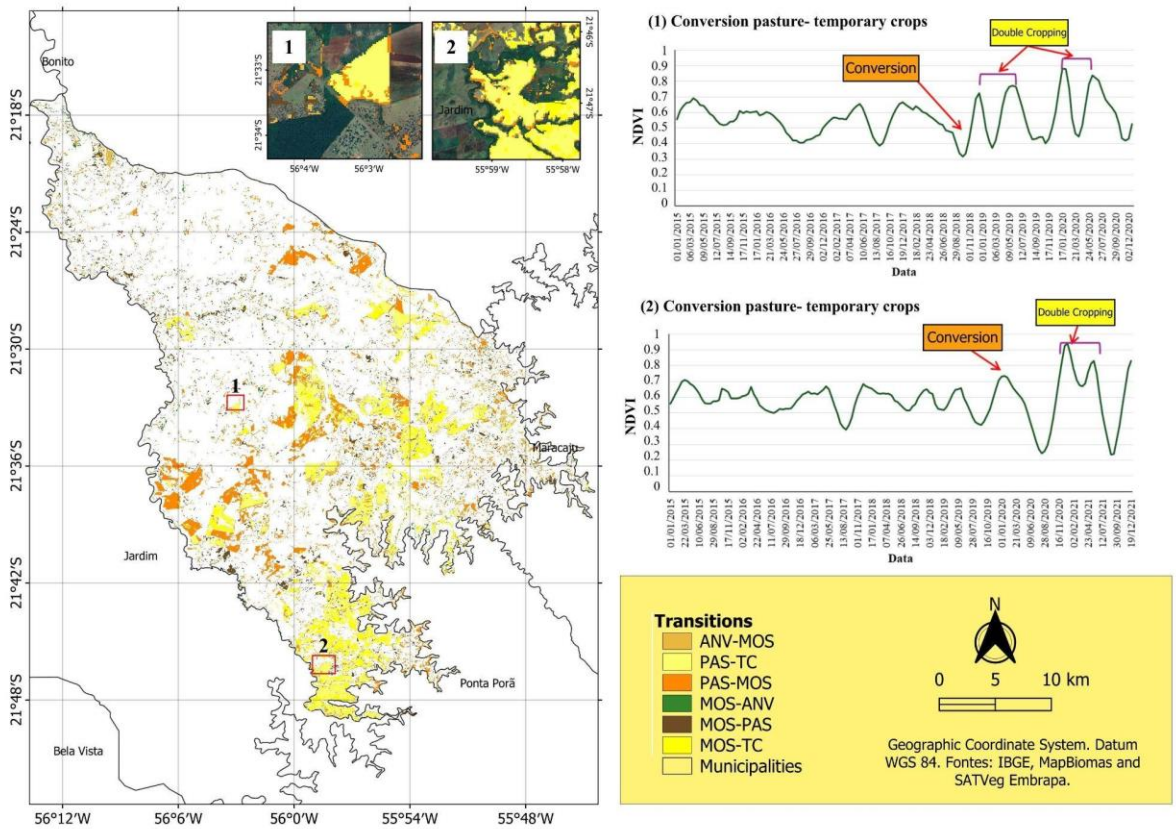

Figure 3. Main agricultural transitions in Guia Lopes da Laguna between 2015 and 2020, and analysis of pasture-agriculture conversion areas with a temporal profile of the vegetation index. Where: ANV (Areas of Natural Vegetation), PAS (Pastures), TC (Temporary Crops), MOS (use mosaics), and NDVI (Normalized Difference Vegetation Index).
Source: MapBiomas Project (2023), Google Satellite and SATVeg Embrapa (https://www.satveg.cnptia.embrapa.br/).

These crops are characterized as flex crops with multiple uses including human food, animal feed, fuel, and industrial applications (Borras Jr. *et al.*, 2014). Santana *et al. (2020)* highlight that edaphoclimatic conditions, public policies, research, innovations, and technical assistance have significantly enhanced productivity and crop diversification in the Cerrado over recent decades, contributing to approximately 40% of the total national production. In addition, Kastens *et al.* (2017) point out that the dynamics of pasture conversions into new agricultural areas may be associated with the Soy Moratorium, even in Cerrado regions, with production being directed towards areas previously deforested to encourage sustainable agricultural development (Heilmayr *et al*., 2020).

Figure 4 illustrates the proportion of agricultural expansion, conversion, and retraction processes in the municipality over the period. The analysis also revealed a predominance of conversion processes throughout the period analyzed. The dynamics of changes in agricultural production systems accounted for 45% (15,100 ha) of all transitions between 1985-1990, progressively increasing to 84% (21,100 ha) between 2015-2020. Considering the goal of reducing deforestation, the data shows that anthropized areas have been used in different ways over time, reducing the pressure for new agricultural areas.

Agricultural expansion, which began with the suppression of 37% of natural vegetation (Figure 2), has been decreasing over time, from 35% (11,600 ha) between 1985-1990, to 11% (2,710 ha) between 2015-2020. The retraction of agricultural areas occurred mainly between 1985-1990 and 2005-2010 and, as shown in Figure 2, was due to the regeneration of natural vegetation on areas previously occupied by mosaics of agriculture and pasture.

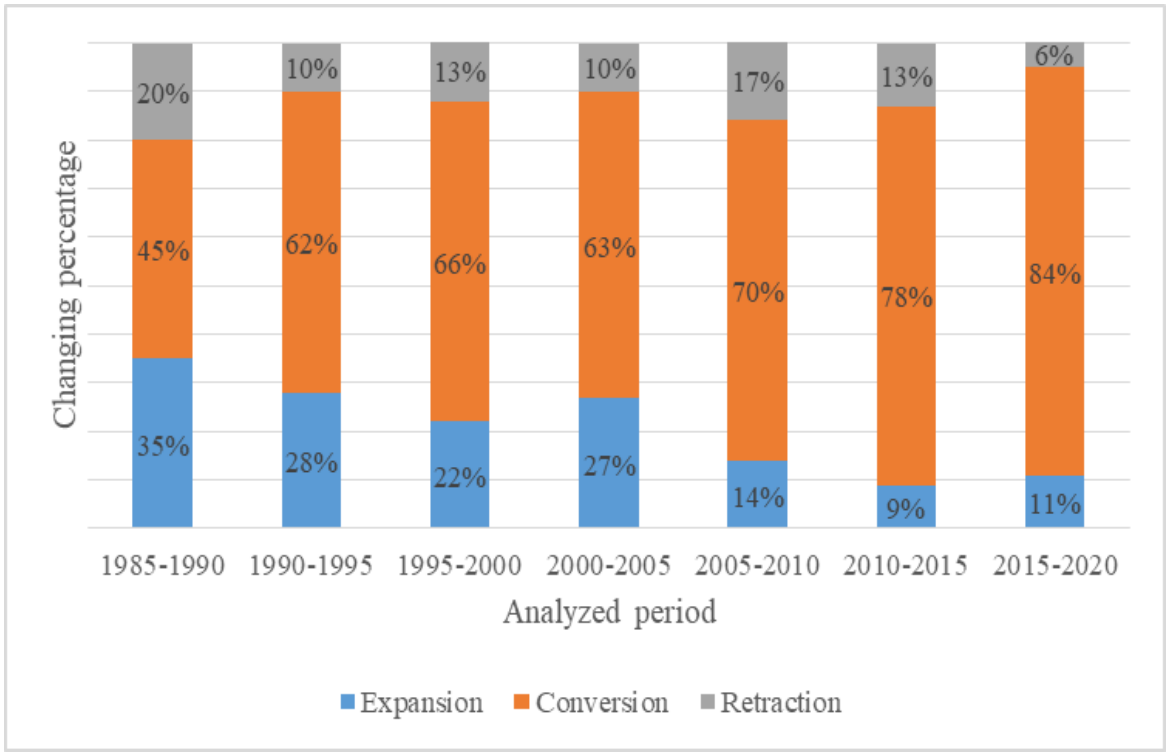

Figure 4. Percentage of each transition class in Guia Lopes da Laguna (MS) between 1985 and 2020.
Source: based on data from MapBiomas (2023).

4. CONCLUSION

The integration of remote sensing and census data enabled the identification of dynamic land use and cover processes in Guia Lopes da Laguna, MS. These dynamics are characterized by two primary phases: initially, the clearing of natural vegetation to expand pasture and agricultural lands until 1995; and more recently, starting from 2015, conversion processes involving the replacement of pasture with areas designated for temporary crops, particularly soybeans and corn production. Future research should delve into agricultural diversification and intensification processes to better grasp their impacts on land structure, thereby supporting more sustainable development initiatives.

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