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LAND USE AND LAND COVER DYNAMICS IN THE CHAPADA DIAMANTINA NATIONAL PARK AND BUFFER ZONE, BAHIA, BRAZIL

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Abstract
This study aimed to analyze, in a multitemporal approach, the changes in land use and land cover within the Chapada Diamantina National Park (PARNA-CD), located in the state of Bahia, Brazil, and its buffer zone between the years 1985 and 2023. The research utilized data from Collection 9.0 of the MapBiomas Project, processed through Google Earth Engine (GEE), based on 30-meter resolution Landsat imagery, applying remote sensing techniques and statistical analysis to identify spatial and temporal trends. The results showed that the internal area of PARNA-CD remained environmentally stable over the study period, with minimal land cover changes, with the predominance of natural vegetation formations and low anthropic occupation. In contrast, the buffer zone experienced an intensification of human activities, particularly the significant growth of silviculture, with an annual rate of 10.3%, and mining, with approximately 6.5% per year, in addition to urban and agricultural expansion. Downward trends were observed in the savanna formation and mosaic of uses classes, indicating changes in landscape patterns. The comparative analysis confirmed the effectiveness of the conservation unit as a barrier against the expansion of anthropic land uses and underscored its importance in preserving biodiversity and vegetation cover. However, land use and occupation processes in the surrounding areas require attention and integration into planning strategies aimed at regional-scale environmental conservation.

Keywords
Remote Sensing — MapBiomas — Protected Areas — PARNA

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1. Introduction

Conservation Units (CUs) are strategies established by countries to preserve and protect essential natural resources such as water, soil, and biological diversity. According to Gonçalves-Souza et al. (2021), these strategies represent the main societal tool to prevent the degradation of natural assets, although their effectiveness is often questioned. Dias-Silva (2021) argues that biodiversity conservation has faced numerous challenges, particularly due to the conversion of natural areas for agriculture, energy production, and mineral extraction. These authors assert that CUs are not fully effective in safeguarding the country's rich biodiversity, especially freshwater ecosystems. Conversely, Colman et al. (2022) contend that legally established protection strategies, such as CUs, can indeed preserve forest cover and biodiversity.

Therefore, studies that assess land use and land cover dynamics in CU territories are essential. Land use and land cover change (LUCC) analysis is crucial for understanding how human activities have influenced a given area over time. As a result, LUCC assessments have become recurrent in the literature (Kogo, Kumar & Koech, 2021; Santos et al., 2022; Guimarães et al., 2023; Oktavia et al., 2024).

According to Global Forest Watch (2024), tropical regions experienced a 10% higher primary forest loss in 2022 compared to 2021. Brazil presented a concerning scenario, as landscape transformations in the country exceeded the average for tropical nations, reaching approximately 15% (Sartorello, Alves Filho & Small, 2025). Furthermore, the authors report that Brazil accounted for about 40% of global tropical primary forest loss in 2002, totaling approximately 1.8 million hectares of de-

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forested land and 1.2 gigatonnes of carbon released into the atmosphere.

In this context, with the aim of protecting the ecosystems of the Serra do Sincorá region and promoting ecotourism, the Chapada Diamantina National Park (CDNP) was established on September 17, 1985, through Decree No. 91,655. The area, formerly occupied by diamond mining an activity that shaped the region's economy during the 19th century began to attract the attention of environmentalists due to the impacts left by mineral extraction (Brazil, 1985). In addition to maintaining vital ecosystem services such as climate regulation and watercourse protection, the park benefits local fauna, flora, and nearby communities (Santos et al., 2019).

However, the influence of the Chapada Diamantina National Park on its surrounding landscapes remains not fully understood. The protection of this core area may positively affect adjacent zones, helping to maintain ecological balance and mitigate the impacts of nearby anthropogenic activities (Caldas, 2012). Thus, evaluating and monitoring these zones is essential to understand the actual effectiveness of protected areas and the role they play in buffering human interventions especially in transitional zones where preserved nature borders socioeconomic development.

In this regard, remote sensing has proven to be a valuable tool, increasingly used to study ecosystem dynamics. It provides spatially explicit information on Earth surface properties over large spatial and temporal scales (Senf, 2022). Through satellite image processing and environmental indicators, it becomes possible to track gradual changes from the park's interior to external zones. This monitoring helps to assess vegetation loss, surface temperature variation, water quality degradation, and the intensification of human activities. Such ”inside-out” analysis reveals how conservation efforts within CUs influence environmental stability in surrounding areas and whether the park functions as a natural barrier against degradation in transitional landscapes (Pereira et al., 2023).

The use of remote sensing data supports environmental planning strategies. Spatial planning is critical for identifying and implementing sustainable development approaches that consider soil degradation and land-use impacts (Santarsiero et al., 2023).

Based on these findings, this study aims to understand the spatial effects of the Chapada Diamantina National Park on land use and land cover dynamics in its surroundings, considering both proximal and more distant zones. It seeks to investigate how this conservation unit contributes to environmental preservation beyond its legal boundaries, especially in the face of increasing anthropogenic pressures. By identifying transition patterns between protected areas and adjacent landscapes, this research intends to advance knowledge on the spatial effectiveness of conservation units and inform integrated territorial management strategies.

2. Methodology

2.1 Study Area

The Chapada Diamantina National Park (CDNP), established in 1985, is located in the central region of the state of Bahia (Figure 1), covering an area of approximately 1,520 km² across the municipalities of Lençóis, Palmeiras, Mucugê, Andaraí, Itaeté, and Ibicoara. Situated within the Caatinga biome, with influences from the Cerrado and Atlantic Forest formations, the park harbors a rich diversity of landscapes, including mountain ranges, valleys, caves, waterfalls, and rocky fields. It plays a vital role in environmental conservation in Brazil (Funch, Harley & Funch, 2009; Carvalho, 2009; Nascimento, 2021).

The park area is located within the Caatinga biome and experiences a semi-humid climate with well-defined rainy seasons between April and September (Mesquita et al., 2011). This region presents a wide variety of vegetation types, including xerophytic formations typical of the Caatinga biome, deciduous and semi-deciduous forest formations associated with the Atlantic Forest biome, and grassland and rocky formations that occur on exposed rock or lithosols, usually found in Cerrado environments. Therefore, the natural vegetation of the region is often described as a mosaic due to its remarkable diversity. Different vegetation types coexist within relatively small areas, influenced by subtle variations in lithology, topography, hydrology, and microclimate. In general, notable formations include clean fields, rocky fields, general grasslands, Cerrado, and seasonal forest. In addition, there are transition zones with unique ecological characteristics, where typical species from different ecosystems coexist (ICMBio, 2007).

The altimetric and topographic diversity directly influences the occurrence of different climatic types, according to the Köppen classification: hot semi-arid climate, high-altitude tropical climate, sub-humid tropical climate, and Caatinga areas with typical desert vegetation and the Northeastern interior ecoregion (Silva et al., 2013).

The altimetric variation in Chapada Diamantina, with altitudes ranging from 400 to 1,700 meters, directly influences the region’s climatic, hydrological, and vegetation cover patterns. Figure 2 presents the topographic (B and D) and elevation (A and C) maps of the internal area and the external 10 km buffer, highlighting the terrain configuration within and around the Chapada Diamantina National Park.

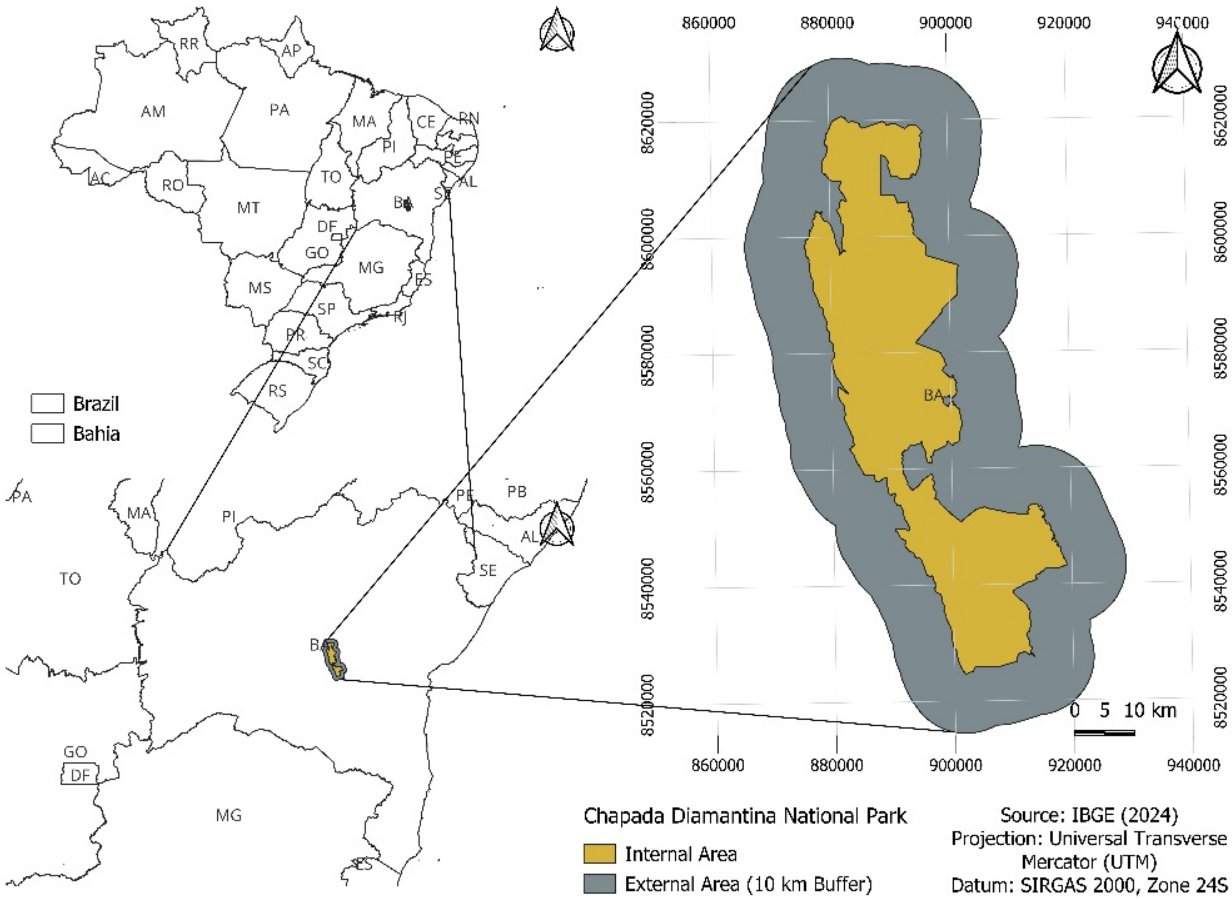

Figure 1. Location map of the sampling area in the study site, corresponding to the internal and external zones (10 km buffer) of the Chapada Diamantina National Park. Source: Authors (2025).

2.2 Data and Information Used in the Analyses

The land use and land cover (LULC) data and information were obtained from the Google Earth Engine (GEE) platform and are produced by the MapBiomas Project, Collection 9.0 (Souza et al., 2020; Rocha et al., 2024). These data provide annual time series of land use and land cover through the lulc toolkit.

According to Martins (2024), the MapBiomas Project conducts extensive studies analyzing land use and cover changes from 1985 to 2023. The author also states that the LULC data are derived from Land Remote Sensing Satellite (LANDSAT) images with a 30-meter spatial resolution, freely available on the Google Earth Engine platform and covering a time series of over 30 years (Martins, 2024).

The MapBiomas network, composed of experts in remote sensing, data science, biomes, and computing, implemented algorithms for preprocessing and image normalization, training a Random Forest classifier to map land use and land cover classes at a national scale (MAPBIOMAS, 2023).

To analyze LULC in the Chapada Diamantina National Park, open access to Landsat data combined with the cloud computing infrastructure of GEE and the application of machine learning algorithms enabled the reconstruction of annual LULC classifications in the park between 1985 and 2023 (Wulder et al., 2012; Phiri & Morgenroth, 2017).

2.3 Methodological Procedures

To define the area of interest (i.e., the Chapada Diamantina National Park), a script was used to intersect the annual LULC raster datasets with the park's boundary, as described by Gorelick et al. (2017).

The script's calculate() function applies to the reducer ee.Reducer.sum().group() to compute the area of each

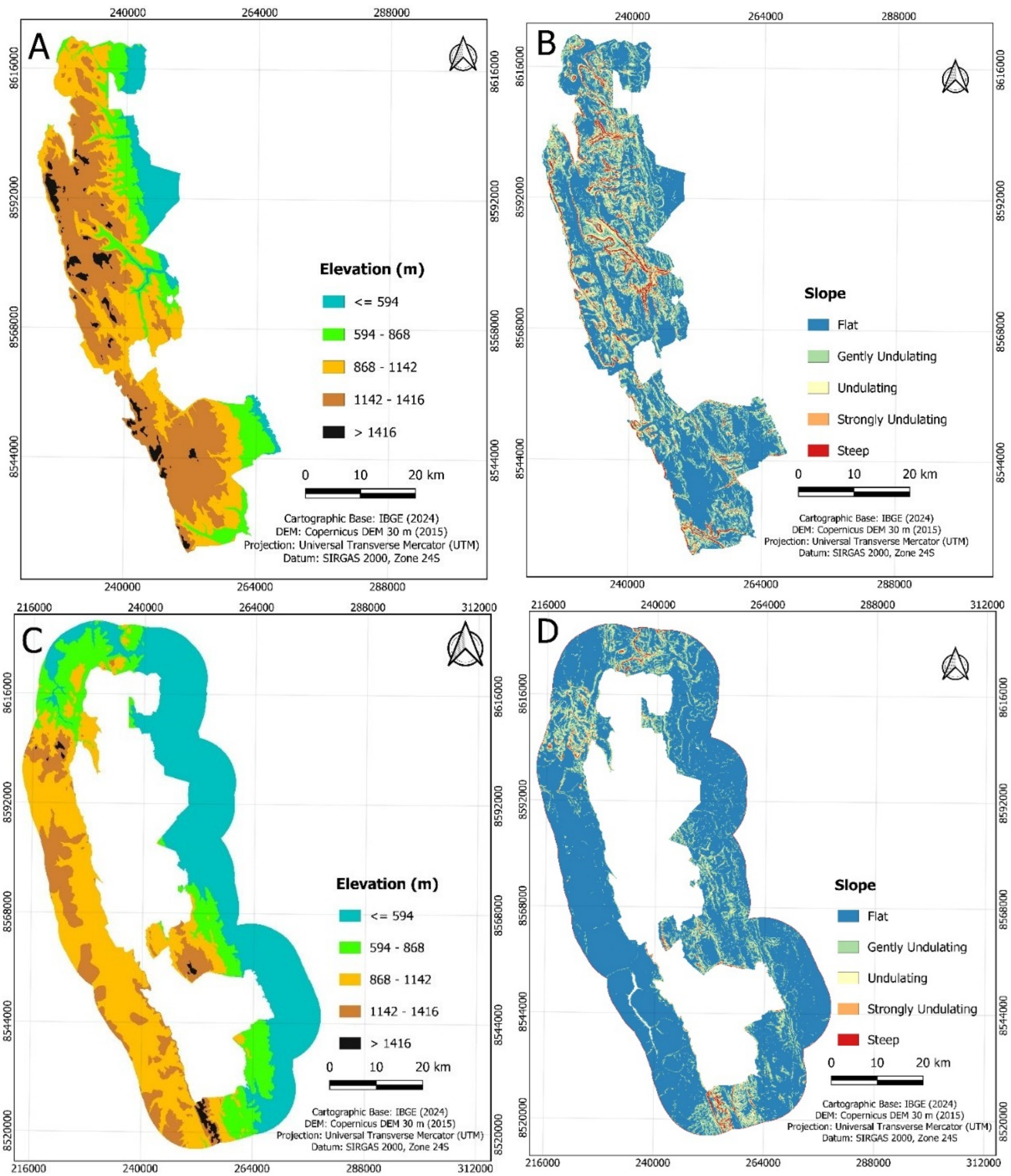

Figure 2. Hypsometric (A and C) and topographic relief (B and D) maps of the study area, encompassing the Chapada Diamantina National Park and its surrounding zone. Source: Prepared by the authors.

class based on the count of classified pixels. Cloud computing via GEE enabled automatic and efficient processing of large data volumes, generating time series with high spatial and temporal consistency over the 39 years analyzed (Souza et al., 2020).

To define the park's buffer zone, a 10 km influence area from the park boundaries was delineated using the buffer tool in the Geographic Information System QGIS. This distance was adopted based on the methodology of Santos et al. (2020).

GeoTIFF images exported from GEE were processed in QGIS with support from GRASS GIS tools, integrated through the corresponding plugin. To quantify the area occupied by different LULC classes, the r.report module was used, which calculates the area corresponding to each class value in a categorical raster.

The LULC raster map was loaded into the GRASS GIS environment, and the r.report command was executed with the following parameters: the area unit was set to square kilometers (km²), the precision was kept according to the GRASS default (adjusted to the 30-meter resolution of LANDSAT), and the spatial extent was defined based on the boundary of the Chapada Diamantina National Park or its buffer zone, depending on the case.

The execution of r.report generated a table listing all land use and cover classes identified in the raster data, along with their respective areas in km². This report was exported and structured in tabular format using Excel, enabling quantitative analyses and temporal comparisons throughout the historical series (1985–2023). Table 1 presents the LULC classes identified in the study area.

2.3.1 Statistical Data Analysis

The statistical analysis was based on temporal data related to the areas occupied by different land use and land cover classes from 1985 to 2023, considering both the interior and the buffer zone of the Chapada Diamantina National Park. The information was organized by land use type, as described in Table 1, allowing for a quantitative, temporal, and comparative evaluation between the two territorial sections.

Initially, the data were standardized to ensure analytical consistency, correcting class name inconsistencies and harmonizing the records. The classes were later grouped into two main categories: (i) natural cover, represented by forest, savanna, and grassland formations; and (ii) anthropic areas, including permanent and temporary crops, pastures, urbanized areas, coffee plantations, forest plantations, mining, and mixed-use mosaics.

Measures of central tendency and dispersion (mean, median, standard deviation, and coefficient of variation) were calculated for each class in both the internal and external zones of the park to describe average occupation patterns and assess variability over the temporal series.

Next, inferential analyses were performed to identify statistically significant differences between the internal and external areas. The Shapiro-Wilk test was used to

Table 1. Classes and Description of Land Cover and Use Legends – MapBiomas Collection 9.0 (2025).

Class	Description
Forest Formation	Vegetation with a closed or nearly closed tree canopy, such as ombrophile's and seasonal forests (includes regenerating areas with forest structure).
Savanna Formation	Vegetation with two layers: an herbaceous-shrub layer and a sparse tree layer. Includes typical, dense, sparse, and rocky Cerrado.
Forest Plantation	Areas planted with exotic or native tree species for economic purposes, usually in regular arrangements (e.g., eucalyptus, pine).
Grassland Formation	Predominantly native herbaceous vegetation, with or without sparse shrubs (e.g., clean, shrubby, and rocky grasslands).
Pasture	Areas used for livestock grazing, dominated by cultivated or managed native grasses.
Land Use Mosaic	Mixed-use agricultural areas where satellite imagery cannot distinguish between cropland and pasture.
Urban Area	Consolidated urban zones with infrastructure such as buildings, streets, industries, and residential areas.
Other Non-Vegetated Areas	Exposed surfaces including fallow cropland, dunes, desert areas, and rocky outcrops.
Mining	Areas of mineral extraction, including artisanal and industrial mining, with features such as pits, tailings piles, and residual ponds.
Rivers, Lakes, and Ocean	Natural or artificial water bodies: rivers, lakes, oceans, reservoirs, and dams.
Other Temporary Crops	Short- or medium-cycle crops (less than one year), such as corn, beans, cotton, rice, and other annual crops.
Coffee	Areas cultivated with coffee, including various management systems (full sun or shaded).
Other Permanent Crops	Permanent agricultural crops other than coffee, such as banana, apple, grape, peach palm, açaí, and other fruit or industrial species.

Source: Adapted from MapBiomas 2025.

verify normality. When the normality assumption was met, the Student's t-test for independent samples was applied. Otherwise, the non-parametric Mann-Whitney U test was used to ensure the robustness of the results. This procedure was applied both to the comparison of specific classes and to the annual comparison of the total anthropic area between the two territorial sections.

All analyses were conducted in R software, using the packages readxl, dplyr, ggplot2, and tidyr, ensuring traceability and reproducibility.

The Mann-Kendall (MK) test, a non-parametric method, was extensively used in this study to detect statistically significant trends in the time series of areas occupied by natural cover and anthropic activities. Since it does not require the assumption of normality, the MK test is especially suitable for environmental series with possible seasonal variations.

Considering that territorial occupation may present systematic changes over the years, the seasonal version of the Mann-Kendall test was also applied, according to the methodology described by Ashraf et al. (2021). This approach allows for the assessment of systematic changes over time, considering potential seasonal effects, and contributes to understanding the processes of territorial expansion, land use and cover, and their environmental impacts in the Chapada Diamantina region.

2.3.2 Results and Discussion

The results obtained demonstrate the effectiveness of the Chapada Diamantina National Park (CDNP) as a barrier against the expansion of anthropogenic activities, contributing to the preservation of vegetation cover and acting as a limiter of intensive land use. These findings support previous studies highlighting the importance of Conservation Units (CUs) (Gonçalves-Souza et al., 2021; Colman et al., 2022). The study reports a lower rate of human occupation within the park's internal area, based on a temporal analysis covering nearly four decades, indicating that current conservation policies are effective in protecting against the advance of agriculture and urban growth.

The analysis of central tendency measures (Table 2) revealed marked differences between the internal and external areas of Chapada Diamantina in terms of land use and land cover. Anthropogenic classes such as urban areas, pasture, perennial and temporary crops, mosaic of uses, and coffee showed significantly higher mean values in the external area compared to the park's interior. This contrast underscores the greater anthropogenic pressure in the surroundings, particularly within the 10 km buffer zone analyzed.
Statistically significant trends ($p < 0.05$) were categorized as “Increase” ($\tau > 0$) or “Reduction” ($\tau < 0$). The most prominent increases were observed in the Forest Plantation (+10.3% per year) and Mining (+6.5% per year) classes, both located outside the park's perimeter. In contrast, the greatest reductions occurred in the Savanna Formation (-0.25% per year) and Mosaic of Uses (-3.2% per year) classes. Meanwhile, some classes remained stable, such as Rivers/Lakes (p = 0.961) and Forest Formation (p = 0.358).

The time series analysis of land use and land cover from 1985 to 2023, considering a 10 km buffer around the Chapada Diamantina National Park (PARNA-CD) (Figure 3), reveals significant changes in the landscape configuration over the past decades. A gradual yet continuous process of replacing natural formations with anthropogenic activities was observed, with emphasis on agricultural and livestock use.

In the early years analyzed, *Forest Formation* and *Savanna Formation* classes predominated, occupying a large portion of the territory. From the 2000s onward, there was a noticeable advance of anthropic classes, especially *Other Temporary Crops*, *Silviculture*, *Pasture*, and *Mosaic of Uses*. Agricultural expansion became more concentrated in the southern and southwestern portions of the area, as represented by the pink and lilac tones on the maps.

Between 2000 and 2023, the intensification of *Silviculture* (in brown tones) and the consolidation of diversified agricultural zones (*mosaics*) stand out. Although less prominent, the presence of *mining* and *urbanized areas* is also evident, revealing the multifunctional character of the analyzed territory. This dynamic indicates a trend of reduction in natural cover in favor of agricultural intensification, highlighting increasing pressure on natural ecosystems and a transformation of the landscape driven by economic interests.

The surroundings of the Chapada Diamantina National Park (PARNA-CD) clearly show a tendency toward land use intensification, raising concerns about the environmental impacts of this process. The expansion of *silviculture* and *mining*, in particular, poses a significant concern, as these activities are associated with environmental degradation, ecosystem disruption, soil degradation, and declines in water quality (Santos et al., 2022; Sartorello et al., 2025).

Although the interior of the park remains protected, the buffer zone is under growing pressure, indicating an urgent need for interventions aimed at managing and monitoring the territory through an integrated approach that goes beyond the legal boundaries of conservation units.

Actions limited to within park boundaries have proven insufficient to mitigate the impacts generated in adjacent areas. Therefore, it is essential to strengthen public policies focused on the sustainable use of land and land cover, as well as to maintain continuous monitoring of land use and land cover as a supporting tool for environmental conservation and territorial planning.

Within the park area (Table 3), the expansion of agriculture and urbanization stands out. Crops such as *Coffee* (+0.082 km^2/year) and *Other Perennial Crops* (+7.43% per year) show rapid growth. The *Urbanized Area* class also showed an increasing trend (+0.506 km^2/year), reflecting greater anthropic pressure.

Conversely, there was a reduction in natural ecosystems, with significant losses in *Rivers/Lakes* (-6.78% per year) and *Other Non-Vegetated Areas* (-3.72% per year). *Savanna Formation* (-0.27% per year) and *Pastures* (-1.19% per year) also showed declining trends. Finally, the reduction of the *Mosaic of Uses* class (-0.99% per year) suggests a process of landscape simplification, possibly associated with the replacement of diverse systems by more homogeneous land use practices (Cerqueira et al., 2021; Noronha, Freitas & Solórzano, 2022).

Table 2. Annual trend of land use and land cover in the external area of the study perimeter.

Area	Land Use Class	Trend	p-value	Annual Rate (km²/year)	Annual Percentage Rate (%)
External	Forest Plantation	Increase	< 0.001	0.003	10.26
External	Mining	Increase	< 0.001	0.001	6.54
External	Other Temporary Crops	Increase	< 0.001	5.068	6.82
External	Coffee	Increase	< 0.001	0.726	7.02
External	Other Perennial Crops	Increase	< 0.001	0.983	6.48
External	Urban Area	Increase	< 0.001	0.198	3.34
External	Grassland Formation	Increase	< 0.001	1.21	1.69
External	Mosaic of Uses	Decrease	3.31×10^{-7}	-3.871	-3.17
External	Savanna Formation	Decrease	5.41×10^{-6}	-3.709	-0.25
External	Other Non-Vegetated Areas	Decrease	2.14×10^{-4}	-0.048	-2.22

Source: Prepared by the authors

Table 3. Annual trend of land use and land cover within the study area perimeter.

Area	Land Use Class	Trend	p-value	Annual Rate (km²/year)	Annual Percentage Rate (%)
Internal	Other Perennial Crops	Increase	< 0.001	0.016	7.43
Internal	Urbanized Area	Increase	< 0.001	0.506	NA
Internal	Coffee	Increase	0	0.082	NA
Internal	Other Temporary Crops	Increase	0	0.004	NA
Internal	Grassland Formation	Increase	7.83×10^{-3}	2.283	0.41
Internal	Rivers, Lakes, and Ocean	Reduction	3.98×10^{-11}	-0.409	-6.78
Internal	Other Non-Vegetated Areas	Reduction	2.55×10^{-9}	-0.030	-3.72
Internal	Pasture	Reduction	3.69×10^{-3}	-0.038	-1.19
Internal	Mosaic of Uses	Reduction	4.65×10^{-3}	-0.209	-0.99
Internal	Savanna Formation	Reduction	1.62×10^{-2}	-1.708	-0.27

Source: elaborated by the authors.

The expansion of agricultural crops, such as coffee and other perennial plantations, as well as the growth of urbanized areas although on a smaller scale within the boundaries of the Chapada Diamantina National Park (Figure 4) reveals a concerning pattern of land occupation, especially when considered in conjunction with what is occurring in the surrounding areas outside the park. This process underscores the importance of recognizing the park's surroundings as a critical transition zone between areas of intensive land use and the remaining patches of natural ecosystems (Santos et al., 2022).

The literature highlights the ecological vulnerability of edge regions. According to Mendenhall et al. (2013), transition zones adjacent to protected areas are particularly susceptible to land use changes and habitat fragmentation, which directly compromise ecological connectivity and, consequently, the ecosystem services that depend on this integrity. Such services include, for example, gene flow among wildlife and plant populations, microclimate regulation, and water regulation elements essential to the resilience of protected ecosystems.

The intensification of land use and land cover on the park's borders tends to break the continuity of nat-

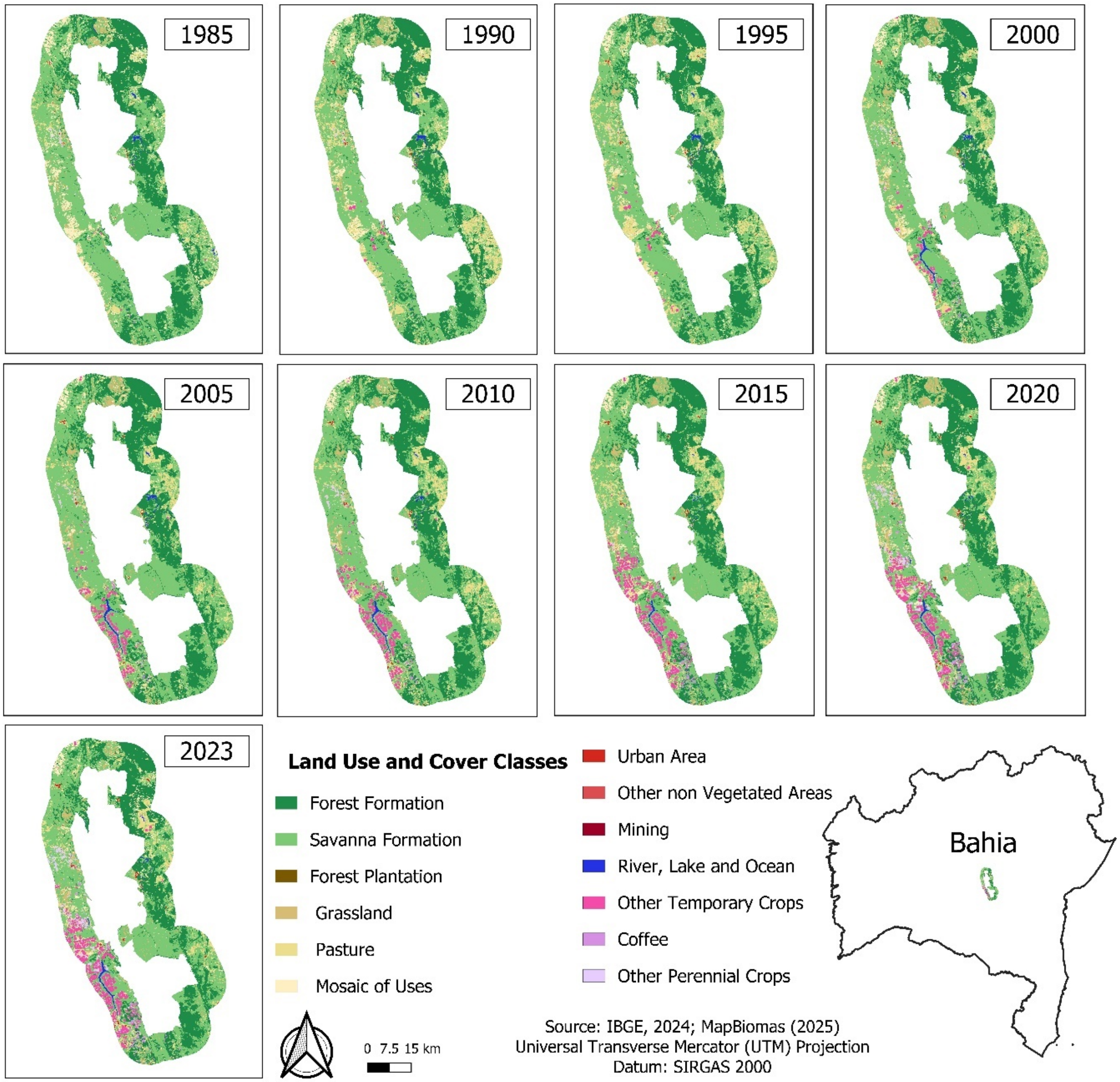

Figure 3. Spatiotemporal evolution map of land use and land cover classes in the external area with a 10 km buffer from the boundaries of Chapada Diamantina National Park (1985–2023). Source: Prepared by the authors.

ural landscapes, transforming heterogeneous mosaics into homogeneous land use matrices, which are less favorable to maintaining biodiversity. This clearly demonstrates the need to extend environmental management beyond the formal boundaries of the conservation unit, incorporating strategies aimed at protecting the broader landscape, including land use policies, conservation incentives on private lands, and the creation of ecological corridors that promote greater connectivity between fragments (Colman et al., 2022).

Urbanized areas were significantly more representative in the surrounding zone (5.93 km^2) than within the park itself (0.06 km^2), a difference that was statistically significant ($t = 15.825$; $p < 0.0001$), as illustrated in Figure

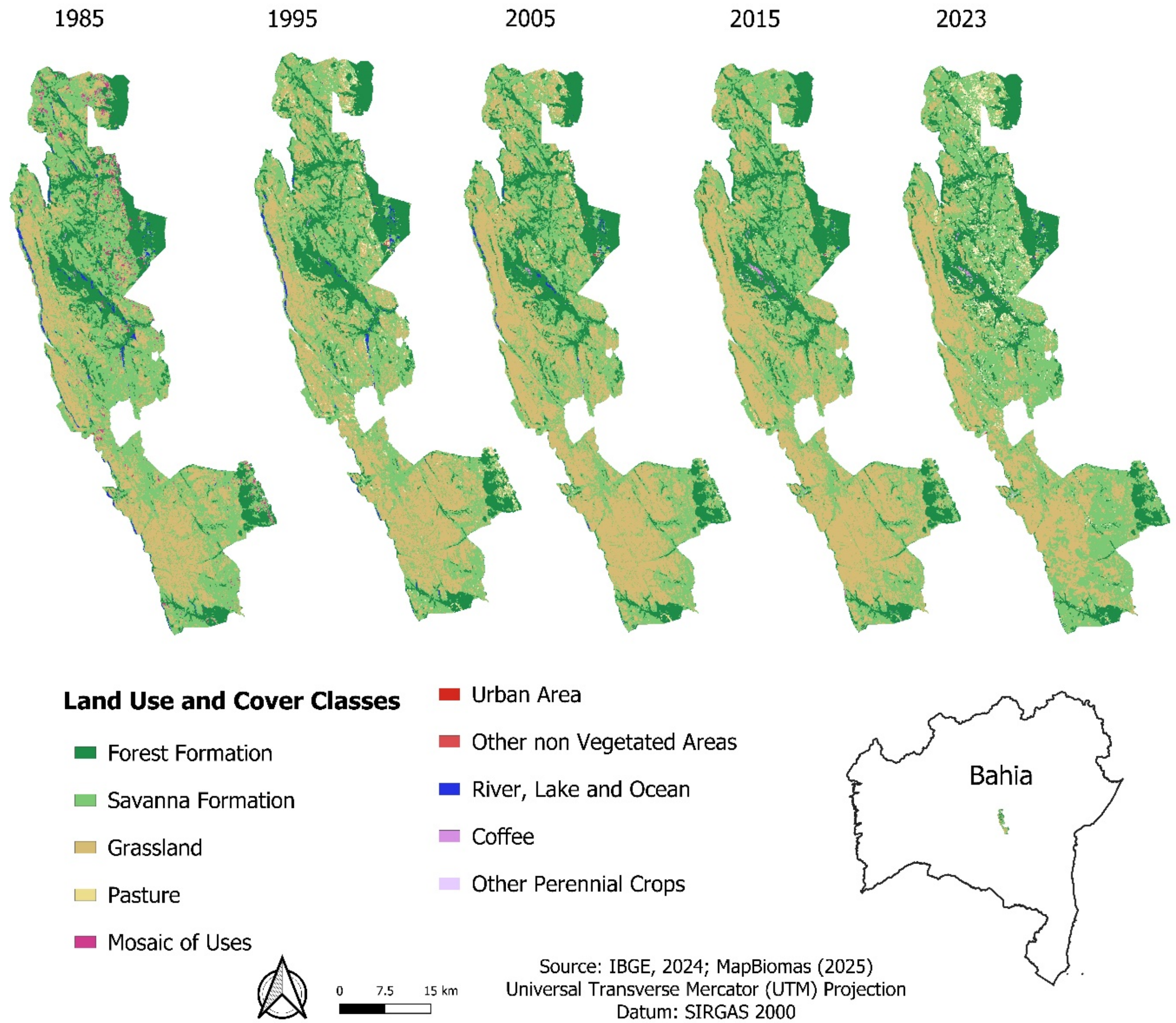

Figure 4. Spatiotemporal evolution map of land use and land cover classes within the Chapada Diamantina National Park (1985–2023). Source: Prepared by the authors.

5. This result reinforces the hypothesis that the internal area functions as a protective barrier against urban and agricultural expansion.

The "Mosaic of Uses" class also showed a statistically significant difference between external and internal areas ($t = 11.381$; $p < 0.0001$), with a higher concentration in the buffer zone. Pastures and both temporary and permanent crops followed the same pattern, with much larger areas outside the Chapada. Temporary crops, for instance, had a mean area of 74.36 km² in the external zone compared to only 0.04 km² inside the park, with a highly significant p-value ($p = 1.8 \times 10^{-9}$). Permanent crops also presented relevant differences ($p = 2.1 \times 10^{-7}$).

Figure 5 also details the temporal evolution of anthropic areas between 1985 and 2023. A consistent increase in anthropic activities was observed in the external area of Chapada, while the internal area remained with low human occupation throughout the entire period. This result reinforces the protective role of the conservation unit in limiting the expansion of anthropic land uses within its boundaries.

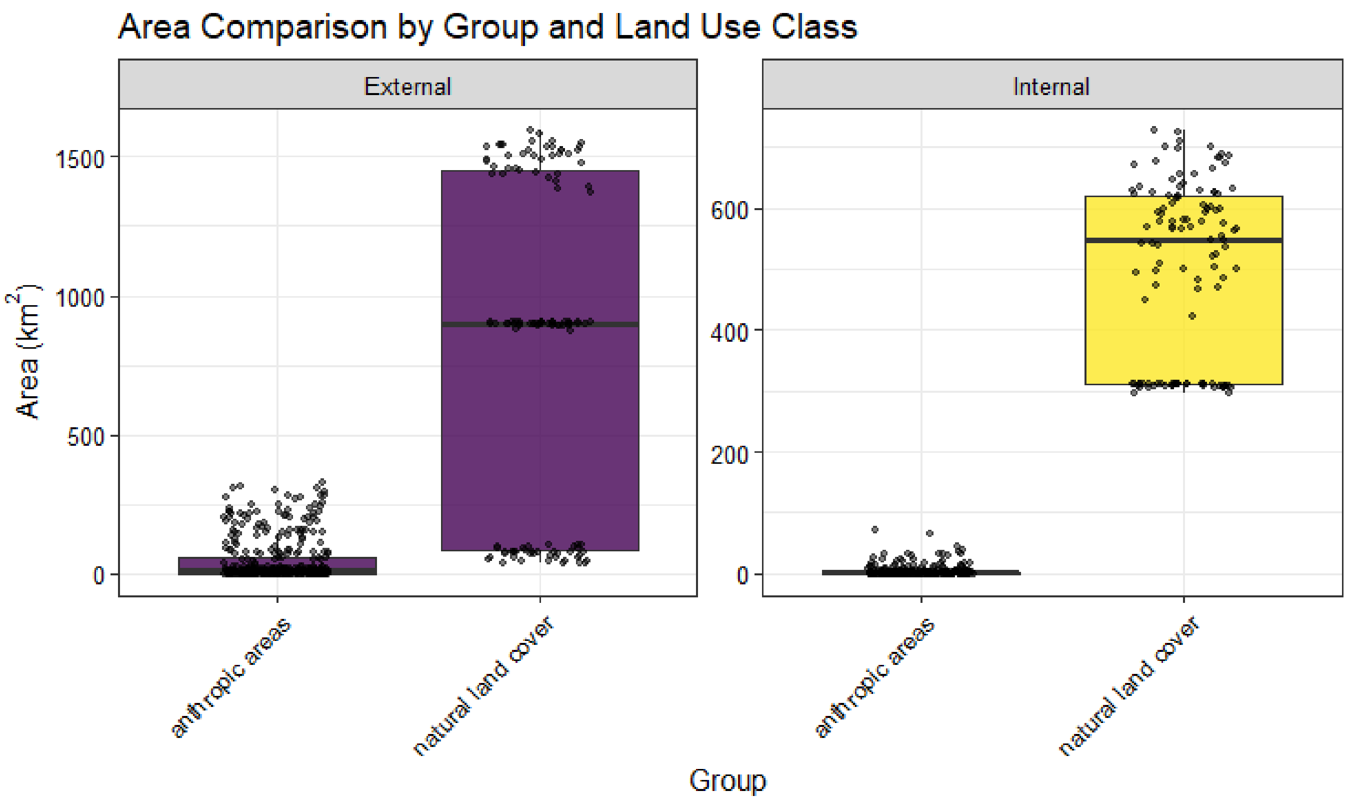

Figure 5. Evolution of anthropic areas between 1985 and 2023 (Inside vs. Outside). Source: Prepared by the authors.

In addition to the comparative analyses of the main land use and land cover classes, the temporal evolution of the coffee, silviculture, and mining classes was assessed, with detailed results presented in Figure 6.

The *coffee* class was present in both the internal and external areas of the Chapada Diamantina. The temporal evolution of this class revealed punctual variations over the years, without showing a continuous pattern of growth or decline. Despite the fluctuations observed, the area dedicated to coffee cultivation remained relatively stable over time. However, the recorded values were consistently higher in the external area compared to the interior of the conservation unit, indicating that this activity is more consolidated around the protected area. This behavior may reflect a traditional agricultural practice that has remained outside the conservation unit's boundaries, with less expansion pressure within the protected area.

The *silviculture* and *mining* classes, in turn, occurred exclusively in the external area of the Chapada Diamantina, with no significant records within the park boundaries. The areas occupied by these activities were considerably smaller compared to other anthropogenic land use classes. However, even on a small scale, their presence in the buffer zone warrants attention, as they may represent potential sources of localized environmental impact (Brito, 2021).

Although restricted to the surroundings of the conservation unit, these activities can, even indirectly, surpass the physical limits of the park, causing effects on overall environmental quality. Mining, for example, brings several negative impacts, such as heavy vehicle traffic, which may disturb the region's fauna and foster fragmentation processes (Brito, 2021).

Silviculture, depending on the species cultivated and the management practices employed, can drastically alter soil composition and hydrological dynamics, in addition to posing obstacles to biodiversity (Beldini, 2009; Moreno et al., 2023). Thus, even if they occupy smaller areas, these activities require careful monitoring and impact mitigation strategies to ensure ecological integration within the Chapada Diamantina and the functionality of its corresponding ecosystems.

The observed reduction in *savanna formations* and *pastures* in the external area is another important finding. This transition may be related to the replacement of heterogeneous vegetation by more uniform and economically driven land uses, such as the expansion of specific crops and silviculture. This homogenization of the land-

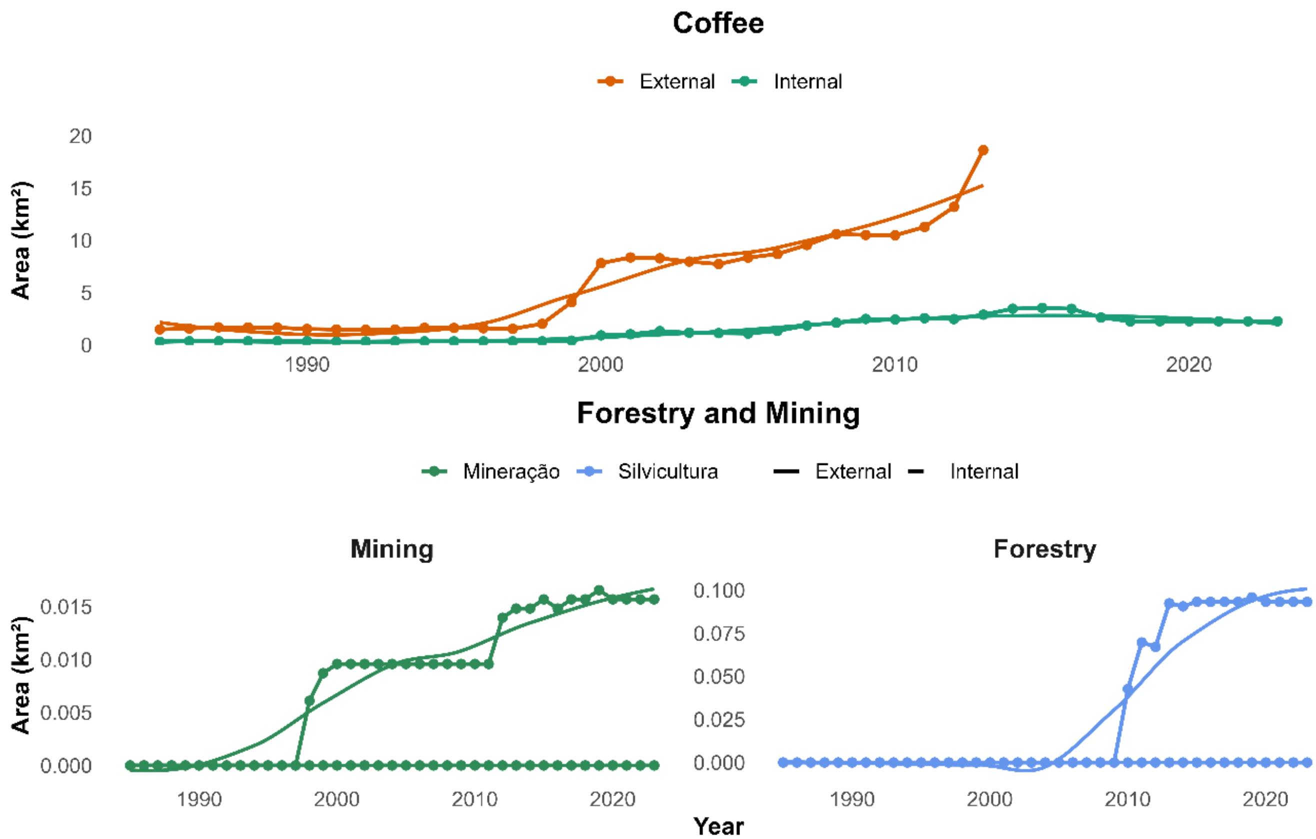

Figure 6. Temporal analysis – Coffee, Silviculture, and Mining. Source: Prepared by the authors.

scape threatens local biodiversity, particularly in ecotonal regions like the Chapada Diamantina, which represents a complex interaction between the Caatinga, Cerrado, and Atlantic Forest biomes (Funch et al., 2009).

The application of parametric tests such as *Mann-Kendall* reinforces the strength of the results, especially since they confirm statistically significant trends in land use change. The lack of significance in some classes, such as *Rivers/Lakes* and *Forest Formation*, is equally relevant, as it suggests relative stability, which can be interpreted as a partial success of conservation policies.

Therefore, the findings of this study reinforce that conservation units do not function in isolation, and their effectiveness is directly linked to the territorial dynamics of their surrounding areas. The accelerated growth of anthropogenic activities outside the boundaries of the Chapada Diamantina National Park negatively affects the balance of ecological processes within the biome and signals the need for governmental public policies and institutional actions focused on sustainable development, including stricter enforcement of regulations, preservation, and strengthening of buffer zones.

The use of remote sensing as a tool, along with technologies such as *Google Earth Engine* and *MapBiomas*, proved to be effective in supporting long-term monitoring of territorial dynamics. This approach aligns with the broader use of data science to support environmental policy decision-making (Senf, 2022; Santarsiero et al., 2023).

3. Conclusions

The Chapada Diamantina National Park (CDNP) is an effective conservation instrument whose existence acts as a barrier against anthropogenic intensification and the resulting ecosystem degradation. The stability of natural formations and the low density of human occupation within its boundaries attest to the success of protection policies, especially when contrasted with the land use and land cover dynamics in the buffer zone.

Although incipient, pressures such as urban and agricultural expansion were detected within the unit, reinforcing the notion that no protected area is immune to the dynamics of its surroundings. These internal threats, combined with external ones, call for continuous monitoring and adaptive management actions.

In light of these findings, it is concluded that the ecological functionality of the CDNP transcends its legal boundaries and is inseparable from the surrounding territorial dynamics. The long-term preservation of its ecological values depends on the implementation of integrated public policies, the promotion of sustainable productive practices, and the establishment of ecological corridors. For this purpose, the application of remote sensing technologies, as employed in this study, has proven to be a strategic and essential tool for large-scale diagnosis and monitoring, supporting evidence-based environmental governance.

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Author Statements

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- ✓ There is no evidence of plagiarism in this article.

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