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FOREST COVER AND MONITORING OF LEGAL RESERVES IN LÁBREA (AM), BRAZILIAN AMAZON

Cobertura florestal e monitoramento de Reservas Legais em Lábrea (AM)

Cobertura forestal y monitoreo de Reservas Legales en Lábrea (AM), Amazonia Brasileña

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ABSTRACT

This study analyzes forest cover conversion in the municipality of Lábrea (AM), focusing on Legal Reserves (LR) declared in the Rural Environmental Registry (CAR). Using geospatial data from 2008 to 2020, we assessed the relationship between property size, pasture expansion, proximity to infrastructure, and territorial overlaps. The results indicate that larger properties tend to preserve greater proportions of native vegetation, while smaller properties show significant forest cover loss. Inconsistencies in CAR were identified, such as overlaps and topological errors, which undermine its effectiveness as an instrument for monitoring and environmental regularization. Moreover, the presence of properties within Conservation Units and overlapping Indigenous Lands generates territorial conflicts and hampers enforcement. Conservation and land consolidation programs were found to have only partial effects without updated monitoring and effective oversight. The findings highlight the need to strengthen environmental governance, improve land tenure regularization, and promote sustainable productive activities to conserve Amazonian biodiversity and ecological integrity.

Keywords: Deforestation; Rural Environmental Registry; Environmental governance; Territorial conflicts; Land cover.

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RESUMO

Este estudo analisa a conversão da cobertura florestal no município de Lábrea (AM), com foco nas Reservas Legais (RL) declaradas no Cadastro Ambiental Rural (CAR). Utilizando dados geoespaciais de 2008 a 2020, avaliou-se a relação entre tamanho das propriedades, expansão de pastagens, proximidade a infraestruturas e sobreposições territoriais. Os resultados indicam que imóveis maiores tendem a manter maiores proporções de vegetação nativa, enquanto propriedades pequenas apresentam perda significativa de cobertura florestal. Identificaram-se inconsistências no CAR, como sobreposições e erros topológicos, que comprometem sua eficácia como instrumento de monitoramento e regularização ambiental. Além disso, a presença de imóveis em áreas protegidas e sobrepostos a Terras Indígenas gera conflitos territoriais e dificulta a fiscalização. Constatou-se que programas de conservação e consolidação fundiária têm efeito parcial sem monitoramento atualizado e fiscalização efetiva. Os achados reforçam a necessidade de fortalecer a governança ambiental, aprimorar a regularização fundiária e incentivar atividades produtivas sustentáveis, a fim de conservar a biodiversidade e a integridade ecológica da Amazônia.

Palavras-chave: Desmatamento; Cadastro Ambiental Rural; Governança ambiental; Conflitos territoriais; Cobertura da terra.

RESUMEN

Este estudio analiza la conversión de la cobertura forestal en el municipio de Lábrea (AM), con énfasis en las Reservas Legales (RL) declaradas en el Registro Ambiental Rural (CAR). Utilizando datos geoespaciales de 2008 a 2020, se evaluó la relación entre el tamaño de las propiedades, la expansión de pastizales, la proximidad a infraestructuras y las superposiciones territoriales. Los resultados indican que las propiedades más grandes tienden a mantener mayores proporciones de vegetación nativa, mientras que las propiedades pequeñas presentan una pérdida significativa de cobertura forestal. Se identificaron inconsistencias en el CAR, como superposiciones y errores topológicos, que comprometen su eficacia como instrumento de monitoreo y regularización ambiental. Además, la presencia de propiedades en Unidades de Conservación y superpuestas a Tierras Indígenas genera conflictos territoriales y dificulta la fiscalización. Se constató que los programas de conservación y consolidación de tierras tienen un efecto parcial sin monitoreo actualizado y fiscalización efectiva. Los hallazgos refuerzan la necesidad de fortalecer la gobernanza ambiental, mejorar la regularización de la tierra e incentivar actividades productivas sostenibles, con el fin de conservar la biodiversidad y la integridad ecológica de la Amazonía.

Palabras clave: Deforestación; Registro Ambiental Rural; Gobernanza ambiental; Conflictos territoriales; Cobertura de la tierra.

1 INTRODUCTION

The protection of Legal Reserves (LRs) is regulated by the Native Vegetation Protection Law (LPVN) (Brazil, 2012), which establishes that, in the Legal Amazon, rural properties must conserve 80% of their native vegetation. This percentage may be reduced to 50% in municipalities where more than 50% of the territory is included within Conservation Units and Indigenous Territories, provided that an approved Ecological-Economic Zoning is in place. In the Purus sub-region, where the municipality of Lábrea (state of Amazonas, Brazil) is located, such reduction is authorized due to pressures from the cattle ranching

sector (Amazonas, 2011). Although political arguments suggest that Legal Reserves restrict agribusiness expansion, these areas can be sustainably managed, including grazing in native grassland ecosystems and the extraction of timber and non-timber products, thereby reconciling biodiversity conservation with productivity and socioeconomic benefits (Alves et al., 2020; Baggio et al., 2020).

The LPVN established the Rural Environmental Registry (CAR) as the central instrument for monitoring and controlling land use in rural areas, with emphasis on reducing deforestation. The CAR is a self-declaratory registry that gathers information on property boundaries, native vegetation cover, Permanent Preservation Areas, restricted-use areas, consolidated areas, and Legal Reserves. When a LR is already registered in the property title, no additional registration in the CAR is required.

The CAR constitutes an essential tool for managing environmental liabilities and assets, enabling the identification of native vegetation deficits, monitoring deforestation, and guiding the restoration of degraded areas in the Amazon (Fernandes et al., 2025). Despite its relevance for environmental monitoring, the CAR does not replace the official Property Registry and cannot serve as proof of ownership, nor can it regularize unregistered areas or those under judicial dispute (Tybusch; Bertoncelli, 2022). Although designed to support the environmental regularization of rural properties, its implementation faces challenges that may contribute to legitimizing the unlawful appropriation of public lands, including insufficient resources, limited institutional capacity, and inadequate oversight (Ferreira Júnior et al., 2023). Despite its conservation function, the CAR presents overlaps between private properties and protected areas, potentially compromising the effectiveness of these areas and facilitating irregular occupations (Beleza et al., 2024).

Since July 22, 2008, deforestation within LRs has been prohibited. Properties that do not meet the minimum required percentage must restore or compensate for their deficit through Environmental Regularization Programs (PRA), which also facilitate access to environmental licenses and rural credit. The CAR and PRA enable environmental recovery, monitor compliance with legal requirements, and provide geospatial data systematically. State Law 4,406/2016 (Amazonas, 2016) and Decree 42,370/2020 (Amazonas, 2020) determine that the Degraded Area Recovery Plan (PRAD) must be implemented over a 20-year period, restoring approximately 10% of the areas every two years, underscoring the need for continuous monitoring.

Environmental governance in the Amazon faces complex challenges related to land occupation, pressures from agricultural expansion, and the need to reconcile conservation

and development (Alves et al., 2021; Rodrigues Neto et al., 2024). In municipalities such as Lábrea (AM), located along the expanding agricultural frontier, these challenges become particularly evident due to the overlap between rural properties, Conservation Units, and Indigenous Territories, often generating territorial conflicts and hindering the implementation of environmental policies (Jesus, 2023). In this context, land cover constitutes a central indicator for assessing the effectiveness of regulatory and monitoring instruments such as the CAR, as well as for revealing local land-use dynamics and pressures on forests. Understanding these interactions is essential for analyzing the limitations of legislation and informing management strategies that strengthen the protection of LRs and the ecological integrity of the Amazon.

This study aims to assess the effectiveness of the Rural Environmental Registry as an instrument of environmental governance in Lábrea (AM), based on the analysis of native vegetation cover within Legal Reserves and rural properties, as well as forest conversion patterns associated with different property size classes. To this end, we examine temporal changes in land cover (2008 - 2020), the integrity of areas declared as Legal Reserve, and the relationship between property size and native vegetation loss.

2 METHODOLOGY

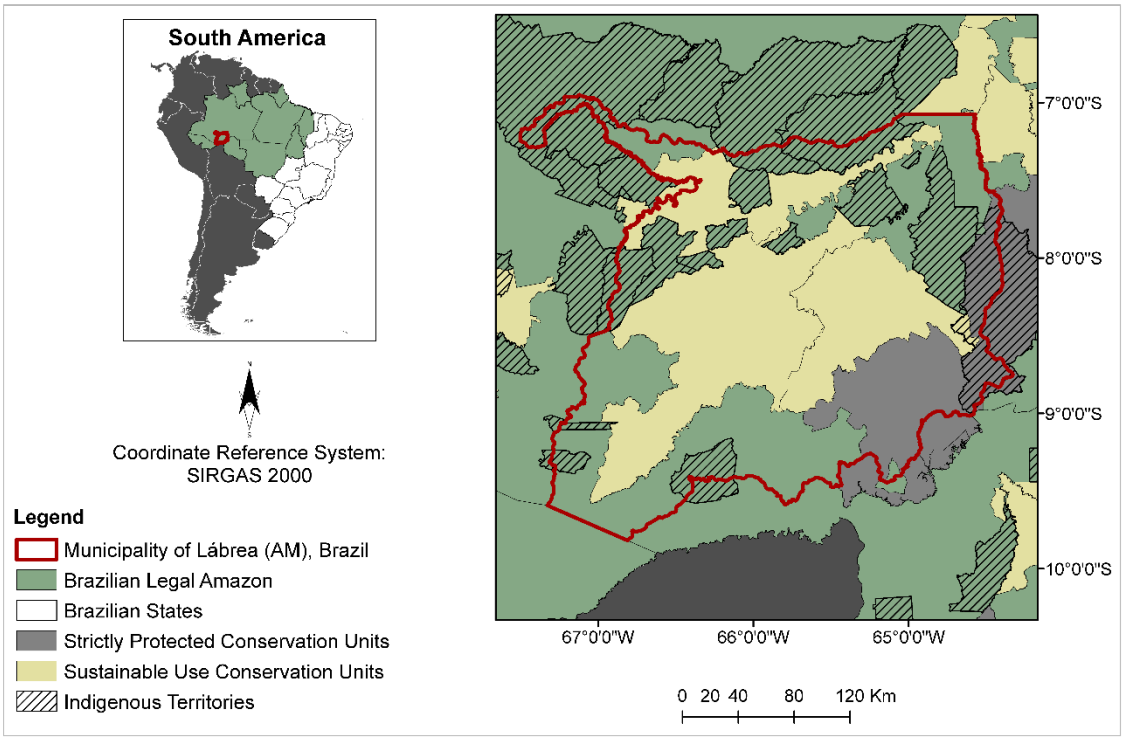
2.1 Study area

The municipality of Lábrea is located in the South Amazon mesoregion, in the state of Amazonas, Brazil (Figure 01). It encompasses approximately 68,000 km², of which only 5.74 km² correspond to urbanized areas (IBGE, 2023). Situated near the borders of the states of Acre and Rondônia, Lábrea is located roughly 30 km from the Bolivian border. As of March 2023, the Rural Environmental Registry (CAR) recorded 3,788 rural properties within the municipality (Ministério da Agricultura, Pecuária e Abastecimento, 2023).

The selection of Lábrea as the study area is justified by its central role in deforestation dynamics in the Amazon. According to the Project for Monitoring Deforestation in the Legal Amazon by Satellite (PRODES), it has been the municipality in the state of Amazonas with the highest annual increase in deforestation since 2001 (INPE, 2023). Lábrea was included in the list of priority municipalities under the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) in 2008 (Bizzo and Farias, 2017), the same year in which four Conservation Units were established within its

territory: the Médio Purús Extractive Reserve, the Ituxi Extractive Reserve, and the Iquiri National Forest (Sustainable Use), as well as the Mapinguari National Park (Strict Protection) (MMA, 2023).

Figure 01 – Geographic location of the study area



Source: Own elaboration.

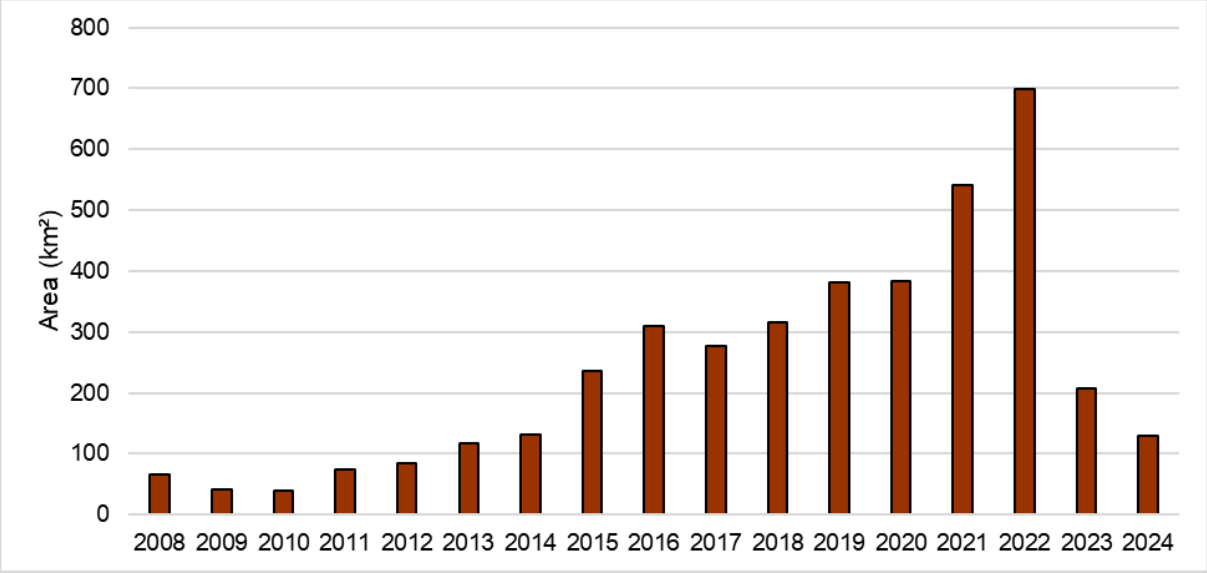
Between 2008 and 2012, annual deforestation increments in Lábrea remained relatively low (40 to 84 hectares), partially reflecting the effects of environmental policies and regulations, such as the creation of Conservation Units under the PPCDAm and Central Bank Resolution No. 3,545 (Banco Central, 2008), which conditioned access to rural credit on compliance with environmental legislation (Assunção et al., 2013). Between 2008 and 2014, the reduction in deforestation was attributed to the integration of monitoring, environmental control, land-tenure regularization, and the use of previously deforested areas.

Phase III of PPCDAm (2012 - 2015) prioritized land-tenure regularization and the implementation of Ecological-Economic Zoning, while the enactment of the Native Vegetation Protection Law (LPVN), which granted amnesty for deforestation prior to 2008, reduced restoration requirements by 58% (West; Fearnside, 2021). Between 2016 and 2019, gaps in implementation and the gradual dismantling of the program became evident (Reis; Corazza, 2025). Phase V of PPCDAm (2023 - 2027) marks the resumption of the plan

after a period of abandonment, reinstating the axes of land-tenure governance, monitoring and environmental control, as well as support for sustainable productive activities.

The temporal evolution of deforestation in Lábrea is presented in Figure 02. Forest loss partially affects protected areas, and nearby rural properties may facilitate the illegal appropriation of public lands (Martins et al., 2018).

Figure 02 – Annual deforestation increment in the municipality of Lábrea



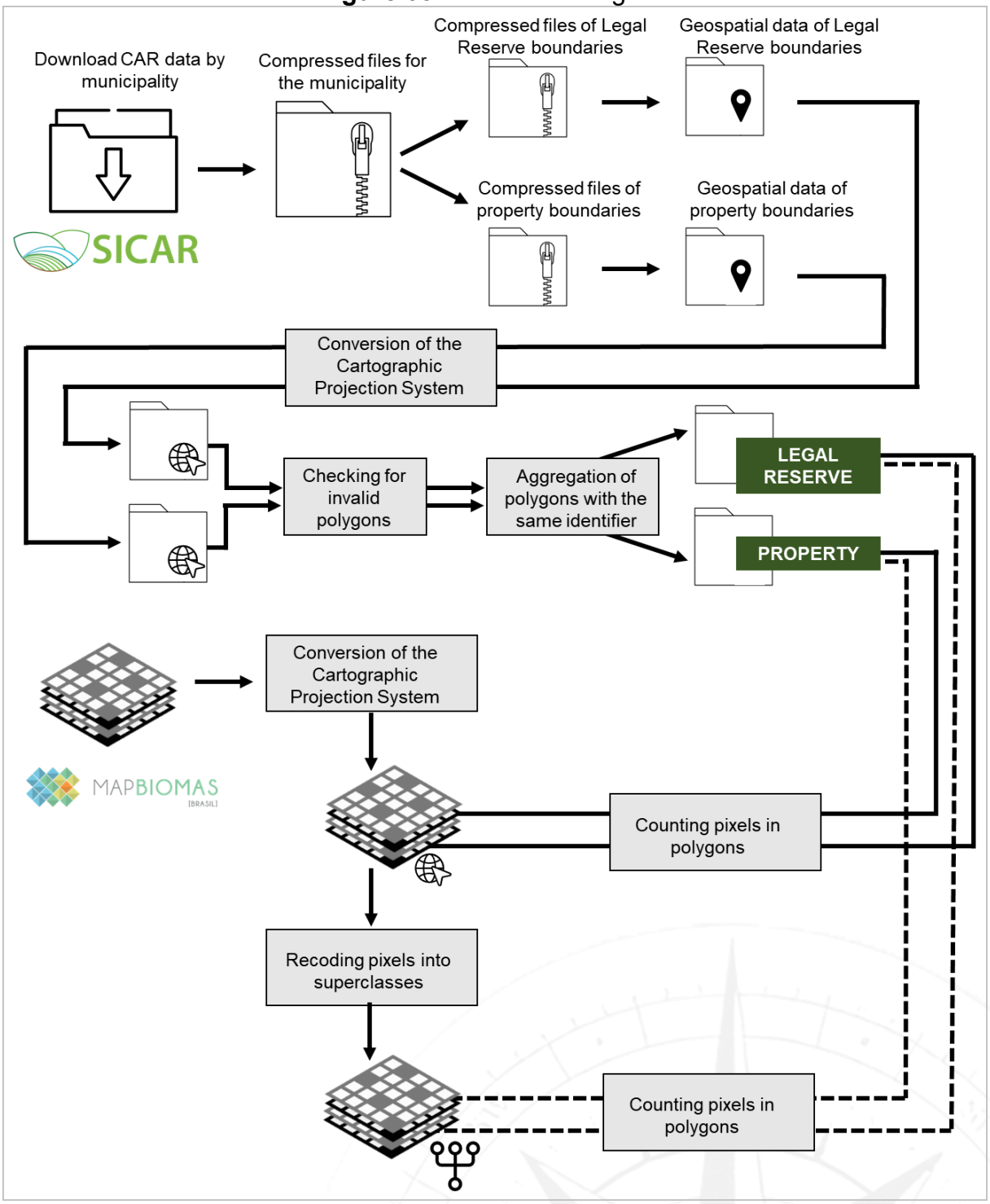
Source: INPE (2025). Own elaboration.

The municipality also encompasses, either fully or partially, the Indigenous Territories Acimã, Alto Sepatini, Apurinã do Igarapé Mucuim, Apurinã km-124 BR-317, Boca do Acre, Caititu, Deni, Hi-Merimã, Jacareúba/Katawixi, Jarawara/Jamamadi/Kanamanti, Kaxarari, Paumari do Lago Marahã, Paumari do Rio Ituxi, São Pedro do Sepatini, Seruini/Marienê, and Tumiã (FUNAI, 2023). These territories, together with Conservation Units cover approximately 50,000 km², equivalent to 73% of the municipality, considering the existing overlaps between protected areas.

2.2 Data processing

Data processing was conducted in Python using virtual notebooks on Google Colab. Although the study focused on Lábrea, the scripts can be adapted for other municipalities or groups of municipalities. The sequence of processing steps is presented in Figure 03.

Figure 03 – Workflow diagram



Source: Own elaboration.

Geospatial data from the National Rural Environmental Registry System (SICAR) (Serviço Florestal Brasileiro, 2023), updated on December 13, 2021, were analyzed. For area calculations, the data were reprojected to the Albers South America cartographic projection (EPSG:102033).

Polygons were validated topologically, including verification of segment intersections. To ensure data consistency, properties were removed according to the criteria of the Open Geospatial Consortium (OGC). Records presenting topological errors (such as self-intersections, invalid or zero-area polygons, or features with incomplete, disconnected, or inconsistent boundaries) were excluded.

The quantification of native vegetation within Legal Reserves and rural properties was based on data from the MapBiomas Project (MapBiomas, 2025), Collection 7, for the years 2008, 2012, 2016, and 2020, available through Google Earth Engine. The accuracy of Collection 7 for the Amazon Biome is approximately 97% (MapBiomas, 2025), providing high reliability for land-cover analyses and enabling a robust assessment of native vegetation distribution across properties and Legal Reserves in Lábrea.

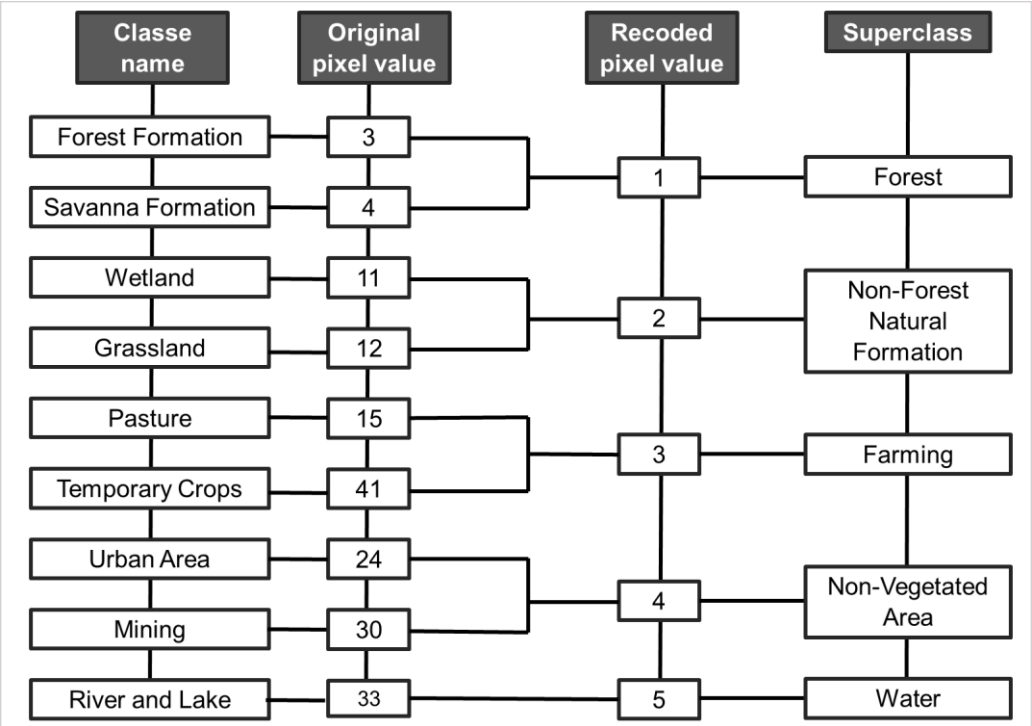
The selected years capture both the consolidation of anthropogenic occupation (2008) and the enactment of Law 12,651/2012 (Brazil, 2012), allowing an evaluation of its effects on native vegetation cover. The years 2016 and 2020 were included to track temporal changes in vegetation and land-use conversion following the implementation of the legislation, enabling the analysis of recent trends in deforestation, agricultural expansion, and changes in the effectiveness of LRs.

Although the dataset used in this study does not include the most recent years, it provides a robust basis for analyzing historical trends in vegetation conversion and the effectiveness of Legal Reserves in Lábrea. The selection of specific time periods allows for the evaluation of the effects of environmental policies and programs, such as the implementation of the LPVN and the different phases of PPCDAm and supports the identification of patterns of forest loss and agricultural expansion that remain relevant for understanding the current context. Moreover, historical data enable consistent comparisons with previous studies, ensuring the integrity and continuity of temporal analyses.

For properties extending beyond municipal boundaries, polygons were retained in their entirety, and a 30-km buffer around the municipality of Lábrea was applied to include all registered holdings.

Raster land-cover data were recoded into five superclasses: Forest; Non-Forest Natural Formation; Farming; Non-Vegetated Area; and Water. For each polygon, the percentage of Native Vegetation (Forest and Non-Forest Natural Formation classes) was calculated both within the Legal Reserve and across the total property area (Figure 04).

Figure 04 – Reclassification of MapBiomas land-cover classes into superclasses for analysis



Source: Own elaboration.

The area of the land-cover classes was converted to hectares following Equation 1. Although this procedure counts the entire pixel area, rather than only the portion located within the area of interest in the case of edge pixels, the computational effort required is substantially lower than that involved in using land-cover layers converted to vector format.

$$area\ in\ hectares = \frac{number\ of\ pixels \times 30^2}{100} \qquad (1)$$

Daugeard (2021) notes that CAR registration relies on self-reported information provided by landowners, who do not always delineate boundaries and internal features accurately, leading to potential inconsistencies. Similarly, Nogueira and Martins (2022) identified topological inconsistencies in CAR data for Lábrea, showing that the self-declaratory nature of the system does not guarantee geometric accuracy or full effectiveness for monitoring and enforcement. Structural limitations, such as spatial overlaps and restrictions in the COD_IMOVEL and IDF attributes, prevent the automatic association of each LR polygon with its corresponding property. For this reason, averages of native vegetation were calculated separately for LRs and for entire properties, and analyses involving property size classes, defined by the number of Fiscal Modules (FM), consider the

full extent of each property.

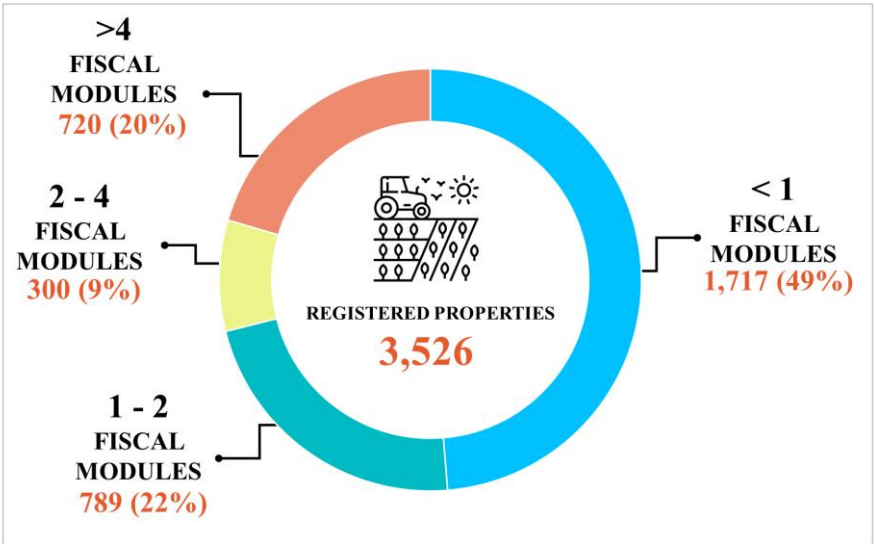
3 RESULTS AND DISCUSSION

The Rural Environmental Registry (CAR) has become a central instrument for monitoring land use and land cover in Brazil, particularly in the Amazon, where pressure on native vegetation is intense. In Lábrea (AM), the LRs declared in the CAR reveal both the potential and the limitations of the system: although it provides relevant geospatial data for environmental governance, its self-declaratory nature generates inconsistencies such as spatial overlaps, registrations within protected areas, and topological errors. These issues intensify territorial conflicts and reduce the effectiveness of conservation policies, underscoring the need for critical analyses of CAR's limitations in the face of the challenges of environmental management in the Amazon.

The CAR database for Lábrea includes 3,527 property polygons and 2,890 Legal Reserve polygons. After geometric consistency checks and the dissolution of multipolygons, 3,526 properties and 2,865 Legal Reserves were retained in the final analytical dataset. The lower number of LR polygons relative to properties results from three common factors in CAR data: the absence of an LR digitized as an autonomous polygon for some properties, the existence of LRs that have not been assessed or lack geometric representation, and the presence of multipolygons that are consolidated into a single unit once dissolved by their IDF attribute.

Figure 05 shows that nearly half of the properties cover less than one FM, while approximately 20% exceed four FM. According to the analyzed records, 71% of registered properties have up to two FM, indicating the predominance of smallholdings. This pattern characterizes the land-tenure structure of the municipality and has important implications for rural territorial management, including greater difficulty in environmental enforcement, increased pressure on protected areas, challenges in implementing conservation incentive policies, and the need for strategies tailored to smallholders.

Figure 05 – Distribution of registered properties by fiscal module classes



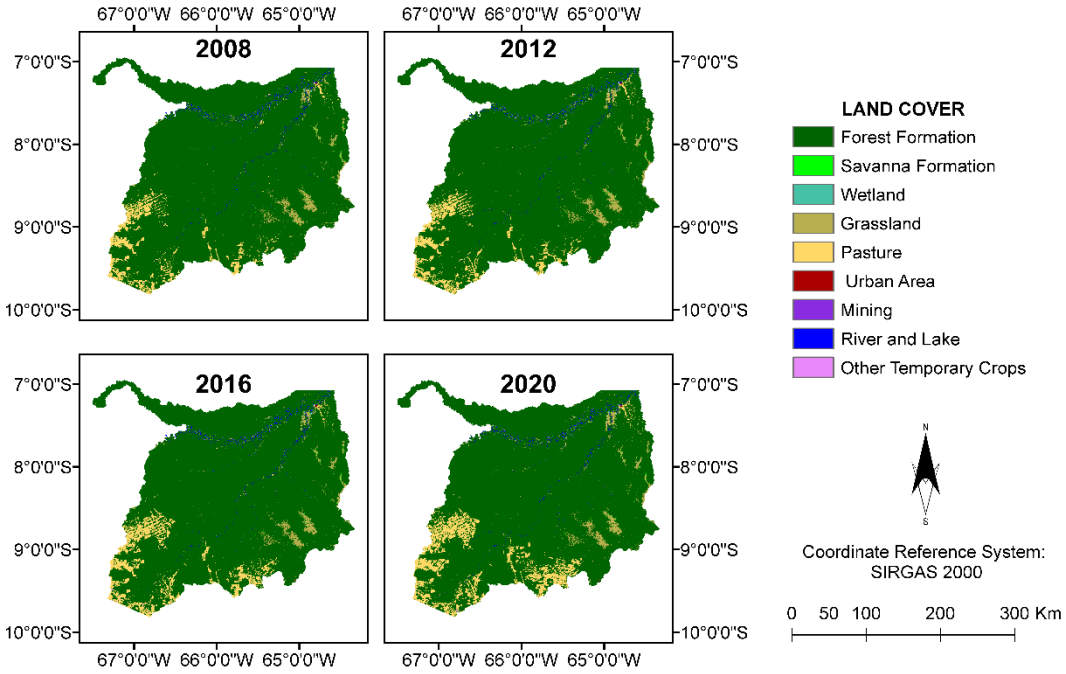
Source: SFB (2023). Own elaboration.

3.1 Land cover in Lábrea (AM)

Although Lábrea was founded during the height of the rubber boom (Fraga et al., 2024) and latex extraction still contributes significantly to the regional economy (Franco; Oliveira, 2020), pasture expansion represents the main driver of forest conversion in the municipality (MapBiomas, 2023). Lábrea leads the Amazon in cattle herd size (IBGE, 2021), highlighting livestock farming as the predominant economic activity.

Forest-to-pasture conversion is most intense in the southwestern part of the municipality, particularly along the BR-317 highway, advancing toward the Iquiri National Forest. Other deforested areas are concentrated in the northeast, near the urban center and the BR-317 and BR-230 highways, as well as in the southern region, crossed by the BR-364 (Figure 06). These patterns suggest that agricultural expansion is strongly influenced by proximity to road infrastructure, indicating that conservation and enforcement policies should consider not only legal regulations but also the impact of physical access on anthropogenic pressure.

Figure 06 – Land cover in Lábrea at the four analysis dates

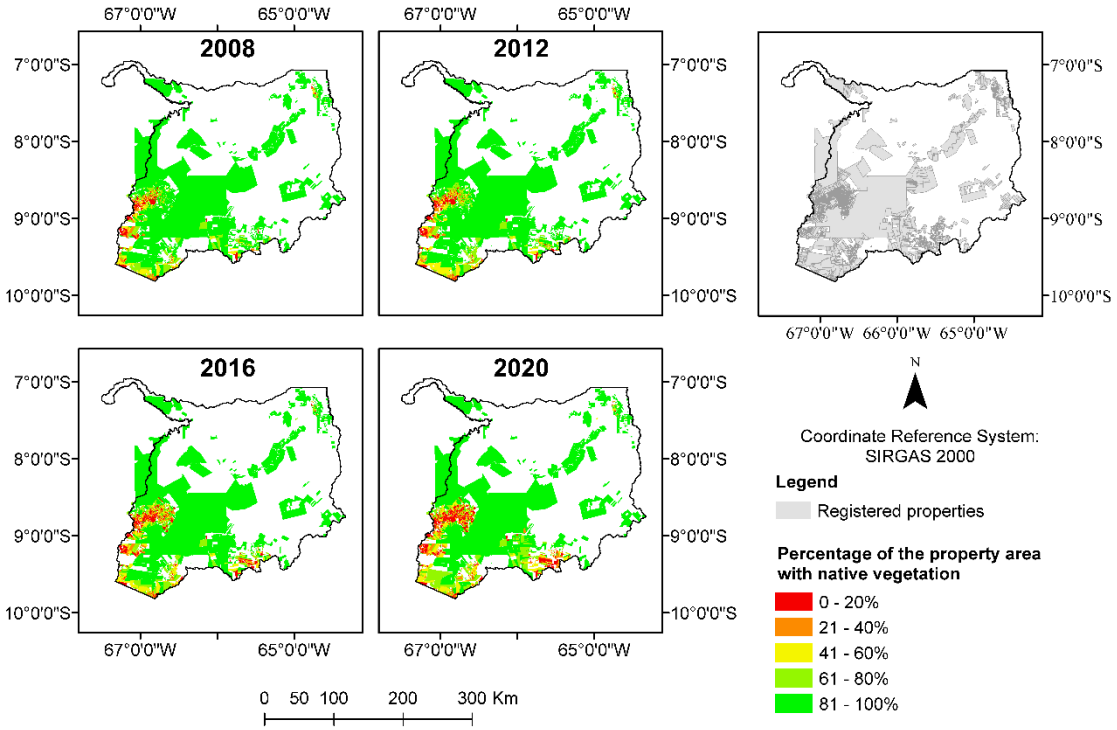


Source: MapBiomas (2023). Own elaboration.

Figure 07 illustrates the variability of properties according to the percentage of native vegetation cover. The spatial configuration shows that areas originally designated as LRs are in regions subject to intensified deforestation.

The multitemporal map highlights that, over the analyzed period, the southwestern and southeastern regions of the municipality concentrate the expansion of areas occupied by properties with less than 20% native vegetation cover, which also corresponds to the highest density of smallholdings.

Figure 07 - Spatiotemporal distribution of properties classified according to their proportion of native vegetation cover



Source: MapBiomas (2023). Own elaboration.

3.2 Native vegetation in registered properties

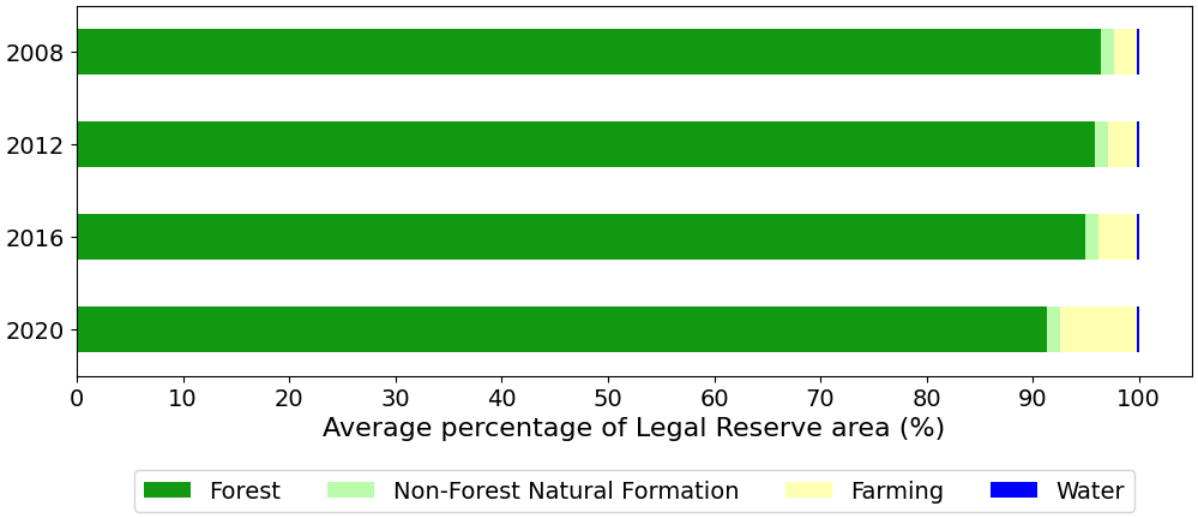
According to the LPVN, properties of up to four FM that did not meet Legal Reserve requirements in 2008 are exempt from reforestation or compensation obligations. This exemption may be associated with land fragmentation practices, in which large properties are formally divided into smaller plots to comply with less restrictive legal limits (Cazula, 2021; Terence, 2019). Such strategies hinder enforcement and facilitate the intensive exploitation of natural resources, and in some cases, constitute mechanisms for illegal land appropriation and avoidance of environmental obligations.

Despite existing legislation, the regulation of land use in LRs has proven limited, particularly in municipalities dominated by smallholdings, where pasture expansion has not led to significant increases in agricultural production (Jung et al., 2021; Oliveira et al., 2018). Many areas declared as LR do not maintain full native vegetation cover, showing a tendency toward conversion into pasture, especially on small properties.

Figure 08 presents the evolution of the average percentage of LR area in Lábrea according to land-cover classes. The “Forest” category predominates throughout the period

but shows a gradual decline, from 96.4% in 2008 to 91.3% in 2020. In contrast, the “Farming” class increases from 2.16% to 7.20% over the same interval, reflecting the expansion of livestock use. The “Non-Forest Natural Formation” class remains stable at approximately 1.2%, while the “Water” class remains negligible, around 0.18–0.19%.

Figure 08 - Temporal evolution of land cover in the Legal Reserves of Lábrea, in terms of mean percentages (2008–2020)



Source: Own elaboration.

The decline in average forest cover, even within LRs, highlights weaknesses in legal protection and suggests that external pressures, such as the expansion of agricultural activities, continue to affect these areas. Although mean data do not allow for a direct assessment of factors such as infrastructure or property size, they reflect a broader process of land conversion that exceeds legal conservation limits. Moreover, the increasing proportion of areas allocated to agriculture and pasture within LRs indicates a persistent pattern of productive land use that reduces forest integrity in these areas.

Therefore, it is important to emphasize that assuming the entirety of the area registered as Legal Reserve corresponds to conserved forest may lead to misleading assessments of the actual state of native vegetation, overestimating the effectiveness of legal protection and underestimating the risk of environmental degradation.

The land-cover percentages calculated for the entire property area reveal a pattern of progressive forest loss and agricultural expansion between 2008 and 2020 (Figure 09). Across all Fiscal Module strata, forest remains the predominant class but exhibits a declining trend. On properties up to 1 FM, forest cover decreased from 37.3% in 2008 to 23.2% in

2020, accompanied by an increase in farming (from 12.1% to 26.3%), indicating greater pressure on forest resources on very small properties. A similar dynamic is observed for properties of 1-2 FM and 2-4 FM: forest cover declined from 32.5% to 18.4% and from 37.6% to 20.2%, respectively, while farming increased from 17.2% to 31.2% (1-2 FM) and from 12.2% to 29.7% (2-4 FM). On properties of 4 FM or more, forest cover, although proportionally higher (40.4% in 2008), also decreased to 32.7% in 2020, with a corresponding increase in farming from 9.2% to 16.9%.

Figure 09 - Dynamics of land cover according to rural property size classes in Lábrea (2008–2020)

Source: Own elaboration.

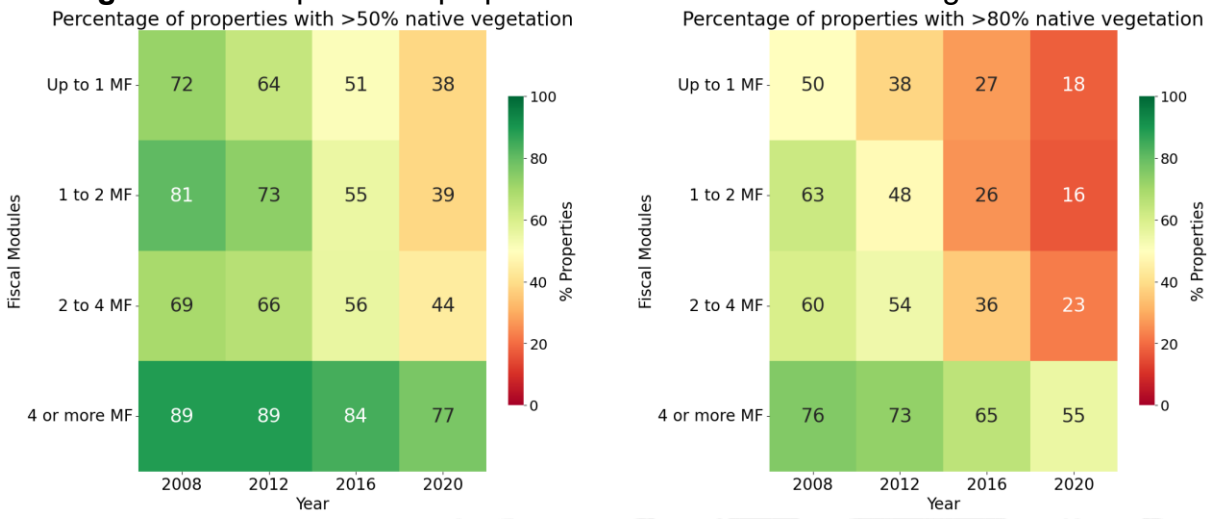
The identified trends indicate that smaller properties exhibited a higher proportion of forest-to-agriculture conversion, possibly due to the need for intensive land use to ensure subsistence or immediate economic returns. Larger properties maintain a relatively higher proportion of forest; however, given their total size, small percentage decreases correspond to extensive areas deforested in absolute terms. Thus, the data reveal two complementary

patterns: higher relative pressure on small properties and greater absolute contribution of large properties to deforestation, despite their higher forest cover percentages. In this context, it is important to note that the LPVN exempts properties of up to four FM that did not meet the minimum Legal Reserve percentage in 2008 from restoration obligations, which may have encouraged post-registration neglect under the CAR system.

The difference between forest loss in areas declared as LR and the loss observed across the entire property shows that forest conversion primarily occurs in productive areas, while LRs maintain greater relative integrity. This pattern is critical for enforcement, as degradation may remain “hidden” if only LRs are considered. Nonetheless, higher conservation within LRs does not eliminate risk, as even small reductions indicate that productive pressures are advancing into legally protected areas. Distinguishing between loss in LR and the rest of the property thus helps identify priority properties for monitoring and areas where illegal conversion is likely to occur first.

Assessing the proportion of properties with native vegetation cover above 50% and 80% reveals clear patterns of gradual forest loss between 2008 and 2020 (Figure 10). This approach considers the entire property rather than only the area registered as a LR, allowing a broader evaluation of the state of natural cover and identification of properties that still maintain sufficient native vegetation, even when their LR areas are partially deforested, thereby supporting conservation and ecological connectivity.

Figure 10 – Proportion of properties with insufficient native vegetation cover



Source: Own elaboration.

Considering properties with more than 50% native vegetation, in 2008 most properties across all Fiscal Module classes exhibited adequate forest cover, particularly

larger properties (>4 FM), where 83.8% maintained more than half of their area under forest. By 2020, this proportion declined significantly, especially for medium and small properties, reaching only 35.5% for properties of 1-2 FM and 38.6% for those of 2-4 FM, while larger properties maintained relatively higher cover (68%).

When evaluting coverage above 80%, the minimum threshold established for the Legal Amazon, the reduction is even more pronounced. In 2008, 71.5% of larger properties exceeded this threshold, whereas only 46.1% of properties of 1-2 FM met it. By 2020, less than 15% of medium and small units maintained coverage above 80%, and even among larger properties, this value fell to 46.8%.

It is evident that, even if a property's Legal Reserve is not entirely covered by native vegetation, the entire property may still retain a significant portion of forest cover. However, the general trend shows a progressive loss of native vegetation over time, more intense in medium and small properties, reflecting their higher vulnerability to anthropogenic pressures such as pasture expansion and agricultural management. This pattern underscores the need for differentiated environmental policies that consider property size and promote the maintenance or restoration of forest cover, particularly in units with lower capacity to conserve areas.

The requirement of a fixed LR percentage for all properties may be disproportionate for smallholdings, whose productive dynamics depend on intensive land use for subsistence or immediate economic return. This vulnerability reduces the ability to maintain native vegetation and may incentivize irregular conversions, highlighting the need for tailored policies.

In Lábrea, where properties up to two FM predominate, instruments such as payments for environmental services, support for non-timber forest production, continuous technical assistance, and conservation-linked credit lines are likely to be more effective than isolated penalties, as they reduce the economic pressures driving deforestation. Given this pattern, Phase V of the PPCDAm (2023 - 2027) reinforces the need for specific strategies for land regularization, active enforcement, and incentives targeting smallholders, who have lower capacity to conserve areas without institutional support. Consequently, the results observed up to 2020 remain essential for identifying where the plan faces the greatest barriers and where territorially differentiated actions can generate the greatest impact.

3.3 Overlap of properties with Conservation Units and Indigenous Territories

Several properties registered in the CAR overlap with Conservation Units. For analytical purposes, only polygons whose overlap exceeded 90% of the Conservation Units area were excluded, avoiding the treatment of entire protected areas as private properties. This filter removed, among other cases, the largest polygon in the database, corresponding entirely to the Iquiri National Forest (14,749 FM). After exclusion, 328 properties (out of 3,526 valid records) remained with partial overlap below 90% and were retained in the analysis. Properties located in Community Use and Commercial Forest Management Zones, as well as in the Community Use, Forest Management, and Conservation Zone of the respective protected area, were also identified.

Table 01 presents the percentages of overlap with federal Conservation Units, all established during the first phase of the PPCDAm as emergency measures for territorial management. The Iquiri National Forest concentrates the largest share of overlaps with registered properties (61.5%), revealing strong pressure on this protected area. The Ituxí (17.9%) and Médio Purus (16.2%) Extractive Reserves also show significant overlaps, although on a smaller scale, indicating potential conflicts between traditional community use and agricultural frontier expansion. The Mapinguari National Park shows a lower percentage of overlap (8.4%) but still reflects the presence of land-use pressures even in strictly protected areas.

Table 01 – Percentage of Conservation Unit areas overlapped by registered properties in Lábrea (AM)

Conservation Unit	Percentage of overlap within the Conservation Unit
Iquiri National Forest	61.50%
Ituxí Extractive Reserve	17.90%
Médio Purus Extractive Reserve	16.20%
Mapinguari National Park	8.40%

Source: Own elaboration.

Table 02 presents the percentage of overlap between registered properties and the different Indigenous Territories in Lábrea, highlighting Alto Sepatini as having the highest overlap (98.9%), followed by Seruini/Marienê (76.8%) and Guajahã (69.0%). One property

of 9,489 FM overlaps 44.2% with the Seruini/Marienê Indigenous Land and 30.4% with the Boca do Acre Indigenous Land. Another property, with 697 FM, overlaps 98.9% with the Alto Sepatini Indigenous Land and 10.5% with the Acimã Indigenous Land. The Jacareúba/Kataúxi Indigenous Land intersects multiple properties, ranging from 4 to 25 FM, including the 697 FM property; collectively, these overlaps correspond to 21.7% of the extent of this Indigenous Land within municipal boundaries. All percentages refer to the proportion of the Indigenous Territories area located within the municipality.

These overlaps highlight governance challenges and the need to integrate accurate spatial information into territorial management. Properties coinciding with protected areas facilitate conflicts and illegal activities, such as land appropriation and deforestation, reinforcing the importance of territorial consolidation programs and effective enforcement (Furumo et al., 2024).

Between 2001 and 2015, according to PRODES data (INPE, 2025), deforestation rates within Conservation Units and Indigenous Territories remained extremely low, with annual increments below 1%. These figures underscore the fundamental role of these areas in mitigating deforestation, conserving biodiversity, and maintaining ecosystem stability in the face of climate change. However, the persistence of external pressures, such as agricultural expansion and illegal resource exploitation, emphasizes the need for continuous monitoring systems and effective enforcement actions to prevent invasions of private properties and ensure the integrity of protected areas.

Tabela 02 – Percentage of Indigenous Territory area overlapped by registered properties in Lábrea

Indigenous Territory	Percentage of overlap within the Indigenous Territory
Alto Sepatini	98.9%
Seruini/Mariene	76.8%
Guajahã	69.0%
Peneri/Tacaquiri	39.9%
Boca do Acre	30.5%
Acimã	10.5%
Tumiã	7.8%
Jacareúba/Katauixi	7,4%

Kaxarari	6.9%
Paumari do Lago Marahã	3.6%
Apurinã Km 124 BR-317	0.6%
Jarawara/Jamamadi/Kanamati	0.4%
Caititu	0.1%

Source: Own elaboration.

Normative Instruction nº 9/2020 of the National Foundation of Indigenous Peoples (FUNAI) granted the institution the authority to request, analyze, and issue Declarations of Boundary Recognition, certifying that property boundaries respect homologated Indigenous Territories. This regulation, by allowing certification over areas not yet homologated, increased the risk of overlap with private properties and exacerbated registration inconsistencies in the CAR, weakening enforcement and compromising territorial governance (FUNAI, 2020). However, the Federal Public Prosecutor's Office annulled the Normative Instruction the following year, reversing this authorization and reinforcing the legal protection of Indigenous Territories (MPF, 2021).

4 CONCLUSIONS

Periodic verification of self-declared information is essential, given that land cover changes over time. Continuous monitoring requires systematic, preferably annual, data collection and automated geospatial and remote sensing processing methodologies, ensuring record validation and reducing registration errors. Therefore, it should not be assumed that areas declared as Legal Reserves are entirely covered by native vegetation, as cadastral delineation alone does not guarantee the maintenance of original cover. Furthermore, the legislation allows for multiple uses of standing forest, meaning that LR areas can be sustainably managed to obtain non-timber products relevant to the local economy.

The results indicate that pasture expansion and deforestation in Lábrea are related to property size. Smaller properties showed greater vulnerability to forest cover loss, while larger properties maintained relatively conserved levels. Regularization and territorial consolidation programs, although important, have limited effectiveness when not accompanied by systematic verification and enforcement of the data.

It is recommended that future research advance methodologies for systematic

verification of self-declared information in the CAR, incorporating automated geospatial analysis, and investigate how economic incentives influence conservation across properties of different sizes. Interdisciplinary studies integrating socioeconomic, ecological, and legal dimensions can strengthen environmental governance in the Amazon, improving resource management, reducing deforestation, and consolidating sustainable development strategies crucial for climate mitigation and biodiversity conservation.

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