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FOREST COVER CONVERSION AND EXPANSION OF CATTLE RANCHING IN THE EXTRACTIVE RESERVES OF VALE DO ACRE, BRAZILIAN AMAZON

Silvia Cristina de Jesus[1]

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[1] PhD in Environmental Sciences (UFSCAR).
São Carlos – SP, Brazil.
E-mail: silviacrisj@gmail.com

ABSTRACT

This study evaluates land-cover changes in Vale do Acre, Brazil, with emphasis on forest-to-pasture conversion in the Chico Mendes and Cazumbá-Iracema Extractive Reserves. This is a quantitative and exploratory study based on geospatial analysis, integrating multitemporal deforestation data (PRODES/INPE), livestock and non-timber forest product (NTFP) statistics (IBGE), and atmospheric methane concentrations (Sentinel-5P/ESA). Data were processed using Geographic Information Systems (GIS) and Python scripts to detect spatial and temporal trends in environmental transformations. Results show deforestation peaks in the Chico Mendes Reserve in 2019 (79 km²) and 2021 (90 km²), mainly in municipalities like Epitaciolândia near highways and urban zones. In Cazumbá-Iracema, deforestation was highest shortly after its establishment, resurging from 2018 onwards. The analysis indicates that cattle ranching expansion and declining NTFP production—especially rubber—are weakening traditional livelihoods in extractive communities. Additionally, pasture expansion correlates with rising atmospheric methane concentrations, particularly in municipalities where pasture areas have overtaken forest cover. These findings highlight the need for public policies focused on sustainable land management, strengthened conservation efforts, and the inclusion of traditional knowledge. The study contributes to the debate on regional development and socio-environmental challenges in the Amazon, emphasizing the role of extractive reserves in balancing conservation and livelihoods.

Keywords: Extractive Reserves; Deforestation; Cattle Ranching; Vale do Acre; Extractive Communities; Land-cover changes

INTRODUCTION

The expansion of livestock farming in the Amazon has significant environmental, economic, and socio-cultural impacts, particularly within Extractive Reserves (ER). This expansion is currently the main driver of deforestation in the Legal Amazon, accounting for approximately 80% of forest conversion to pastures in recent decades (MapBiomas, 2023). These changes threaten the sustainability of traditional practices and the conservation of biodiversity, especially in territories where extractive communities depend on forest resources and small-scale agriculture for their livelihoods (Kröger, 2019; Freitas et al., 2024).

Extractive Reserves, established as part of Brazil's National System of Conservation Units (SNUC), aim to safeguard the culture, economy, and way of life of traditional populations. They promote participatory management, involving local communities in decision-making and natural resource governance. In this context, ERs are central to Brazil's broader socio-environmental strategy, particularly in the Amazon (Tabagiba et al., 2018; Medina et al., 2022). The origins of ERs date back to the 1970s and 1980s, when Brazil implemented developmental policies such as the National Integration Policy. These strategies aimed to populate and economically integrate the Amazon through colonization and agricultural settlement projects (Joanoni Neto & Guimarães Neto, 2021). While such policies attracted migrants, they also intensified deforestation, environmental degradation, and conflicts over land use. In response, traditional populations mobilized to defend their territorial rights and natural resources, advocating for models of land use based on extractivism and family farming (Kröger, 2019). Although the creation of Extractive Reserves in the 1990s marked an important achievement for the Rubber Tappers' Movement, their implementation was not without challenges. Tensions between local and state interests, along with neoliberal reforms that weakened state protection, compromised the capacity of ERs to fully achieve their goals of conservation and sustainable development (Cunha, 2010; Spínola & Carneiro Filho, 2019).

This work aims to assess land cover changes in Vale do Acre, focusing on the conversion of forests to pastures in the Chico Mendes and Cazumbá-Iracema Extractive Reserves (RESEX). The research also examines the production of non-timber forest products (NTFPs) and methane distribution in the area. By analyzing land use changes and the expansion of livestock farming in the municipalities of Vale do Acre, this study contributes to the field of regional development. It highlights the complex interplay between

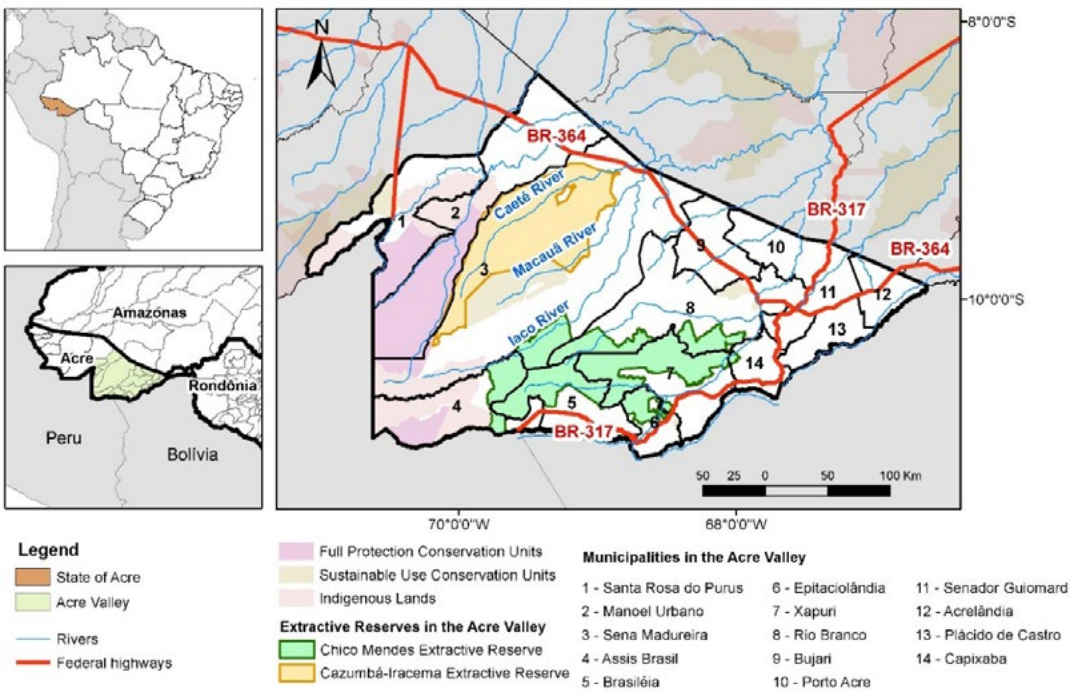
conservation policies, local economic activities, and environmental consequences, offering valuable insights into the dynamics shaping regional governance and sustainable development.

METHODOLOGY

STUDY AREA

Vale do Acre mesoregion is in the state of Acre, in the northern region of Brazil. It comprises 12 municipalities: Acrelândia, Bujari, Capixaba, Epitaciolândia, Plácido de Castro, Porto Acre, Rio Branco, Senador Guiomard, Sena Madureira, Tarauacá, Xapuri, and Brasiléia (Figure 1). The economy of Vale do Acre is primarily based on agriculture, livestock farming, plant extractivism, and ecological tourism. Vale do Acre includes 10 conservation units totaling 27,716 km², with ER being the predominant category in the region in terms of area (62%). These are: Rio Acre Ecological Station and Chandless State Park (Full Protection), Santa Rosa do Purus National Forest, São Francisco National Forest, Macauã National Forest, São Francisco Environmental Protection Area, Lago do Amapá Environmental Protection Area, Chico Mendes Extractive Reserve, and Cazumbá-Iracema Extractive Reserve (Sustainable Use) (MMA, 2024a).

Figure 1 | Location of Vale do Acre.



Source: Prepared by the author.

The Chico Mendes Extractive Reserve, established in 1990, covers approximately 970,000 hectares and was born from conflicts between rubber tappers and Brazil nut collectors, who depended on natural resources, and cattle ranchers and landowners, who cleared land for pastures and agriculture. When its Management Plan was developed (ICMBio, 2006), the primary economic activities in the area were extractivism, particularly rubber and Brazil nuts, along with subsistence agriculture and cattle ranching. The ER was a pioneer in the concept of a sustainable-use conservation unit, enabling traditional populations to live and carry out extractive activities.

The Cazumbá-Iracema Extractive Reserve, created in 2002, spans about 770,000 hectares and occupies land originally designated for settlements that were never implemented. Among the Amazonian conservation units evaluated by the Brazilian Federal Court of Accounts, it received one of the highest implementation and management scores (TCU, 2014). In 2022, the Chico Mendes Resistance Award in the Personality category was given to Nenzinho, a local socio-environmental activist and co-creator of the Extractive Reserves with Chico Mendes.

DATA ORGANIZATION AND PROCESSING

Multitemporal land cover data were essential for this analysis as they allow for the assessment of land use changes over time, offering insights into the dynamics of forest conversion, pasture expansion, and the long-term impacts of these processes on both the environment and local communities. Data on land cover dynamics and the local economy were collected and processed using Geographic Information Systems (GIS) and spreadsheet software. MapBiomas and PRODES data were used to analyze land cover changes and deforestation trends, as they provide reliable and comprehensive information on land use dynamics and forest loss over time, which are vital for understanding the environmental impacts in the study area. Specifically, multitemporal deforestation data from the Program for the Calculation of Deforestation in the Legal Amazon (PRODES) (INPE, 2024a; INPE, 2024b) were evaluated for the Chico Mendes and Cazumbá-Iracema ER, while municipal-level data assessed land cover variations, particularly regarding Forest Formation and Pasture classes (MapBiomas, 2024).

Data on cattle production and non-timber forest products were also essential as they reflect key economic activities influencing land use. Cattle ranching drives pasture expansion, while non-timber forest products reflect local communities' dependence on extractive activities, providing a clearer picture of the socio-economic and environmental changes in the region. The annual production of cattle (IBGE, 2024a) and major non-timber forest products (IBGE, 2024b) in the municipalities were analyzed. Methane data were used to estimate emissions associated with the expansion of livestock farming, as cattle ranching in pasture areas significantly contributes to methane emissions, a major greenhouse gas from agricultural activities. Data from the Sentinel-5P OFFL CH4 (ESA, 2024), with a spatial resolution of 1,113.2 meters, covering 2019 to 2023, were used for methane concentration analysis. Annual images were generated using the median of the data for each year, providing a robust assessment of temporal variations in methane levels. Access to these images was through the Earth Engine Data Catalog platform, with processing carried out using Python scripts, ensuring accuracy and consistency in the analysis of the extractive reserves and their connection to environmental and economic changes in the region.

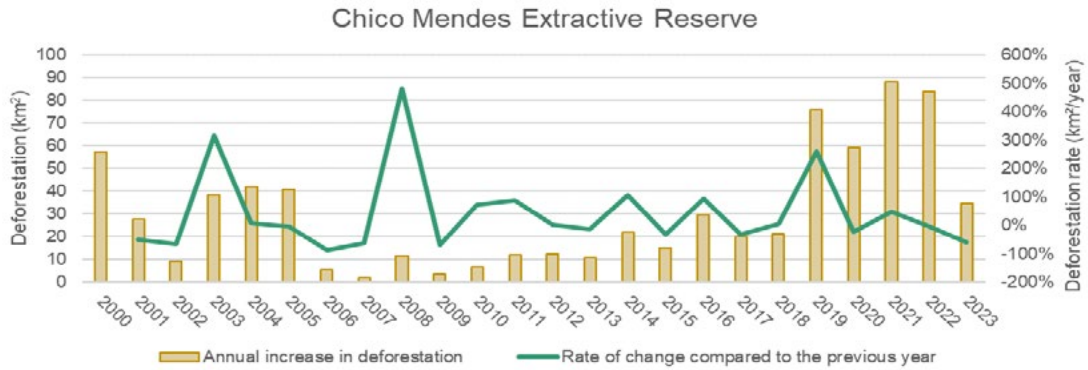
RESULTS AND DISCUSSION

DEFORESTATION AND FOREST CONVERSION TO PASTURE IN THE ER AND MUNICIPALITIES OF VALE DO ACRE

Considering the broader context of the Brazilian Legal Amazon, there was a period of reduced deforestation starting in 2008, driven by the Action Plan for Prevention and Control of Deforestation in the Amazon (PPCDAm) (MMA, 2024b). This was a sociopolitical process that emphasized biodiversity and sustainable forest management, including the creation of new extractive reserves and other conservation units. However, there was a resurgence of forest suppression, encouraged by the enactment of the Native Vegetation Law (Law 12.651/2012) (Brasil, 2012), and subsequently, the far-right policies (2018-2022) supported deforestation within protected areas, such as the Chico Mendes ER in Acre.

The Chico Mendes ER showed increases in deforestation throughout the available data period from PRODES (2000-2023), ranking among the top three federal conservation units with the highest deforestation increases since 2016. Notably, it recorded the highest increases in deforestation in 2019 (79 km², a 210% increase from the previous year) and in 2021 (90 km², a 47% increase from the previous year) (Figure 2). These post-2019 increases are representative of a broader pattern of weakening environmental governance in the region, driven by deregulatory federal policies, reduced enforcement by IBAMA and ICMBio, and the rollback of protected areas. The period also saw increased land speculation and illegal land grabbing within and around the reserve. In the context of Vale do Acre, such dynamics intensified pressures on forest-dependent communities and accelerated the shift from extractivism to cattle ranching, making the region emblematic of Amazonian frontier expansion driven by political and economic incentives (Kröger, 2020).

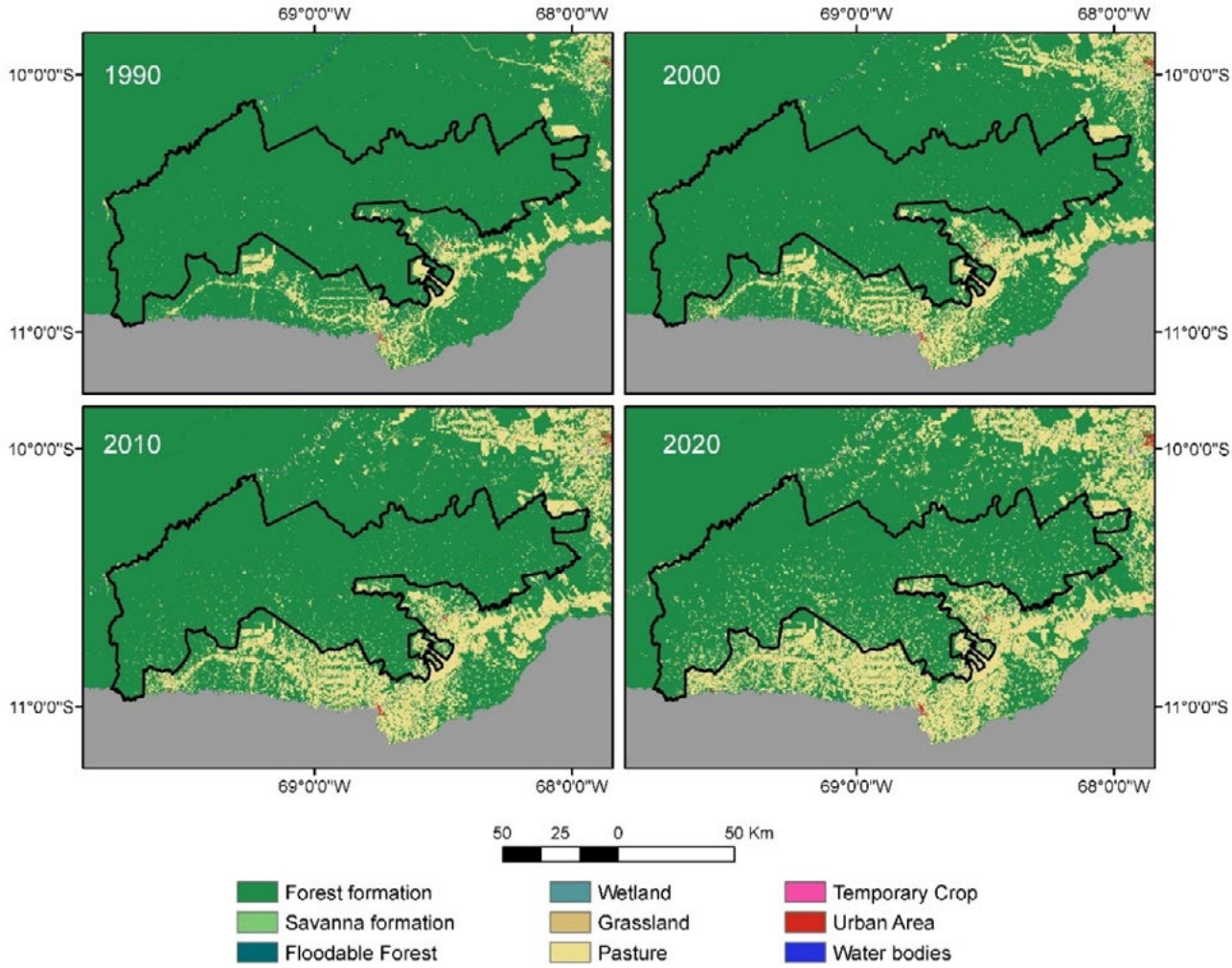
Figure 2 | Deforestation in the Chico Mendes ER over time.



Source: INPE, 2024a; INPE, 2024b. Prepared by the author.

The area of the Chico Mendes ER located in the municipality of Epitaciolândia has seen the most concentrated deforestation within the conservation unit. In the municipalities of Brasiléia and Xapuri, the ER faces deforestation pressure in its surroundings, in a region where forest suppression is intense in the state of Acre due to BR-317 highway, which borders the southern part of the Chico Mendes ER and connects to BR-364 highway further northeast, heading towards the urban area of Rio Branco, the state capital (Figure 3). The deforested area south of the ER extends towards the urban area of Epitaciolândia, which forms a conurbation with the Bolivian municipality of Cobija.

Figure 3 | Land Cover in the Chico Mendes ER.

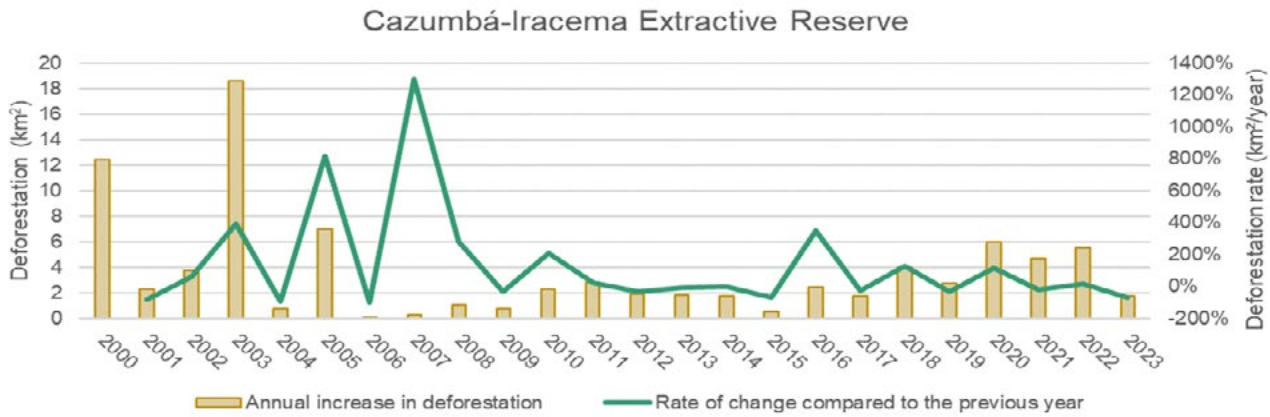


Source: MapBiomas (2024). Prepared by the author.

Kröger (2020) observes that Amazonian peasants, who once had only a few cattle for subsistence, now maintain large herds in the Chico Mendes Extractive Reserve. The author links this transformation to recent public policies that have reduced the capacity of organized rural populations to manage their territories. The intensification of deforestation in the reserve is associated with the increasing integration of local communities into livestock production chains, driven by external pressures such as governmental directives and market dynamics. These changes have significantly influenced their productive practices and ways of life (Kröger, 2019).

The Cazumbá-Iracema ER, on the other hand, saw the highest increases in deforestation shortly after its creation in 2002 (18.6 km² in 2003, with a deforestation rate of 396% compared to the previous year). Families in this conservation unit rely on extractivism and family farming for their subsistence, so it is common to see deforestation at the beginning of occupation to establish croplands. There was a period of stability starting in 2010, with a trend of increasing deforestation rates beginning around 2018 (Figure 4). The rise in deforestation in the Cazumbá-Iracema ER post-2018 mirrors trends seen in other regions of the Amazon, where extractive activities such as Brazil nut collection and subsistence farming are being displaced by larger-scale agricultural ventures, particularly cattle ranching.

Figure 4 | Deforestation in the Cazumbá-Iracema ER over time.



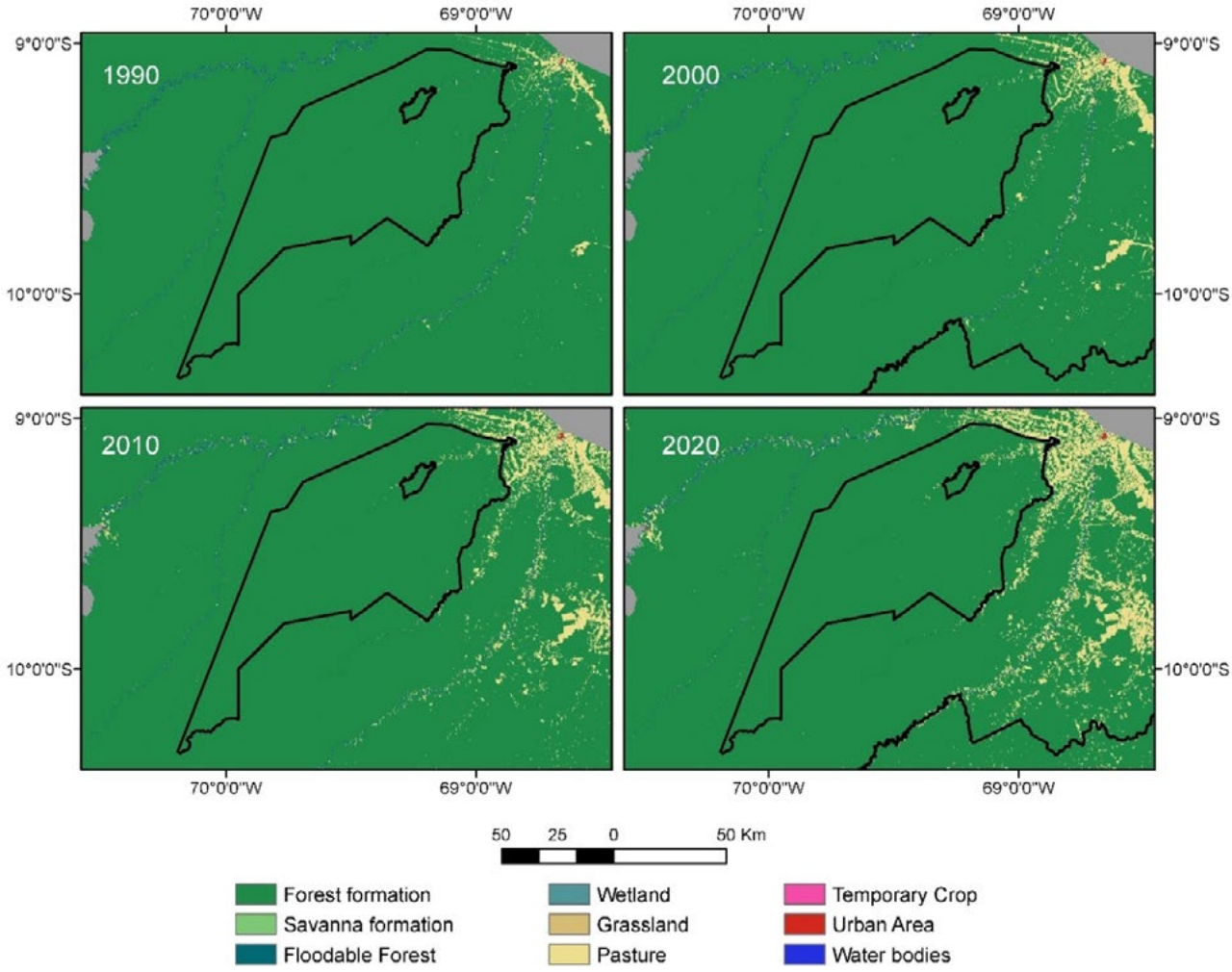
Source: INPE, 2024a; INPE, 2024b. Prepared by the author.

In the Cazumbá-Iracema ER, family farmers raise backyard poultry and horses, diversifying income, contributing to food security, and promoting sustainable management practices (Costa et al., 2022). Plese and Pereira (2020) highlight that income generation is diversified, with a focus on Brazil nuts and flour, while cattle ranching is growing, particularly along the Médio Caeté river where the forest is being cleared. According to the authors, residents express pessimism about the future of extractive activities and call for more effective public policies and investments to strengthen productive chains and improve quality of life. Lelis (2016) emphasizes the importance

of collective governance and self-governance in the sustainable management of common resources, identifying challenges such as external pressure and lack of institutional support, but also opportunities to strengthen collaborative management, such as valuing traditional knowledge, promoting collaborative networks, and investing in training and education. However, these initiatives are increasingly undermined by the large-scale encroachment of agricultural land and the absence of comprehensive government support. For instance, while family farming and extractivism continue to provide a livelihood for many, their long-term viability is threatened by market forces that incentivize large landholders to clear forest for pasture and monocultures, especially in regions with weak enforcement of land use regulations. This situation calls for a renewed focus on land tenure security and stronger support for agroecological practices to balance conservation and local development (Plese & Pereira, 2020; Lelis, 2016).

The Cazumbá-Iracema ER is almost entirely within the municipality of Sena Madureira, which has agriculture and livestock as its main economic activities (IBGE, 2024c). Due to the significant increase in deforestation, in 2023, the municipality of Sena Madureira was listed by the federal government as one of the priority municipalities for actions to prevent, control, and reduce deforestation and forest degradation in the Amazon biome (MMA, 2024c). From 1985 to 2023, the percentage of the municipality's area allocated to pastures increased from 1.0% to 9.6% (MapBiomas, 2024). This increase occurred primarily in the northeastern portion of the municipality along BR-364 highway, passing through the urban area of Sena Madureira, and along the banks of the Iaco, Macauã, and Caeté rivers. The latter enters the Cazumbá-Iracema ER, where deforestation within the unit occurs. Figure 5 shows the expansion of pasture areas from 1990 to 2020 in the Cazumbá-Iracema ER.

Figure 5 | Land Cover in the Cazumbá-Iracema ER.

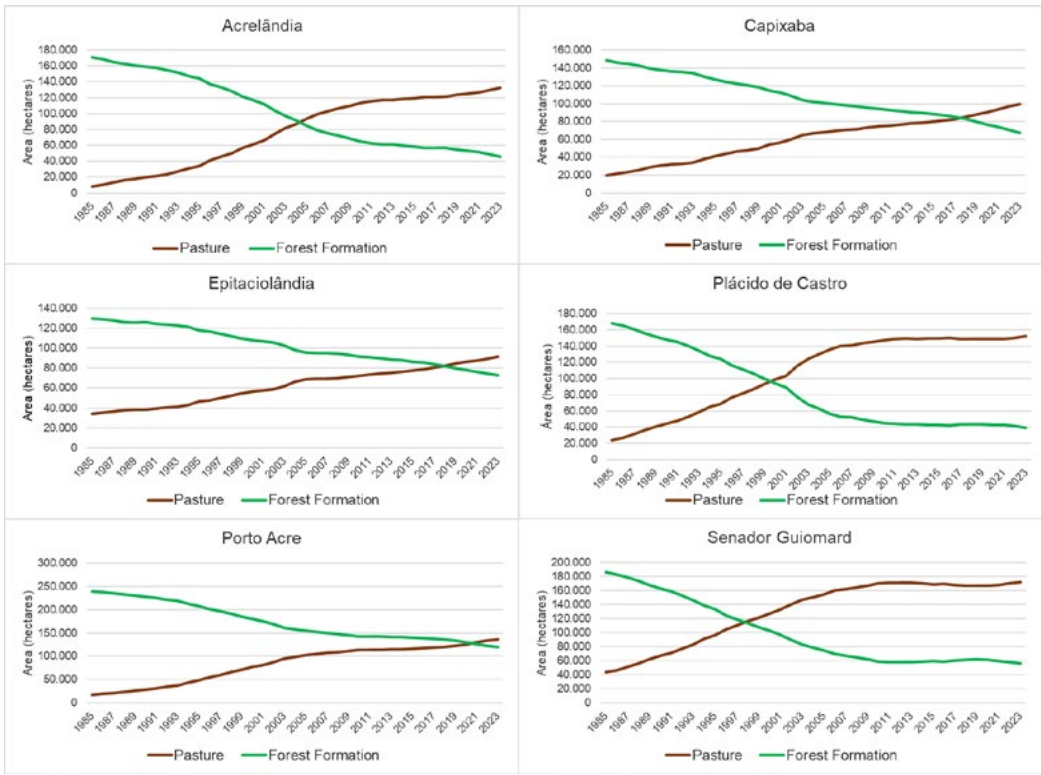


Source: MapBiomas (2024). Prepared by the author.

Both in Chico Mendes ER and in Cazumbá-Iracema ER, the presence of roads acts as a vector for deforestation as reported in the literature (Barber et al., 2014; Laurance et al., 2002; Millien et al., 2020; Pfaff et al., 2007). In extractive reserves, these roads present a significant trade-off: while they facilitate access to remote areas and the extraction of natural resources, they are also essential for the flow of production, allowing for the commercialization of products and generating income for local communities. Therefore, road management and monitoring must be part of any sustainable development strategy for the region.

Assessing land cover in municipalities near extractive reserves is important to understand the regional scenario, monitor changes over time, and identify factors that may drive deforestation, such as the dynamics of local economic activities, including the extraction and trade of non-timber forest products. In municipalities within the Chico Mendes ER, pasture areas are predominant over forest formation areas. Figure 6 illustrates the transition from forest cover to pasture over the years in municipalities of Vale do Acre where pasture areas have become predominant: Plácido de Castro (78%), Senador Guiomard (74%), Acrelândia (73%), Capixaba (58%), Epitaciolândia (55%) and Porto Acre (52%).

Figure 6 | Transition from Forest Cover to Pasture in the Municipalities of Vale do Acre.



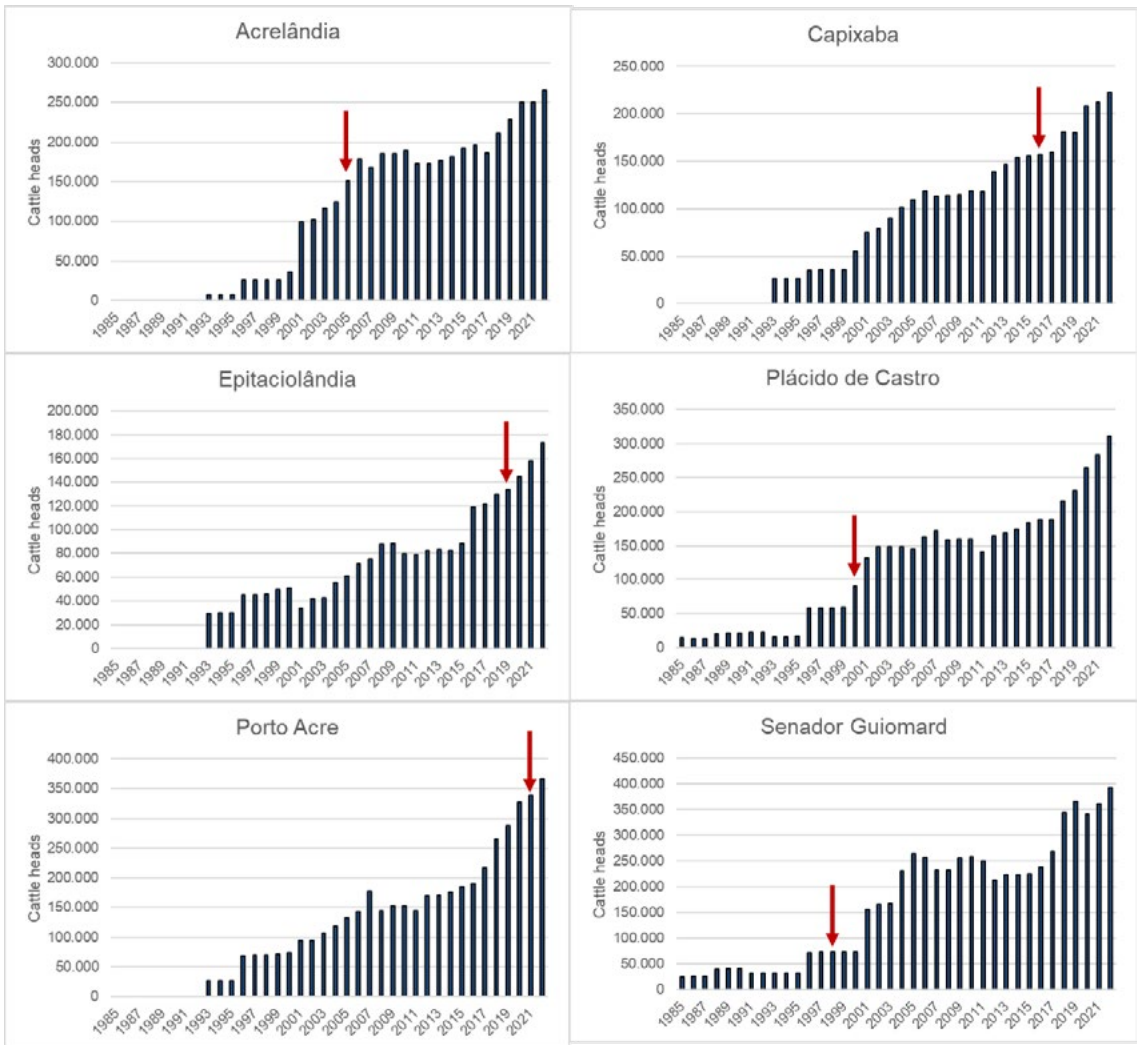
Source: MapBiomas, 2024. Prepared by the author.

In this set of municipalities, while the pasture area continues to grow, the rate of expansion has declined since 2003, when it increased by 8% annually; since 2006, the annual growth rate has not surpassed 3%. This slowdown in pasture area expansion after 2006 could be attributed to several factors, including lower demand for land from the expanding cattle industry, reduced availability of land for

conversion, and the influence of conservation policies in the region. However, the persistence of pasture dominance in these municipalities indicates that even with these slowdowns, land-use change remains a significant driver of deforestation in Vale do Acre (MapBiomas, 2024). Although the data are presented by municipality, the observed patterns reflect a broader regional trend that affects the extractive reserves under analysis, justifying a more integrated interpretation of the results.

In these municipalities, cattle ranching production is increasing; Figure 7 shows this rise, indicating the year when the anthropized area exceeded the forest area (red arrow). Braziléia, Bujari, Porto Acre, Rio Branco, and Xapuri tend to exhibit the same situation.

Figure 7 | Temporal series of cattle heads.



Source: IBGE, 2024a. Prepared by the author.

This regional behavior supports the understanding of a shift in land use dynamics that has implications for the surrounding extractive reserves, without requiring a municipality-by-municipality breakdown. This type of land cover conversion is associated with biodiversity loss and soil degradation, as well as social impacts, such as land conflicts and resource use among different interest groups, including farmers, ranchers, indigenous communities, and conservationists. This can result in social tensions and even violence. In extractive reserves, the conversion of forests to pastures can have significant impacts on the livelihoods of local communities, leading to the loss of essential natural resources and traditional knowledge about sustainable forest management. The social tensions resulting from the expansion of cattle ranching are further compounded by the increased competition for land and resources, which can lead to disputes not only among local farmers but also between indigenous groups, environmental NGOs, and government authorities. In the case of the Chico Mendes and Cazumbá-Iracema ERs, these conflicts highlight the need for stronger governance structures and community-based management approaches that can reconcile conservation and development goals in a way that benefits both people and the environment.

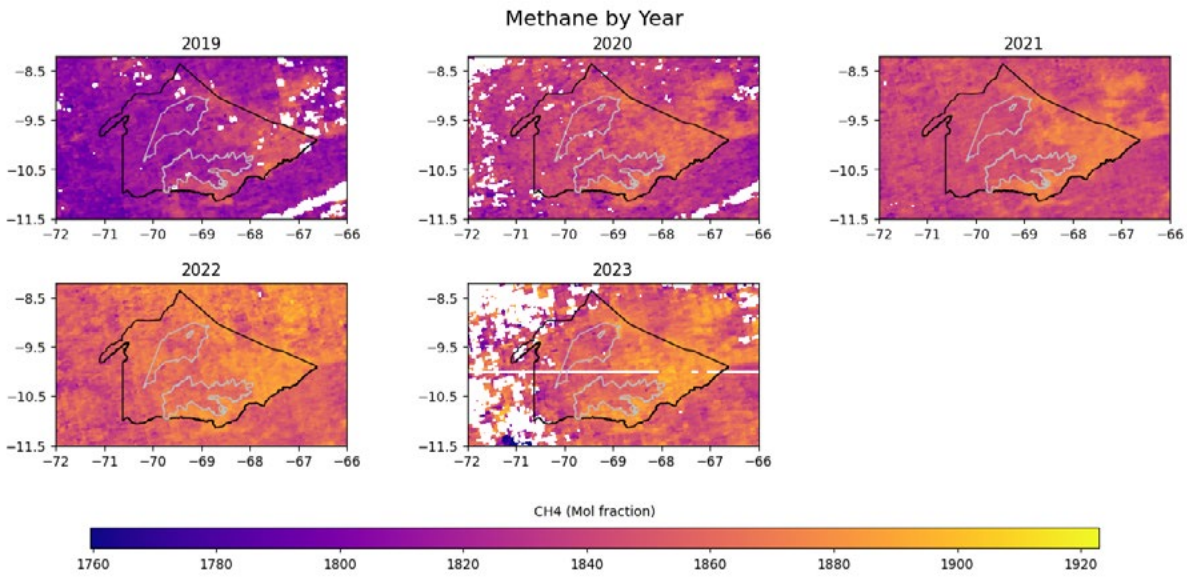
During the 1970s and 1980s, the Gross Domestic Product of the State of Acre experienced rapid growth, though it still lagged both the national average and the average for the Northern Region. The state's cattle herd increased significantly, especially in Vale do Acre, which concentrated 85% of the state's human activity (Campos & Costa, 1993). Although cattle ranching is essential for subsistence and food security in local communities by providing animal protein and reducing hunting, large-scale livestock farming has several negative impacts. Environmentally, it contributes to deforestation, biodiversity loss, soil erosion, water pollution, and significant carbon and methane emissions. Additionally, overgrazing can lead to soil compaction and loss of native vegetation, affecting forest ecosystem services. Socially, the expansion of livestock farming can result in land concentration in the hands of large landowners, excluding small producers and local communities, and create conflicts with communities that rely on the forest for their subsistence (Spínola & Carneiro Filho, 2019; Castelo & Macedo, 2015; Kraham, 2017; Lopes & Lima, 2022). Salisbury and Schmink (2007) note that rubber tappers turned to cattle raising to generate income after the interruption of rubber subsidies in the 1990s. Kröger (2020) emphasizes that beef production in Brazil is supported by accessible rural credits and policies favorable to large companies, with Acre being one of the highest per capita consumers in the country.

METHANE (CH4) EMISSIONS IN VALE DO ACRE

Anthropogenic activities in terrestrial ecosystems, such as land-cover changes, deforestation, forest conversion to agriculture, burning, cattle raising, waste management, and river damming, can reduce the soil's capacity to absorb methane and increase its emissions (Malhi et al., 2021). In the Amazon, the conversion of tropical forests into cattle pastures transforms the soil from a methane sink to a methane source (Meyer et al., 2017). Locally, in the ER of Vale do Acre, livestock farming significantly contributes to greenhouse gas emissions, primarily through forest conversion into pastures and methane emissions from ruminants. The historical series of atmospheric methane concentration data, provided by the Sentinel-5P satellite, extends from 2019 to the present. The median was used for annual methane data as it is less affected by extreme values and outliers, offering a more reliable representation of central concentration trends.

Multitemporal images indicate a rise in methane concentrations in Vale do Acre, as evidenced by the color gradient showing significant changes over the analyzed period (Figure 8). The white pixels represent missing data.

Figure 8 | Spatial distribution of methane concentrations in Vale do Acre.



Source: ESA, 2024.

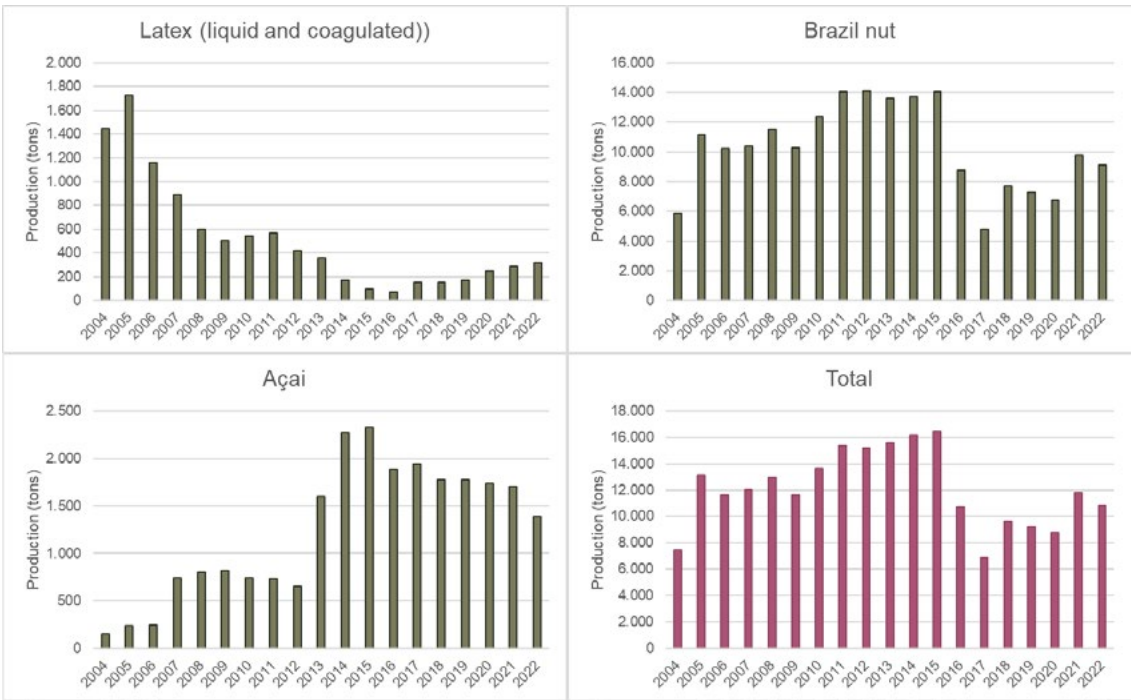
The average concentration rose from 1826.71 to 1867.27 Mol fraction, indicating a steady increase. Similarly, the maximum concentration also grew, peaking at 1922.99 Mol fraction in 2023, the highest value recorded during this period. Methane dispersion in the atmosphere is influenced by atmospheric movements, weather conditions, and geographical characteristics such as topography and vegetation cover. Despite the physical factors influencing pollutant dispersion, a distinct spatial pattern in methane concentration is evident. Over time, the highest concentrations are observed in the eastern part of Vale do Acre, particularly in municipalities where pasture areas have exceeded forest areas (Acrelândia, Capixaba, Epitaciolândia, Plácido de Castro, Porto Acre, and Senador Guiomard). This pattern extends to the vicinity of extractive reserves and other conservation units. This highlights the impact of land cover conversion on methane production and highlights the critical role of protected areas in mitigating atmospheric pollution. It also reveals that, if deforestation in extractive reserves is not controlled, these areas could become susceptible to similar levels of atmospheric contamination.

Methane (CH_4) is a potent greenhouse gas with a global warming potential (GWP) 81.2 times greater than carbon dioxide (CO_2) over 20 years (Mar et al., 2022). It disrupts biogeochemical cycles and vegetation patterns, impacting biodiversity (Whiticar, 2020), and significantly contributes to atmospheric pollution as a precursor to ozone (O_3), which is linked to health issues like asthma and reduced lung function (Mar et al., 2022). In this context, increased methane emissions from converting forests to pastures in Vale do Acre disproportionately affect traditional communities, highlighting significant environmental justice concerns. These communities, reliant on natural resources and ecosystem services provided by forests, face severe impacts on their quality of life. Methane-induced climate change can intensify extreme weather events such as droughts and floods, threatening food and water security. Moreover, environmental degradation diminishes access to vital resources like clean water and medicinal plants, undermining traditional practices and ways of life.

NON-TIMBER FOREST PRODUCTS (NTFPS)

While the expansion of livestock farming has contributed to increased deforestation in Vale do Acre, including within Extractive Reserves, it is essential to understand how changes in the production of non-timber forest products (NTFPs) reflect and influence these dynamics. The production of NTFPs can strengthen local value chains, creating market opportunities and stimulating economic development in rural areas. Particularly, the extraction of latex for natural rubber production, which is one of the main economic activities in the region, has been declining since the beginning of the historical series provided by IBGE (2024b). At the end of the 20th century, the rubber industry crisis was triggered by several factors: competition with cheaper synthetic rubber, the decline in international natural rubber prices, lack of investment in technology and infrastructure, and the expansion of agriculture and deforestation in the region. As a result, many rubber tappers lost their sources of income and sought new forms of livelihood, either migrating to urban areas in search of employment or turning to agriculture and other economic activities (Campos & Costa, 1993; ICMBio, 2006; Miguel & Santos, 2011; Vadjunec et al., 2011). The production of key non-timber forest products has not shown a decreasing trend in Vale do Acre mesoregion (Figure 9).

Figure 9 | Non-Timber Forest Product Production in Vale do Acre.

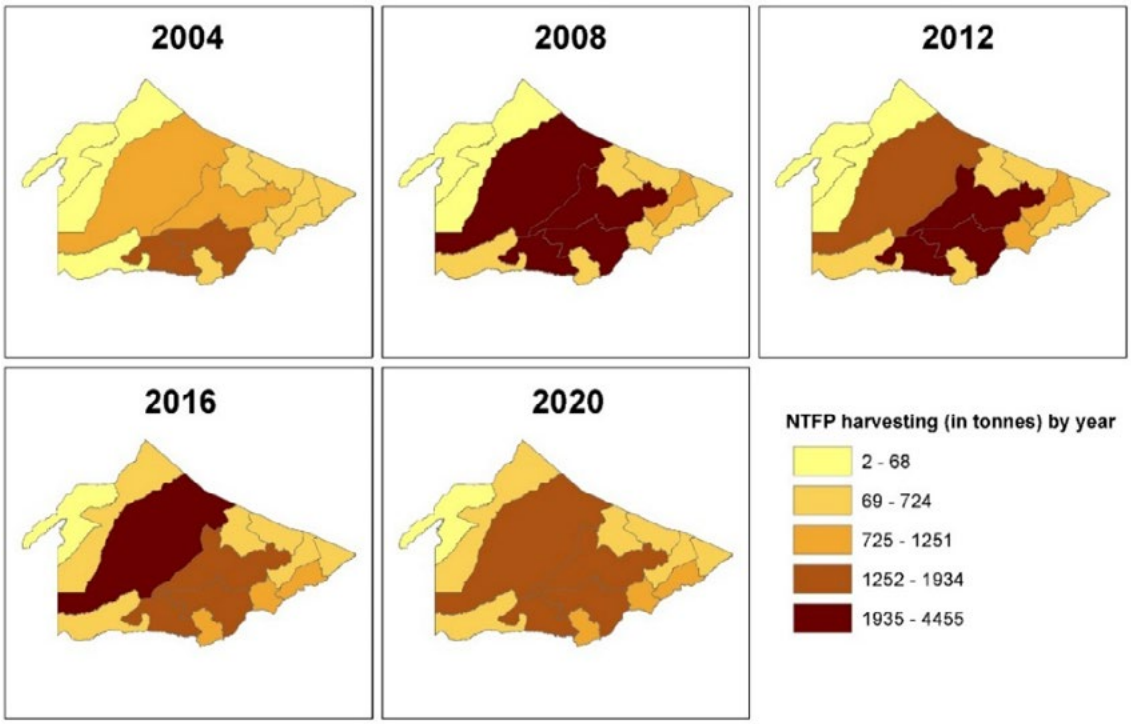


Source: IBGE, 2024b. Prepared by the author.

The production of Brazil nuts is related to the presence of continuous and healthy forests, as it is a species that grows naturally in the Amazon rainforest and relies on an intact forest ecosystem for its development (Guariguata et al., 2017) and to maintain viable minimum populations (Wadt et al., 2008). Therefore, the conversion of forests into pastures can reduce the availability of suitable habitat for Brazil nuts, potentially negatively affecting its production in the long term. This means it is essential to consider sustainable land management strategies that allow for the coexistence of Brazil nut production with agricultural expansion in the Amazon region. In the municipalities of Vale do Acre, Brazil nut production remained constant until 2015, when it declined and started to fluctuate. This condition may result from deforestation in previous years.

Brazil nut production in Acre remains stable due to the demand for primary products, driven by global interest in natural and sustainable products. Diversification into oils, cosmetics, and food products can increase demand and add value, ensuring stable income for local producers. Meanwhile, the production of açaí in Acre, although growing, is primarily for local consumption. Global demand for açaí, due to its nutritional qualities, has rapidly increased, with Brazil being the leading producer and exporter. In 2020, 66% of açaí exports went to the United States, the largest processor and exporter of açaí-based industrialized products (Conab, 2021a). In 2022, Acre produced only 5% of the açaí from the Northern region of Brazil (IBGE, 2024b), facing competition from Pará, which offers a more commercially accepted and abundant variety. Although Acre has a local market for açaí, excessive reliance on this product can lead to vulnerabilities related to price fluctuations and distribution issues, affecting the most remote and economically disadvantaged communities (Moraes & Mello, 2022). The cartogram in Figure 10 shows the spatial distribution of total non-timber forest production (including latex, Brazil nuts, and açaí) at four-year intervals. The color ranges on the maps represent the harvesting of NTFP in tons. The classification uses the Jenks Natural Breaks method to emphasize natural clusters and variations over the years.

Figure 10 | Spatial distribution of NTFP.



Source: IBGE, 2024b. Prepared by the author.

The municipalities of Sena Madureira, Rio Branco, Brasiléia, and Xapuri stood out in these assessed dates. The average values varied over the years, showing a peak in 2012 (1,156 tons) and a subsequent decline in 2016 (862 tons) and 2020 (711 tons). NTFP harvesting varied significantly between municipalities, especially in years like 2008 (3 to 2,681 tons in Santa Rosa do Purus and Rio Branco, respectively, with a standard deviation of 983 tons) and 2012 (5 to 4,455 tons in Santa Rosa do Purus and Brasiléia, respectively, with a standard deviation of 1,319 tons), and decreased in 2020 (18 to 1,581 tons in Santa Rosa do Purus and Xapuri, respectively, with a standard deviation of 527 tons).

At each date represented, there was an event that, to some extent, could either promote or hinder production. In 2004, when production was still low (the lowest median across the five dates, with 225 tons produced), significant deforestation control policies were initiated, such as PPCDAm which directly impacted forest activities. That year, Xapuri (1,856 tons) and Brasiléia (1,694 tons) had production more than three times higher than the average of the municipalities (533 tons). In 2008, the global financial crisis reduced the demand and prices for NTFPs, affecting profitability and increasing dependency on these products for employment and income, which put pressure on

some species (Canova and Hickey, 2012). In 2012, the revision of the Brazilian Forest Code introduced the Environmental Regularization Program, allowing the recovery of up to 50% of environmental liabilities with agroforestry systems and mixed plantings, which could stimulate NTFP production in areas outside conservation units (Homma, 2012). In 2016, political changes in Brazil led to a record increase in deforestation. The freezing of the Ministry of the Environment's budget and attempts to weaken protective agencies such as Ibama and ICMBio compromised environmental oversight and contributed to degradation (Pereira et al., 2019). The COVID-19 pandemic in 2020 significantly impacted communities dependent on NTFPs. In the case of açaí, the pandemic reduced supply, demand, and price, resulting in low price indices in the first half of 2020, according to the National Supply Company (Conab, 2021b). Muttilainen and Vilko (2022) observed that many forest owners faced declines in demand and cancellation of events and contracts due to the pandemic.

INTEGRATED STRATEGIES FOR MITIGATING ENVIRONMENTAL AND SOCIAL IMPACTS

The rapid conversion of forests into pastures, driven by cattle ranching and land cover changes, threatens ecological balance, causing biodiversity loss, soil degradation, and significant methane emissions. These impacts are worsened by the decline in NTFP production, crucial for the local economy and extractive communities' livelihoods. Land-use conflicts intensify social inequalities, particularly in areas contested by farmers, ranchers, indigenous groups, and conservationists. The concentration of land in the hands of large landowners and the erosion of traditional practices highlight the need for interventions that consider the region's cultural and social characteristics.

To address these challenges, strategies combining technological solutions, like satellite monitoring and drones, with sustainable management approaches, such as Crop-Livestock-Forest Integration, are needed. These practices enhance resource management, reduce methane emissions, and promote community-based ecotourism. Strengthening the legal framework for Conservation Units and promoting participatory governance are also essential. By integrating technological, cultural, and political efforts, it is possible to mitigate environmental and social impacts while fostering inclusive, sustainable development for Vale do Acre. This strategy aims to balance conservation, traditional livelihoods, and local economic development, ensuring a more resilient future for the region's communities.

CONCLUSIONS

The analysis of deforestation data from the Chico Mendes and Cazumbá-Iracema ERs, along with municipalities in Vale do Acre, highlights the conversion of forests into pastures for cattle ranching. Both conservation units face deforestation challenges due to their proximity to highways and urban areas, although the intensity varies. The Chico Mendes ER has experienced significant deforestation, driven by the decline in rubber extraction and the expansion of livestock farming. In contrast, the Cazumbá-Iracema ER has seen minimal deforestation, primarily around the Caeté river. Both ERs were established during a time of heavy livestock pressure, fueled by the rubber crisis and pro-cattle policies, leading to increased subsistence farming.

Municipalities in Vale do Acre are undergoing substantial landscape changes, with pastures replacing forests. The growth of cattle ranching and the decline in NTFP harvesting, such as latex, is affecting extractive communities that have traditionally relied on these resources. This shift threatens the sustainability of traditional practices and cultural heritage. Although NTFP production holds potential for local economic growth, its vulnerability to external shocks underscores the need for economic diversification and sustainable management.

This study contributes to the field of regional development by providing a detailed analysis of land use changes and their impacts on local communities, with a focus on Extractive Reserves. By examining the dynamics between conservation policies, local economic activities, and environmental consequences, the research offers valuable insights for public policies aimed at balancing environmental conservation with sustainable economic development.

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