Programa de Pós-Graduação Desenvolvimento Regional Mestrado e Doutorado

DOI: 10.17058/j2wv3512

Paths to forest recovery by family farmers in the northeastern Brazilian Amazon

Karla de Souza Santos
Land Institute of Pará (ITERPA), Belém, Pará, Brazil
ORCID: https://orcid.org/0000-0002-3407-5727

Livia de Freitas Navegantes Alves
Federal University of Pará (UFPA), Belém, Pará, Brazil
ORCID: https://orcid.org/0000-0003-0668-8670

Emilie Suzanne Coudel
CIRAD, Montpellier, Languedoc-Roussillon, France
ORCID: https://orcid.org/0000-0001-8272-8051

Abstract
Faced with the ongoing degradation of forest landscapes in the Amazon due to human activities, studies on forest recovery practices are increasingly relevant. An example of this dynamic occurs in the municipality of Irituia, in northeastern Pará, Brazilian Amazon, where there has been an increase in the scale of forest recovery resulting from the practices of family farmers. This article analyzes the influence of family farmers on the evolution of this process of landscape restoration. The research combines multiscale and temporal analyses, based on questionnaires, retrospective interviews, and direct observation with family farmers. Results indicate that changes in Irituia's family farming systems are shaped by a variety of factors operating at different scales, both internal, such as family demands, and external, such as incentives from the Municipal Department of Agriculture. The transition temporary cultivation areas to natural regeneration, along with the replacement of pastures by agroforestry systems, has significantly contributed to local forest recovery. In addition, conservation practices have contributed to the maintenance of biodiversity. By incorporating these experiences into the debate on regional development, the study demonstrates that family farming in Irituia not only resists production homogenization driven by the expansion of agricultural and livestock commodities but also generates sustainable alternatives for land use. The originality of this case underscores the relevance of local experiences as a reference for public policies aimed at promoting socio-environmental sustainability in the Amazon.
Keywords: Landscape trajectory. Amazonian agricultural systems. Rainforest. Family farming.

1 Introduction

Tropical forests stand out among the most complex ecosystems in the world, as they have high biological diversity, provide numerous ecosystem services, and are highly relevant to global hydrological cycles (Almeida et al., 2022; Xavier et al. 2022; Araújo and Mourão, 2023). In this context, Brazil stands out for hosting approximately 67% of all global tropical forests in the Amazon biome (Imazon, 2009), accounting for 35% of total global carbon sequestration, according to Feitosa et al. (2023).

However, the increasing degradation of these forest areas, due to the intensification of anthropogenic activities, has contributed to a scenario of great environmental destruction (Ribeiro, Melo, and Valente, 2020). The conversion of tropical forests to other land uses, mainly as a result of deforestation, is a real threat to biodiversity and the maintenance of global ecosystem services (Xavier et al., 2022; Precinoto et al., 2022).

This scenario of environmental degradation cannot be understood in isolation, but must be linked to the broader economic dynamics that shape the Amazon. Furthermore, it is important to emphasize that the transformations of the Amazonian landscapes are part of a broader context of territorial dynamics linked to the expansion of agricultural and livestock commodity production, which promote processes of productive homogenization and a redefinition of economic forces across the state of Pará. Studies such as those by Escada, Amaral, and Fernandes (2023) and Costa (2013) show that the Amazon, and Pará in particular, has been shaped by such dynamics, often in contrast to the productive diversity of family farming. In this sense, Becker (2005) points out that the region's subordinate insertion into the national and international economy limits the construction of local development alternatives.

This perspective raises intense debates about the transformations of the landscape in the Amazon, especially those associated with the expansion of commodity-oriented agricultural systems, often related to the deforestation of tropical forests and considered crucial in landscape changes (Viana, Steward, and Richers, 2016).

There is also a line of researchers who have been highlighting the emergence of a more sustainable outlook for the Amazon, based on family farming. Studies such as those by Carneiro and Navegantes-Alves (2019) have shown that certain traditional practices have been promoting forest recovery by family farmers on the scale of agricultural establishments in northeastern Pará, a region where, according to Cordeiro, Arbage, and Schwartz (2017), much of the original vegetation was devastated during the colonization process.

In light of this scenario, it is worth highlighting the municipality of Irituia, located in the aforementioned mesoregion, which, according to Braga, Navegantes-Alves, and Coudel (2020) and Santos (2024a), has gained prominence due to the increase in the scale of forest recovery in family farms, where the expansion of agroforestry systems has surpassed the traditional land use system (Monteiro; Oliveira, 2022).

Therefore, it is necessary to understand the changes that have taken place in these landscapes, seeking to understand the spatial and temporal patterns, their causes and consequences resulting from the complex interaction between human and natural systems (Amaral et al., 2022), as well as the potential influence of individual and localized practices on a broader spatial scale. From a broader perspective, Batistela and Moran (2005) emphasize that this understanding of the evolution and dynamics of landscapes is not only based on an understanding of past changes in land use, but also on multiple social and economic pathways, which, according to Rodriguez et al. (2004), are generally overlapping.

Given the above, the following research question arises: How does the influence of family farms affect the dynamics of forest landscape recovery in Irituia, Pará? Therefore, this article aims to analyze how family farmers contribute to the evolution of forest landscape recovery in Irituia, Pará, considering the complex interaction between social, economic, and environmental factors that shape this process.

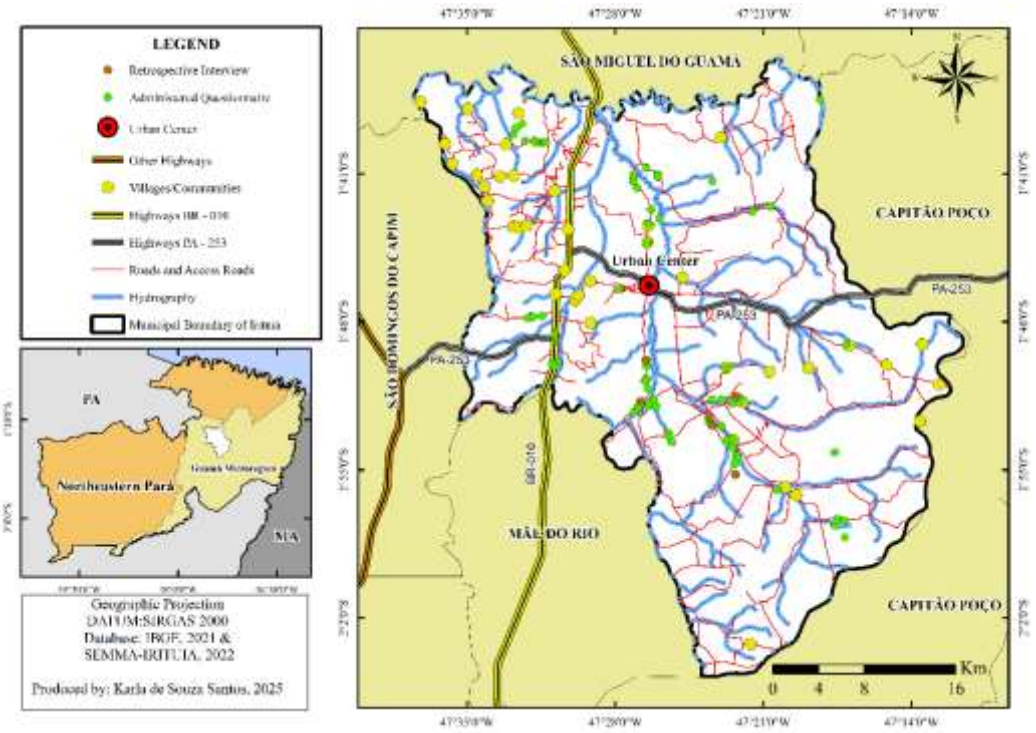
2 Methodology

2.1 Study area

The study area comprises the municipality of Irituia (Figure 1), located in the state of Pará, Brazil, at approximately 01°46'16" S and 47°26'17" W. It belongs to the Guamá Microregion and the Northeastern Pará Mesoregion, covering an area of 1,385.21 km². According to Semagri (2021), Irituia has 1,697 agricultural establishments, 91.69% of which are classified as smallholdings by Embrapa (2021), as they occupy an area of up to one fiscal module.

In Irituia, the population density is 23.6 people per square kilometer, and there are 32,550 people in its territory (IBGE, 2021). According to the Population Census (2010), about 79% of the population lives in rural areas, which reinforces the agricultural identity of Irituia's residents (Sablayrolles; Assis, 2020).

Figure 1 - Location Map of the Study Area



Source: Authors, 2024.

This research focuses on family farms in Irituia to analyze the influence of these establishments on the trajectory of forest landscapes in the municipality of Irituia, using a systemic approach that allows for the analysis of phenomena at different levels and, consequently, promotes a better understanding of reality.

2.2 Materials and methods

To analyze deforestation and forest recovery trajectories at the family farm level, we employed a mixed-methods approach combining a semi-structured questionnaire (Melo & Bianchi, 2015; Pessôa, Ruckert & Ramires, 2017), the retrospective interview method (Navegantes-Alves et al., 2012), direct observation (Gerhardt & Silveira, 2009), and spatial analysis using remote sensing data (Hessel et al., 2012).

Seventy-nine questionnaires were administered to family farmers throughout the municipality of Irituia between September and October 2021, as shown in Figure 1, with the aim of investigating the individual factors at the establishment level that contributed to forest recovery on the properties and identifying the main changes in family farming establishments in the municipality of Irituia that contributed to the evolution of forest recovery trajectories.

For a more accurate diagnosis, a retrospective analysis method was used to gather oral historical knowledge about the main events that led to changes in the landscape, observing the internal and external factors affecting family farms that influenced the trajectory of deforestation and forest recovery. This method was employed because it refers to the reconstruction of memories, facts, and historical events that occurred on farms and influenced certain activities (Navegantes-Alves et al., 2012).

Based on the main types of forest landscape trajectories identified through the questionnaire applied to family farms (slash-and-burn cassava field to natural

regeneration (Type 01); pasture for agroforestry systems (Type 02), conservation (Type 03), six farmers were selected for the retrospective interview, two farmers for each type, thus tracing the trajectory of these farmers' production systems.

In addition, the direct observation method was used to analyze changes in the forest landscape of agricultural establishments resulting from the evolution of production systems, with an emphasis on the trajectory of forest recovery. It should be noted that direct observation uses the senses to assimilate aspects of the reality under investigation (Gerhardt and Silveira, 2009). In this method, it is assumed that the "phenomena of interest are not purely historical in nature and are available for observation" (Yin, 2001, p.94).

To add to the understanding of the forest recovery trajectory of agricultural establishments, spatial/temporal analyses were carried out of specific areas where family farmers claimed to have changed land use as a result of changes in the production system. For this analysis, one farmer was selected from each type of trajectory (01, 02, and 03) of forest landscapes. These were chosen because they had a Rural Environmental Registry (CAR) to facilitate the definition of the area where forest recovery occurs. In addition, the coordinates of the area were collected to provide a more accurate location during the analysis.

For spatial analysis, we used the European Commission's Joint Research Center (JRC) dataset on forest cover change in Tropical Moist Forests (TMF), which "depicts the extent of TMF, disturbances related to deforestation and degradation, and post-deforestation recovery (or forest regeneration) through Landsat time series" (JRC, 2023), respecting the period highlighted by family farmers in retrospective interviews regarding changes in the production system.

This method made it possible to highlight the perception of family farmers regarding the spatial evolution of their agricultural establishments and also how the spatialization of forest recovery in these establishments has been occurring over time. It is therefore worth highlighting the importance of remote sensing in environmental analyses, which is widely used to optimize fieldwork by monitoring changes in land use and land cover (Umeda et al., 2015; Rosa et al., 2020).

3 Results and Discussions

Based on the questionnaire, it was observed that 99% of the family farmers interviewed in the municipality of Irituia have some type of forest recovery on their properties, predominantly in two forms: natural regeneration, occurring on 49% of the properties of the family farmers interviewed, and agroforestry systems, present on 68% of these establishments. In addition, forest conservation practices were found to exist on 46% of these properties.

The results reveal a remarkable adherence by family farmers in the municipality of Irituia to the implementation of practices aimed at forest recovery on their establishments. The presence of two predominant types (natural regeneration and agroforestry systems) highlights the diversity of approaches adopted by these farmers.

These types of forest recovery identified in Irituia are common in the region, as explained by Carneiro and Navegantes-Alves (2019) and Oliveira Neto (2020), as

they are among the main forms of forest recovery carried out by family farmers in northeastern Pará.

The natural regeneration observed in these establishments stands out as an element of utmost importance for forest recovery in the municipality of Irituia, since, according to Chazdon (2016), natural regeneration is capable of recovering the function and nutrient stock lost by the original forest ecosystem. It is worth noting that 49% of the family farmers interviewed expressed their intention to maintain these areas in the long term, beyond the fallow period—a practice used to restore vegetation over a period of approximately three to five years so that the soil can regain its productive capacity (Rego and Kato, 2018).

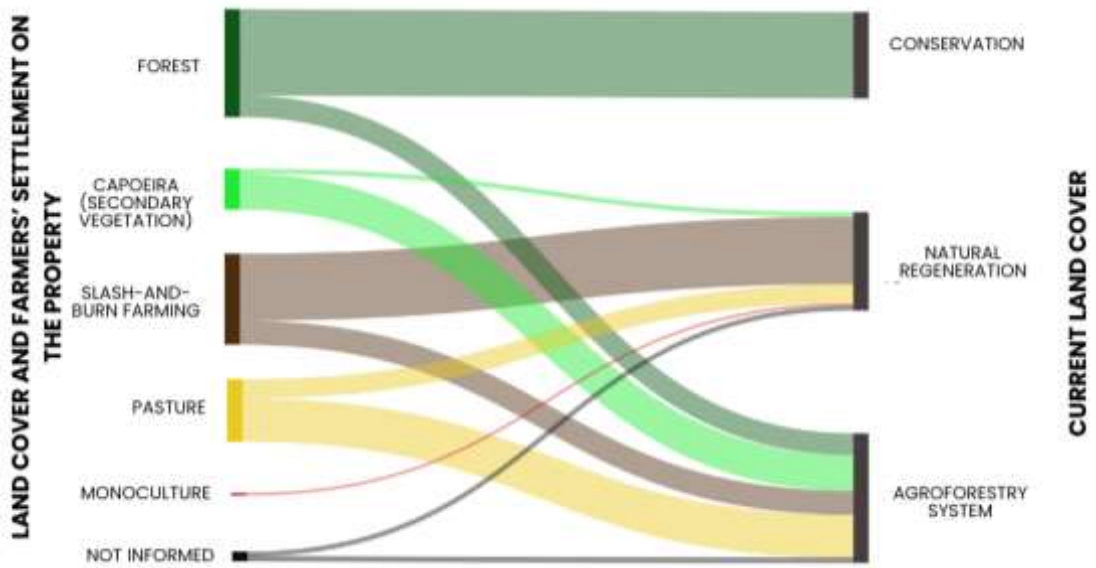
The significant adoption of agroforestry systems (68%) by these farmers emerges as a fundamental component for forest recovery in the municipality. In fact, SAFs are an important tool for family farming, as they reconcile income generation with forest recovery, as explained by Rego and Kato (2018).

However, according to Vasconcellos and Beltran (2018, p.204), for SAFs to be equivalent to natural forests, "proper planning is necessary regarding the species to be used, which must be appropriate to the local climate and have high plant density and diversity."

It is noteworthy that almost half of the properties (46%) incorporate conservation practices. It was also observed that practices related to conservation, natural regeneration, and SAFs are, in most cases, associated and occur simultaneously on the properties, contributing to forest growth in the landscape. In a municipality located in a region of early colonization, where there are few areas of primary forest due to the high rate of deforestation, as is the case in Irituia, the association between conservation practices and forest recovery is essential for forested areas to be maintained over time.

Figure 2 shows the land uses that preceded forest recovery on the family farms analyzed: forest, slash-and-burn cassava field, agriculture and livestock (pasture), capoeira (secondary forest), and açaí monoculture. With regard to the forest, 17% claim to have removed the vegetation) to introduce agroforestry systems. As for the Capoeira (secondary forest), the farmers were unable to say what activity had been carried out on the site, as it predated their settlement in the area, with only secondary vegetation, referred to by them as Capoeirão, remaining in the area. As for the monoculture of açaí, this activity ended due to the death of the plants as a result of a prolonged drought that culminated in widespread burning in the municipality around 1985, as reported by the interviewees.

Figure 2 - Sankey diagram representing forest recovery trajectories on family farms in Irituia.



Source: Authors, 2024.

Within the diversity of trajectories, two groups stand out in terms of the main changes in the production systems of the establishments: i) farmers who cultivated cassava fields and decided to regenerate the area, which accounts for 72% of family farmers who practice natural regeneration, and ii) farmers who owned pastureland and introduced agroforestry systems, accounting for 33% of family farmers who own SAFs (Figure 2).

3.1 Type of trajectory - 01: slash-and-burn farming to natural regeneration (49% of farmers).

In forest recovery trajectory 01, farmers stop planting cassava fields (cultivated using the slash-and-burn system), enabling natural regeneration in a specific area of the establishment. These trajectories show two different situations: one where farmers are from the municipality of Irituia and another involving immigrant farmers, mainly from northeastern Brazil, which led farmers to settle on the property at different times, as shown in Figure 3.

In these trajectories, both farmers native to Irituia and immigrants begin by clearing native forest or secondary forest (locally known as capoeira). The difference lies in the timing of these trajectories. In the oldest trajectories analyzed, around 1960, the forest cover was cleared and replaced with fields of cassava, rice, corn, mallow, tobacco, among others, products that were also in high demand in the market at the time.

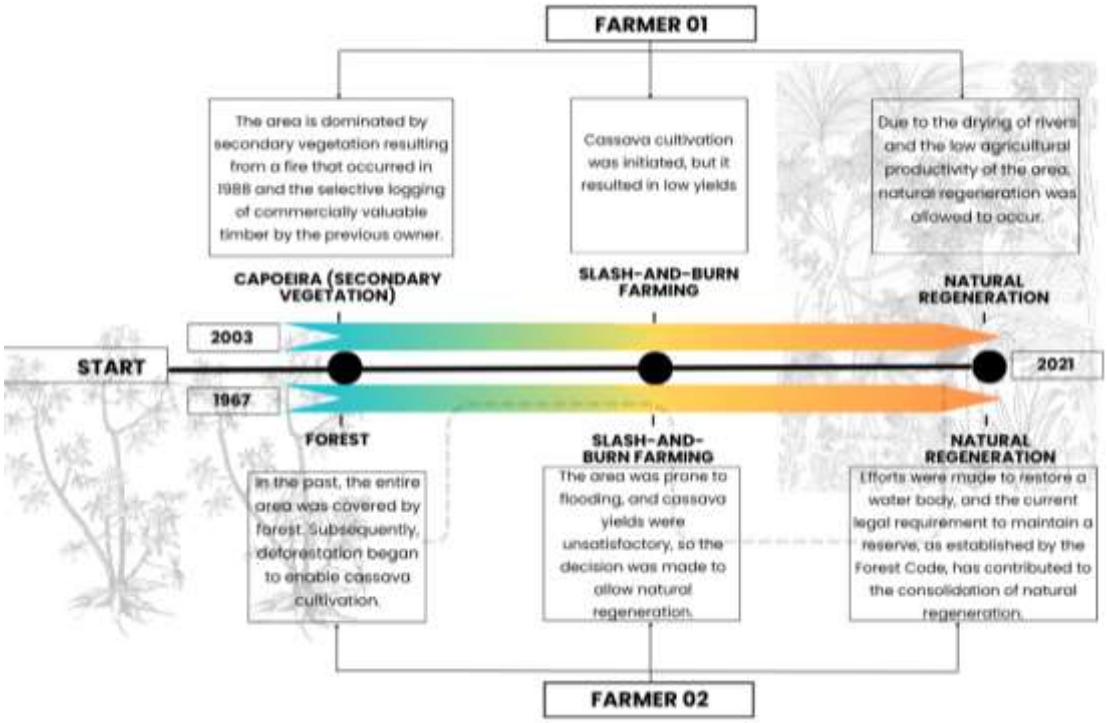
During this period, commercially valuable timber was also harvested for sale as a means of supplementing family income. In more recent times, the area's vegetation cover has not consisted of primary forests, but rather secondary vegetation, which was generally removed to make way for slash-and-burn cassava and corn fields. It should be noted that despite the temporary nature of these activities, deforestation occurs for the same purpose: to generate economic resources for families.

The conversion from farming to natural regeneration on the properties was, in many cases, directly related to crop failure in these areas, mainly linked to cassava rot disease—a highly destructive disease caused by different microorganisms, whose

occurrence is related to planting in poorly drained soils (Alves, 2020). Due to this problem, farmers chose to abandon the area, contributing to natural regeneration.

Other factors that contributed to natural regeneration were family demand for timber resources for consumption. In addition, over time, the imposition of legal reserve areas and permanent preservation areas on properties, as established by Law 12.651/2012, also known as the Forest Code, encouraged farmers to preserve these spaces.

Figure 3 - Trajectory of the production system of family farmers who have natural regeneration on their properties.



Source: Authors, 2024.

In this process, the perception of the cause-and-effect relationship of deforestation, such as the decrease in water availability due to river droughts, played a fundamental role in changing farmers' perspectives and behavior, in addition to initiatives promoted by municipal agencies, such as the Municipal Secretariat of Agriculture (SEMAGRI), such as lectures and the promotion of exchanges in other municipalities, which contributed to broader awareness of the environment.

It is worth noting that despite the existence of several initiatives to recover tropical forests, Poorter et al. (2021) state that these have the potential to regenerate naturally and quickly, without human interference, even on abandoned agricultural land, and have the capacity to contribute to restoration goals at local and global levels.

Although it is important to emphasize that even if natural regeneration of landscapes occurs without direct or artificial intervention, its potential can be affected depending on the disturbance suffered by ecosystems, as extensive and intense actions on the soil contribute to the loss of its resilience (Arroyo-Rodríguez et al., 2017).

However, it is important to note that in both subtypes of trajectories presented, after initial deforestation, there was a single form of land use, "slash-and-burn agriculture," as illustrated in Figure 3. Even in the slash-and-burn system, changes in the area cannot be equated with the impacts of transformations resulting from intensive use, which presents a promising scenario for forest recovery.

It is also worth noting that 95% of farmers with areas of natural regeneration consume some product derived from these spaces, and 74% of them sell them. Among the products harvested are tucumã (Astrocaryum aculeatum), native açaí (Euterpe oleracea), bacaba (Oenocarpus bacaba), piquiá (Caryocar brasiliense), honey, including medicinal products, among others. These data emphasize the significant importance of these areas both for food provision and for generating income for family farmers.

3.2 Type of trajectory - 02: pasture for agroforestry systems (68% of farmers)

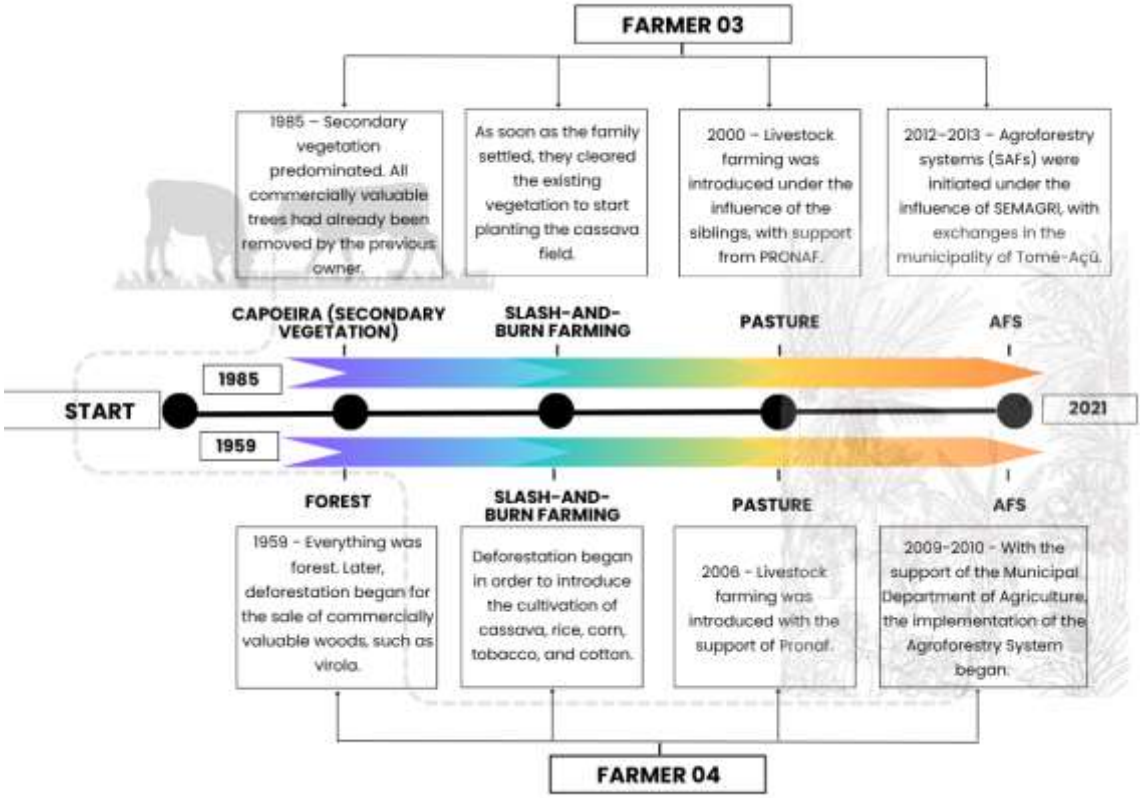
Trajectory 02 of forest recovery starts with the transition from pasture to agroforestry systems. In this trajectory, the interviewees are immigrants with different lengths of time settled in the establishment:

Farmers in trajectory 02 (Figure 4), like most residents of Irituia, began using the land by clearing either secondary vegetation or primary forests to grow corn (Zea mays), rice *(Oryza sativa)*, cassava *(Manihot esculenta)*, tobacco *(Nicoatiana tabacum)*, and cotton *(Gossypium hirsutum L)* to obtain income and food for their families. They report that the commercially valuable wood in these areas was sold to sawmills.

Around the 2000s, farmers introduced livestock farming on their properties with the support of the National Program for Strengthening Family Agriculture (PRONAF), either to improve their livelihoods or because they were unsuccessful in growing cassava. However, the expansion of livestock farming became a major driver of deforestation on farms. This activity did not remain on family farms for long, however, as about a decade after the start of livestock farming, most farmers began to reduce their pasture areas. The decision to reduce or abandon cattle raising stemmed from a combination of factors, such as: lack of financial conditions to maintain the activity; the task became very tiring due to the distance of the pasture areas from the residence; the loss of labor due to the emigration of children to the cities, which destabilizes the family production system and constitutes such an important and sudden change that it requires a restructuring of activities.

Starting in 2009, the Municipal Secretariat of Agriculture of Irituia (Semagri) promoted incentives for the implementation of agroforestry systems through seedling donations, collective efforts, and exchanges in the municipality of Tomé-Açu, which is recognized as a benchmark in agroforestry systems (Homma, 1998). These initiatives contributed to farmers' adherence to the implementation of SAFs in Irituia, as shown in Figure 4. However, there was also a historical context favorable to the implementation of more market-oriented SAFs, as there was a strong tradition of diversified production in Irituia through agroforestry backyards, which were more focused on family consumption and well-being.

Figure 4 - Trajectory of the production system of Irituia family farmers type 02 - Pasture for Agroforestry Systems.



Source: Authors, 2024.

In trajectory 02, it can be observed that, as in trajectory 01, the family is the determining factor for any activity implemented in the establishments and for decisions regarding changes made over time. Thus, the activities carried out on the properties are directly focused on the internal needs of the family group.

However, it is clear that, unlike natural regeneration, the implementation of agroforestry systems is strongly supported by incentives, whether from social organizations, through associations and cooperatives, or from government institutions, such as Semagri, through exchanges and seedling donations.

This view is also confirmed by Braga, Navegantes-Alves, and Coudel (2020, p. 01), whose research on the transformations in agroforestry systems in the municipality of Irituia found that "local public incentives were the main precursors to the consolidation of SAFs within family production systems."

As reported by several authors (Oliveira, 2006), (Braga, Navegantes-Alves, and Coudel, 2020), (Santos, 2021), (Quadros et al., 2023), the municipality of Irituia has historically had a traditional relationship with backyard farming systems, an activity connected to SAFs, considering backyards as the gateway to these systems. However, what we observe is the occurrence of an "impulse" for these systems to expand agroforestry backyards into a production system covering other areas of the property and aimed at both consumption and the sale of surplus.

Thus, the agroforestry systems implemented by these farmers show great potential for forest recovery, with several successful experiences observed throughout Brazil, as reported by Felipe et al. (2023). In family farming, forest recovery through agroforestry is even more promising because, in addition to enabling the recovery of degraded areas and providing countless ecosystem services,

it contributes to generating income and food sovereignty for families. Additionally, it is worth noting that agroforestry systems are recognized by the Forest Code (Law No. 12,651/2012) as a method for restoring degraded areas and recomposing Legal Reserves, which reinforces their legitimacy as a sustainable and legally accepted alternative in the Brazilian context.

In this regard, it should be noted that 93% of products from agroforestry systems (SAFs) are intended for household consumption, while 33% obtain income through the sale of products such as cocoa (Theobroma cacao), açaí (Euterpe oleracea), cupuaçu (Theobroma grandiflorum), banana (Musa spp.), pupunha (Bactris gasipaes), among others. The low commercialization rate is associated with the age range of the systems (1 to 3 years old) at the time of the field research, when most species were still in vegetative growth, and production, when obtained, was mainly directed towards household consumption.

3.3 Type of trajectory - 03: conservation (46% of farmers)

Farmers who fall under trajectory type 03, i.e., those who have forest conservation areas, are natives of Irituia and have always lived on the property. These areas, in their entirety, have no record of previous degradation and are presented in this study as native forests.

The forest conservation trajectories observed in this study originate mainly from a practice consolidated in family heritage, since, since their parents' time, there has always been a concern to conserve areas of the establishment, especially for the protection of rivers. Throughout the history of these establishments, there have been some disturbances in the areas, mainly due to two events: a) the opening of local roads around the 1980s, when a lot of wood was removed for the construction of these roads, and b) the construction of bridges to access the new local roads, in which farmers donated a tree to the city government, but the city government removed others without their consent. It should be noted that, during this period, the government did not show concern for conservation; on the contrary, it exhibited an attitude geared toward deforestation.

Additionally, appreciation for nature was indicated as a strong motivator for forest conservation, with the same meaning observed by Carneiro and Navegantes-Alves (2019, p. 46) regarding the motivations for restoring forests on family farms in northeastern Pará, where forests are valued "as a source of exuberant natural beauty and ideal for contemplation." For Fearnside (2021), this intrinsic value of Amazonian biodiversity is key to the conservation of Amazonian ecosystems.

It should be noted that many farmers choose to conserve certain areas on their properties in order to also have access to wood when necessary, especially for the construction and maintenance of their homes. Therefore, by preserving these areas, farmers ensure access to natural resources that are essential for their daily activities.

Off-property income options and property size were decisive factors in the conservation of these areas. Work outside the property contributed to the longevity of these forests, as there was no financial need or even labor to work these areas. The size of the property contributed to the choice of where to work, with areas of dry land being most sought after, mainly for cassava cultivation, reducing deforestation in lower areas with a higher concentration of native forests.

In trajectory 03, farmers report that disturbances such as the removal of timber plants occurred in conservation areas, but not for income, but for the benefit of the community, with no mention of the sale of wood for any purpose. Studies conducted by Noda and Noda (2003) in the Amazon suggest that traditional agriculture has contributed to the conservation of forest resources, helping to preserve genetic resources.

Santos (2024a) highlights that, in the municipality of Irituia, between 1990 and 2020, there was a significant 38% reduction in untouched (native) forest cover, which initially accounted for 53%, leaving only about 15% remaining in 2020. Of this 15%, approximately 10% is located within family farming areas (Santos, 2024b).

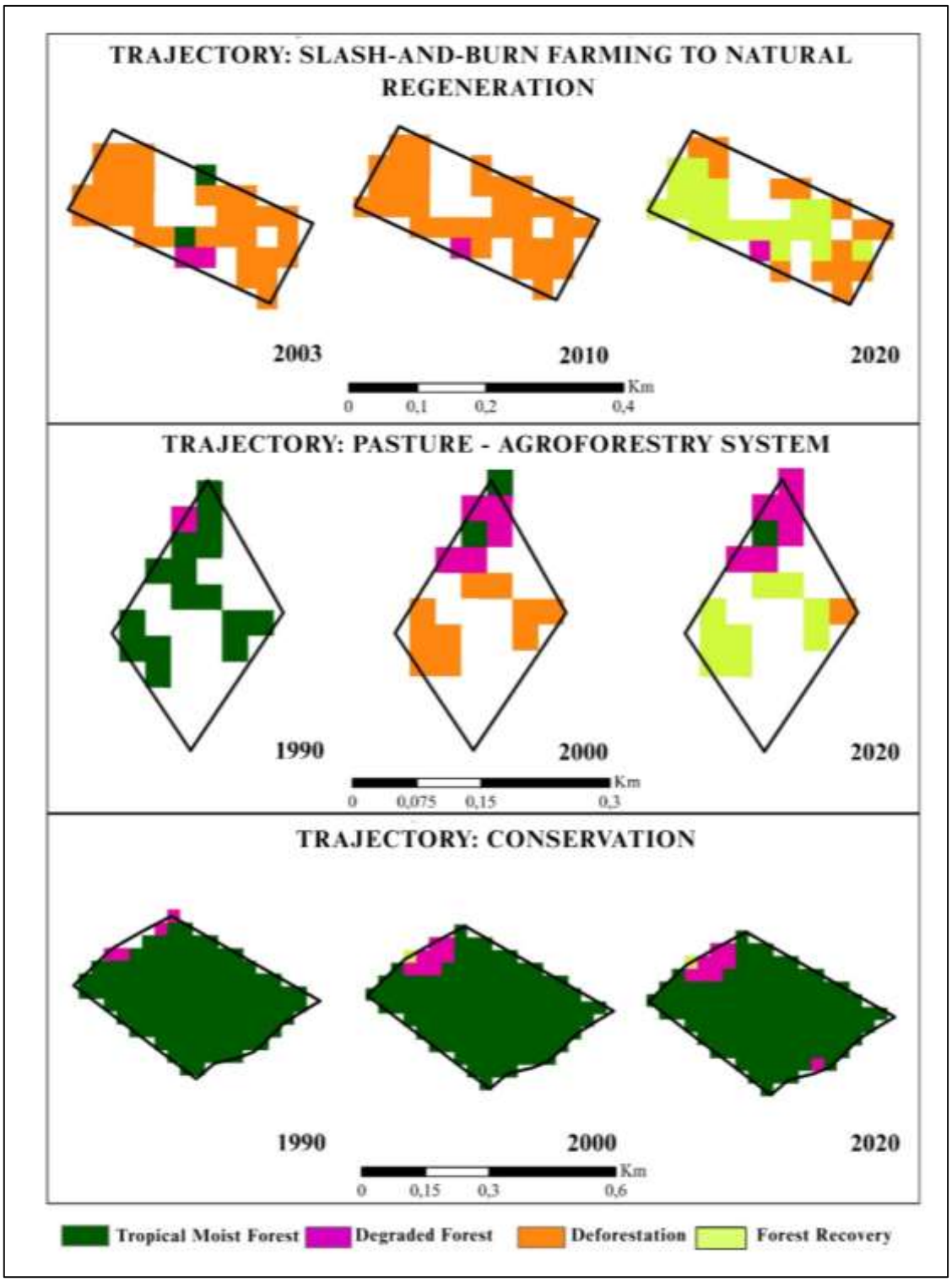
The conservation practices carried out by farmers in Irituia are important because, according to Mackey et al. (2020), primary tropical forests store, on average, 35% more carbon than production forests (a term used for forests planted for timber extraction), and their older plants provide longer and more stable carbon residence times.

It is also noteworthy that among the total number of farmers interviewed, 46% have conserved areas on their properties. Of these, 65% maintain a relationship with nature conservation that allows them to live harmoniously with the forest. They consume forest products, including Brazil nuts (*Bertholletia excelsa*), native açaí (*Euterpe oleracea*), wood, andiroba (*Carapa guianensis*), patauá (*Oenocarpus bataua*), taperebá (*Spondias mombin*), medicinal products, among others. Approximately 35% of these farmers also sell these products. Thus, in addition to playing a fundamental role in the protection and preservation of natural ecosystems and the promotion of biodiversity, forests help meet food demand and increase the income of these farmers.

3.4 Trajectory of forest landscapes on family farms

In this analysis, we investigated whether the changes in production systems reported in the retrospective interviews are reflected on a landscape scale. Thus, based on spatial analyses of classified JRC images, figure 5 aims to show the trajectory of the forest landscape of three properties: the first referring to group 1: trajectory of cultivation/natural regeneration; the second referring to group 2: trajectory of pasture/agroforestry system; and the third relating to group 3: forest conservation.

Figure 05 - Trajectories of forest landscapes in areas undergoing forest recovery and conservation on family farms in Irituia.



Source: Authors, 2024.

In the first trajectory (slash-and-burn farming /natural regeneration), the area had already been deforested previously, as shown in Figure 5 (a). It should be noted that this practice was common in the region, characteristic of a history of colonization. After the family settled on the property, the remaining vegetation was removed. Only after 2010 was natural regeneration deliberate in the area, with a significant change in the forest landscape in the establishment area in 2020, when

forest restoration was highlighted through the forest recovery process in the area resulting from natural regeneration.

In the second trajectory, Figure 5(b), it can be seen that, as reported by the farmer, there was still forest vegetation in part of the analyzed area until the 1990s. It should be noted that even though the farmer referred to the existing vegetation as "capoeirão", as secondary forests in an advanced stage of succession, over 20 years old, resulting from a natural regeneration process (Salomão et al., 2012) are locally called, it still had a structure that resembled a primary forest.

Subsequently, this area was cleared for the introduction of cassava cultivation, followed by the establishment of pasture for cattle breeding. Around 2012, the implementation of the agroforestry system began, with a notable change in the deforestation class due to the recovery of the area, resulting from forest regrowth following the implementation of agroforestry systems.

In the third trajectory, Figure 5(c), referring to forest conservation, it can be seen that there was disturbance in the area of untouched forest, with a visible increase over the years, rather than something that occurred at a specific point in time. However, despite the change from untouched forest to degraded forest in some specific locations, the vegetation remained well structured during the 30 years analyzed.

The removal of some trees for the construction of non-profit branch bridges was reported between 1990 and 2000, when these plants were donated to the city government in view of the need for traffic in the region. In addition, after this period, some trees were used in the construction of residences. It is worth emphasizing the importance of the efforts of farmers who still have primary forests on their property, going against the dominant forces that drive deforestation. These farmers play an active role in protecting the forests on their properties, including against accidental or deliberate burning.

It is noteworthy that changes in the production practices of the farmers analyzed have played a significant role in the forest recovery of their properties, a trajectory shared by several other farmers in the municipality who, through different paths, have led Irituia to a privileged position in terms of forest recovery. However, in most cases, these farmers are not fully aware of how their local practices impact the environment not only at the municipal level but also at the regional level, as reported by Santos (2024b), and they are not recognized or valued for these practices.

It is crucial to emphasize that these forest recovery practices rarely occur in isolation on family farms. In most cases, they are intertwined and complement each other, so that one practice often paves the way for the adoption of another. According to Carneiro and Navegantes-Alves (2019), the types of forest recovery coexist on family farms in this region and may migrate from one type to another at any given time.

This reality becomes even more relevant when placed within the context of the debate on regional development. While the expansion of commodities in the Amazon has been associated with productive homogenization, land concentration, and pressure for deforestation, the trajectories analyzed in Irituia reveal an alternative path based on species diversity, with an emphasis on species native to the Amazon, and on the leading role of local family farmers. By promoting natural

regeneration practices, agroforestry systems, and conservation, these farmers demonstrate how local strategies can contribute not only to forest recovery but also to more sustainable, diverse, and inclusive regional development.

It is essential to emphasize the importance of forest recovery in transforming landscapes degraded by activities that contribute to deforestation. Although there are numerous public and private initiatives that support these practices, it is important to note that there are fewer incentives and less support for forest conservation. In this scenario, the proposal for "zero deforestation" takes on significant relevance, as emphasized by Vieira, Silva, and Toledo (2005), in which the adoption of the zero deforestation principle in the Amazon plays a crucial role in mitigating the loss of natural resources and promoting sustainable development in the region.

In the context of agricultural establishments, new carbon market opportunities stand out as an initiative to enhance and collaborate with these forest restoration practices. In this sense, according to Souza (2023), the state of Pará has enormous potential for generating carbon credits. Considering that a large part of the extractive products from forest regeneration and conserved areas is currently destined for consumption, initiatives related to the carbon market have the potential to substantially increase the income of family farmers and, consequently, expand areas of forest recovery, whether through natural regeneration, agroforestry systems, or conservation practices.

4 Conclusion

The study showed how the trajectories of certain areas of family farms have impacted the current forest landscape of Irituia through the restoration and conservation of forest areas on the properties, leading to an increase in forested areas at the municipal level.

Changes in the production systems of these family farmers in Irituia play a key role in the dynamics of forest landscape recovery on farms. This is due to the interaction of a variety of internal and external factors operating on multiple scales, ranging from the family level to the regional context.

These factors, manifested over time, have contributed to the recovery of the forest landscape in the municipality through natural regeneration and the adoption of agroforestry systems, with conservation practices also acting as an ally in the preservation of biodiversity.

The results of this study highlight that natural regeneration is more prevalent in previously abandoned areas, meaning that forest resilience is a crucial factor in this process. The intervention of family farmers focused mainly on the decision to allow the area to recover naturally, without disturbance, reflecting not only a decision but also a conscious strategy to protect water resources and ensure timber resources for future use.

With regard to agroforests as a form of forest recovery, they demonstrate the need for external incentives for families, although agroforestry backyards serve as a starting point for these systems to expand. We found that initiatives endogenous to local communities and municipal incentives (donation of seedlings, collective efforts,

and exchanges) played a decisive role in the consolidation of agroforestry systems by family farmers in Irituia.

On the other hand, in the context of conservation practices, we observed that the motivation to maintain forest areas on family properties is mainly internal, based on the family's own interest and appreciation for nature. In contrast, disturbances to the forest in these areas were mainly driven by public investments (bridge construction/trafficability).

In analyzing landscape trajectories through changes in forest cover, using classified images, there is a significant occurrence of forest restoration in the establishments, attributed to changes in production systems. It is also important to highlight the need to provide additional incentives to stimulate and expand these recovery practices, as well as to support conservation, which plays an extremely important role, especially in the pursuit of zero deforestation and the enhancement of environmental services, since these practices rarely occur in isolation on Amazonian family farms. These results point to the importance of understanding forest restoration not only on a local scale, but also in the broader context of the debate on regional development, in which commodity-based land use models are contrasted with sustainable alternatives associated with family farming.

Finally, it should be noted that landscape recovery in the trajectories of the family farms studied does not occur immediately, as it took 10 to 20 years to begin restoring the landscapes analyzed. In addition, these actions occur in small, scattered areas on each property, making it difficult to identify them accurately using low-resolution satellite images. This suggests the use of more detailed sensors for future analyses, since on-site visits more clearly show the positive impacts on the landscape generated by the individual and collective actions of family farmers in Irituia. Thus, the Irituia experience demonstrates that forest recovery, by articulating environmental conservation and the social reproduction of family farming, can contribute to more sustainable, diverse, and inclusive regional development.

REFERENCES

ALMEIDA, A. S.; LAMEIRA, W. J. D. M.; PEREIRA, J. G.; THALÊS, M. C.; SALES, G. M. Potencial de pressão antrópica na região Nordeste Paraense, Brasil. **Ciência Florestal**, v. 32, p. 1-18, 2022. DOI: https://doi.org/10.5902/1980509834844.

ALVES, R.; MODESTO JUNIOR, M. D. S.; SILVA, A., NAKASONE, A.; FARIAS NETO, J. T. **Podridões em raízes de mandioca: problemas e soluções para o seu controle.** Embrapa Amazônia Oriental. Belém, 2020.

ALVES, R.; MODESTO JUNIOR, M. D. S.; SILVA, A., NAKASONE, A.; FARIAS NETO, J. T. Podridões em raízes de mandioca: problemas e soluções para o seu controle. Embrapa Amazônia Oriental. Belém, 2020.

AMARAL, F. G.; MAGALHÃES, D. M.; DE OLIVEIRA, B. A. G.; PAOLINO, C. C.; SANTANA, B. D. S. F.; CRUZ, C. B. M. **Evolução Recente do Desflorestamento na Amazônia Legal: Supressão, Trajetórias e seus Padrões**. Cartografias do Ontem, Hoje e Amanhã. Appris, Rio de Janeiro, 2022.

ARAÚJO, R.; MOURÃO, J. The amazon domino effect how deforestation can trigger widespread degradation. Climate Policy Initiative – CPI, 2023. Disponível em: https://www.climatepolicyinitiative.org/publication/the-amazon-domino-effect-how-deforestation-can-trigger-widespread-degradation/. Acesso em: 05/04/2024.

ARROYO-RODRÍGUEZ, V.; MELO, F. P.; MARTÍNEZ-RAMOS, M.; BONGERS, F.; CHAZDON, R. L.; MEAVE, J. A.; NORDEN, N.; SANTOS, B. A; LEAL, I. R; TABARELLI, M. Multiple successional pathways in human-modified tropical landscapes: new insights from forest succession, forest fragmentation and landscape ecology research. **Biological Reviews**, v. 92, n. 1, p. 326-340, 2017.DOI: https://doi.org/10.1111/brv.12231.

BATISTELLA, M.; MORAN, E. F. Dimensões humanas do uso e cobertura das terras na Amazônia: uma contribuição do LBA. Projeto LBA. **Acta Amaz**, 2005. DOI: https://doi.org/10.1590/S0044-59672005000200014.

BECKER, B. K**. Dinâmica e sustentabilidade na Amazônia: territorialidade e economia**. *Belém: Museu Paraense Emílio Goeldi, 2005*.

BRAGA, L. N. G.; NAVEGANTES-ALVES, L. F.; COUDEL, E. Transformações na trajetória dos sistemas agroflorestais no município de Irituia–PA. **Revista IDeAS** – Interfaces em Desenvolvimento, Agricultura e Sociedade, 2020, p. 01.

BRASIL. **Lei nº 12.651, de 25 de maio de 2012**. Dispõe sobre a proteção da vegetação nativa; altera as Leis nºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nºs 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de agosto de 2001; e dá outras providências. Brasília, 25 de maio de 2012.

CARNEIRO, R. V.; NAVEGANTES-ALVES, L. F. A diversidade de experiências de recuperação florestal praticada por agricultores familiares do Nordeste do Pará. **Geoambiente On-line**, n. 35, p. 293-314, 2019. DOI: https://doi.org/10.5216/revgeoamb.v0i35.57152.

CHAZDON, R. L. **Renascimento de florestas: regeneração na era do desmatamento** / Robin L. Chazdon. -- São Paulo: Oficina de Textos, 2016.

CORDEIRO, M. C. C.; ARBAGE, M. J. C; SCHWARTZ, C. **Nordeste do Pará: Configuração Atual e Aspectos Identitários**. In: CORDEIRO, M. C. C.; RANGEL-VASCONCELOS, L.G.T; SCHWARTZ, G; OLIVEIRA, F.A. Nordeste Paraense: Panorama geral e uso sustentável das florestas secundárias. - Belém: EDUFRA, 2017.

COSTA, F. A. Heterogeneidade estrutural, tecnologias concorrentes, desenvolvimento sustentável: uma proposta teórica para o tratamento da dinâmica agrária referida a território, com menção especial à Amazônia. ***Boletim Regional, Urbano e Ambiental (IPEA)***, 8, 11-34, 2013.

Empresa Brasileira de Pesquisa Agropecuária - Embrapa. Código Florestal: Adequação Ambiental da Paisagem Rural. Módulos Fiscais - Portal Embrapa, 2021. Disponível em: https://www.embrapa.br/codigo-florestal/area-de-reserva-legal-arl/modulo-fiscal. Acesso em 27/06/2024.

ESCADA, M. I. S.; AMARAL, S.; FERNANDES, D. A. Dinâmicas de ocupação e as transformações das paisagens na Amazônia, Brasil. ***Cadernos de Saúde Pública***, 39, 2023.

European Commission's Joint Research Centre – JRC. Tropical Forest Monitoring :Tracking long-term (1990-2022) deforestation and degradation in tropical moist forests, 2023. Disponível em: https://forobs.jrc.ec.europa.eu/TMF. Acesso em: 10/04/2024.

FEARNSIDE, P.M. The intrinsic value of Amazon biodiversity. **Biodiversity and Conservation,** 2021. DOI:https://doi.org/10.1007/s10531-021-02133-7.

FEITOSA, T. B.; FERNANDES, M. M.; SANTOS, C. A. G.; SILVA, R. M.; GARCIA, J. R., DE ARAUJO FILHO, R. N.; FERNANDES, M. R. M.; CUNHA, E. R. Assessing economic and ecological impacts of carbon stock and land use changes in Brazil's Amazon Forest: A 2050 projection. **Sustainable Production and Consumption**, v. 41, p. 64-74, 2023. DOI: https://doi.org/10.1016/j.spc.2023.07.009.

FELIPE, R. T. A.; RAYOL, B. P., VASCONCELOS, B. N. F., SALES, E. F., PENEIREIRO, F. M., FRANCO, F. S.; FONÊNCA, F. D.; NOBRE, H.G.; SIDDIQUE, I.; PADOVAN, M.P.;KATO, O. R.; SÁ, T. D.A.; STEENBOCK, W. Sistemas Agroflorestais Agroecológicos: Trajetórias, Perspectivas e Desafios nos Territórios Do Brasil**. Revista Brasileira de Agroecologia,** v. 18, n. 1, p. 9-43, 2023. ISSN: 1980-9735. DOI: https://doi.org/10.33240/rba.v18i1.23702.

GERHARDT, T. E.; SILVEIRA, D. T. **Métodos de pesquisa**. Plageder, 2009.

HESSEL, F. O.; CARVALHO JUNIOR, O. A.; GOMES, R. A. T.; SOUZA MARTINS, E.; GUIMARÃES, R. F. Dinâmica e Sucessão dos Padrões da Paisagem Agrícola no Município de Cocos (Bahia). **Raega: O Espaço Geográfico em Análise**, v. 26, 2012.

HOMMA, A. K. O**. Dinâmica dos sistemas agroflorestais: o caso da colônia agrícola de Tomé-Açu**. Pará Embrapa-CPATU, 1998.

Instituto Brasileiro de Geografia e Estatística – IBGE. Irituia. 2021. Disponível em: https://cidades.ibge.gov.br/brasil/pa/irituia/panorama. Acesso em: 15/07/2024.

Instituto Brasileiro de Geografia e Estatística - IBGE. Sistema IBGE de Recuperação Automática – SIDRA/Censo Demográfico, 2010/População. Disponível em: https://sidra.ibge.gov.br/Tabela/1378. Acesso em 24/05/2024.

Instituto do Homem e Meio Ambiente da Amazônia - IMAZON. A Amazônia em números: Raio X da Ocupação da Amazônia, 2009. Disponível em: https://imazon.org.br/imprensa/a-amazonia-em-numeros/. Acesso em 01/01/2024.

MACKEY, B; Kormos, C. F.; Keith, H.; Moomaw, W. R.; Houghton, R. A.; Mittermeier, R. A.; HOLE, D.; Hugh, S. Understanding the importance of primary tropical forest protection as a mitigation strategy. **Mitigation and adaptation strategies for global change**, v. 25, n. 5, p. 763-787, 2020. DOI: https://doi.org/10.1007/s11027-019- 09891-4.

MELO, W. V.; BIANCHI, C. S. Discutindo estratégias para a construção de questionários como ferramenta de pesquisa. **Revista Brasileira de Ensino de Ciência e Tecnologia,** v. 8, n. 3, 2015. DOI: 10.3895/rbect.v8n3.1946.

MONTEIRO, A. S.; OLIVEIRA, J. S. R. Produção agroecológica e análise do impacto ambiental aplicando o ambitec-agro em Irituia-PA. **Agroamazon,** vol. 1, n.1, p.124-136, 2022.

NAVEGANTE-ALVES, L. F.; POCCARD-CHAPUIS, RENÉ; FERREIRA, L. A; MOULIN, C. Transformações nas práticas de criação de bovinos mediante a evolução da fronteira agrária no sudeste do Pará. **Cadernos de Ciência & tecnologia**, v. 29, n. 1, p. 243-268, 2012.

NODA, H.; NODA, S. N**. Agricultura familiar tradicional e conservação da sócio-biodiversidade/ amazônica**. Interações (Campo Grande), 2003.

OLIVEIRA NETO, M. M. Análise sistêmica da biodiversidade de sistemas agroflorestais (SAF) de agricultores familiares em Tomé Açu, PA. Dissertação (Mestrado) - Universidade Federal do Pará, Instituto Amazônico de Agriculturas Familiares, Programa de Pós-Graduação em Agriculturas Amazônicas, Belém, 2020.

OLIVEIRA, J.S.R. Uso do território, experiências inovadoras e sustentabilidade: um estudo em unidades de produção familiares de agricultores/as na área de abrangência do Programa Proambiente, Nordeste Paraense. Dissertação (Mestrado em Agricultura Familiar e Desenvolvimento Sustentável) –Núcleo de Estudos em Agricultura Familiar, Universidade Federal do Pará, 2006.

PESSÔA, V. L. S.; RUCKERT, A. A.; RAMIRES, J. C. L. **Pesquisa qualitativa: aplicações em Geografia**. Porto Alegre: Imprensa Livre, 2017.

POORTER, Lourens et al. Multidimensional tropical forest recovery. **Science**, v. 374, n. 6573, pág. 1370-1376, 2021.

PRECINOTO, R. S.; PRIETO, P. V.; FIGUEIREDO, M. D. S. L.; LORINI, M. L. Edges as hotspots and drivers of forest cover change in a tropical landscape. **Perspectives in Ecology and Conservation,** 20.4 (2022). DOI: https://doi.org/10.1016/j.pecon.2022.07.001.

QUADROS, T. C. F.; Barbosa, M. J. S.; Pinheiro, K. A. O.; Santos, L. B.; da Silva Carneiro, F., Rios; H. K. S.; Frazão, A. S. Dos quintais florestais aos sistemas agroflorestais no município de Irituia-Pará-Brasil. **Research, Society and Development**, v. 12, n. 3, p. e16812337958-e16812337958, 2023. DOI: https://doi.org/10.33448/rsd-v12i3.37958.

REGO, A. K. C; KATO, O. R. Agricultura de corte e queima e alternativas agroecológicas na Amazônia. **Novos Cadernos NAEA**, v. 20, n. 3, 2018. DOI: https://doi.org/10.5801/ncn.v20i3.3482.

RIBEIRO, M. P.; MELLO, K.; VALENTE, R. A. Avaliação da estrutura da paisagem visando à conservação da biodiversidade em paisagem urbanizada**. Ciência Florestal**, v. 30, p. 819-834, 2020. DOI: https://doi.org/10.5902/1980509837683.

RODRÍGUEZ, J. M. M.; SILVA, E. V. da; CAVALCANTI, A. P. B**. Geoecologia das paisagens: uma visão geossistêmica da análise ambiental**. Fortaleza: Editora UFC, 2004.

ROSA, J. C. S; SOUZA, B. A.; SÁNCHEZ, L. E. Identificação de serviços ecossistêmicos em áreas de floresta mediante sensoriamento remoto. Desenvolvimento e Meio ambiente, v. 53, 2020. DOI: 10.5380/dma.v53i0.62669.

SABLAYROLLES, P. J. L.; ASSIS, W. S. A Certificação Participativa de Orgânicos como Tecnologia Social: Estudo de caso da Cooperativa D'Irituia. Desenvolvimento Rural Interdisciplinar, v. 3, n. 1, p. 191-217, 2020.

SALOMÃO, R. D. P.; VIEIRA, I. C. G.; BRIENZA JUNIOR, S.; AMARAL, D. D.; SANTANA, A. C. Sistema Capoeira Classe: uma proposta de sistema de classificação de estágios sucessionais de florestas secundárias para o estado do Pará. Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais, 2012.

SANTOS, K. S. A Recuperação Das Paisagens Florestais É Possível Na Amazônia? Estudo De Caso No Município De Irituia, Nordeste Do Pará. In: Análise multiescalar das trajetórias de desmatamento e recuperação florestal das paisagens, no município de Irituia - PA: Iniciativas de agricultores familiares no redesenho de paisagens. Tese (Doutorado em Agricultura Amazônicas). Universidade Federal do Pará. Programa de Pós-Graduação em agriculturas Amazônicas, Belém, 2024a.

SANTOS, K. S. O Protagonismo Dos Agricultores Familiares Na Recuperação Florestal Na Amazônia Oriental: Análise Das Dinâmicas Da Paisagem No Município De Irituia. In: Tese (Doutorado em Agricultura Amazônicas). Universidade Federal do Pará. Programa de Pós-Graduação em agriculturas Amazônicas, Belém, 2024.

SANTOS, T. F. Agrobiodiversidade e as relações de trocas entre agricultores familiares que possuem sistemas agroflorestais na região de Itabocal, Irituia (PA). Dissertação (Mestrado em Agriculturas Familiares e Desenvolvimento Sustentável) - Instituto Amazônico de Agriculturas Familiares, Universidade Federal do Pará, Belém, 2021.

Secretaria Municipal de Agricultura de Irituia – SEMAGRI. Cadastro Agrícola de Irituia, IRITUIA, 2021.

SOUZA, T. L. M. O mercado de crédito de carbono no estado do Pará: cenário atual e estimativa para os próximos anos. Trabalho de Conclusão de Curso (Graduação em Engenharia Ambiental e Energias Renováveis) - Universidade Federal Rural da Amazônia, Campus Belém, PA, 2023.

UMEDA, C. Y. L.; SANTOS, T. H. L.; LASTORIA, G.; OLIVEIRA, A. P. G. COUTINHO, H. L. C.; PARANHOS FILHO, A. C. Uso de sensoriamento remoto na identificação de corredores ecológicos: estudo de caso da Bacia Hidrográfica do Rio Formoso, Bonito, MS. **Engenharia Sanitária e Ambiental,** v. 20, n. 4, p. 551-557, 2015. DOI: https://doi.org/10.1590/S1413-41522015020040079011.

VASCONCELLOS, R. C.; BELTRÃO, N. E. S. Avaliação de prestação de serviços ecossistêmicos em sistemas agroflorestais através de indicadores ambientais. **Interações (Campo Grande)**, 2018. DOI: https://doi.org/10.20435/inter.v19i1.1494.

VIANA, F. M. F.; STEWARD, A. M.; RICHERS, B. T. T. Cultivo itinerante na Amazônia central: manejo tradicional e transformações da paisagem. **Novos cadernos NAEA**, v. 19, n. 1, 2016. DOI: http://dx.doi.org/10.5801/ncn.v19i1.1816.

VIEIRA, I. C. G.; SILVA, J. M. C; TOLEDO, P. M. Estratégias para evitar a perda de biodiversidade na Amazônia. **Estudos Avançados**, v. 19, p. 153-164, 2005. https://doi.org/10.1590/S0103-40142005000200009.

XAVIER, J. A.; MUNIZ, B. R. B.; MUNIZ, B. R. B., KANIESKI, M. R., CAMPOS, C. G. C.; HENKES, J. A. IMPACTOS das Mudanças Climáticas nas Florestas Tropicais. **Revista Gestão e Sustentabilidade Ambiental,** v. 11, n. 2, p. 65-82, jun. 2022. DOI: https://doi.org/10.59306/rgsa.v11e2202265-82.

YIN, R. K. Estudo de Caso: **Planejamento e métodos**. Bookman editora, 2001.

Karla de Souza Santos. Doutora em Agricultura Familiar e Desenvolvimento Sustentável. Instituto de Terras do Pará - ITERPA. Técnico em Desenvolvimento e Gestão Agrícola Fundiária. Rua dos Ypês – 508. Centro, Ananindeua-PA. E-mail: karla.pehse@gmail.com.

Livia de Freitas Navegantes Alves. Doutora em Agroecossistemas. Universidade Federal do Pará - UFPA. Docente. Rua Igarapé Tucunduba - Universitário, Belém. E-mail: lnavegantes@ufpa.br.

Emilie Suzanne Coudel. Doutora em Economia Rural. Centro de Cooperação Internacional em Pesquisa Agronômica para o Desenvolvimento - CIRAD. Pesquisadora. Montpellier, Languedoc-Roussillon, França. E-mail: *emilie.coudel@cirad.fr.*

Submetido em: 04/10/2024 **Aprovado em: 04/10/2025**

CONTRIBUIÇÃO DE CADA AUTOR

Conceituação (Conceptualization): SANTOS, K. S.; NAVEGANTES-ALVES, L. F.; COUDEL, E. S.
Curadoria de Dados (Data curation): SANTOS, K.S.
Análise Formal (Formal analysis): SANTOS, K. S.
Obtenção de Financiamento (Funding acquisition): NAVEGANTES-ALVES, L. F.; COUDEL, E.S.
Investigação/Pesquisa (Investigation): SANTOS, K. S.
Metodologia (Methodology): SANTOS, K. S.; NAVEGANTES-ALVES, L. F.; COUDEL, E. S.
Administração do Projeto (Project administration): SANTOS, K. S.; NAVEGANTES-ALVES, L. F.
Recursos (Resources): SANTOS, K. S.; NAVEGANTES-ALVES, L. F.; COUDEL, E. S.
Software: SANTOS, K. S.
Supervisão/orientação (Supervision): NAVEGANTES-ALVES, L. F.; COUDEL, E. S.
Validação (Validation):
Visualização (Visualization)
Escrita – Primeira Redação (Writing – original draft): SANTOS, K.S.

Escrita – Revisão e Edição (Writing – review & editing): SANTOS, K. S.; NAVEGANTES-ALVES, L. F.; COUDEL, E. S.

Fontes de financiamento:
Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES & Centro de Cooperação Internacional em Pesquisa Agronômica para o Desenvolvimento - CIRAD