



National policies encounter municipal realities: A critical analysis of the outcomes of the List of Priority Municipalities in curbing deforestation in the Brazilian Amazon



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ARTICLE INFO

Article history:

Accepted 9 June 2022

Available online 20 June 2022

Keywords:

List of Priority Municipalities

Collective action

Deforestation frontier

Jurisdictional approach

Anti-deforestation policy

Intra-regional diversity

ABSTRACT

At the peak of Amazonian deforestation in the mid-2000s, a suite of initiatives to curb deforestation was implemented, narrowing their scopes to particular agents, critical municipalities, and economic activities and supply chains. The List of Priority Municipalities (LPM) launched in 2008 became a central tenet of these efforts. It requires local agents in listed municipalities to individually and collectively reduce deforestation and implement a comprehensive farm-geocoding registry across the municipality. We combine region-wide spatial-temporal land-cover analysis and census data with in-depth fieldwork to examine the LPM policy at regional and municipal levels, discussing the policy's limitations in inducing effective responses across diverse municipalities. At the regional level, our study presents a new historical-geographic categorization and map of 530 Amazonian municipalities. We propose four regional clusters of municipalities according to patterns of deforestation, agricultural activities, demographic and agrarian structures, emancipation history, and socioenvironmental protection. We draw on this analysis to contextualize the trajectories of the 62 listed municipalities within the region's moving deforestation frontier and discuss why many of the achievements observed locally have not been replicated regionally. At the municipal level, we investigate four case studies in-depth to unveil the factors underlying the LPM policy mixed outcomes. We discuss how local agents' responses to the LPM policy are context-specific, reflecting their perception of trade-offs between the economic impacts of sanctions, incentives to collaborate, and potential benefits arising from environmental compliance. We detail and discuss how dynamic macro-political and institutional settings altering law enforcement mechanisms and market incentives interact with subnational environmental governance, either facilitating or inhibiting individual and collective actions locally. Finally, we discuss the role of inter-institutional collaboration and coordination among command-and-control policies, market-oriented initiatives, and incentives for local collective actions in triggering incentives for land-use and governance innovations against deforestation, both locally and regionally.

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1. Introduction

National policies tackling deforestation in the Brazilian Amazon have been designed and implemented at the regional level, framing rules for either the entire biome or the geopolitical area of the Legal Amazon. The region encompasses a vast territory (4–5 million sq.km) characterized by varied ecosystems overlapping nine

states and hundreds of municipalities¹ home to 25+ million people – including a diverse population of 617,000 individual landholders occupying over 720,000 sq.km². Moreover, anti-deforestation policies often target individual agents associated with forest clearings, usually at the end of a chain of forces driving land cover changes. Such a strategy has had some success once implemented

¹ The Legal Amazon (*Amazônia Legal*), a geopolitical division defined in 1953, covers 5 million sq.km and overlaps totally or partially the territory of 772 municipalities. The Brazilian Amazon biome, a biogeographic and ecological division defined by the Brazilian Institute for Geography and Statistics (IBGE), has its limits almost completely within the Legal Amazon, covering 4.2 million sq.km and overlapping totally or partially the territory of 559 municipalities.

² Censo Agro 2017 (SIDRA/IBGE, Table 6719).

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with political will and strong command-and-control measures (Arima et al., 2014). That was the case when an inter-ministerial coordination devised a suite of initiatives to control deforestation at its highest peak (the PPCDAm program³), which contributed to decreasing deforestation rates from over 27,000 sq.km in 2004 to 4,500 sq.km in 2012. The PPCDAm fostered stricter monitoring and sanctioning initiatives and prompted states, municipalities, stakeholders, and land users to actively seek alternatives to deforestation through multi-partnership initiatives addressing territorial planning, sustainable production systems, and restoration programs (de Mello & Artaxo, 2017; West & Fearnside, 2021).

Deforestation, however, has persisted, advancing in a predictable pattern across a region characterized by an active land market and the illegal occupation of public areas and indigenous and protected lands (Azevedo-Ramos & Moutinho, 2018; Brito et al., 2019). Recent political shifts and economic turmoil have accelerated deforestation and worsened the already limited law enforcement in the region (Rochedo et al., 2018), where the Brazilian environmental agency collects only 36%⁴ of assessed environmental fines⁵. In 2019, the first year of Bolsonaro's government, deforestation rates increased by 30%⁶, whereas environmental fines declined by more than 30% (Brant & Watanabe, 2020). What have been the main outcomes of anti-deforestation policies at the municipal level? Can lessons learned over the past 15 years from social and political efforts to curb deforestation help avoid a new wave of deforestation expansion in the Amazon?

National policies face the challenge of being relevant and enforceable to diverse groups of agents and local realities. Region-wide policies tend to be insensitive to intraregional variability, unable to capture the multiple and dynamic incentives driving land-use decisions impacting forests (Brondizio & Moran, 2012). On the other hand, in different parts of the world, novel hybrid modes of governance involving multiple agents have succeeded in halting deforestation by narrowing their scope and tackling forest loss associated with particular sets of agents, economic activities and supply chains, and critical territories (Lambin et al., 2014; Lemos & Agrawal, 2006).

In Brazil, the Ministry of Environment (MMA) implemented the List of Priority Municipalities (LPM) in 2008 – infamously labeled as '*lista negra do desmatamento*' (deforestation blacklist). This policy defines criteria to both include (i.e., high yearly deforestation rates) and exclude (i.e., achieving deforestation control and expanding the registration of private landholdings in the national environmental cadastral system – SICAR) municipalities from the LPM. The policy imposes sanctions such as limiting land titling, environmental licenses, bank credit, and commercialization of agricultural resource products. As such, the LPM policy narrows government monitoring and sanctioning initiatives towards a few municipalities considered deforestation hotspots. Since the removal criteria are set at the municipality level, thus sanctioning both the municipality and individual landholders and stakeholders, this policy is intended to trigger cooperation among local agents towards getting the municipality off the LPM.

At the regional level, the LPM policy has been praised as a successful initiative contributing to the sharp decline in deforestation rates in the Amazon (Arima et al., 2014; Assunção & Rocha, 2019;

Cisneros et al., 2015). At the local level, case studies have emphasized the role of government decentralization, local leadership, institutional support, and stakeholders' cooperation in successful outcomes (Neves, 2015; Viana et al., 2016). Yet, this policy has challenged municipalities and local stakeholders in complying with its one-size-fits-all removal criteria. One decade after its implementation, only 22 out of 62 municipalities got off the LPM, suggesting the LPM outcomes "differ substantially depending on the ability of local stakeholders to organize themselves towards the goal of being removed from a blacklist" (Cisneros et al., 2015).

While existing regional-level analyses have offered valuable insights into the overall role of the LPM policy in controlling deforestation in different parts of the region, limited attention has been given to how the LPM policy operates at the local level – including how contextual conditions and incentives have influenced municipal responses to this policy. Building upon a review of previous studies, this article intends to examine the evolution of the LPM policy and its outcomes by integrating analyses at both regional and municipal scales. We argue that municipal responses to the LPM policy sanctions and incentives must be understood within the historical and current contexts of the regional frontier expansion.

At the regional scale, we examine how the implementation and results of the LPM policy relate to historical patterns of colonization, agricultural development, and deforestation across all 530 municipalities of the Brazilian Amazon biome. The regional-level analysis provides us with the means to understand the diversity of municipal realities in the Amazon and the context surrounding the 62 municipalities targeted by the LPM policy. We complement the regional analysis by focusing on the case studies of four municipalities located across a spatial-temporal gradient of frontier expansion.

At the municipal scale, our case studies allow us to systematically examine how municipal stakeholders interacted and responded once sanctioned by the LPM policy. In other words, how have LPM sanctions and incentives facilitated or inhibited cooperation among local agents seeking alternatives to reconcile agricultural production and forest conservation in a dynamic and rapidly transforming social-ecological system. In each of our case studies, we have examined the history of conflict and cooperation among stakeholders, their perceptions of the potential impact of the LPM (including market sanctions), the role of local leadership, information and experience exchange among municipalities, inter-governmental coordination (e.g., additional anti-deforestation initiatives in place), and the role of non-governmental actors (e.g., NGOs). We consider our four case studies illustrative of other listed municipalities and representative of the intra-regional diversity of municipalities across the Brazilian Amazon deforestation frontier. To our knowledge, this is the first article combining spatial and temporal analysis, census data, and in-depth fieldwork to examine the LPM policy outcomes at both regional and municipal levels.

Next, we provide a brief review of regional development and deforestation patterns in the Brazilian Amazon, as well as of anti-deforestation initiatives implemented during the last 15 years, particularly the List of Priority Municipalities. We then present our research design and methodology, followed by our findings at both regional and local levels. Discussion follows examining interactions between the LPM policy, regional deforestation patterns, and local conditions, paying particular attention to and drawing lessons from the factors that have allowed some municipalities to lower and revert deforestation trends while others do not. We conclude by pointing out some limitations of the study and discussing four key lessons of broader application of our findings in the region.

³ PPCDAm – The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon.

⁴ Payment rate totals 36% of the number of fines (i.e., 120,012) related to flora and ecosystem crimes applied in the 1996–2019 period, which represents 30% of the total value of fines (R\$26 bi).

⁵ Database for the search of Environmental Fines and Embargoes (IBAMA). Available at: <https://servicos.ibama.gov.br/ctf/publico/areaseembargadas/ConsultaPublicaAreasEmbargadas.php>.

⁶ PRODES Program (INPE). Available at: <https://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes>.

2. Frontier expansion and policy instruments to control deforestation

2.1. Amazonian municipalities as shaped by a moving frontier

The Brazilian Amazon was considered “homogeneous and isotropic,” an isolated and demographically empty region when economic incentives, infrastructure projects, and colonization programs triggered substantial changes across the region (Becker, 2001). Since the 1970s, government-led infrastructure projects have extended historical transportation axes from rivers to roadways. Along with communication improvements, those changes have expanded the local circulation of goods, information, and people across the Amazon, as well as the regional connection with national and international markets. Financial incentives encouraged agricultural and industrial endeavors alongside traditional extractive activities, and colonization programs and infrastructure projects (roadways, settlements, mining, and energy) reconfigured territorial occupation. These changes attracted waves of migrants, gave rise to unplanned urban centers, drove violent land conflicts, and resulted in varied patterns of social, economic, political, and territorial organization (Becker, 2005), including the designation of novel categories of protected territories for indigenous and traditional groups (Freitas, 2021). In a relatively short period (50yrs), these historical conditions have shaped the Amazon as a mosaic of social and environmental realities experiencing rapid transformation (Brondizio, 2013).

Rather than evenly spread, some 75% of the regional land cover change takes place in the “arc of deforestation,” a swath of land occupation from East to West along the Southern rim of the basin (Alves, 2001). Its emergence and shape have gone in tandem with the roadway axes (Alves, 2002), land reform projects (Alston et al., 2000; Moran, 1981; Smith, 1982), pervasive land grabbing (Fearnside, 2005), and large agricultural ventures for cattle ranching (Hecht, 1985, 1993) and large-scale monocropping such as soybean (Delaroché, 2019). Patterns of deforestation in this region have also been diverse as different groups of actors have responded to changing incentives, public policies, economic shocks, market demands, and demographic dynamics (Brondizio & Moran, 2012; Fearnside, 2008; Godar et al., 2014; Rosa et al., 2012).

To date, the Brazilian Amazon has lost roughly 20% (780,000 sq. km) of its original forest cover, and it is estimated that logging and fires have degraded more extensive areas of remaining natural forestlands (Foley et al., 2007; Matricardi et al., 2020; Rappaport et al., 2018). At the current rate of deforestation and forest degradation, climate change is projected to lead the biome towards an ecological tipping point, transforming the region's eastern part from a humid to a drier forest ecosystem (Lovejoy & Nobre, 2018; Nobre et al., 2016).

2.2. Novel mechanisms to tackle deforestation

Conventional command-and-control policies have been implemented amid conflicting narratives of environmental sustainability and commodity production and extraction. As such, these policies have come short in tackling the direct and indirect drivers of deforestation in such a dynamic and complex region as the arc of deforestation. Implementing, monitoring, and enforcing ambitious command-and-control regulations require information and institutional capacity to identify the processes and track the agents of forest loss. That has been challenging in a region of continental proportion marked by limited – and now decreasing – capacity of government agencies to enforce legislation (Abessa et al., 2019; Rochedo et al., 2018).

An essential contribution to overcoming these limitations has been the systematic development of satellite-based monitoring systems since the late 1980s. Building upon the PRODES⁷ program (Shimabukuro et al., 2012), a new satellite monitoring system for detecting real-time deforestation (DETER) started operating in 2004 (Diniz et al., 2015). Additionally, data linking individual land ownership to forest clearings have been compiled in the last ten years (SICAR). While such systems provide means for identifying deforestation events and agents, ultimately, their use depends on the willingness of policymakers and public officials to enforce legislation that requires landholders to geocode and register their properties in the national land registry.

In addition to command-and-control policies, novel demand-side initiatives have emerged in different sectors to control deforestation. The roundtable on sustainable oil palm and the soybean and beef moratoria are pointed out as promising initiatives in curbing deforestation (Barreto & Gibbs, 2015; Gibbs et al., 2015, 2016; Nepstad et al., 2014) – but see Santos & Costa (2018) and Skidmore et al. (2021) for more recent analyses pointing to the challenges these instruments face in recently expanding cattle ranching and agricultural areas in the region. In Brazil, the soy and beef moratoria have contributed to bringing together key stakeholders to devise agreements and co-share responsibility in implementing, monitoring, and enforcing commitments to dissociate deforestation from their supply chains.

Unlike command-and-control policies relying exclusively on government implementation and enforcement, hybrid initiatives have brought a broader set of stakeholders, including the public and private sectors and civil society. Thus, these initiatives can dissolve communication barriers among decision-makers and reduce the distance – literally and metaphorically – between interested parties, resulting in collectively agreed commitments based on shared information that creates a sense of co-responsibility among those involved (2018; Garrett et al., 2018; Lambin et al., 2014) – but see Barletti and Larson (2021) for a critical analysis on power inequality in multi-stakeholder forums.

2.3. The Ministry of Environment's List of Priority municipalities

As part of the PPCDAm, the List of Priority Municipalities (LPM) designed by the Brazilian Ministry of Environment⁸ shifted the focus from monitoring and law enforcement of the entire Amazon to a reduced number of municipalities concentrating highest rates of forest loss. By setting its compliance criteria at the municipality level, the LPM policy created shared responsibilities between the federal, state, and municipal governments. More important, the LPM policy encouraged horizontal sharing of responsibility within municipalities, requiring both collective and individual actions among local stakeholders. The LPM policy was also innovative in mandating farmers to geocode landholdings in a public cadastral system (SICAR), which allows linking forest clearings to individual landholders, thus enhancing deforestation monitoring and law enforcement. In short, to clear the sanctions associated with the LPM policy (e.g., credit restrictions, market embargo, damage to the municipal image), listed municipalities are required to keep yearly deforestation rates below 40 sq.km and to geocode and register in the SICAR at least 80% of their territory held by private landowners.

Econometric analyses confirmed the role played by the LPM policy in curbing deforestation in listed municipalities compared

⁷ The Brazilian Institute for Space Research (INPE) runs the PRODES project, which performs the annual monitoring of the Amazon forest using Landsat-type imagery since 1988. The PRODES program is the official deforestation monitoring system for the Brazilian Amazon.

⁸ Decreto Federal 6.321/2007.

to non-listed ones (Arima et al., 2014; Assunção & Rocha, 2019; Cisneros et al., 2015; Sills et al., 2015). However, the channels by which such outcomes were achieved in some municipalities but not in others remain unclear. Despite its deterrence effect at the regional level, only one in three municipalities have complied with the LPM policy removal criteria by 2018. On the other hand, case studies have focused on the successful and virtuous case of Paragominas, where partnerships among local stakeholders, NGOs, and state and federal governments led to a “novel multi-partner governance arrangement” (Viana et al., 2016, 2012). Such an innovative arrangement led Paragominas to get off the LPM in 2010, rendering it possible for the municipality to self-declare as the first ‘green municipality’ (Zwick & Calderon, 2016). But the ability of local stakeholders in different circumstances to organize themselves towards complying with the LPM removal criteria represents a paramount aspect that remains largely unexamined, and towards which we contribute the analysis that follows.

3. Research design and methods

Rules leading to productive outcomes in one setting may fail drastically when local settings differ (Ostrom, 2005), challenging decision-makers to devise strategies to govern complex social-ecological systems. In the Brazilian Amazon, this is particularly relevant because the regional history of colonization, development and frontier expansion has forged a dynamic and diverse mosaic of juxtaposed social and environmental realities. Further, local actors and governments at the state and municipal levels have assumed an increasing role in mediating external incentives, setting directions and strategies driving land use and cover changes at local scales (Becker, 2005; Thaler et al., 2019). In such a context, how do region-wide policies aimed at controlling forest loss in the Amazon interact within the region, and what are the outcomes emerging from diverse municipalities and local agents in response to anti-deforestation regulations?

3.1. Integrating regional- and municipal-level analyses

We tackle the above mentioned puzzle by integrating two levels of analyses within one analytical approach to examine how the implementation of the LPM policy has affected deforestation and influenced municipal responses over time (Fig. 1). At the regional level, the study compiles a set of attributes of all 530 municipalities in the Brazilian Amazon biome to identify and cluster municipalities sharing similar features and land-use trajectories. At this level, we ask how the LPM policy applies to groups of municipalities shaped by different periods of colonization and development across the region and along the expanding frontier (Question 1). At the local level, the study uses an institutional analysis approach informed by the Institutional Analysis and Development (IAD) framework (Ostrom, 1990, 2005) and based on in-depth field research. We analyze four municipalities in Northeastern Pará, the state historically concentrating the highest deforestation rates in the Amazon. We systematically examine municipalities as ‘municipal action arenas,’ i.e., an arena in which stakeholders holding different positions, interests, powers, and worldviews interact and engage in initiatives to solve the collective action dilemma of complying with the LPM criteria to overcome sanctions applied to all.

We draw on the IAD framework as a roadmap to systematically consider the ‘contextual factors’ that structure the ‘municipal action arena’ and generate ‘interactions’ that produce ‘outcomes’ (Ostrom, 2005). The ‘contextual factors’ result to a large extent

from historical patterns of colonization, development, and land-use and -cover changes shaping municipalities, notably their biophysical and socioeconomic attributes and the institutions (i.e., the formal and informal rules, including the LPM policy) affecting agents’ land-use decision-making and patterns of interactions to comply with the LPM policy. These factors structure local conditions and stakeholders’ ability to interact and react individually and collectively in the ‘municipal action arena.’ We pay close attention to reactions and initiatives emerging in response to sanctions and incentives triggered by the LPM policy in each municipality, which gradually modify – through feedbacks – the sanctions, incentives, initiatives, and interaction patterns locally. We finally examine the ‘outcomes’ arising from such processes, specifically whether municipalities were able to comply with LPM requirements of deforestation control and the geocoding of farms. At this level of analysis, we ask how and under which conditions local agents and organizations cooperate and devise local arrangements in response to the LPM policy (Question 2).

Our selection of four municipal cases for detailed field research and analysis was partially based on our regional spatial-temporal analysis and partly informed by preliminary fieldwork visits to five listed municipalities in Pará. During the regional analysis (2016), we selected a gradient of municipalities in the state of Pará representing different phases of expansion – i.e., from older to newer cleared areas – in the so-called ‘Arc of Deforestation,’ in the eastern rim of the basin. We selected cases within a single state (Pará) to control state-level processes affecting municipalities (see 5.4 Limitations). We considered the 21 listed municipalities in Pará as possible candidates for sampling. Following a preliminary field trip to five municipalities across the abovementioned gradient, we selected four for extended and detailed fieldwork (2017–2018). Triangulation across these four cases enabled us to complement and nuance the findings regarding potential factors mediating municipal responses from each case study. Our intention using this integrated approach was to draw relevant lessons from individual municipal action arenas that might be relevant to municipal conditions in the Amazon more broadly.

3.2. The regional level analysis: examining regional and intra-regional diversity

Informed by the extensive literature analyzing the factors and processes that have driven and shaped the expansion of the Amazonian frontier (Section 2.1), we compiled official data for the 530 municipalities⁹ defined by the MMA¹⁰ as part of the Brazilian Amazon biome – an area smaller than the Legal Amazon. The dataset consists of eight indicators depicting land use and cover change, demography, agrarian structure, social-environmental governance, and the political-administrative history of municipalities (Table 1). Indicators were collected to reflect municipal attributes at the time of the LPM policy implementation in 2008. Together, these indicators reflect attributes associated with different regional development and colonization patterns in the Amazon. In addition to conventional indicators applied to characterize the region, such as related to agricultural commodities and deforestation rates, we selected indicators also relevant to municipalities beyond the arc of deforestation, which in many cases rely on river-based transportation and a forest- and river-based economy (see Supplementary Material 1 for further information on the regional dataset compilation and rationale for indicators’ selection).

⁹ Mojuí dos Campos (Pará), officially emancipated on January 1, 2013, was removed from the analysis for the lack of official data used in the study. Grajaú (Maranhão), despite not considered part of the Brazilian Amazon biome by the MMA, was included in the analysis since it was listed in the LPM in 2011.

¹⁰ Portaria MMA 96/2008.

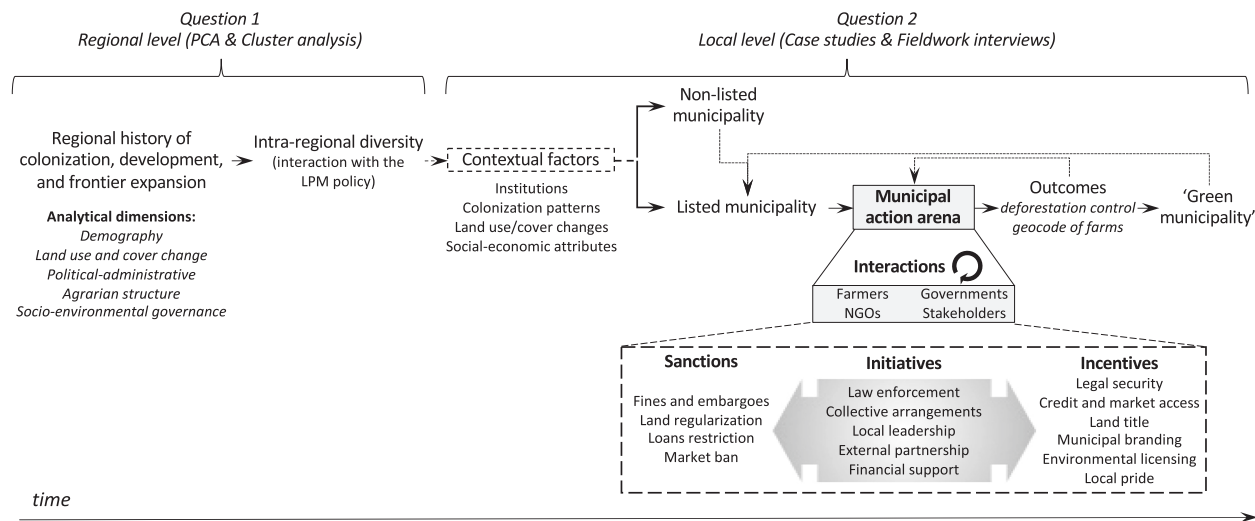


Fig. 1. The conceptual framework underlying the rationale, questions, and methods of the study.

Table 1
The set of dimensions and indicators compiled to analyze how the regional history of colonization, development and frontier expansion have shaped municipalities in the Brazilian Amazon biome.

Dimension	Indicator	Source
Demography	Proportion of migrants 40 + age in the total population in 2010	IBGE
Land use and cover change	Cattle density (number of cattle heads/municipal area) in 2008	IBGE
Land use and cover change	Proportion of soy plantations over the total area cultivated in 2008	IBGE
Land use and cover change	Proportion of the original forest cover cleared by 2008	PRODES
Land use and cover change	Proportion of the original forest cover lost between 2004 and 2008	PRODES
Political-administrative	Year of municipality emancipation	IBGE
Agrarian structure	Gini index on land concentration in 2006	IBGE
Socio-environmental governance	Proportion of Indigenous and Protected Lands (PAs) in 2008	MMA

We applied a principal component analysis (PCA) followed by a clustering analysis to identify municipalities sharing similar attributes based on the selected set of indicators. We selected the principal component axes capturing the above-average variance of the original dataset, i.e., eigenvalue >1 and then applied an agglomerative non-hierarchical clustering algorithm (k-means) (Supplementary Material 4). This cluster analysis was then cross-tabulated with the LPM, allowing us to examine the relationship between listed municipalities (LPM) and clusters representing municipalities associated with different phases of frontier expansion and land use and cover patterns across the region.

3.3. The municipal level analysis: selecting municipal case studies and research participants

Complementing our regional-level analyses, we carried out in-depth field studies in the municipalities of Paragominas, Tailândia, Moju, and Portel (Fig. 2). These municipalities were included in the LPM in different periods – 2008 (Paragominas), 2009 (Tailândia), 2011 (Moju), and 2017 (Portel). Whereas Paragominas and Tailândia got off the LPM in 2010 and 2013, respectively, Moju and Portel remain. We selected these municipalities because they are geographically located across a gradient of the expanding deforestation frontier in the Eastern portion of the arc of deforestation, in the state of Pará. The municipalities represent different periods of colonization of the Amazon, from the consolidation of the riverine town of Portel in 1843 to the emancipation of Paragominas along the Belém-Brasília highway in 1965. Portel combines large segments of riverine populations and a forest-based and extractive economy with an expanding road-based deforestation front leak-

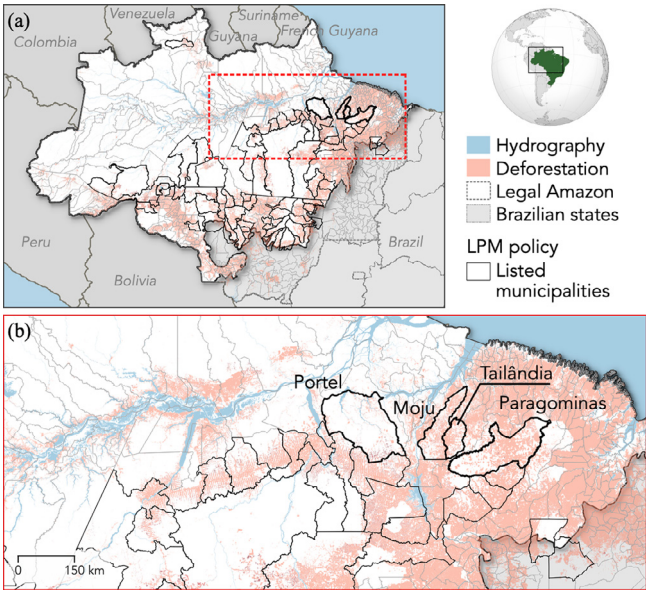


Fig. 2. The Brazilian Amazon biome. (a) The 62 municipalities included in the Brazilian Ministry of Environment's List of Priority Municipalities (LPM) between 2008 and 2018. (b) The case studies of four municipalities along a gradient from older to newer areas of expanding deforestation in Pará.

ing from neighboring municipalities in the South. Likewise, Moju presents a riverine-based forest economy and small-scale agricultural activities, but like Paragominas and Tailândia, it has an

expanding production of agricultural commodities at various scales along the roadways that crisscross their territories (see Supplementary Material 2 for further contextualization about each municipality).

Fieldwork campaigns between 2016 and 2018 were carried out in these four municipalities and the state capital (Belém). Semi-structured interviews were conducted with a broad set of actors involved with initiatives linked to the LPM policy, from government officials and extensionists to practitioners, researchers, bank managers, directors of unions and cooperatives, local community leaders, ranchers, and small- and large-scale farmers. We stratified our sampling to ensure visits to places and interviews with research participants who provided varying perspectives on historical and current local development processes and land cover changes, the impacts of the LMP policy, and the design and emergence of local initiatives to remove the municipality from the LPM. Information gathered from the interviews was triangulated across different interviewees and compared to secondary data to provide a more detailed picture of how diverse agents in these four municipalities responded to their inclusion – and ensuing sanctions – in the LPM (Supplementary Material 3).

4. Results

4.1. Regional-level analysis

4.1.1. The regional and intra-regional diversity of Amazonian municipalities

The PCA analysis resulted in three principal component axes (PCn). Together, they explain 66.4% of the variation in the original data (Table 4 SM). The first principal component (PC1) presents high coefficients for '% migrants 40+ age,' '% original forest cover loss,' 'cattle density,' and 'year of municipal emancipation' (Table 5 SM). This set of attributes relates to municipalities that, starting in the early 1970s, began to emancipate after receiving waves of migrants and experiencing massive deforestation boosted by cattle ranching following the implementation of regional colonization and infrastructure development programs. We call the first principal component (PC1) "regional integration" to reflect the role of development programs implemented during the military government programs on socioeconomic, demographic, and land cover indicators (Table 2).

The second principal component (PC2) presents a high correlation with '% indigenous and protected lands' and '% original forest cover loss.' The opposite sign of these coefficients reveals a trade-off between the two attributes in the same municipality, i.e., the more indigenous and protected lands, the lower the proportion of forest loss. PC2, thus, represents a dimension of the "social-environmental protection" in the municipalities, which reflects the side-by-side expansion of the deforestation frontier into the Amazon and the designation of indigenous and protected lands to safeguard local land rights and buffer forest loss.

Table 2

Coefficients associated with the indicators upon which the three principal component axes (PCn) were computed. The brackets' value indicates the proportion of variation explained by each PCn. Figures in bold represent indicators contributing substantially (above the average) to the principal component.

Indicator	PC1 (32.7%) <i>Regional integration</i>	PC2 (18.8%) <i>Social-environmental protection</i>	PC3 (14.9%) <i>Agricultural expansion</i>
land inequality (Gini index)	−0.17	−0.34	0.50
% migrants 40 + age	0.48	0.33	0.12
deforestation activity (2004–2008)	0.29	0.07	0.33
% original forest cover loss	0.42	− 0.49	−0.11
Year of municipal emancipation	0.37	0.34	−0.10
% soybean plantations	0.17	0.24	0.69
cattle density	0.47	−0.04	−0.32
% indigenous and protected lands	−0.29	0.60	−0.15

The third dimension of the PCA (PC3) characterizes municipalities in which land inequality (high coefficient for the 'Gini index') correlates with the market-driven expansion of croplands (high '% soybean plantations') in large-scale landholdings. These features characterize municipalities bordering the south of the biome, which have emerged since the 1950s following the expansion of agriculture to the Brazilian *Cerrado* and progressively to the Amazon-*Cerrado* ecotone. PC3 thus provides a characterization of the 'agricultural expansion' in the region.

Our exploratory analysis employing the three principal component axes suggested four groups as the optimum number for the clustering analysis (data not shown). The result is the organization of the Brazilian Amazon biome into four mostly contiguous blocks of municipalities closely associated with periods of occupation and patterns of development and forest cover (Fig. 3).

The Forest-dominated Amazon encompasses 121 municipalities covering the biome's most extensive forested area (2.8 mi sq.km). Located on both sides of the Amazon River and extending to the borders with all the neighboring Amazonian countries, these municipalities have been relatively less influenced by government-driven settlements, agricultural expansion incentives, and infrastructure development – as indicated by the lowest average value of the PCA 'regional integration' axis (Table 3). These municipalities were mostly consolidated before 1965, extending back to the early 19th Century. They have remained relatively isolated from, but not immune to, the primary drivers of deforestation, such as cattle ranching (Table 4). Most municipalities safeguard 50%+ of their territories in indigenous and protected lands, and four in every five municipalities still conserve 85%+ of their original forest cover (data not shown), as indicated by the highest average value for the 'social-environmental protection' axis of the PCA.

The Colonial Settlements cluster includes 141 municipalities covering ~515,000 sq.km. This cluster features municipalities emancipated between the early colonial period (17th Century) and the 1930s mainly. This cluster encompasses municipalities with origins in various economic cycles and periods of colonial settlement expansion, both along the coast and upstream of the Amazon River and its main tributaries. Municipalities in this cluster share the highest level of land concentration and the lowest rate of migrants 40+ age. While municipalities to the north of the basin have been arguably less impacted by road-based development and recent land reform colonization programs (as indicated by the negative average value for the 'regional integration' axis), several municipalities to the east of the region (in the states of Pará and Maranhão) have limited definition of indigenous and protected lands (as indicated by the lowest average value for the 'social-environmental protection' axis), high land inequality, and high rates of forest loss (Table 4). 60% of these municipalities have no indigenous or protected lands in their territories (data not shown).

The third and fourth clusters of municipalities correspond to the area conventionally called the arc of deforestation. Although

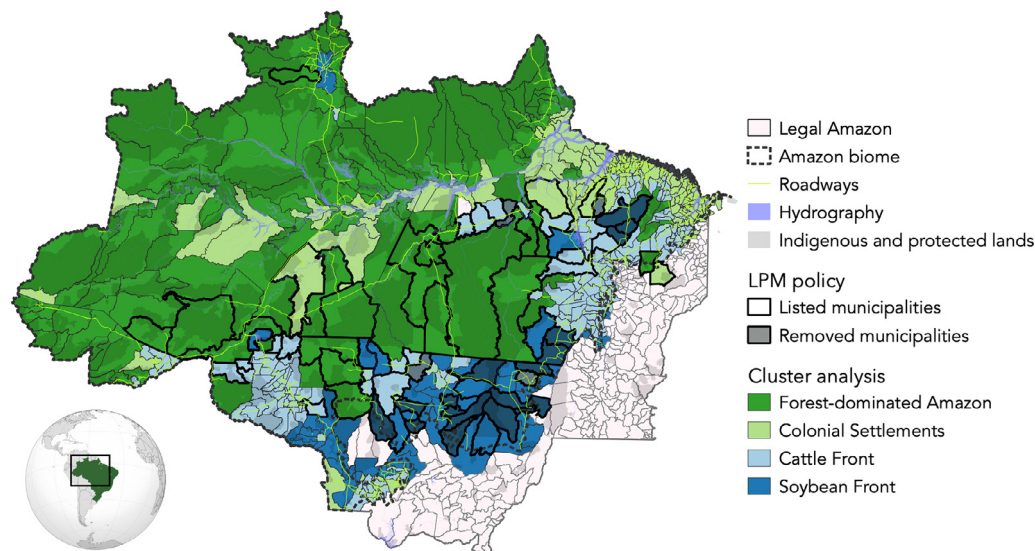


Fig. 3. The four clusters of municipalities in the Brazilian Amazon biome and the 62 municipalities targeted by the Ministry of Environment List of Priority Municipalities in the 2008–2018 period.

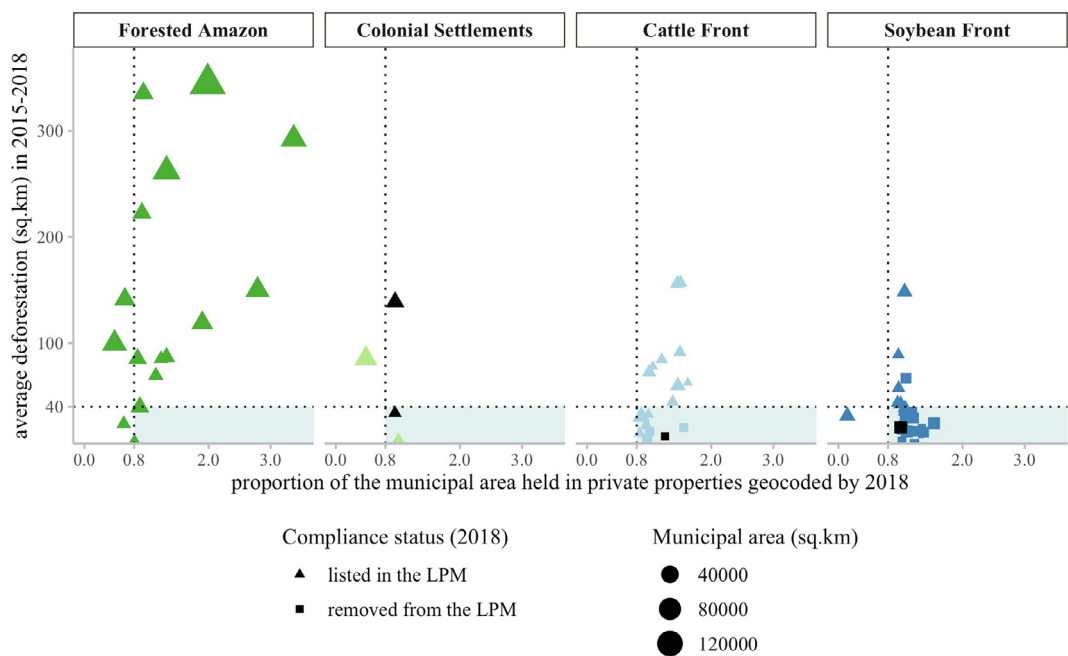


Fig. 4. Municipalities' compliance with two removal criteria of the List of Priority Municipalities policy in 2018. Municipalities not complying (triangles) and complying (squares) with the LPM policy. The shaded area indicates the “compliance” zone, i.e., at least 80% of the municipal area held in private properties registered in the national database (SICAR), and the average yearly deforestation rates below 40 sq.km in the previous four years (2015–2018).

Table 3
Typology of municipalities and cluster results (within clusters' mean and frequency) based on the three principal components axes.

Cluster (k-means)	PC1	PC2	PC3	N
	Regional integration	Social-environmental protection	Agricultural expansion	
Forest-dominated Amazon	−1.657	1.274	−0.486	121
Colonial Settlements	−1.149	−1.200	0.266	141
Cattle Front	1.415	−0.233	−0.607	198
Soybean Front	1.178	0.874	2.023	70

referred often as a homogeneous region, our analysis revealed two distinct groups. The cluster we call Cattle Front encompasses 198 municipalities covering around 513,000 sq.km over the Southeastern and Northeastern areas of the arc of deforestation and portions

along the Transamazon highway. This cluster includes municipalities that were substantially shaped by development programs implemented during the military period, as the highest value of the ‘regional integration’ axis indicates (Table 3). These are munic-

Table 4Average $\pm$ SD values of the original indicators (i.e., not scaled) for each cluster of municipalities. Data distribution is presented in the supplementary material (Fig. 1 SM).

Variable	Forest-dominated Amazon (n = 121)	Colonial Settlements (n = 141)	Cattle Front (n = 198)	Soybean Front (n = 70)
land inequality (Gini index)	0.69 $\pm$ 0.17	0.83 $\pm$ 0.09	0.68 $\pm$ 0.11	0.77 $\pm$ 0.08
% migrants 40 + age	0.28 $\pm$ 0.30	0.08 $\pm$ 0.11	0.65 $\pm$ 0.31	0.80 $\pm$ 0.18
deforestation activity (2004–2008)	0.01 $\pm$ 0.01	0.02 $\pm$ 0.02	0.03 $\pm$ 0.02	0.04 $\pm$ 0.02
% original forest loss	0.09 $\pm$ 0.10	0.51 $\pm$ 0.32	0.76 $\pm$ 0.20	0.50 $\pm$ 0.20
Year of municipal emancipation	1952 $\pm$ 43	1919 $\pm$ 67	1983 $\pm$ 14	1983 $\pm$ 18
% soybean plantations	0.01 $\pm$ 0.07	0.01 $\pm$ 0.05	0.02 $\pm$ 0.07	0.51 $\pm$ 0.25
cattle density	13.9 $\pm$ 22.9	13.7 $\pm$ 15.3	76.7 $\pm$ 40.9	33.5 $\pm$ 21.5
% indigenous and protected lands	0.54 $\pm$ 0.24	0.05 $\pm$ 0.10	0.06 $\pm$ 0.14	0.14 $\pm$ 0.17

Table 5

The number of municipalities targeted by the LPM policy in the 2008–2018 period.

Cluster	2008	2009	2011	2012	2017	2018	Total
Forest-dominated Amazon	8	2	1	2	3		16
Colonial Settlements			2		2		4
Cattle Front	9	4			2	2	17
Soybean Front	19	1	4		1		25
Total	36	7	7	2	8	2	62

ipalities recently emancipated along roadways and land reform projects – seven in 10 municipalities were emancipated after 1980 (data not shown). They present the highest cattle density, the second-highest proportion of migrants 40+ age, and the largest proportion of the original forest area cleared by 2008 (Table 4) – 80% of these municipalities have less than 50% of their original forest cover (data not shown).

Finally, the cluster we call Soybean Front covers 525,000 sq.km and groups 70 municipalities mainly over the ecotone where the *Cerrado* and Amazon biomes overlap, extending across the states of Rondônia and Mato Grosso in the Southern portion of the biome to its Northeastern fringes in the states of Tocantins and Pará. These municipalities present the highest average proportion of soybean plantations in the Brazilian Amazon, and together, they form one of Brazil's largest soybean production areas (Table 4). Accordingly, the cluster presents the highest average value for the 'agricultural expansion' axis (Table 3). These municipalities were influenced by government initiatives starting as early as the 1940s, which were intensified during the military period, as confirmed by the high values of the 'regional integration' PCA axis. In that regard, the Soybean Front is marked by a high '% migrants 40+ age' and deforestation activities – both total and recent forest loss (Table 4).

4.1.2. The priority municipalities as part of a moving deforestation frontier

The 62 municipalities listed in the LPM between 2008 and 2018 are found in the four clusters identified in this study. Two-thirds of the municipalities belong to either the Soybean or Cattle Fronts, coinciding with the evolution of the arc of deforestation. In contrast, a smaller but growing proportion of listed municipalities belongs to the Colonial Settlements and Forested-dominated Amazon clusters, which confirms the continuous advance of the frontier (Table 5).

All municipalities removed from the LPM, thus receiving the stamp of "green municipality," are in the arc of deforestation, notably in the Soybean Front, where seven in every ten municipalities have gotten off the LPM (Table 6).

4.2. Local-level analysis: understanding municipal responses to the LPM policy from the ground

Our case studies of four municipalities represent three of the four clusters of municipalities identified in the regional analysis:

Soybean Front (Paragominas), Cattle Front (Tailândia), and Colonial Settlements (Moju and Portel). These clusters encompass municipalities featuring the highest rates of forest loss in the biome and represent the main clusters in the study area in Northeastern Pará. As anticipated, these municipalities illustrate the gradient of the frontier that has moved from Paragominas to Portel, depicting different local conditions underlying the responses to the LPM policy. Whereas Paragominas and Tailândia successfully managed to get off the LPM, Moju and Portel did not. In this section, we drew on the more detailed information collected during field research to examine how varying sanctions (Section 4.2.1) and incentives (Section 4.2.2) have triggered diverse initiatives among local agents (Section 4.2.3) towards controlling deforestation and geocoding farms (Section 4.2.4) to comply with the LPM criteria.

4.2.1. The role of sanctioning both municipalities and local stakeholders

Since the LPM policy focused on monitoring and enforcement initiatives in a few municipalities, stiffer police operations resulted in a surge in environmental fines and the embargo of goods and properties. Inter-institutional cooperation among federal government agencies resulted in additional rules tying bank loans to farms' geocoding and environmental regularization. Further, the LPM became a referential device for external agents to enforce parallel initiatives, such as market moratoriums on listed municipalities intended to prevent the trade with producers potentially engaged in illegal activities. The sanctions varied in intensity depending on context-specific circumstances and enforcement measures, the latter changing with the period in which the municipalities were listed.

Following the disclosure of the first LPM in January 2008, the federal government deployed stronger and coordinated police operations along with local police forces and the National Guard. The operations labeled as *Arco de Fogo* (arc of fire) impacted a substantial number of agents and organizations associated with logging, charcoal production, cattle ranching, and agriculture (Arima et al., 2014; Assunção & Rocha, 2019). Tailândia was the first municipality to receive the *Arco de Fogo* operation in February 2008 (da Silva, 2010). Hundreds of police agents landed in the town in helicopters and vehicles one year before the municipality figured in the LPM. A new directive by the federal government¹¹

¹¹ Instrução Normativa MMA 001/2008.

Table 6

The number of municipalities removed from the LPM policy in the 2008–2018 period.

Cluster	2010	2011	2012	2013	2017	2018	Total
Forest-dominated Amazon							0
Colonial Settlements							0
Cattle Front			1	2	1		4
Soybean Front	1	1	3	3	9	1	18
Total	1	1	4	5	10	1	22

authorized the police to apprehend equipment and goods and seize properties and facilities (Ortiz, 2014). Contrary to fines rarely paid (Börner et al., 2015), the seizure of investments and capital – many resulting from bank loans – prevented rule-breakers from benefiting from and continuing their activities (Interviewees 16 and 138). After eight months, the police operations left a trail of public outcries, unemployment, and economic crisis (Phillips, 2009). As voiced by numerous interviewees, the termination of about 16,000¹² primarily informal jobs (Kern et al., 2012, p. 112) and ventures linked to logging and charcoal production was perceived to have driven Tailândia to its end.

The *Arco de Fogo* operations had similar impacts once deployed in Paragominas in April 2008. Figuring among the listed municipalities deepened the already notorious reputation of Paragominas, infamously known for its history of violence and natural resources degradation (Bergamin, 2015). In addition, parallel initiatives synergistically impacted Paragominas. Following the Public Prosecutor Office (MPF) threat of sanctioning agents involved in the beef supply chain, slaughterhouses and supermarkets restricted trade with Paragominas (Bergamin, 2015, p. 89; Mengardo, 2018). Second, INCRA, the federal agency running land regularization programs, conditioned the emission of land titling documents upon the georeferencing of farms (Interview 124) (Bergamin, 2015, p. 80). Further, a new Central Bank decree¹³ demanded farmers present proof of land regularization before contracting bank loans, restricting access to agricultural credits (Interviewee 24) (Bergamin, 2015, p. 80).

After this initial and intense period of enforcement, a surge in complaints from local organizations, mayors, and state representatives (Agência Senado, 2008) contested the disproportional damage that followed police operations, which weakened the *Arco de Fogo*. Conversely, the gradual consolidation of municipal secretariats of the environment assumed an increasing role in the enforcement of environmental regulations locally. When Moju was listed in 2011, therefore, the LPM resulted in stricter conditions for wood-processing facilities to operate, for which many were shut down (Interviews 94, 97). However, the broader economic impacts that hit Paragominas and Tailândia were only marginal in Moju. First, Moju's logging industry does not employ many people since timber is sourced mainly from other municipalities (Interviewee 102). The palm-oil industry is the main economic activity hiring the local workforce (Interview 28). Further, restrictions for bank loans and requirements for the geocoding of farms had limited impact in Moju, where small-scale family farmers (area <4 fiscal modules or 280 ha) represent the bulk of local landholdings. Accordingly, family farmers were exempted from geocoding their farms to contract agricultural loans (Interviewee 116). Besides, a substantive number of family farmers were already ineligible to contract agricultural loans because of previous bank debts (Interview 97). Thus, credit restrictions associated with the LPM policy have remained largely innocuous in Moju.

Finally, although joint police operations have increased since Portel was listed in 2017 (Interviewee 94), sanctions had been

marginally noticed by local stakeholders and government officials during the first months since the inclusion in the LPM. While officials in the municipal secretary of the environment were aware of the LPM (Interviewees 94 and 153), officials in the city hall and representatives of the agriculture, industry, and commercial sectors ignored the fact (Interviews 82, 85, and 86).

4.2.2. From sanctions to incentives for local arrangements and multi-partner cooperation

The economic impact and the sanctions imposed on municipalities by the LPM policy represented tangible incentives to encourage partnership and cooperation towards tackling deforestation and geocoding farms. However, the extent to which such sanctions were perceived as threatening varied significantly depending on local contexts and the year the LPM targeted the municipality. Stakeholders in some municipalities, such as Paragominas, perceived these sanctions as a window of opportunity to adapt to a new reality, thus benefiting from an otherwise adverse circumstance (Chaffin & Gunderson, 2016).

At the farmer level, incentives underlying practical actions to comply with the LMP included obtaining land titling, environmental licensing for agricultural activities, bank loans, and avoiding market moratoriums or figuring in the official list of embargoed properties. However, individual attitudes towards ceasing forest clearings and farms' geocoding have not emerged voluntarily everywhere. Instead, municipal governments strictly enforced bans on new clearings (and the use of fire in agriculture), as well as "persuaded" farmers about the critical importance of geocoding their farms, offering the service for free (Interviewees 36 and 39).

At the municipal level, incentives for collective action have revolved around rebranding the municipality's image (e.g., as a 'green municipality'), consolidating an attractive environment for businesses to regain and expand market access, and restoring local pride in agriculture and forestry activities. Finally, the enrollment in government initiatives assisting municipalities in getting off the LPM requires collective commitments towards achieving deforestation and geocoding goals (Interviewee 92).

In Paragominas, the economic elite had urgency in overcoming barriers restricting bank loans and business with regional and national markets. Therefore, controlling yearly deforestation and farm geocoding represented pressing demands (Bergamin, 2015). Additionally, becoming the first municipality to get off the LPM was envisioned as an opportunity to replace Paragomina's negative reputation with a modern image reflecting the reconciliation between sustainable agriculture and environmental conservation (Marconato & Queiroz, 2012) (Interviewee 1). This was expected to reduce the juridical insecurity damaging businesses and refraining investments in a municipality regularly targeted by monitoring and law enforcement initiatives for its historical association with illegal activities. Paragominas largely succeeded in achieving these goals.

Tailândia and its stakeholders experienced a completely different suite of incentives. By the time the municipality was listed in 2009, the local economy had already collapsed following the *Arco de Fogo* operations. Moreover, since the economic matrix in Tailândia revolved around the timber and charcoal industries, the

¹² The estimated population in Tailândia was 69,581 in 2008 (IBGE).

¹³ Resolução Banco Central 3.545/2008.

embargo set by companies in the beef supply chain was innocuous. Unsurprisingly, residents interviewed in Tailândia barely remember or know about the LPM policy and its links with the *Arco de Fogo* operations. However, they understood the importance of finding alternative land uses and economic activities. In that regard, following examples of other municipalities struggling with economic uncertainty, the geocoding of farms and control of deforestation emerged in the local narrative as an incentive for Tailândia to find a new path forward.

In Moju, having experienced no tangible impacts from the LPM policy, incentives for controlling deforestation and geocoding landholdings have been at best diffuse. However, Moju is among more than a hundred municipalities in Pará that have joined the Green Municipalities Program (PMV), a state initiative launched in 2011 to support municipalities to get off the LPM. Inspired by the positive experience and the successful institutional arrangements in Paragominas, the PMV has provided municipal environmental agencies with training and technical and infrastructure support towards removing these municipalities from the LPM. In return, municipalities commit to monitoring deforestation and fostering actions to geocode farms (Interview 105). That, however, has not sufficed for Moju – and most municipalities in Pará – to conclude the georeferencing of its landholdings, even after the new Forest Code enacted in 2012 made the geocoding of farms mandatory nationwide.

Similarly, incentives to comply with the requirements of the LPM policy seem to lack in Portel. Among those in the municipal administration aware that Portel was figuring among the listed municipalities, some admit the LPM policy and the PMV program are pointless for a municipality that still preserves 99% of its original forest cover (Interviewee 92). Deforestation in Portel illustrates the continuous advance of the frontier, particularly over forested municipalities where the land rights of indigenous groups and traditional communities are not secure – a feature of the Colonial Settlements cluster. In Portel, deforestation has taken place in distant areas disconnected from riverine regions characteristic of the municipality. For this reason, deforestation is considered a leaking process from neighboring municipalities in the arc of deforestation, deserving marginal attention by local authorities (Interviewee 92). Joining the PMV and committing to monitor and halt local deforestation represents an overburden for the recently constituted environment secretariat, with limited infrastructure and staff to oversee the remote areas of its vast territory. On top of that, public prosecutors to back up law enforcement and the work by official and municipal agencies are absent in distant rural areas, for which actors targeted by local police operations do not fear persecution.

On the contrary, it is not uncommon for local environmental agents to be threatened (Interviews 78 and 94). At the same time, the 2012 Forest Code institutionalized the rural environmental registry (CAR), triggering a pervasive surge in the interest in land geocoding in the Amazon. Driven by traditional riverine communities seeking the customary rights over their lands, the geocode of properties has skyrocketed in Portel based on the false expectation that such a registry alone will configure a proof of – or even constitute – an official land title.

4.2.3. Local arrangements and multi-partner cooperation contributed to policy compliance

Patterns of interaction among agents engaged in initiatives to respond to the LPM policy varied across municipal arenas. Among factors affecting their interactions, it is worth mentioning the diversity and number of local agents directly impacted and interested in pursuing solutions; their varying political and economic power; the presence of local leadership and social networks; the diversity and dedication of external agents supporting and partic-

ipating in local arrangements and initiatives; the synergistic interaction between the LPM and other policies and programs emerging over time; and the learning experiences exchanged among agents across municipalities (Fig. 5).

Pioneering initiatives towards responding to the LPM policy emerged in Paragominas. Led by the mayor and supported by the patronal farmers' union – representing the local economic and political elite (Viana et al., 2016) – and by two NGOs, a municipal pact (a.k.a. Green Municipal Pact) was designed in 2008 aimed at accomplishing the required tasks to get Paragominas off the LPM. The mayor's leadership and coordination with the farmers' union equipped them with the necessary legitimacy to convey among angry and distrustful farmers and stakeholders the unpopular strategy of collaborating with environmental NGOs (often regarded as enemies by the agricultural sector in Brazil), geocoding landholdings in the CAR system (a contentious task in a region marked by pervasive land tenure conflicts), and curtailing forest clearings.

Although the commitment among local agents was important in limiting individual forest clearings and prompting farms' geocoding, the technical support and expertise received from two NGOs (i.e., Imazon and The Nature Conservancy) were fundamental (Interviewee 10). Besides surveying and compiling critical social, economic, and biophysical information about the municipality (Pinto et al., 2009), their know-how and network expanded the suite of alternatives and strategies to tackle the LPM policy. This provided local stakeholders with privileged conditions to benefit from existing tools, techniques, and funding opportunities and devise alternative actions to get off the LPM. Their collaboration was also instrumental in updating cartographic maps and developing and improving methods and tools required for the geocoding and monitoring tasks at the farm level (Interviewee 3). The support received for geocoding and registering farms represented a 20-fold reduction in the regular cost farmers would have paid otherwise (Guimarães et al., 2011). In that regard, private funds received from third-party agents were fundamental to support the projects and activities carried out in Paragominas (Interviewees 1 and 10).

Finally, the institutional support received from the federal and state governments to advance the local Green Municipal Pact legitimated the municipal commitments and strategy to get Paragominas off the LPM, boosting trust and local cooperation (Bergamin, 2015) (Interviewee 1). It is noteworthy that, underlying such an arrangement, local agents and municipal officials pressed for and managed to transfer tasks usually centralized by the state environmental agency to the municipal level, satisfying old demands to reduce bureaucracy and expedite environmental licensing. Further, they lobbied for the Central Bank to loosen the requirements for agricultural loans in municipalities removed from the LPM policy, which resulted in a new decree authorizing banks to accept the farm's geocoding receipt rather than the INCRA official land document (Interviewee 24). Finally, responding to complaints regarding the damages and aggressiveness of the *Arco de Fogo* operations, the federal government launched the *Arco-Verde*¹⁴ operations (Green-Arc Operation) to support listed municipalities in transitioning towards sustainable economies.

Inspired by the experience of Paragominas, although limited by the economic crisis following the *Arco de Fogo* operations, Tailândia's pathway to cope with the LPM requirements went at a slower pace. Committed to restoring the municipal economy, the recently elected mayor gave carte blanche to the secretaries of environment and agriculture. Working in close collaboration, they head initiatives in partnership with local and external agents and government agencies (Interviewees 36, 39, and 72). As the former president of the rural farmers' union, the agriculture secretary enjoyed prestige

¹⁴ Decreto Federal 7.008/2009.

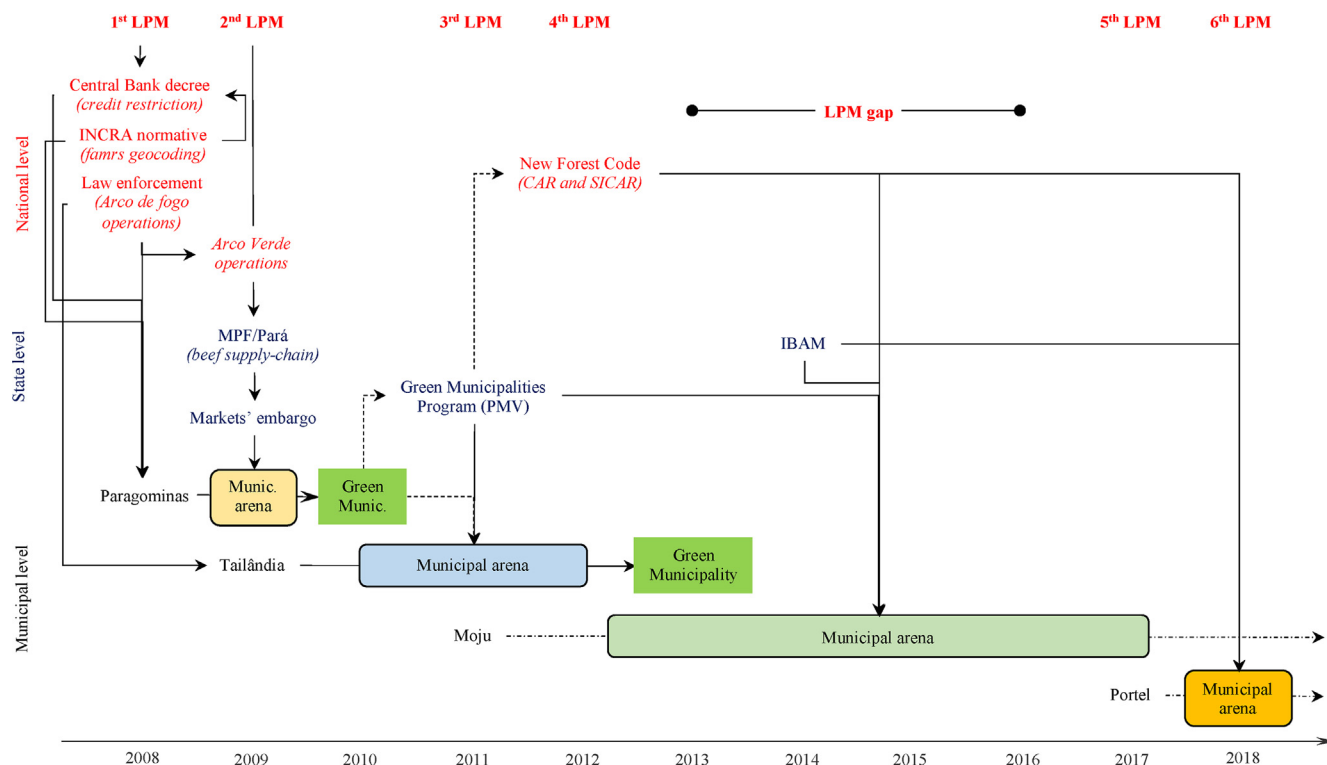


Fig. 5. Set of initiatives and regulations affecting municipalities listed by the LPM policy. From the local to the national level, interconnected initiatives emerging across different government levels have resulted in sanctions, engendered incentives, and motivated individual and collective actions from local agents embedded in diverse municipal arenas.

and trust among the rural community to convince farmers to geocode their farms. Along with community leaders and the staff of local environmental, agricultural, and rural extension agencies, the municipal administration deployed task forces across the territory to fulfill the LPM removal criteria. Starting in 2011, Tailândia also benefited from joining the PMV, which in addition to training and infrastructure support, has contracted with private firms to advance the geocoding services in participant municipalities.

Despite prior learning experiences and emerging institutional arrangements supporting listed municipalities to get off the LPM, successful collaborative efforts have not developed outside the arc of deforestation, such as in Moju and Portel. Alongside the weakening of sanctions as the *Arco de Fogo* operation faded away, the lack of political cohesion and social organization to steer the diverse social groups settled in Moju have provided little incentives for action, limiting the scope of both individual and collective responses. On the one hand, a historical dispute between a handful of local rival families has marked the political arena in Moju (Interviewee 42), where power alternation among groups pursuing individual interests rather than common ones has undermined the advance of public programs of mutual interest. A visit to the city hall after the mayor's impeachment in April 2018 verified that official files had been destroyed or hidden from the new administration.

On the other hand, and for reasons beyond the scope of this study, social organizations have faced substantial challenges in running their activities and supporting their members, for which trust in them has melted (Interviewees 39, 64, 114, and 122). That is troublesome given the positive influence rural workers' unions and communitarian associations have exercised in mediating the tasks of geocoding farms and ceasing deforestation and fires among their members. The diffusion of social leadership among various social organizations holding divergent agendas for diverse actors in Moju – family farmers, Afro-Brazilian descendants, oil-

palm industry employees, timber workers – has also limited the engagement of local actors. Thus, contrary to Paragominas and Tailândia, political willingness and social commitment to cope with the LPM policy have remained diffuse in Moju despite the institutional support the municipal secretariat of the environment has received from the PMV.

Finally, the municipal administration in Portel, besides ignoring the LPM policy, has resisted joining the PMV – contrary to most municipalities in Pará – even after its inclusion in the LPM in September 2017. Portel's secretariat of the environment has benefited from support received by the state environmental agency, which gradually matched the PMV in providing municipalities with technical and training support aimed at the decentralization of the environmental agenda. Besides, Portel has also taken advantage of an initiative launched in 2014 by the Brazilian Institute of Municipal Administration (IBAM¹⁵) to enhance municipal environmental governance in Pará. Despite that, facing no sanctions or incentives to control deforestation, the local government has taken limited action to halt forest loss driven by external agents in the remote areas of Portel. Thus, initiatives at the municipal level remain limited to traditional riverine communities' independent efforts to geocode their lands, regardless of the LPM policy.

4.2.4. The LPM policy outcomes at the municipal scale

4.2.4.1. Deforestation control. By 2018, Portel was the only municipality discussed in this study that had not complied with the removal criterium set by the LPM policy – i.e., yearly deforestation rates below 40 sq.km in the previous four years.¹⁶ In 2018, Portel registered some 100 sq.km of forest clearings – an average of 138 sq.km since 2015. The official deforestation data for Amazonian

¹⁵ Programa de Qualificação Gestão Ambiental. Available at: <https://www.amazonia-ibam.org.br/>.

¹⁶ Portaria MMA 427/2018.

municipalities (PRODES) reveals that controlling deforestation rates below the LPM policy threshold has been challenging, mainly for the forested municipalities in the most extensive territories.

4.2.4.2. Farms' geocoding. Regarding the geocode of 80% of the municipal territory held in private properties, the total area registered in the official government database (SICAR) by 2019 suggests that the four municipalities have achieved the goal. Further, the data reveals that only five out of 62 municipalities have not geocoded and registered farms in the official database. However, the SICAR database calls for caution in its analysis. In 20 out of 62 listed municipalities, the area of geocoded farms is larger than the municipality's total area (data not shown). Besides, the total area of farms geocoded and registered on SICAR in 41 municipalities exceeds the municipality's area outside indigenous and protected lands, i.e., the area to be geocoded by law. That issue is acute in the largest and most forested municipalities – mainly in the Forest-dominated Amazon cluster (Fig. 4).

5. Discussion

This study analyzed the interaction between the LPM national policy and diverse municipalities across Brazil's Amazon biome. This is the most extensive analysis of the LPM policy since its implementation in 2008. This is also the first study combining spatial and temporal analysis, census data, and fieldwork to examine the LPM policy at the regional and local levels. Based on these analyses, we first revisit conclusions on the effectiveness of the LPM policy towards halting deforestation. While existing studies have highlighted the successes of the LPM, we broaden such analyses to show the LPM policy limitations in inducing effective responses across diverse municipal realities, the reason many of the achievements observed at the local level have not been replicated regionally.

At the regional level, our analysis rendered a new map revealing the intra-regional diversity of Amazonian municipalities, as shaped by deforestation patterns, agricultural activities, demography, agrarian structure, emancipation history, and social-environmental protection. We drew on this map to examine the trajectories of listed municipalities and understand patterns of success and failures in compliance with the LPM policy. At the municipal level, we examined four case studies in-depth to unveil the factors underlying the mixed outcomes of the LPM policy. Notably, we looked at how their particular attributes and conditions have mediated individual and collective responses to sanctions and incentives triggered by the LPM policy. We examined how inter-institutional cooperation across government levels and the interaction between the public policies and market-oriented initiatives, context-specific incentives, collective actions, and new regulations and government programs have steered local agents towards controlling, to different degrees, deforestation and geocoding their farms (Table 6 SM).

5.1. The promising LPM policy outcomes have failed the test of time

Previous analyses of the LPM policy covered the 2008–2012 period when favorable environmental governance conditions – mainly the stricter enforcement of forest legislation – contributed to the drastic reduction in forest loss detected between 2004 and 2012 in the Amazon (Arima *et al.*, 2014; Assunção & Rocha, 2019; Cisneros *et al.*, 2015; Nepstad *et al.*, 2014; Rochedo *et al.*, 2018; Sills *et al.*, 2015). Analyzing this process over a more extended period reveals a different picture. Ten years after the LPM policy implementation, forest legislation in Brazil has been loosened (Brançalon *et al.*, 2016) in a context of political and eco-

nomic instability that has eroded environmental governance (Fearnside, 2016; Ferrante & Fearnside, 2019; Pires, 2014). Our extensive temporal analysis reveals that the challenges of reducing deforestation and geocoding farms have persisted across most municipalities. In 2018, only one-third of the listed municipalities had complied with the LPM policy, and one municipality was re-listed.

Unsurprisingly, our study confirms that most listed municipalities are within the arc of deforestation, representing the most active expanding frontier driven by colonization and infrastructure development programs, cattle and soybean production incentives, and an active illegal land market. However, our analysis also shows that a growing proportion of listed municipalities are now in areas beyond the arc of deforestation (Table 5). These new deforestation hotspots include forest-dominated municipalities along the Amazon river floodplain and the Estuary-Delta regions where the local population has historically relied upon small and medium-scale farming and extractive (forest-based and river-based) economic activities. This result reveals the continuous advance of the frontier towards areas that have remained relatively immune to deforestation forces, suggesting the limitations of existing strategies – including the LPM policy and the PMV program in Pará – in tackling deforestation forces and halting the frontier expansion (Londres *et al.*, 2021).

5.2. The role of contextual factors, enforcing sanctions, and inter-institutional coordination in promoting local individual and collective responses

This study identifies and examines critical factors affecting the LPM policy outcomes across listed municipalities. One set of factors refers to the local conditions in each municipality, such as leadership, political capital, social cohesion, and primary economic activities. Another set of factors refers to external forces, including the synergy between the LPM policy with additional regulations (e.g., Central Bank decree, INCRA's normative), programs (e.g., *Arco Verde* operations, PMV, IBAM), market-driven incentives (e.g., soybean and beef moratoria), and law enforcement (*Arco de Fogo* operations). Since local conditions and external forces change over time, the year the municipality was listed becomes crucial. That defines a temporal dimension to understand the specific sanctions and incentives at stake in a given moment and place and the opportunities for local agents to exchange experiences and interact with emerging opportunities (Fig. 5).

These aspects relate directly to the patterns of interactions among multiple agents at the municipal level. As reported in our case studies and extensively documented in Paragominas, attributes such as the mayoral leadership, public agencies engagement, local pride, social cohesion, and financial and institutional support were critical elements steering diverse local stakeholders towards collectively responding to the LPM policy (Nepstad, 2017; Piketty *et al.*, 2015; Viana *et al.*, 2016), notably among local agricultural elites (Londres *et al.*, 2021). However, these factors alone do not explain success if detached from the broader historical and current context within which municipalities are embedded.

Particular colonization and development pathways have defined conditions equipping municipalities with specific capacities to sustain individual and collective responses to crises engendered by external forces such as the LPM policy (Chaffin & Gunderson, 2016). On the one hand, on the fringes of the frontier, the diversity of agents faces the challenge of devising novel development strategies according to sustainable paradigms while buffering an aggressive frontier that moves prompted by external forces of commodity markets and contradictory national development goals and incentives. On the other hand, in older and consolidated areas of the frontier, stakeholders and agricultural elites

face the task of adapting long-established production strategies to new external demands but, in many cases, under more favorable conditions. These contrasting circumstances endow municipalities with very distinct capacities to respond to the one-size-fits-all type of policies.

Paragominas and Tailândia illustrate how these changes unfold locally as the frontier expands. Both municipalities were emancipated in Northeastern Pará between the 1960s and 1980s and followed development trajectories associated with a national plan for regional integration. Despite the early similarities in their development, Paragominas had already experienced the boom-and-bust cycles related to the frontier expansion in the 1990s, which opened up opportunities for political coordination, social organization, and economic diversification before local stakeholders faced the LPM policy in 2008. These conditions allowed Paragominas to devise and develop the emblematic response to the LPM policy.

Contrastingly, Tailândia still relied upon a predatory economic model characteristic of active resource frontiers (Kröger & Nygren, 2020), marked by a high degree of illegal activities, land grabbing and conflicts, informal jobs revolving around logging, charcoal production, and extensive ranching. Despite the substantial economic impacts resulting from the set of sanctions imposed by the LPM policy in both municipalities, existing conditions provided local stakeholders with contrasting windows of opportunities to react and respond in a critical moment. Stakeholders in Paragominas perceived an opportunity to rebrand its image from an unregulated and violent frontier to a consolidated, sustainable-oriented municipality, besides negotiating the decentralization of environmental licensing from the state to the municipal sphere. In Tailândia, fearing the imminent economic collapse of the city, stakeholders' response was limited to compliance with the LPM policy as a path towards recovering and diversifying the local economy. That, however, has not revolved around rebranding the municipal image as it did in Paragominas, nor has it resulted in the empowerment of local organizations or the consolidation of partnerships with external organizations.

Besides the historical conditions shaping context-specific responses, looking at the year in which a municipality was listed complements understanding the degree of sanctions and the incentives at stake for local stakeholders. All the 22 municipalities removed from the LPM were listed by 2011, of which 16 in 2008. In this short period, a suite of initiatives and regulations – decisive command-and-control actions, stricter credit and land regularization rules, inter-institutional collaboration, market-oriented initiatives – synergistically impacted listed municipalities, significantly damaging their image and economies.

In that context, immediate reactions involved multiple stakeholders and ranged from violent outcries to proactive initiatives to address a new collective dilemma. On the one hand, a coordinated political movement pushed for a gradual flexibilization of sanctions, restrictions, and law enforcement, bargaining for greater autonomy for the local environmental governance (Bergamin, 2015). On the other hand, significant learning and sharing of experiences cumulated, thus supporting the implementation of new government programs and regulations and the emergence of funding opportunities and projects supporting local initiatives (Fig. 5). Together, this set of circumstances has progressively changed the scope of the LPM policy over the years, departing from the strict sanctioning to the institutional support for law compliance by listed municipalities. However, amidst the erosion of environmental governance in Brazil, the inter-ministerial collaboration supporting coordinated command-and-control actions and law enforcement was disrupted, undermining the cornerstones that had promoted the promising outcomes of the LPM policy in its earlier stages. Consequently, the MMA has not disclosed the LPM in 2014–2016 and 2019, and its future remains uncertain.

5.3. Looking back and ahead: embracing diversity and complexity in tackling deforestation in the Amazon

Historical processes of development and colonization that have forged diverse municipalities in the Amazon have created challenges and opened-up opportunities upon which environmental policies to halt deforestation operate. Our findings confirm that region-wide policies effectively control deforestation when followed by effective monitoring and enforcement actions (Arima et al., 2014; Assunção and Rocha, 2019; Nepstad et al., 2014). The strict implementation of the LPM in its early years represented a referential landmark that leveraged parallel initiatives to control deforestation and improve land tenure regulation. The coordination and synergy among various initiatives and policy instruments were fundamental in triggering the emergence of bottom-up strategies and the cooperation among stakeholders seeking solutions to control deforestation and geocode landholdings at the sub-national level (Viana et al., 2016, 2012). However, we also show that initiatives effective in particular settings – such as the Green Municipal Pact in Paragominas – achieve limited outcomes when scaled up and replicated as a blueprint across different municipalities.

Our integrated analytical approach to examine the LPM policy outcomes at both regional and municipal levels has highlighted general and context-specific factors influencing municipal responses to the policy. We call attention to four key lessons regarding controlling deforestation at the municipal level that we believe are broadly relevant to municipalities across the Brazilian Amazon. *First, law enforcement is critical.* The government's ability to effectively enforce the law and sanction rule-breakers was critical in triggering local agents' responses to the LPM policy. The focus on critical municipalities – rather than on the entire region or individual agents – narrowed the policy scope, facilitating and strengthening monitoring and policing actions. *Second, establishing clear but revisable criteria and rules.* Facing the challenge of tackling deforestation across diverse and complex municipal contexts, policy instruments require clear criteria and flexibility to remain relevant over time in a region in rapid transformation (DeCaro et al., 2017). The MMA has adopted more transparent criteria to list municipalities over time, besides adjusting these criteria to capture changes in regional deforestation trends. However, the MMA has ignored requests to review the LPM's rigid removal criteria by officials, organizations, and stakeholders working in the frontline of municipal initiatives. The dialogue among diverse actors involved in conflict-resolution and rule-crafting, although not a panacea, represents a fundamental principle underlying the design of long-term and successful institutions that could encourage and favor compliance with the LPM policy (Ostrom, 1990).

The threshold of 40 sq.km of yearly deforestation has been unattainable for the most extensive forested municipalities on the fringes of the biome, as discussed by Thaler et al. (2019) regarding São Félix do Xingu. Adopting a removal target considering reducing deforestation rates relative to a given baseline would set a fairer goal. One alternative, for instance, would be requiring listed municipalities to reduce yearly deforestation rates by 80% relative to the five previous years before the listing and to eliminate illegal deforestation. That aligns with and contributes to the national voluntary goal with which Brazil had committed by 2020¹⁷. In the 2008–2018 period, 45 municipalities would have reached the alternative compliance target. This exercise shows that, despite facing different pressures and contrasting realities to tackle forest loss along a moving frontier, local stakeholders and landown-

¹⁷ Decreto Federal 7.390/2010.

ers have also made a significant effort to control deforestation in parts of the region.

Third, inter-governmental and inter-institutional cooperation are fundamental. The collaboration among government agencies and organizations enables additional policy measures to align, which leverages the incentives already in place for local agents and municipalities to react. Such inter-institutional cooperation creates a chain of enacted rules, norms, and sanctions affecting multiple agents and tackling various forces underlying deforestation in different spatial scales and commodities' supply chains. *Fourth, recognize bottom-up initiatives and responses.* The final lesson we draw from this study relates to the importance of government support to institutional arrangements devised by local agents on the ground. Recognizing initiatives emerging from the bottom-up tailored to context-specific conditions allows the distribution of power across multiple decision-making centers that can design solutions to the appropriate scale. The consolidation of such polycentric governance systems can support more effective problem-solving for complex collective tasks (Cole, 2015), such as controlling deforestation and the geocode of municipal territories across contested frontiers in rapid transformation.

As the deforestation frontier advances and the Brazilian Amazon changes, so do local agents settled in the region, whether indigenous groups and traditional communities, colonists, ranchers, farmers, companies, gold miners, and local governments. Within this diverse social landscape, conflicting economic and political interests intermingle amidst alternative ideas and worldviews from agents mediating processes at various scales. While the deforestation frontier continues to expand destructively in the hands of legal and illegal actors, now empowered by the federal government, a new generation of local groups has gradually advocated for sustainability, devising pioneering models and pointing out alternative development pathways that reconcile socioeconomic progress and environmental conservation for the region (Brondizio et al., 2021). Therefore, identifying local initiatives and supporting institutional arrangements that empower stakeholders to craft strategies and development models tailored to context-specific realities become fundamental in designing and implementing any program and policy instrument for the region.

5.4. A note on limitations and future directions

Our regional analysis depicted but a snapshot of the intra-regional diversity of municipalities in the region around 2008 when the LPM policy was implemented. As we stressed, the Amazon region and its moving deforestation frontier continue to be highly dynamic and experiencing rapid transformation. Alternative clusters and typologies to represent the diversity of municipalities in the Amazon would emerge depending on the list of indicators and timeframe considered. Our case studies of four municipalities in the state of Pará allowed us to control for state-level factors mediating local responses. However, it is important to note that other states in the Brazilian Amazon have devised and implemented analogous programs to support their municipalities in developing sustainability-oriented agendas, such as Mato Grosso and Rondônia¹⁸. Comparative case studies in other Amazonian states would deepen our understanding of the role of state-level initiatives and the importance of coordination across governance levels towards leveraging positive responses on the ground. Finally, we hope this study will encourage further comparative case studies, such as among municipalities experiencing different phases of the frontier expansion process, thus subjected to diverse drivers of land

use and cover change and different levels of environmental policy enforcement. As the Brazilian Amazon continues a trajectory of rapid transformation, halting forest loss and fostering sustainable development will increasingly depend on aligning national environmental and development goals with the diverse conditions and capacities of municipalities to implement them.

CRediT authorship contribution statement

Paulo Eduardo dos Santos Massoca: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Funding acquisition. **Eduardo Sonnewend Brondizio:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The Ostrom Workshop, the Center for Latin-American and Caribbean Studies (CLACS), and the Office of Sustainability at Indiana University Bloomington provided research grants for fieldwork carried out by the first author. PM was funded by the Brazilian Science without Borders program (ScF/CNPq 234533/2014-5) and the Ostrom Workshop Fellowship. The authors thank colleagues of the Ostrom Workshop and the Center for the Analysis of Social-Ecological Landscapes (CASEL) at Indiana University Bloomington for their helpful comments and suggestions on the manuscript. The authors are also thankful to colleagues and local organizations in Pará for institutional support during fieldwork. We are immensely grateful to the farmers, government officials, local leaders and representatives, researchers, and individuals from various sectors and organizations who gave their attention, time, and commitment to advance this research. We are also thankful for the support of the Sustainable Food Systems Science project, which is part of Indiana University's Emerging Areas of Research program. This study was approved by the Indiana University Institutional Review Board (IRB) for Research Involving Human Subjects (Study #1604611588). The authors thank the suggestions and critical comments received from three anonymous reviewers in earlier versions of the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.worlddev.2022.106004>.

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¹⁸ In Mato Grosso, the Sustainable Municipalities Program was implemented in 2014, and Rondônia implemented the State Program for Decentralization of Environmental Management Actions in 2011.

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