Forest policy diagnostics for Brazil

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The present report builds on the analytical framework introduced in the deforestation archetypes paper (de Sy et al. 2026). It applies this framework to examine national deforestation policies in Brazil in relation to identified archetypes. In parallel, similar analyses have been conducted for the Democratic Republic of the Congo (DRC), Indonesia, and Peru. Together, these country studies and the archetypes paper form the foundation of the deforestation diagnostic framework.

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The assessments and views expressed in this report are those of the authors alone.

Summary

This report applies a deforestation diagnostics approach to identify which forest policies are most likely to work, where, and why. The diagnostics framework links policy effectiveness to forest context and behavioural mechanisms, recognizing that policies achieve results by acting on behavioural responses—such as sensitivity to incentives, enforcement credibility, and motivational drivers—which ultimately determine land-use decisions. Developed under CIFOR's Global Comparative Study on REDD+, the approach combines three complementary components. First, it develops a spatial 'deforestation archetype' analysis that classifies Brazil's forest landscapes according to forest cover, degradation, deforestation severity, and hotspot dynamics. Second, it constructs a typology of forest policies based on a behavioural theory of change, which categorizes policies according to the actors they target, the mechanisms they activate (material incentives, compliance and enforcement, social belongingness, or competence/self-efficacy), and the forest threats they address. Third, it links archetypes and policy types to assess the effectiveness of these policies in each circumstance. It integrates these three levels of analysis to provide a contextualized alternative to one-size-fits-all solutions to forest policy design while also avoiding a purely case-by-case analysis, thereby improving policy design supposed to target the right levers, enhance comparability, and achieve strategic learning within and across countries.

Applied to the Legal Brazilian Amazon (LAM) region as defined in Brazil, the archetype analysis identifies seven forest archetypes, including intact forest areas, stable forest mosaics, stabilized transition areas, chronic deforestation areas, accelerating deforestation areas, gradual deforestation areas and fragmented forest remnants. Brazil's annual deforestation rate peaked at close to 0.8% of forest area in the mid-2000s, declined to around 0.1–0.2% by 2012 following implementation of PPCDAm, rose again to roughly 0.3% during 2019–2021, and has again declined since 2023. Approximately 20% of the original forest cover have been lost, with deforestation concentrated in chronic and accelerating deforestation archetypes, particularly across the states of Pará, Mato Grosso and Rondônia. Pasture expansion remains the dominant proximate driver, followed by soy cultivation and infrastructure-induced land speculation.

Brazil has implemented one of the most comprehensive and multi-layered anti-deforestation policy mixes globally. Key instruments include command-and-control measures (Forest Code enforcement, DETER satellite monitoring, Rural Environmental Registry, protected areas), supply-chain agreements (Soy Moratorium, Cattle Agreements), credit restrictions in high-deforestation municipalities, land tenure clarification programmes (Terra Legal), decentralization initiatives, and jurisdictional REDD+ schemes. Evidence indicates that enforcement and monitoring were central to the sharp decline in deforestation after 2004, particularly when linked to credit constraints and market exclusion. However, enforcement effectiveness depends on institutional capacity and political commitment; periods of weakened oversight correspond with rising deforestation.

Findings show that policy performance varies significantly depending on local conditions. Enforcement-based policies have been effective in curbing large-scale illegal deforestation in frontier areas when combined with satellite monitoring and credit restrictions. In intact forest and stable mosaic archetypes, tenure security, Indigenous territories and protected areas have proven more robust than reactive enforcement. Incentive and competence-oriented programmes—such as community forestry and environmental service payments—show positive but context-dependent impacts, often constrained by limited reach, funding gaps and institutional challenges. . The concentration of deforestation among a small number of landholders also points to the need for more targeted enforcement and tenure reform.

The diagnostics highlight that Brazil's success has relied not on single instruments but on synergistic policy packages linking monitoring transparency, credible sanctions and economic conditionalities. Sustaining these gains will require continued alignment between policy instruments and the specific risk profiles shown by the different archetypes within the Legal Amazon.

1 Introduction

Maximizing the impact of current and future deforestation-reduction initiatives requires leveraging prior evidence on how similar policies have performed in comparable contexts. This offers practitioners and policymakers a critical advantage in designing more effective strategies. For this reason, it felt imperative to develop and operationalize an approach to deforestation diagnostics that addressed the question: which policies and measures are likely to work where, and why? This diagnostics approach can help to identify the most robust policy interventions, based on previous lessons from policy experiences in comparable contexts. The approach offers a pragmatic middle ground, avoiding the pitfalls of one-size-fits-all solutions while improving scalability when compared to purely case-by-case interventions.

The deforestation diagnostics approach consists of three main stages (Angelsen 2022; Chervier 2022). First, a set of stylized forest contexts or **archetypes** is identified for the country, based on a set of diagnostic variables. These diagnostic variables describe the critical elements of the deforestation context that are most likely to affect policy impacts and outcomes. Second, **policies and measures** that are relevant for addressing deforestation (or forest management and land cover change more generally) must be identified. Finally, the question of 'what is likely to work where?' can be addressed by examining available evidence around **context-dependent policy impact**.

This deforestation diagnostic approach is both a decision-making and research tool. For decision makers, the approach can identify the contexts in which different conservation measures are being implemented, as well as the most appropriate measures and public policies for each context. For researchers, the approach can help identify factors critical to understanding individual cases and place them within broader tropical forest contexts. For civil society, the archetypes can increase information and transparency about the different processes and dynamics of deforestation at the national level, including deforestation risks.

The current report presents progress on the deforestation diagnostic approach as applied to the Legal Brazilian Amazon (LAM). The LAM encompasses the Amazon Basin and surrounding Cerrado (savannah), including the total territory of eight states (Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins) and part of Maranhão, covering 5 million km^2, or 60% of Brazil's national territory (IBGE 2024). As of 2022, the region was home to 27.8 million people, representing 13.7% of the Brazilian population (IBGE 2024). Over the past 50 years, the LAM has grown into Brazil's largest livestock region and third-largest grain-producing area (Haddad et al. 2024), despite contributing only 10.2% to the national gross income (Amazônia Legal em Dados 2024). Approximately 20% of original forest cover in the Brazilian Amazon has already been lost (Santos et al. 2021), not accounting for the extensive areas degraded by fires and logging, pushing the region closer to a 'tipping point' that could trigger large-scale ecosystem collapse (Flores et al. 2024; Lovejoy and Nobre 2018).

Deforestation in the LAM is driven by a complex interplay of direct and indirect factors operating at local, national and global scales (Berenguer et al. 2021; Margulis 2003). The primary proximate driver is agricultural expansion, particularly cattle ranching (Hänggli et al. 2023). Other direct drivers include infrastructure development, urbanization, mining, logging, fires and natural causes (Hänggli et al. 2023). These drivers are often interconnected. For example, the construction of major roads and other government infrastructure projects in the Brazilian Amazon, beginning in the 1970s (including mining, settlement and energy projects), led to an influx of migrants, resulting in unplanned urban centres, land grabbing and diverse social and land-use transformations (Becker 2005). Deforestation in the LAM is also closely related to international and domestic demand for agricultural products (Haddad al. 2024).

As an attempt to address the complexity and heterogeneity of deforestation contexts and drivers in the LAM, a diversity of policies has been applied across different scales in the last two decades. As a result, LAM provides substantial evidence for applying the deforestation diagnostic approach. The report is organized as follows: Section 2, Archetypes: Defining the deforestation context presents a methodological approach for defining archetypes, together with the archetype maps generated for the Legal Brazilian Amazon. Section 3, Typology for forest policies and measures, outlines the theory of change for forest policies and describes the three key attributes used to classify these policies. In Section 4, Gathering the evidence, we provide an overview of the policy context in the Brazilian Amazon and present a sample of policies, classified according to policy type and forest archetypes. Finally, in Section 5, Discussion and recommendations, we discuss how Brazilian policies are differentiated and targeted towards various forest archetypes, assess the usefulness of the diagnostic tool in the LAM context, and propose ways to improve it.

2 Archetypes: Defining the deforestation context

2.1 Overview of the archetype approach

To understand the contexts in which deforestation is occurring, we use archetype analysis. Archetype analysis is a methodological approach that identifies repeated, generalizable patterns of a specific phenomenon (Eisenack et al. 2021; Oberlack et al. 2019); this approach has recently been applied to studying deforestation patterns (Baumann et al. 2022; Buchadas et al. 2022). Archetype analysis classifies regions and landscapes into different categories (archetypes) according to a set of attributes, which we call the diagnostic variables. Each 'case' (i.e., geographical area) is assigned an archetype, which represents that particular type of landscape. An archetype is therefore a group of geographical areas which share a set of key attributes, or diagnostics variables.

We built the archetypes using a nested approach (Figure 1). A nested approach allows us to introduce regional complexity step-by-step: a first set of variables (i.e., building block) defines a small number of broad categories, the next set of variables further splits these into subcategories, and a final set of variables gives a more detailed set of archetypes. Based on literature reviews and experimenting with several global, spatial datasets, we propose a two-level nested approach (Figure 1). The first level identifies archetypes based on three 'typologies' that are built using data on deforestation trends, forest cover and forest degradation. This is explained in Section 2.2. The second level defines 'nested archetypes' by incorporating metrics that describe drivers of deforestation as well as deforestation risks, and is explained in Section 2.3.

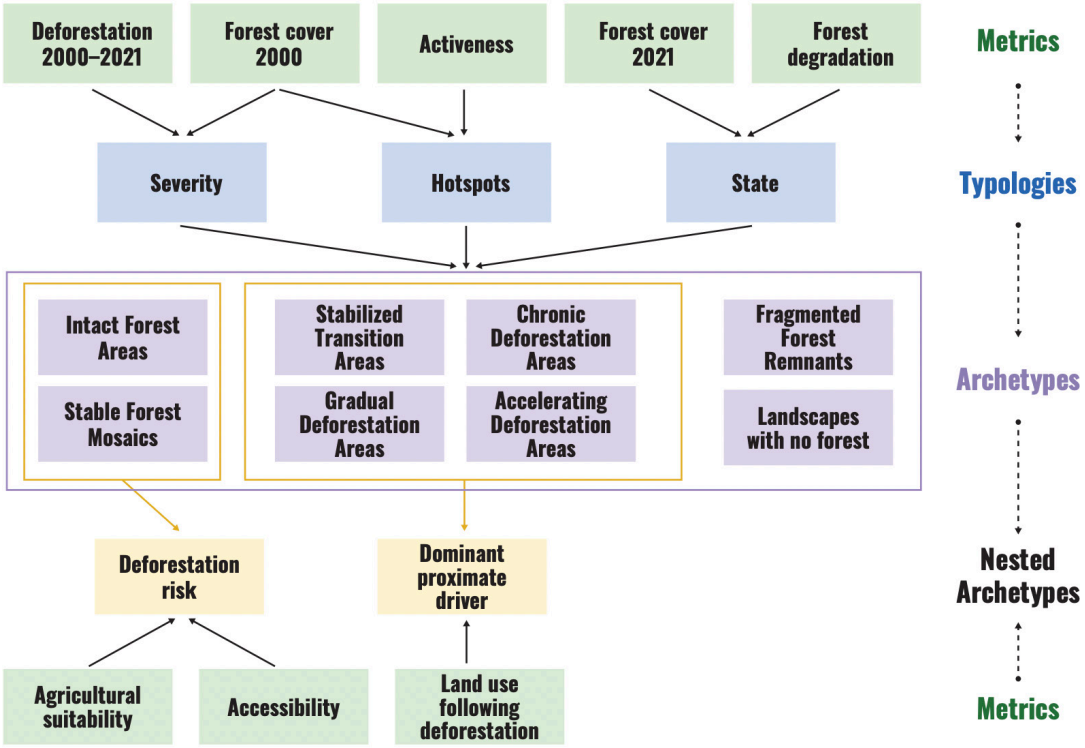

Figure 1. Conceptual framework used to build the archetypes and nested archetypes

2.2 Archetypes of deforestation

To build the archetypes we use the data from the Tropical Moist Forest dataset (Vancutsem et al. 2021). The unit of analysis is a 'landscape', defined as a 5x5 km pixel. We selected the TMF dataset because, in addition to information on forest cover and deforestation, it also provides detailed information on forest degradation and post-deforestation recovery. This dataset characterises forest state from the initial observation period (2000) until the end of 2021. We describe the landscape according to three main characteristics or 'typologies': (i) current forest state; (ii) severity of deforestation; and (iii) whether the landscape is a deforestation hotspot.

'Current forest state' describes the state of the forest in the 5x5 km landscape based on two metrics: forest cover in 2021 (as a percentage of land) and forest degradation in 2021 (as a percentage of forest). For instance, 56% of LAM has landscapes with high forest cover with low levels of degradation, and 17% has low forest cover and high forest degradation (Figure 2).

'Severity of deforestation' (Figure 3) describes the landscapes according to the extent of total forest cover lost since 2000, and is built using two metrics – the forest cover in 2000 (as a percentage of land) and gross forest cover lost in 2000 to 2021 (as a percentage of land). The map shows that most of the areas that had high forest cover in 2000 have had low deforestation rates in the last two decades (35% of national territory).

'Deforestation hotspots' (Figure 4) highlights which landscapes have average annual deforestation rates above 1%, and which are below that threshold. We also describe the hotspots considering changes over time, for example whether this high deforestation rate (above 1%) is before 2015, after 2015, or high throughout the entire period. The analysis shows that the areas with the highest forest cover loss between 2000 and 2021 are in the central, eastern and northern parts of Brazil. Most deforestation hotspots have had consistently high deforestation rates over the years, in the sense that they have maintained deforestation rates above 1% before and after 2015.

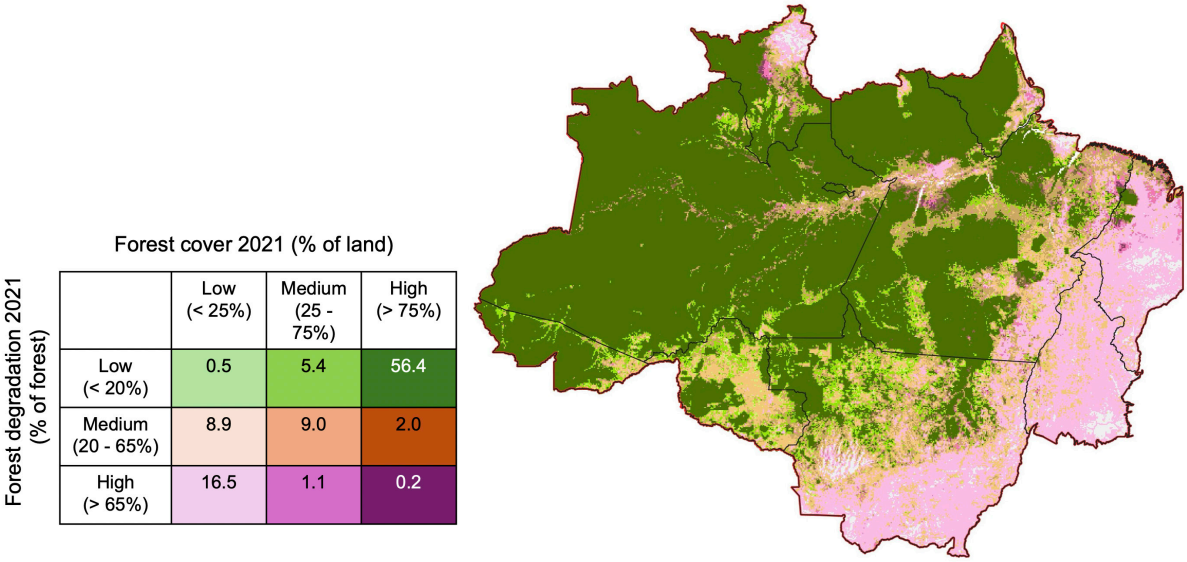

Figure 2. The current state of the Brazilian Amazon, considering forest cover and forest degradation in 2021

Forest cover 2000 (% of land)

Total forest loss (% of land) 2000- 2021	Low (< 25%)	Medium (25 - 75%)	High (> 75%)
Low (< 5%)	16.2	2.5	53.0
Medium (5 - 20%)	3.9	5.3	6.5
High (>20%)	0.1	5.2	7.5

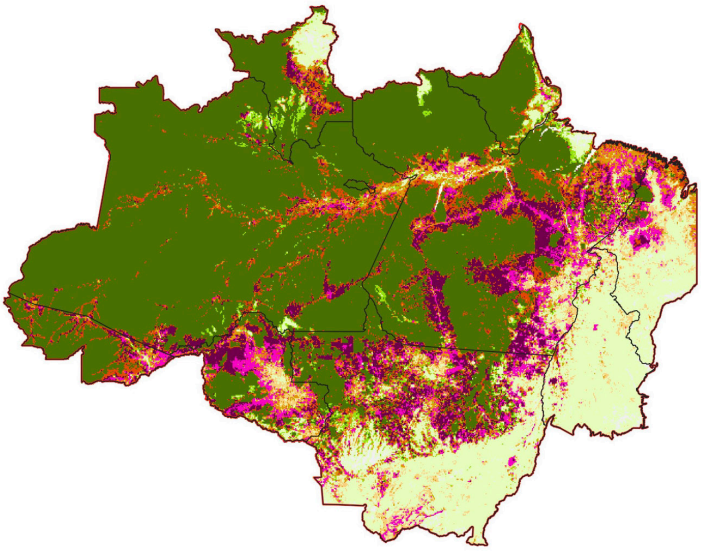

Figure 3. Severity of deforestation in the Brazilian Amazon, based on forest cover in 2000 and total forest loss between 2000 and 2021

Forest cover 2000 (% of land)

Average annual deforestation rate	Low (<25%)	Medium (25% to 75%)	High (>75%)
Gradual (<1%)	17.1	3.3	54.3
Stabilized transition (>1% before 2015)	2.2	5.5	3.9
Chronic (>1% before and after 2015)	0.4	3.7	7.2
Accelerating (>1% after 2015)	0.4	0.5	1.5

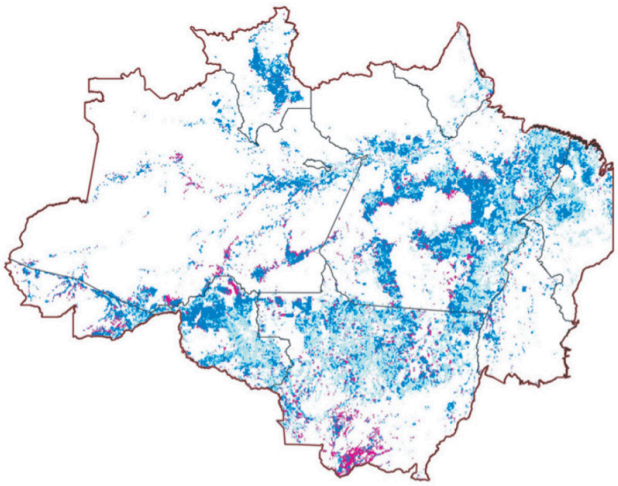

Figure 4. Deforestation areas with higher than 1% average annual deforestation (Hotspots)

Archetype	Percentage
Intact Forest Areas	52.5
Stable Forest Mosaics	2.5
Stabilized Transition Areas	11.6
Chronic Deforestation Areas	11.1
Accelerating Deforestation Areas	2.4
Gradual Deforestation Areas	3.7
Fragmented Forest Remnants	16.1

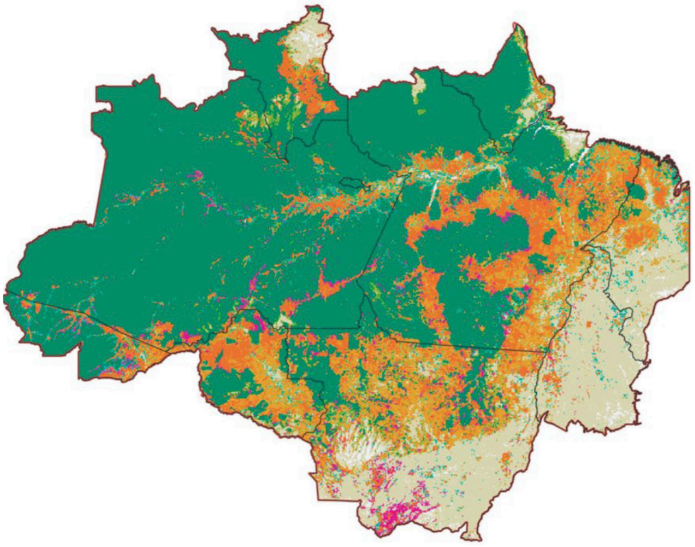

Figure 5. Archetypes of deforestation in the Brazilian Amazon

Qualitative evaluation of the state, severity and hotspot typologies resulted in seven archetypes (Figure 5), with an eighth category of non-forest land that is no proper forest or deforestation archetype. We first defined two archetypes where deforestation has been historically low: 'intact forest areas' and 'stable forest mosaics'. These two archetypes share low overall deforestation during 2000–2021, with intact forest areas having lower forest degradation. These two archetypes therefore consist of landscapes with relatively undisturbed forest.

We then distinguished four archetypes under the label 'deforestation areas'. These landscapes describe areas where deforestation during 2000–2021 has been high or medium, or where the deforestation rate is higher than 1%, and therefore classified as hotspots. We also describe them considering how they have changed over time – 'stabilized transition areas' (i.e., old deforestation areas) are those with deforestation rates higher than 1% only before 2015, while 'chronic deforestation areas' have deforestation rates higher than 1% both before and after 2015, and 'accelerating deforestation areas' are those with deforestation rates higher than 1% only after 2015. 'Gradual deforestation areas' are those that have at least lost 20% of their forest cover since 2000, but where average annual deforestation rates have not been higher than 1% on average. The LAM states with the highest proportion of deforestation areas are Pará, Mato Grosso and Rondônia (Figure 5).

The last two archetypes are 'fragmented forest remnants' and 'landscapes with no forest'. Their main characteristic is having lower than 25% of forest cover in 2000 and 2021, and therefore having lower deforestation in the last two decades and lower deforestation rates. Most of the land below the Amazon region is covered by fragmented forest remnants. In the case of Brazil there are no landscapes with no forest.

Historically, since the large-scale Amazon colonization led by the government starting in the 1970s, deforestation has been concentrated in the 'arc of deforestation', a region along the southern edge of the Amazon basin. The arc has been developed alongside roadway construction, mainly Belem- Brasilia (BR-153) and Cuiaba-Porto Velho (BR-364); land reform projects (Moran 1981; Smith 1982); widespread land grabbing (Fearnside 2005); large-scale agricultural activities like cattle ranching; and starting in the 1990s, soy monocropping (Barona et al. 2010; Brown et al. 2004; Macedo et al. 2012) . The arc region extends from western Maranhão and southern Pará towards the west, passing through Mato Grosso, Rondônia and Acre (Figure 5), encompassing 256 municipalities in which 75% of deforestation in LAM was concentrated in 2019 (Oviedo et al. 2019). However, over the last decade this 'arc of deforestation' has been advancing deeper into the Amazon, extending towards southwest of Pará, west of Acre and

south of Amazonas, especially along federal highways that cross these states, like the BR-163, BR-319, and BR-364 (Brasil 2023; Oviedo et al. 2019).

According to the latest version of the National Plan for Deforestation Control in the Amazon (PPCDAm) (Brasil 2023), the expansion of deforestation deeper into the Amazon can be attributed to three main factors: the indirect impact of large infrastructure projects, the consolidation of the agricultural frontier in Mato Grosso, and the anticipation of profit through the invasion of public lands. The paving of the BR-163 highway starting in 2017, for example, has redirected deforestation from northern Mato Grosso to southern Pará. Meanwhile, population migration and rising land values, linked to the construction of the Belo Monte hydroelectric plant in Pará, have contributed to increased deforestation in the Altamira and BR-230 area. A similar pattern is seen along the BR-319 highway corridor between Porto Velho and Manaus, where plans for road reconstruction have spurred deforestation in southern Amazonas (Brasil 2023).

In Figure 5, we can observe large patches of recent deforestation in the southern part of Amazonas along BR-319. This road was built in the 1970s, but became impassable in 1988 (Fearnside and Graça 2006). The reconstruction of the road is expected to shift deforestation from the arc of deforestation in Rondônia to the interior of the forest (Fearnside and Graça 2006). Several NGOs and researchers have warned about the socioenvironmental impacts of paving the highway, highlighting the spontaneous construction of secondary roads, accompanied by deforestation, illegal logging, invasion of Indigenous lands and land grabbing (Ferrante 2020; Ferrante et al. 2021a, 2021b). In fact, many of these impacts are already occurring and in 2022 the Ministry of Public Accounts of Amazonas called for action regarding the alarming number of side roads along BR-319 (A Crítica 2022).

Another deforestation hotspot connected with BR-319 is the border region between the states of Amazonas, Acre and Rondônia, which form a recent agrobusiness frontier known as AMACRO (Figure 5). This region has been experiencing significant expansion of deforestation, cattle ranching and crops in the last decade, as well as land grabbing and speculation, land conflicts and violence (Chaves et al. 2024; Craveira and da Silva 2024). In 2022, the municipality of Apuí in Amazonas, which is part of this deforestation area, recorded the highest deforestation rate of the Amazon biome, with 586 km² of forest loss (Imazon 2023).

The state of Roraima has also emerged as a new deforestation area, with high annual deforestation rates. In contrast to national climate goals for reducing deforestation, in 2022 the state enacted legislation lowering the area of private properties that were to be legally protected (legal reserves) from 80% to 50%, increasing pressure on forested areas (Lopes and Minsky 2023).

2.3 Nested archetypes

The second level of the archetype analysis provides more detail on the deforestation areas, intact forest areas and stable forest mosaics, through nested archetypes (see Figure 1). For deforestation areas, we considered what the direct drivers of deforestation are (Figure 6). We included the following land uses/covers: tree plantations, forest regrowth, water, cropland, grassland, urban and shrubland (see Annex Table 4 for a description of each category). The most important land use following deforestation is grassland, related to pastures (Figure 6).

According to a systematic analysis of deforestation drivers and policy effectiveness across the Amazon, pasture expansion was the primary proximate cause of deforestation in the Brazilian Amazon from 2000 to 2021 (Hänggli 2023). In 1985, pasture areas covered 13.7 million hectares in the Amazon, expanding to 57.7 million hectares by 2022. This growth made the Amazon the biome with the largest pasture area, followed by the Cerrado with 51.3 million hectares (Mapbiomas 2023). Commodity crops, mainly soy, are the second leading cause of deforestation (Hänggli 2023), concentrated primarily in the southern part of the region, as shown in the map (Figure 6).

Land use/cover	Percentage
Tree plantation	0.3 %
Cropland	6.9 %
Pasture	63.9 %
Urban / built up	0.1 %
Forest regrowth	10.7 %
Grass- & shrubland	16.7 %
Bare soil	0.1 %
Water	1.1 %

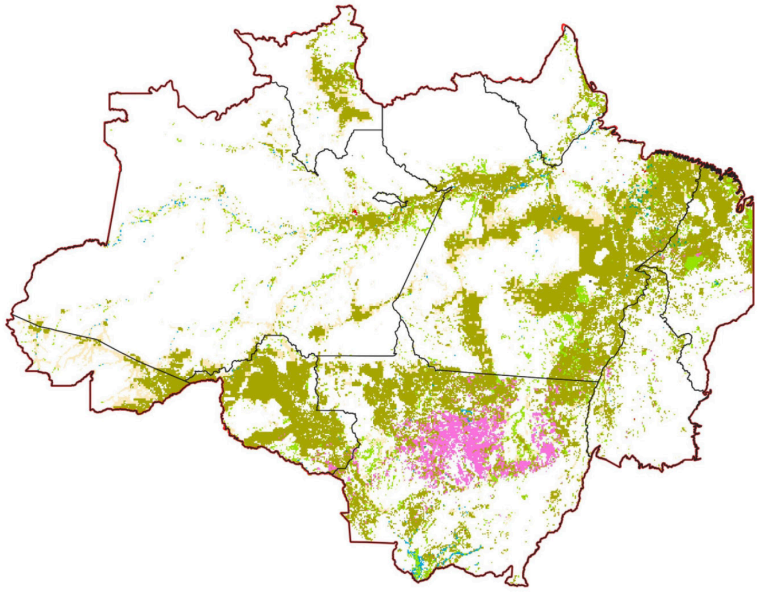

Figure 6. Land use following deforestation, considering only deforestation areas (see Figure 5).

A key underlying driver of deforestation in the Legal Amazon (LAM) is illegal land grabbing, initiated through forest clearing. This illicit activity typically occurs on public lands owned by the government but not yet designated for a specific use, and is frequently followed by the establishment of low-productivity cattle ranching with the expectation that the land will be legalized in the future (Azevedo-Ramos et al. 2020). A recent study found that over the past two decades, half of the deforestation in the LAM occurred on public lands due to land grabbing, especially in undesignated areas (Moutinho et al. 2023).

Importantly, deforestation in the LAM is unevenly distributed among landholders. One study revealed that in 2021, 1% of properties were responsible for 82.5% of deforestation (Camara et al. 2023). Similarly, Rajão et al. (2020) found that 2% of properties in the Amazon and Cerrado accounted for 62% of all potentially illegal deforestation, highlighting the concentrated nature of deforestation in the region.

To further describe intact forest areas and stable forest mosaics, we used variables relating to accessibility to urban areas and agricultural potential; this helped to describe the risk of agricultural-driven deforestation (Figure 7). Accessibility is defined by travel time to cities (Weiss et al. 2018) – travel time required to reach the nearest urban centre, defined as a contiguous area with 1,500 or more inhabitants per km^2 or a majority of built-up land cover coincident with a population centre of at least 50,000 inhabitants.

Agricultural potential represents the agroclimatic potential for low input, rainfed agriculture of main commodity crops (wheat, soy, maize, rice, cassava, banana, cocoa, coffee, tea, sugarcane and oil palm), based on data available in the tropics during 1961–1990. The potential is summed and standardized across crops.

	Agricultural suitability		
Accessibility	Low suitability	Medium suitability	High suitability
Low access	35.9	38.7	7.5
Medium access	6.1	5.6	3.1
High access	1.2	1.1	0.8

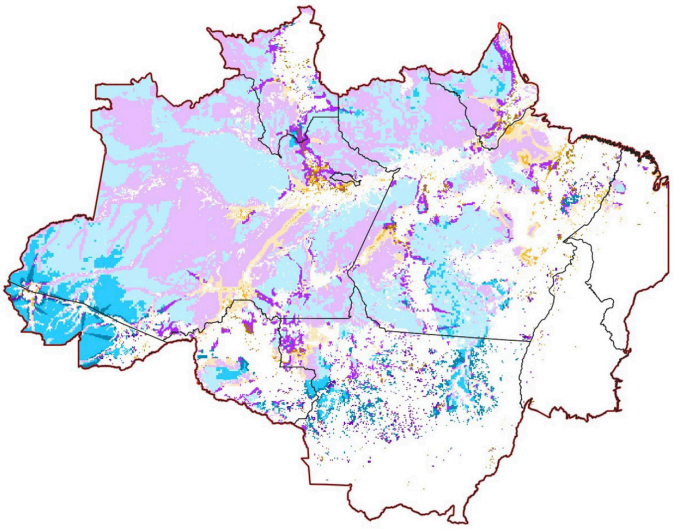

Figure 7. Risk of agricultural expansion in intact forest areas and stable forest mosaics considering accessibility and agricultural suitability

According to Figure 7 the areas of highest risk of agricultural expansion, considering accessibility and agricultural suitability, are concentrated around the city of Manaus in Amazonas, in Amapá along the BR-156, in Pará along BR-163 and BR-230, patches in Roraima, northwest of Mato Grosso and on the Acre, Amazonas and Rondônia border. The border area of these three last states is where the AMACRO frontier is being established.

3 Typology for forest policies and measures

3.1 Forest policy theory of change

In their attempts to curb deforestation, decision makers have depended on a heterogeneous set of policies and tools. Yet tropical deforestation continues, and has even increased in certain areas (Vancutsem et al. 2021). One possible explanation is that such policies and measures are not being implemented in ways and contexts in which they are likely to be most effective.

The second part of this diagnostics approach is to establish a typology of forest policies, with the view to advance our understanding of which policy works in which context. A policy typology is a classification system that groups deforestation policies according to how similar or different they are. Establishing this policy typology is vital due to the diversity of policies available, and how limited the evidence is around the impact of each specific policy or tool. Our underlying theory of change (ToC) is that by identifying commonalities in forest policies and measures, we can make assumptions about common contexts of effectiveness.

To build the forest policy typology, we conducted a literature review and examined policy documents in Brazil, Indonesia, Peru and the DRC. We identified a total of 35 policies and measures relevant to reducing deforestation (see Annex Table 5 for the list of policies and their definitions). We define a forest policy as any policy, programme or action aimed at changing or significantly affecting the behaviour of forest-related actors, thereby directly or indirectly contributing to avoiding deforestation (Chervier et al. 2022). With this definition, policies and measures like agricultural policies, rural development policies and infrastructure development (roads) can be included in the analysis, to the extent they are implemented in forested landscapes and therefore influence the behaviours of forest dwellers.

We built a generic theory of change to describe the general causal pathway in which the policies generate impact, following the primary steps identified in the theory-based literature (Börner et al. 2020; Niel et al. 2019; Weiss 1997; White 2009). This ToC differs from other ToCs for forest policies and measures seen in the literature, as it puts emphasis on what behavioural motivations are catalysed following policies and measures being implemented (Figure 8).

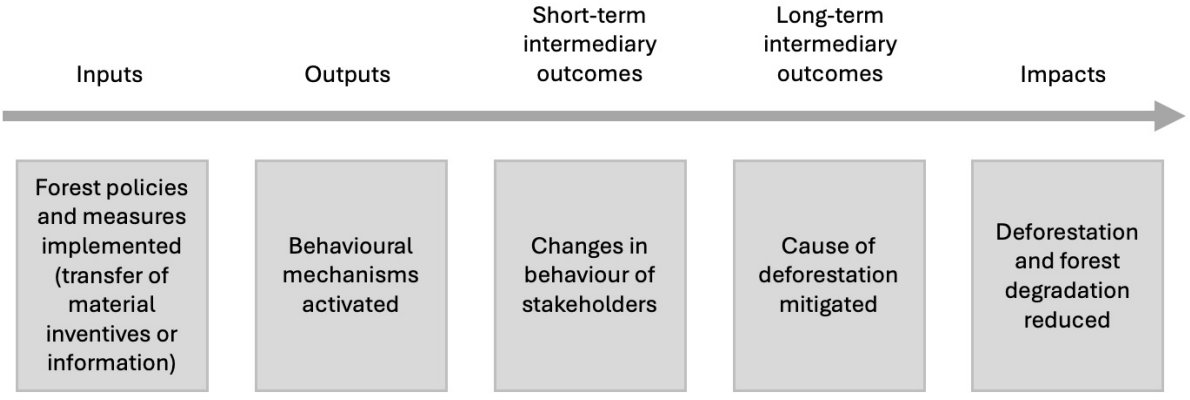

Figure 8. Generic theory of change for forest policies considered in deforestation diagnostics.
Source: Chervier et al. (2022)

Based on our ToC, we focus on describing policies according to three traits of forest policies and measures that characterize the three primary steps of our generic theory of change: (i) the stakeholders, (ii) the behavioural mechanisms[1] activated by policies, and (iii) the forest threat intentionally or unintentionally addressed by the policy. These three attributes are used to build the policy typology.

3.2 Actors targeted by forest policies

Five main categories of actors are identified for the forest policy typology. The first is *producers* – these are those land/forest owners and users involved in forest-friendly, or forest-risk, products and commodities. We distinguish between small-scale subsistence-oriented landholders, medium/large scale landholders, and companies with concessions. This distinction is necessary because the behavioural and economic responses of these actors are likely to be significantly different (Angelsen 1999; Pfaff et al. 2013).

The second category of actors includes the *stakeholders involved in the value chains* of forest-risk or forest-friendly commodities and products, who are not producers or consumers. These supply chain actors are the input suppliers, slaughterhouse and agro-industrial multinational companies that play a role in transforming a raw, deforestation related or a forest-friendly product into a final consumption product.

The third category of actors is *consumers* – the end-users of deforestation related products. Here we find private individuals and public entities located in producing and importing countries. For example, households consuming firewood or charcoal in forest-rich countries are considered consumers.

The fourth category of actors is *governments and public institutions* located in forested-risk tropical countries that have mandates to regulate land use. These actors can have responsibility at national, regional or local level.

The fifth and final category is the *finance actors and investors*, including donors. These are involved almost exclusively in transferring assets, capital and resources that ultimately impact land-use changes in the tropics. This includes both public and private entities, for example investors, insurance companies, banks, asset managers and pension funds.

3.3 Behavioural mechanisms targeted by the forest policies

Drawing from both economics as well as psychological literature, we identified four main behavioural mechanisms (or motivational drivers) triggered by forest policies. These behavioural mechanisms are underlying factors that influence how individuals or institutions respond to policies, including expectations of rewards or penalties, feelings of social belonging, or confidence in their own capacity to act.

Our basis is the Self-Determination Theory (SDT), which encompasses the concepts of intrinsic and extrinsic motivation, extrinsic motivations that are internalized, as well as human basic needs. Together this helps to account for the diversity of behaviour targeted by forest policies and measures (Deci and Ryan 1985). This theory has been applied extensively across natural resource conservation and management (Ezzine-de-Blas et al. 2019; Rode et al. 2015). The four behavioural mechanisms are: (i) maximization of material payoffs; (ii) compliance and obedience; (iii) social belongingness and satisfaction; (iv) competence and self-efficacy.

1 In previous work, for example by Chervier et al (2022), these are referred to as 'psychological mechanisms'. Here we have opted to change this term to 'behavioural mechanisms', as the focus is on the behavioural change of forest actors.

Maximization of material payoffs assumes that individuals make decisions to maximize one's own material payoffs – the neoclassical conceptualization of human behaviour (homo economicus). This mechanism is associated with policies that either increase payoffs from desired behaviour, or decrease payoffs connected to undesired behaviour through a transfer of material resources that can be conditional or non-conditional, e.g., subsidies or taxes.

Compliance and obedience assumes that individuals respond to fear of punishment if they are not compliant with restrictions or standards established by norms or laws (Karp and Gaulding 1995). Authority figures, for example state entities, usually can exert power as a means of coercion to induce obedience or compliance. This behavioural mechanism has been associated with command-and-control policies like protected areas. While it can have implications in terms of maximization of material payoffs, it differs in the sense that incentives are given on a non-voluntary basis and there is coercion.[2]

Social belongingness satisfaction assumes that humans aim to feel a sense of social belonging, in other words, a subjective feeling of inclusion or acceptance into a group of people, and this drives the tendency to conform to behaviours they believe to be approved by peers or wider society (Baumeister and Leary 1995). Pro-social motivations – for example reputation and honour, social approval and image, shame, pride and guilt – are triggered by this behavioural mechanism (Rode et al. 2015). This mechanism is usually connected to informational policies, like consumers awareness campaigns or disclosure initiatives that aim at revealing inconsistencies between corporate or individual behaviour and broader social values.

Competence/self-efficacy is the fourth behavioural mechanism. This assumes that people are more likely to implement a given behaviour if they are confident that they are competent enough to successfully implement it. Bandura (1977) labels this as self-efficacy or "people's beliefs in their capabilities to exercise control over their own functioning and over events that affect their lives". This mechanism is typically associated with capacity-building, like technology extension services, which aim to give beneficiaries a chance to practice the target behaviour, thereby developing experience and mastery of it.

Diversity among these identified behavioural motivations reflects the evolution of paradigms underlying the conservation of natural resources. This evolution has been characterized by a shift from command-and-control mechanisms, to economic incentives (Gómez-Baggethun et al. 2010), towards mechanisms that integrate lessons from psychology literature and social motivations to create behavioural change in forest users (Belinga et al. 2020; Moros et al. 2019).

3.4 Forest threat targeted by the policies

Any forest policy or measure aims to mitigate at least one assumed cause of deforestation and forest degradation, be it direct or indirect. We identified five forest threats targeted by policies and measures. According to literature on direct and underlying drivers of deforestation (Geist and Lambin 2002), these can be broadly classified into direct and indirect threats.

Two types of policies and measures address the direct threat of deforestation. The first includes policies aiming to: increase the limited perceived value of forests or the captured values of standing natural forests, both when in use and not (Pascual et al. 2010); increase the benefits of forest-friendly activities contributing to reduce deforestation and forest degradation (e.g., agroforestry, sustainable timber harvesting); and/or enhance the supplying of forest ecosystem services. The second direct threat for forests stems from the significant benefits forest-degrading activities generate. Policies addressing this

2 There is, however, a fine line between command-and-control mechanisms and taxes, as the (expected) fines in a command-and-control system can be seen as a form of taxation.

threat aim to reduce the benefits of actions that result in deforestation, forest degradation or loss of forest ecosystem services, including unsustainable timber extraction and agricultural expansion.

We then identified three distinct indirect deforestation threats targeted by policies: weak governance, ineffective human development, and insufficient demand for forest-related commodities. The policies and measures that address weak governance address the underlying drivers of deforestation and forest degradation correlated with governance failures, like corruption, weak law enforcement, and open access conditions. This is not to say that all measures for improved governance reduce deforestation. Good governance may also reduce the risk of investments, including those that involve forest clearing.

Policies and measures to address inadequate human development also indirectly reduce deforestation, by addressing the underlying drivers of deforestation and forest degradation that are associated with lack of economic alternatives or demographic pressures. Again, a forest conservation outcome is far from guaranteed. For example, high poverty rates are often associated with low deforestation (Babigumira et al. 2014; Busch and Ferretti-Gallon 2017, 2023)

Finally, policies and measures aiming to address inadequate demand for forest-related commodities frequently seek to reduce demand for forest-risk and forest-friendly commodities and products.

3.5 Applying the policy typology to Brazil

To apply our forest typology to Brazil's forest policies, we focused on the Legal Amazon region. First, we compiled a list of relevant national policies that have been or are currently being implemented in the country, and selected three states to examine some examples of jurisdictional policies. After creating a preliminary list, we narrowed this down to select a sample of policies that incorporate a diverse range of mechanisms – compliance and obedience, maximization of material payoffs and competence and self-efficacy – targeting various actors. Once these policies were selected, we analysed legal documents, academic literature and grey literature, to gain a comprehensive understanding of these policies and classify them according to our three forest policy attributes.

We recognize that any given forest-related measure or policy could fall under several classifications and be assigned various attributes. For example, compliance with a forest protection norm might be triggered by a behavioural mechanism (fear of punishment), as well as motivation for social belongingness. To categorize each policy and measure into one singular type, we identified a dominant attribute for each policy, for each of the three main steps of the ToC: the main actor targeted by the policy, the main behavioural mechanism, and the deforestation threat. In a sense, this categorization should be understood as 'ideal types' (Weber 1952) with which to think through these kinds of initiatives. The 'ideal' part of the concept should not be understood as value judgement, but to their nature as idea-constructure. By this we mean they act as interpretive devices – they serve as tools to think through social reality but are also permeable and seldom exist in their pure form in practice. For a similar exercise in the Peruvian Amazon, see Sarmiento Barletti and Larson (2020).

Our classification of forest archetypes was also conducted as an interpretive assessment based on the analysis of policy documents. While in this study we created archetype maps, it was not possible to directly relate a policy to these maps, given the lack of additional layers for land tenure and governance mechanisms associated with these maps.

Although several Amazonian states in Brazil have implemented noteworthy anti-deforestation policies and jurisdictional approaches for REDD+, for this classification exercise we focused on three states: Pará, Acre and Tocantins.

Pará is Brazil's second-largest state, and has a complex history of government-led colonization policies beginning in the 1960s that led to widespread deforestation and enduring social challenges. Despite its reputation for high deforestation rates, Pará has also served as a testing ground for jurisdictional efforts to protect forests, particularly through initiatives like the Green Municipalities programme (Sills et al. 2020; Thaler et al. 2019; Viana et al. 2016) and other municipal-level actions aimed at reducing deforestation (Brandão et al. 2021).

Acre, situated in the western Brazilian Amazon, has been recognized for its focus on community-based forest management and sustainable development programmes, offering economic alternatives to deforestation through agroforestry, non-timber forest products (e.g., rubber and Brazil nuts) and ecotourism. The state's Statewide System for Environmental Services (SISA) programme provides incentives for ecosystem service conservation among Indigenous Peoples, local communities, smallholders and other stakeholders (de los Rios et al. 2018). However, Acre has also experienced periods of high deforestation rates and is currently facing the expansion of agribusiness along its borders with Amazonas and Rondônia.

Tocantins, Brazil's newest state, is located in the Tocantins-Araguaia Hydrographic Region and spans two biomes: the Amazon (13%) and Cerrado (87%), each with distinct environmental policies and governance structures (de los Rios et al. 2020). The state is part of MATOPIBA, an expanding agricultural frontier that also includes Maranhão, Piauí and Bahia. Agriculture and cattle ranching dominate land use, with 947,287 hectares of natural forest converted to soy and livestock areas between 2008 and 2017 (de los Rios et al. 2020). Despite agricultural expansion, Tocantins managed to reduce its emissions from 2016 to 2020 by combining compliance and enforcement measures with incentives for low carbon agriculture and conservation (EII 2023). Tocantins ranks third in the number of contracts signed under the national Low-Carbon Agriculture Plan (ABC), with 784 contracts during 2018–2019, totalling approximately USD 44 million in financing (de los Rios et al. 2020).

4 Policies implemented

In this section, we present a selection of national-level policies and sectoral agreements (described in subsection 4.2) alongside state-level policies (outlined in subsection 4.3) within the Legal Amazon. These policies are categorized based on their primary mechanisms, relevant forest archetypes, activated behavioural mechanisms, key actors and associated deforestation threats, and are grouped into three main behavioural categories: compliance and obedience, maximization of material payoffs, and competence and self-efficacy.

Table 1 presents compliance and obedience policies, which include measures focused on land-use restrictions and enforcement mechanisms for non-compliance. These command-and-control policies encompass national land-use regulations like the Forest Code and the Rural Environmental Registry (CAR) system, protected territories, satellite monitoring, strengthened enforcement of forest protection laws through the Critical Municipalities programme, and supply chain moratoriums. Most of these policies primarily address the threat of deforestation stemming from other land-use benefits, except for protected territories policies which focus on governance.

The material payoff maximization policies in Table 2 include those that use rewards as motivation. Examples include conditional credit policies like the Central Bank Resolution 3545 and the ABC programme. Resolution 3545 restricts credit access for those who are non-compliant with the Forest Code, targeting the deforestation threat associated with benefits from other land uses. In contrast, the ABC programme rewards producers who establish low-carbon practices that increase productivity of already opened areas, thereby reducing deforestation pressure. Both policies are directed at medium and large producers in deforestation areas. As examples of programmes aimed at small-scale producers, Indigenous groups and traditional communities, the Bolsa Verde programme and Floresta+ programme use conditional payments to increase the value and benefits of forest-friendly activities. At the subnational level, two REDD+ jurisdictional initiatives serve as examples of policies that aim to improve governance by creating economic incentives. The Green Seal programme in Pará offers transparency and certification within the cattle value chain for improved market access, while the ecological fiscal transfer provides municipalities with tax revenue contingent on meeting environmental criteria established by their state.

Table 3 presents policies designed to change behaviour by enhancing competencies and capabilities. This category includes policies related to tenure rights clarification, like the Terra Legal programme, as well as initiatives that promote decentralization to improve governance, forest concessions and the Community and Family Forestry programme. At the subnational level, examples include the Indigenous Agroforestry Agent programme in Acre and the Green Municipalities programme in Pará. Most policies in this group target the limited value and benefits associated with forests, except for decentralization under the Public Forest Management Law, which focuses on governance.

4.1 National and private sector policies selected for the Brazilian Legal Amazon (LAM) and how they are classified

The **Forest Code** is the main legal framework regulating forest use in the Brazilian Legal Amazon (LAM). The original 1965 version (Law 4,771) required private landowners to maintain 80% forest cover in the Amazon biome and 35% in the Cerrado as a legal reserve in the LAM (with some exceptions[3]). It also mandated special protection for riparian zones and hilltops (for more details on these requirements see Chiavari and Lopes 2015a, 2015b). The 2012 revision (Law 12,651) retained these requirements and introduced the **Rural Environmental Registry (CAR)**, which made registering every rural property mandatory so as to support socioeconomic planning and improve deforestation monitoring (Azevedo et al. 2017; Chiavari and Lopes 2015a, 2015b; Soares-Filho et al. 2014). The Forest Code and CAR primarily operate through the behavioural mechanism of compliance and obedience, and apply to all forest archetypes (Table 1).

Non-compliance with key environmental regulations, including the 1965 Forest Code, the 1981 National Environmental Policy Law, and the 1998 Environmental Crimes Law, was widespread across the LAM until the early 2000s (West and Fearnside 2021). By the early 2000s, deforestation rates had peaked, prompting the Brazilian government to launch the first **Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm)** in mid-2004 (2004–2008). This plan marked a pivotal moment in Brazil's anti-deforestation strategy, introducing innovative measures and positioning the fight against deforestation as an interministerial responsibility involving 13 ministries (Gandour 2021; West and Fearnside 2021).

The first PPCDAm plan was structured around three key axes: i) territorial planning and land tenure; ii) improved law enforcement and monitoring; and iii) incentives for the sustainable use of natural resources. While these three axes incorporate a range of behavioural mechanisms, the first PPCDAm focused primarily on compliance and obedience policies, particularly targeting deforestation area archetypes along the 'arc of deforestation' and the deforestation threat stemming from the benefits from other land uses (see Table 1). These policies are presented below.

A key focus of this PPCDAm was the expansion of **protected territories**[4] through the creation of protected areas, as part of the Amazon Protected Areas Program (ARPA), established by Decree 4326 of 2002, particularly in deforestation areas (see Table 1). Other efforts included the homologation of Indigenous lands. According to Soares-Filho et al. (2010), the expansion of protected territories in the Brazilian Amazon aimed not only to safeguard biodiversity but also to establish extensive forest blocks as 'green barriers' against deforestation. Until the mid-2000s, protection was primarily based on biological and ecological criteria, focusing on conserving biodiversity and natural habitats. However, under the PPCDAm, an additional goal was introduced: to block advancing the four deforestation archetypes through improved governance (Assunção and Gandour 2018). During the first phase of PPCDAm, 50 million hectares of protected areas were created, and 10 million hectares of Indigenous territories were homologated (West and Fearnside 2021).

As part of PPCDAm's monitoring efforts, the **DETER system** – a satellite-based early warning system for detecting deforestation – was developed in 2004 by the National Institute for Space Research (INPE). This system enabled near real-time deforestation detection, greatly enhancing law enforcement efforts in priority areas (Assunção and Rocha 2019; Diniz et al. 2015). Alerts from DETER are shared daily

3 State governments can reduce the size of a legal reserve on private land outside a protected area from 80% to 50% for the purpose of compliance, through designating a particular area as an agricultural production zone, through the process of Ecological–Economic Zoning plans.

4 In Brazil, protected territories are formed mainly by protected areas (PAs) and Indigenous lands (ILs). The formal system of protected areas, known as the Conservation Units National System (SNUC), encompass two types of PAs: Conservation Units of Restrict Use (CURU; IUCN Categories I-IV), and Conservation Units of Sustainable Use (CUSU; IUCN Categories V-VI; SNUC; MMA 2019).

with the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) which is the national environmental enforcement agency for the Amazon, as well as to state environmental agencies (Silva Junior et al. 2023). These alerts allowed IBAMA to carry out a series of command-and-control operations (for compliance and obedience), often in collaboration with the army and federal police, aimed at combating illegal deforestation (Diniz et al. 2015; Rosa et al. 2012). Assunção et al. (2019) estimated that without the monitoring and enforcement actions allowed by DETER, deforestation in the Amazon would have been almost five times higher than that observed between 2007 and 2016. Monitoring through DETER is relevant to all forest and deforestation archetypes, but it was particularly crucial in restraining the advance of the frontier in the deforestation area archetypes.

The improved monitoring capabilities provided by DETER facilitated the implementation of several related policy interventions, including the **Critical Municipalities** programme, which targeted the 36 municipalities responsible for 45% of deforestation in the Amazon during the previous year (Arima et al. 2014; Assunção and Rocha 2019; Cisnero et al. 2015). These municipalities, often located in the 'arc of deforestation', were blacklisted and subjected to intense environmental monitoring, restrictions on deforestation permits, embargoes[5] on areas that had been cleared illegally, and restricted access to credit and markets (West and Fearnside 2021). To be removed from the list, municipalities had to meet strict requirements, including property registration, effective monitoring, and keeping their deforestation rates below a threshold set by the Ministry of the Environment (MMA) (Gandour 2021). While most blacklisted municipalities are located in areas dominated by deforestation archetypes – like stabilized transition areas, gradual, chronic and accelerating deforestation areas – recent studies have shown that some are also situated in regions with intact forest areas, indicating the ongoing expansion of deforestation areas (Massoca and Brondízio 2022).

By establishing compliance criteria at municipal level, the policy fostered a collaborative approach among federal, state and municipal governments (Massoca and Brondízio 2022). Numerous studies have highlighted significant reductions in deforestation within the listed municipalities (Arima et al. 2014; Assunção and Rocha 2019; Chagas and Andrade 2024; Cisneros et al. 2015; Gonçalves 2022; Koch et al. 2019). PRODES[6] estimates showed deforestation rates in blacklisted municipalities declining from 5,310 km^2 in 2007 to 4,902 km^2 in 2008 (West and Fearnside 2021).

The Critical Municipalities programme primarily functioned through the behavioural mechanism of compliance and obedience, but its success also depended on complementary policies that engaged additional behavioural mechanisms. A key example is the **2008 Resolution No. 3545** from the Brazilian Central Bank/National Monetary Council, which restricted access to public bank loans for landowners who were noncompliant with environmental and rural regulations. This policy leverages the behavioural mechanism of maximization of material payoffs, using financial penalties as a deterrent to incentivize compliance (Table 2). Credit restrictions imposed by Resolution 3545 were estimated to have reduced (counterfactual) deforestation by approximately 60% during 2009–2011 (Assunção et al. 2020). Since the two main activities targeted by the policy are cattle ranching and agriculture, the most important archetypes related to this initiative are the deforestation area archetypes (Table 2).

5 Collaboration between state-level public prosecutors and the Brazilian Environmental Protection Agency (IBAMA) strengthened legal enforcement, for example through property embargoes (Mueller 2010).

6 In addition to DETER, INPE coordinates the Project for Amazon Deforestation Monitoring by Satellite, known as PRODES. Since 1988, PRODES has monitored deforestation caused by clear-cutting in the Legal Amazon with the use of satellite imagery and has produced annual deforestation rates. These rates are used by the Brazilian government to inform and establish public policies.

The **Rural Environmental Registry (CAR)** [7], a spatially explicit database designed to register both legal and illegal cleared areas on rural properties and determine forest restoration requirements according to the Forest Code, also played a critical role. Blacklisted municipalities were required to register at least 80% of their properties in CAR to be removed from the list. CAR had already been implemented in states like Mato Grosso and Pará before it became mandatory under the 2012 Forest Code, to serve as a key tool for promoting environmental compliance (Table 1).

Alongside government actions aimed at curbing deforestation in frontier regions, the private sector introduced two voluntary supply-chain initiatives that leverage the behavioural mechanism of compliance and obedience. These initiatives were developed as a reaction to demands from NGOs and civil society: (i) the Soy Moratorium in 2006, and (ii) the Cattle Agreements in 2009. The Soy Moratorium is an agreement between the Brazilian Vegetable Oils Industry Association (ABIOVE), the National Association of Cereal Exporters (ANEC) — representing major soybean traders — and environmental NGOs to eliminate deforestation from soy production (Gibbs et al. 2015; Heilmayr et al. 2020; Nepstad et al. 2014). The Cattle Agreements include zero-deforestation commitments by the four most significant beef processors (known as the G4 Agreement) and Terms of Adjustment of Conduct agreements between the Public Prosecutor's Office and beef processors, both aiming for a deforestation-free beef supply chain (Gibbs et al. 2016; Greenpeace 2009, 2020; Levy et al. 2023). Companies that signed these agreements pledged not to source soy or beef from recently deforested areas within the Amazon. Both initiatives primarily target deforestation-area regions, which are mainly concentrated within the 'arc of deforestation' (Table 1).

Table 1. Compliance and obedience focused national and subnational policies, classified according to relevant forest archetype, actors and deforestation threat

Policy	Main mechanism	Relevant forest archetypes*	Behavioural mechanism activated	Actors	Deforestation threat
Forest Code (1965; 2012)	Command and control	Intact forest areas, stable forest mosaics, deforestation areas	Compliance and obedience	Producers	Benefits from other land uses
Protected Territories	Protected areas	Intact forest areas, stable forest mosaics, accelerating deforestation areas	Compliance and obedience	Producers	Governance
DETER	Satellite Monitoring	Intact forest areas, stable forest mosaics, deforestation areas	Compliance and obedience	Producers	Benefits from other land uses
Critical Municipalities	Command and control	Deforestation areas	Compliance and obedience	Multiple	Benefits from other land uses
Soy Moratorium	Moratoriums bans (commodities)	Deforestation areas	Compliance and obedience	Supply chain producers	Benefits from other land uses
Cattle Agreement	Moratoriums bans (commodities)	Deforestation areas	Compliance and obedience	Supply chain producers	Benefits from other land uses
Rural Environmental Registry (CAR)	Environmental monitoring/ land tenure regularization	Intact forest areas, stable forest mosaics, deforestation areas	Compliance and obedience	Producers	Benefits from other land uses

7 Mato Grosso's State Law 343 of 2008 introduced an environmental and land tenure regularization programme known as Mato Grosso Legal, aimed at rural landholdings within the state. This programme served as a model for a similar initiative launched in Pará later that year (State Decree 1148 of 2008), which ultimately contributed to the creation of the national Rural Environmental Registry (CAR) system introduced by the 2012 revision of the Forest Code.

Several studies indicate a decrease in soy expansion in recently cleared areas (Gibbs et al. 2015; Gollnow et al. 2018; Heilmayr et al. 2020; Macedo et al. 2012; Nepstad et al. 2014; Rudorff et al. 2011). However, these reductions were largely dependent on the presence of other governmental anti-deforestation policies, like CAR and deforestation monitoring through DETER (Heilmayr et al. 2020; Svahn and Brunner 2018). For example, Svahn and Brunner (2018) found that the Soy Moratorium in Mato Grosso had a significant impact only after being reinforced by DETER satellite monitoring from 2008 onwards. Despite the success of the moratorium, in 2024, the state governments of Mato Grosso (Law 12.709/2024) and Rondônia (Law 5.837/2024) enacted laws to penalize companies that adhere to the moratorium, aiming to dismantle the agreement within their states. However, in December 2024, the federal government issued a preliminary suspension of the Mato Grosso state law, deeming it unconstitutional for violating environmental rights, economic order principles and tax regulations (Greenpeace 2025).

Levy et al. (2023) reported that the G4 Agreement helped reduce cattle-driven deforestation between 2010 and 2018. Nevertheless, cattle agreement success hinges on broad adoption, effective monitoring and strict enforcement, which are currently lacking to prevent large scale deforestation (Gibs et al. 2016). Gibbs et al. (2016) noted that the limited scope of the cattle agreement diminishes its effectiveness in preventing deforestation, as it is prone to issues like leakage and cattle laundering.

Although the promotion of sustainable land-use activities was the axis that received less attention during the first phase of PPCDAm (West and Fearnside 2021) one relevant policy was the Public Forest Management Law (Law 11,284 of 2006). This law focused on the decentralization (Table 3) of forest management (Rocha et al. 2020) and the promotion of logging concessions (Table 3). However, at that time most jurisdictions lacked capacity to assume new responsibilities for the use and conservation of forests, and currently the states' capacities to govern environmental issues are very diverse (Greenpeace 2006; Rocha et al. 2020). Regarding logging concessions, implementation has been slow. As of 2024, Brazil has placed a total of 1.88 million hectares under forest concession, primarily in the state of Pará. However, this figure accounts for only 14% of the established target of 13 million hectares by 2020 (Pereira et al. 2024). While forest concessions are advocated to reduce deforestation and illegal logging in public areas, and to create jobs and improve local incomes, there is a notable lack of studies evaluating their social and environmental impacts in the Brazilian Amazon (Pereira et al. 2024). Recently, a new law (Law No. 14,590/2023) has allowed for the generation and commercialization of carbon credits from these forest concessions, potentially enhancing their benefits.

Both policies introduced by the Public Forest Management Law are linked to the competence/self-efficacy mechanism (Table 3). The decentralization of governance affects all forest archetypes in this study's typology. However, forest concessions are specifically designed for intact forest area and stable forest mosaic archetypes, allowing for sustainable timber exploration in areas with low levels of degradation. Two other important policies, not analysed in this study but also established during the first phase of PPCDAm in 2008, are the Amazon Fund (Decree 6527 of 2008), which was created to raise donations for projects aimed at reducing deforestation and promoting sustainable development in the Amazon, and the National Climate Change Plan.

According to West and Fearnside (2021), the first phase of PPCDAm was successful in curbing illegal large-scale deforestation in frontier areas. However, the second phase (2009–2011) faced more complex challenges, as it needed to address persistent issues like the lack of sustainable economic alternatives and unclear land tenure in the region. While the programme maintained its focus on expanding protected areas, recognizing Indigenous land rights, strengthening monitoring and enforcement and promoting the CAR registry – particularly in blacklisted municipalities – it also introduced new initiatives that targeted the behavioural mechanisms of maximizing material payoffs (e.g., Bolsa Verde and ABC programme, see Table 2) and competence/self-efficacy (e.g., Terra Legal and Community and Family Forestry programme, see Table 3) as discussed below.

Table 2. Maximization of material payoff-focused national and subnational policies, classified according to relevant forest archetype, behavioural mechanism activated, actors and deforestation threat

Policy	Main mechanism	Relevant forest archetype*	Behavioural mechanism activated	Actors target	Deforestation threat
Rural Credit Conditioning (Resolution 3545, of 2008)	Conditional credit and subsidies	Deforestation areas	Maximization of material payoffs	Producers (medium and large scale)	Benefits from other land uses
Bolsa Verde (Green Grant)	Conditional payments	Intact forest areas, stable forest mosaics	Maximization of material payoffs	Producers (smallholders), Indigenous communities, local communities	Forest values and benefits
ABC programme (credit subsidies for low carbon agriculture)	Conditional credit and subsidies	Deforestation areas	Maximization of material payoffs	Producers (medium and large scale)	Forest values and benefits
Floresta+ Amazonia	Conditional payments	Intact forest areas, stable forest mosaics, deforestation areas	Maximization of material payoffs	Producers (smallholders), indigenous communities, local communities	Forest values and benefits
Ecologic ICMS (ICMS-E)	Ecological fiscal transfers (EFTs)	Intact forest areas, stable forest mosaics, deforestation areas	Maximization of material payoffs	Multiple	Governance
Selo Verde Green Seal (Pará)	Value chain transparency/ certification programme	Deforestation areas	Maximization of material payoffs	Producers, supply chain	Forest values and benefits
SISA (Acre)	Jurisdictional REDD+ programme	Intact forest areas, stable forest mosaics, deforestation areas	Maximization of material payoffs	Multiple	Governance
Jurisdictional REDD+ programme	Jurisdictional REDD+ programme	Intact forest areas, stable forest mosaics, deforestation areas	Maximization of material payoffs	Multiple	Governance
REDD+ projects	REDD+ projects, conditional payments	Intact forest areas, stable forest mosaics, deforestation areas	Maximization of material payoffs	Producers (smallholders), Indigenous communities, local communities	Forest values and benefits

The **Terra Legal** programme, a competence/self-efficacy policy, was launched under Law 11,952 of 2009 (later amended by Law 13,465 of 2017) with the goals of reducing deforestation, resolving land disputes, and curbing violent land-grabbing (Lipscomb and Prabakaran 2020). It aimed to provide legal land titles for thousands of small and medium-sized landholders in the Amazon, initially focusing on 43 blacklisted municipalities and targeting approximately 67 million hectares of public land (IPEA- GIZ- CEPAL 2011; West and Fearnside 2021). According to the archetype typology, the programme primarily targets deforestation areas where land has already been converted for agriculture or cattle ranching.

The programme required compliance with the Forest Code (i.e., maintaining 80% forest cover as a legal reserve) as a condition for titling. However, it faced controversy following a 2017 amendment, which increased the land legalization limit from 1,500 hectares to 2,500 hectares per taxpayer. This change facilitated land sales in government-recognized smallholder settlements, leading to land concentration, with smallholders being replaced by medium and large ranches, and creating new groups of landless farmers. The programme's progress was also slowed by difficulties in land regularization due to conflicting and scattered tenure data across state and federal databases (West and Fearnside 2021).

The limited research that exists on the Terra Legal programme's impact on deforestation shows mixed results. Assunção and Szerman (2018) estimated significant reductions in deforestation at the property level, with decreases ranging from 9.2% to 11.2% due to the full titling process. In contrast, another study at the county level, which considered only the initial farm registration process from 2007 to 2012, found no overall effect on deforestation (Lipscomb and Prabakaran 2020).

Another competence and self-efficacy initiative was the **Community and Family Forest Management** programme (Table 3), launched in 2009 to improve local livelihoods and combat illegal timber exploitation. The programme aimed to promote forest management as a sustainable practice that could generate income for local communities, recognizing its potential benefits. However, the complexity of regulatory requirements was not adequately addressed, making it difficult for smallholders to formalize the management of timber and non-timber products. The programme also encountered coordination challenges and was eventually discontinued (Azevedo-Ramos and Pacheco 2017).

PPCDAm II equally introduced policies aimed at maximizing material payoffs, two of which are presented here. The first is the **ABC** programme, which uses subsidized credit to incentivize low-carbon agricultural practices, primarily targeting deforestation area archetypes (Table 2). The ABC programme is part of Brazil's National Plan for Low Carbon Emission in Agriculture (ABC Plan), which sought to reduce greenhouse gas emissions from agriculture between 2010 and 2020. The programme provided low-interest loans to support sustainable practices like no-till farming, degraded pasture restoration, crop-livestock-forest integration, commercial forestry, biological nitrogen fixation and animal waste management (CGIAR n.d.).

A specific credit line within the programme focused on pasture restoration, designed to ease financial constraints for producers. Restoring degraded pastures is a costly and high-risk investment, involving not only direct expenses but also temporary loss of land use and the potential for unmet expectations. The ABC Plan set a goal of restoring 15 million hectares of degraded pasture by 2020. However, it is estimated that the credit line contributed to only about 2.5% of this target (Oliveira et al. 2024). In 2020, Brazil launched the Plano ABC+, a continuation of the previous plan for the period 2020–2030, aiming to consolidate sustainable and productive farming systems while enhancing global food security (MAP 2023).

The other maximization of material payoffs policy is **Bolsa Verde** ('Green Grant'), a cash transference programme conditioned to socioenvironmental criteria (Table 2). The programme was launched at the end of 2011 (Law 12,512), as part of Brazil's social security efforts against poverty (Decree 7492 of 2011). It targeted the rural population living in extreme poverty, providing them with quarterly payments of BRL 300 per family. The programme benefited 44,388 families living in settlements and protected areas,

at a cost of BRL 69 million from 2011 to 2013 (Viana 2014). The Bolsa Verde programme aims to reduce deforestation in remote and densely forested areas of the Brazilian Amazon, where low enforcement is more costly[8] (Wong et al. 2023). As such, the programme relates to intact forest area and stable forest mosaic archetypes. In 2018, the programme was discontinued but a new version was launched in 2023 (Decree 11.635 of 2023).

There is limited evidence on the programme's impacts on deforestation. Wong et al. (2023) used a difference-in-differences approach and found that the programme reduced deforestation in treated areas compared to similar untreated areas. However, this decrease did not occur within the areas controlled by programme beneficiaries, but rather regionally. The authors attributed this effect to increased monitoring by the programme's beneficiaries, who were incentivized to report deforestation near their residences. Other studies have shown positive effects on food security and poverty reduction (Andrade 2018; MDS 2016). Reports on the programme's implementation emphasize the need to strengthen complementary practices, like technical support for agroforestry and sustainable management of natural resources (MMA 2018; Pires 2016).

During PPCDAM II REDD+ projects led by NGOs and the private sector began to emerge. Counterfactual analysis shows that such projects can have small, positive effects in reducing deforestation (Carrilho et al. 2022; Simonet et al. 2019), but the amounts of carbon credits reductions claims are in most cases overstated, because of inflated deforestation baselines from carbon project developers (West et al. 2020).

Table 3. Competence/self-efficacy focused national and subnational policies, classified according to relevant forest archetype, actors and deforestation threat

Policies (in country)	Main mechanism	Relevant forest archetype*	Behavioural mechanism activated	Actors	Deforestation threat
Law on Management of Public Forests (Law nº 11.284 of 2006)	Decentralization	Intact forest area, stable forest mosaics, deforestation areas	Competence/ self-efficacy	Government	Governance
Forest Concessions Law on Management of Public Forests (Law nº 11.284 of 2006)	Forest concessions	Intact forest area, stable forest mosaics	Competence, Competence/ self-efficacy	Private enterprises	Forest values and benefits
Terra Legal programme	Land tenure clarification	Deforestation areas	Competence/ self-efficacy	Producers (smallholders)	Forest values and benefits
Community and Family Forest Management programme	Community forestry in Brazil	Intact forest area, stable forest mosaics	Competence/ self-efficacy	Local communities, smallholders	Forest values and benefits
Indigenous Agroforestry Agent (Acre)	Training, technical assistance	Intact forest area, stable forest mosaics	Competence, Competence/ self-efficacy	Indigenous communities	Forest values and benefits
Green Municipalities programme (Pará)	Multistakeholder forum, land tenure clarification, support for improved municipal environmental governance	Intact forest area, stable forest mosaics, deforestation areas	Competence, Competence/ self-efficacy	Multiple	Forest values and benefits

8 The programme targets families living in Sustainable Use Conservation Units, environmentally differentiated settlements within the National Institute of Agrarian Reform, and territories inhabited by traditional communities like riverside dwellers, extractivists, Indigenous Peoples and *quilombolas*.

In the PPCDAM III (2012–2015), the three main axes were kept, and the most relevant policy was the controversial revision of the Brazilian Forest Code in 2012 (Laws 12,651 and 12,727). While it retained the foundational structure and principles of the previous code, like the obligation to ensure 80% of land was a legal reserve for the Amazon, it was highly criticized because it granted amnesty for illegal deforestation that occurred prior to 2008. The legislation absolved the legal reserve obligations for 'small' properties, which vary in size from 20 ha in the south of Brazil to 440 ha in the Amazon region. According to Soares-Filho et al. (2014) under these new regulations, approximately 90% of rural properties in Brazil were eligible for amnesty. The 2012 Forest Code both waived fines for areas deforested illegally prior to 2008, as well as diminished the obligations for ecological restoration. However, the reformed Forest Code introduced new mechanisms aimed at promoting compliance with the legal framework and facilitating its enforcement, like the CAR and the Environmental Reserve Quota (CRA), a marketable legal entitlement representing areas with native vegetation outside of Forest Code stipulations.[9] Sant'Anna (2021) assessed amendments to the Forest Code and determined that the amnesty provided to landholders who engaged in illegal deforestation before 2008 has inadvertently encouraged opportunistic behaviour, leading to a surge in deforestation on rural Amazonian properties.

During PPCDAm III, REDD+ initiatives were formally acknowledged as part of the plan. In 2014, Brazil submitted to the UNFCCC a Forest Reference Emission Level (FREL) for the Amazon biome to claim results-based REDD+ payments, in accordance with the Bali Action Plan and the country's climate change mitigation commitment, or Nationally Determined Contribution (NDC), to the UNFCCC (West and Fearnside 2021).

For the first time during a PPCDAm phase, deforestation rates did not continue to decline but instead rose by 36%, increasing from 4,571 km² in 2012 to 6,207 km² in 2015. Data from PRODES also showed a rise in the contribution of large, deforested areas (>100 ha) to total deforestation during PPCDAm-III, increasing from 17% in 2012 to 28% in 2015 (West and Fearnside 2021).

PPCDAm IV (2016–2020) introduced a fourth thematic axis, expanding beyond the original three to include the development of regulations and economic instruments for deforestation prevention and control (Brasil 2016). The plan placed a stronger emphasis on climate mitigation, aiming to meet the targets set by the National Climate Change Plan for 2020 under Brazil's NDC to the UNFCCC.

During this phase, Brazil became the first country to receive payment from the Green Climate Fund's REDD+ results-based payments pilot programme, amounting to USD 96.5 million, for reducing 18.8 million Mg CO_2 emissions from deforestation between 2014 and 2015 based on comparisons with the 1996–2010 baseline. These funds were allocated to the **Floresta + Amazônia** project, which provides payments for environmental services to smallholders, traditional community residents and Indigenous Peoples who protect or restore native vegetation in the Legal Amazon. Launched in January 2020, the project is scheduled to run for six years (2020–2026) (Floresta + Amazônia 2024).

The PES programme is divided into four modalities: Modality 1 (Forest + Conservation): incentives for small properties (family farming, up to four fiscal modules) to conserve remnants of legal reserves; Modality 2 (Forest + Restoration): incentives for small properties or family rural holdings to restore permanent preservation areas; Modality 3 (Forest + Communities): support for representatives and associations of Indigenous Peoples and traditional communities; and Modality 4 (Forest + Innovation): support for innovative actions and activities that develop, implement and use public policies for native vegetation conservation and restoration (Floresta + Amazônia 2024; INESC 2023). The project addresses all forest archetypes, with the main mechanism being payment for environmental services, which activates the maximization of material payoffs as a behavioural motivator. Currently, the project remains in the implementation phase, and no published evaluations were found.

9 This surplus vegetation, or CRA, from one property can be utilized to reconcile legal reserve deficits on another, within the confines of the same biome and, ideally, within the same state.

4.2 State level policies

In parallel with the PPCDAm, since 2008 Amazon states have developed their State Plans for the Prevention and Control of Deforestation to align with federal PPCDAm efforts. The creation, implementation and periodic review of these plans are requirements for accessing resources from the Amazon Fund (Gandour 2021). Several Brazilian states have also been developing jurisdictional approaches to promote conservation and sustainable development in a more integrated manner while securing financial incentives for implementing various measures (Boyd et al. 2018). This section presents examples of policies aimed at maximizing material payoffs, as well as competence and self-efficacy initiatives, from the states of Acre, Pará and Tocantins. For material payoff policies, we include the **SISA** programme in Acre, the **Tocantins jurisdictional REDD+** programme, the ecological fiscal transfer known as **ICMS-E**, and the **Green Seal** programme in Pará (Table 2). Examples of competence and self-efficacy policies at the state level include **the Green Municipalities** programme in Pará and the **Indigenous Agroforestry Agent** programme in Acre (Table 3).

4.2.1 Subnational maximization of payoff policies

The **State System of Incentives for Environmental Services (SISA)** in Acre, Brazil, is the first jurisdictional REDD+ programme in the world (Duchelle et al. 2014). Established through State Law 2 308 in October 2010, following an extensive consultation process and building on earlier state policy initiatives like the Policy for Valuing Forest and Environmental Assets and the Ecological-Economic Zoning (ZEE) (Duchelle et al. 2014), SISA aims to conserve and enhance environmental services within the state (Acre 2010). The first programme implemented under SISA, ISA Carbono provides a framework for reducing emissions from deforestation and forest degradation (REDD+), adopting a stock-flux approach (Acre 2018). Financial resources generated by avoided emissions are primarily invested in strengthening existing state government programmes that aim to diversify sustainable land uses, enhance the outputs of already cleared land, and increase the economic value of standing forests, by promoting sustainable timber and non-timber forest products (NTFPs) (Duchelle et al. 2014). Since 2012, the programme has primarily been funded through results-based payments for emissions reductions under the Global Initiative REDD+ Early Movers (REM) from the German Development Bank (KfW) (Acre 2018). Although resources from ISA Carbono are used to fund several competence and self-efficacy programmes in the state, we consider the programme itself a maximization of material payoffs initiative, in which the state government receives financial benefits for reducing deforestation through improved governance. The SISA programme spans the entire state and includes initiatives across various archetypes. On Indigenous lands, the initiatives primarily cover intact forest area and stable forest mosaic archetypes. The territories where sustainable production initiatives are implemented encompass a mix of both intact forest area and stable forest mosaic archetypes as well as deforestation area archetypes. Meanwhile, the areas designated for sustainable cattle ranching initiatives are found in regions with consolidated pastures in deforestation areas.

Tocantins is another state that has developed a jurisdictional REDD+ programme. Through a combination of environmental policies and enforcement efforts, Tocantins successfully reduced its carbon emissions by 32% between 2016 and 2020, a reduction officially recognized by the federal government through the National Commission for REDD+ (EII 2023). In 2019, Tocantins signed a commitment with the NGO Earth Innovation Institute to participate in the Tropical Forest Champions initiative that supports states in developing partnerships, accessing markets, and securing investments to promote sustainable economies, forest conservation and reduced greenhouse gas emissions. One outcome of this partnership was the development of the **Tocantins Jurisdictional REDD+ programme** that involves the Amazon and the Cerrado biomes (Tocantins 2021).

On 5 June 2023, the Tocantins state government signed with Mercuria Energy Trading a ten-year agreement to purchase forest carbon credits, to support implementation of its pioneering jurisdictional REDD+. This is the first purchase in the world between a company and a subnational government.

Revenue from the state's carbon credit sales will be used to promote climate-positive and socially inclusive development by fostering sustainable agricultural practices and providing benefits to Indigenous Peoples, traditional communities and farmers in the region (EII 2023).

In 2021, the Lowering Emissions by Accelerating Forest Finance (LEAF) Coalition pledged USD 1 billion to support jurisdictional initiatives focused on reducing deforestation, significantly influencing states in Latin America. In response to this pledge, all Amazonian states – except Rondônia – submitted proposals to begin the qualification process for accessing LEAF funds through the REDD+ Environmental Excellence Standard (TREES) of the Architecture for REDD+ Transactions (ART) (Gueiros et al. 2023). The states of Amapá (2020), Maranhão (2020), Mato Grosso (2020), Pará (2024) and Tocantins (2020) have all submitted at least one concept note to ART (the year of submission is noted in parenthesis after each state). Among these states only Tocantins have reached the next step of the TREES certification process, which is publishing/submitting a Registration Document.[10] The state of Pará has also signed an agreement with the LEAF coalition to receive a result-based payment of 180 million USD for reduction in deforestation between 2023 and 2026.[11] Acre is in the process of forming an ERPA but only signed a 'Term Sheet' with LEAF for up to 10 million credits.[12]

Another payoff mechanism adopted by several Amazonian states – including Acre, Tocantins and Pará – is the **Ecological ICMS (ICMS-E)**.[13] The ICMS-E came into being based on the constitutional right that states can legally allocate 25% of revenue devolved to municipalities from value added taxation, according to their own environmental criteria (May et al. 2012). The ICMS-E was first implemented in Paraná State in 1991, initially to compensate municipalities for protected areas that could not be used for economic activities. Over time, it evolved into an incentive mechanism aiming to reward municipalities that adopt environmentally sound practices and promoting conservation at the municipal level (Castro et al. 2022; May et al. 2012). Currently, seven of the nine Amazonian states have adopted the ICMS-E, with Rondônia and Amazonas being the only two that have not yet implemented it.

The definition of environmental criteria for revenue distribution is a strategic and political decision made by each state. In the Brazilian Amazon, many states use the presence of protected areas as a criterion to compensate municipalities for the opportunity costs associated with land-use restrictions (Carneiro et al. 2018). Other states, like Tocantins, leverage the tax to promote sound environmental management practices, with criteria including basic sanitation, water conservation, sustainable tourism, waste management and soil conservation (Castro et al. 2022). It is important to note that the municipal funds received through ICMS-E transfers are not automatically allotted to environmental expenditures. Two studies have found that conditional fund transfers, like the ICMS-E, promoted the creation of new protected areas (PAs) (May et al. 2012; Ruggiero et al. 2022).

Finally, the **Green Seal platform** in Pará provides open data to enable traceability across the entire livestock production chain in the state. Developed by the government of Pará in collaboration with the Federal University of Minas Gerais and launched in 2021, the platform cross-references official data from multiple government agencies to identify the origin of each animal, track direct and indirect suppliers, and detect potential environmental violations throughout the stages of breeding, rearing, fattening and slaughtering. This initiative – the first of its kind by a state government – supports producers in regularizing their properties and ensuring compliance with environmental and labour

10 https://www.artredd.org/art-accepts-trees-documents-submitted-by-tocantins-brazil/

11 Para-ERPA-announcement-Emergent-Final.pdf

12 https://art.apx.com/myModule/rpt/myrpt.asp

13 Brazilian Value Added Tax (ICMS), imposed on intermunicipal and interstate transactions of goods and services, is a state tax regulated by Articles 155 and 158 of the 1988 Federal Constitution. According to Article 158, 25% of the total ICMS revenue collected by the states must be transferred to municipalities. Of this total, 65% is to be allocated based on the value added by economic activities in the municipality of origin. The remaining 35% can be allotted in accordance with criteria established by state legislation, with the requirement that a minimum of 10% is allocated based on education-related indicators (Brasil 1988).

laws. Producers who meet legal requirements receive a Green Seal, which appeals to the growing demand from investors and buyers for deforestation-free meat. By certifying compliant producers, the platform enables them to expand market access and add value to their products, leveraging the behavioural mechanism of maximizing material payoffs. Additionally, the platform allows the state to monitor irregularities, thereby activating compliance and obedience mechanisms. This policy primarily targets deforestation area archetypes.

In September 2024, Pará officially launched a project aimed at enhancing cattle supply chain traceability by tracking cattle from birth to slaughter (Decree 3533, of 2023). This system, integrated with the Selo Verde platform, aims to tag all cattle in Pará with chips and ear tags bearing individual identification numbers by December 2026. These measures enable authorities to monitor whether cattle have passed through farms associated with environmental violations or social violations. The initiative addresses a significant gap in the Cattle Agreements by reinforcing monitoring to prevent leakage and cattle laundering along the supply chain (Gibbs et al. 2016; Greenpeace 2020). It also serves as a proactive response to the European Union's Deforestation-Free Regulation, which plans to ban the import of products linked to deforestation starting in December 2025.

4.2.2 Subnational competence and self-efficacy policies

Pará has sought to expand the ability of municipal governments to respond to the compliance and obedience measure of the federal blacklist (Critical Municipalities programme) through a **Green Municipalities programme**[14] (or Programa Municípios Verdes) that prepares municipalities through a series of competence and self-efficacy mechanisms to exit the critical list. In 2011, The Green Municipalities programme was established by the governor of Pará as a special programme in his office, although it lacked its own budget until it received a substantial grant from the Amazon Fund in 2014[15] (Sills et al. 2020).

The Green Municipalities programme was overseen by a steering committee, a multistakeholder forum primarily consisting of government institutions, private sector representatives, NGOs and rural producers, mainly from agribusiness (CIFOR 2019). The main objectives were an 80% reduction in deforestation by 2020, a boost in the number of rural property registrations in CAR, removal of Pará municipalities from the federal government priority deforestation list, decentralization of enforcement mechanisms to the municipal level, and active involvement of municipalities in the programme (CIFOR 2019). To achieve these goals, the programme focused on establishing local agreements with municipalities (a non-binding social pact to reduce deforestation rates), controlling and monitoring deforestation, and strengthening collaborative management of the environment through supporting local environmental agencies (CIFOR 2019; Sills et al. 2020).

Although the programme's priority were the listed municipalities, 124 out of 144 municipalities in the state chose to voluntarily participate in the programme, attracted by its stated advantages, including securing legalities (for example, making sure producers were protected from economic embargoes and fines), higher market value for agricultural products (through certification for avoided deforestation and ethical operating conditions), and the potential to attract investments due to enhanced legal security (CIFOR 2019). The programme targeted deforestation area and intact forest areas and stable forest

14 The Green Municipalities programme was inspired by the pioneering and successful experience of the municipality of Paragominas. In 2008 this municipality was blacklisted and had its economy severely impacted by fines, credit restriction and embargoes (Thaler et al. 2019; Viana et al. 2016). However, the mayor – supported by rural elites committed to zero deforestation – partnered with NGOs to fill the technical gap for promoting compliance to environmental regulations and sustainable agriculture practices. Paragominas achieved a significant reduction in deforestation in the next year (Brito et al. 2010) and registered 94% of its territory under the CAR system. Consequently, Paragominas was removed from the Priority Municipalities List in April 2010 (Thaler et al. 2019).

15 The last funding from the Amazon Fund for the Green Municipalities programme ended in 2022 (Pará 2023).

mosaic archetypes; the participant municipalities were therefore categorized[16] based on deforestation pressure and forest degradation level to create more targeted measures for each context.

Sills et al. (2020) found that, overall, the Green Municipalities programme did not significantly reduce deforestation beyond the impact of the federal blacklist (Priority Municipalities), except for in the large municipality of Cumaru do Norte. Importantly, the municipality of Paragominas was excluded from the analysis, due to it being the model for the programme and because it had already been 'treated' prior to the programme starting. However, the programme did have a positive effect on the economic performance of participating blacklisted municipalities, increasing their total value added. This suggests that the programme helped to offset the economic costs of complying with federal deforestation mandates, potentially making forest conservation more sustainable in the long term.

Another example of a competence and self-efficacy policy is the Indigenous **Agroforestry Agents programme** in Acre. Developed in 1996 by the NGO Comissão Pró-Indio do Acre, this programme serves as an educational initiative that integrates territorial and environmental management with food security (Bianchini and Bianchini 2007). Indigenous agroforestry agents are trained to work within their communities, combining traditional and technical knowledge in a participatory way (Bianchini and Bianchini 2007). These agents play a critical role in their communities by implementing agroforestry systems, managing natural resources sustainably, providing environmental education and conducting territorial monitoring. Recognizing their valuable contributions, the government of Acre has supported their work by guaranteeing scholarships for their remuneration since 1999 (Acre n.d.). Through REM funding, the SISA programme has awarded 176 scholarships to agroforestry agents across 32 Indigenous lands, supporting their efforts in territory protection, promoting sustainable practices and preserving traditional cultures. The Acre government also provides training opportunities and facilitates Indigenous participation in workshops and events focused on climate change (Acre n.d.). The programme targets Indigenous lands that were originally predominantly covered by intact forest area and stable forest mosaic archetypes. However, many of these areas have been increasingly subjected to deforestation pressures, which intensified during Bolsonaro's presidency from 2019 to 2022 (Silva Junior et al. 2023).

4.3 Current outlook and policy gaps

After a significant reduction in deforestation rates between 2004 and 2012, Brazil has witnessed a gradual increase in deforestation. In 2020, the deforestation rate reached the highest of the decade at 10,851 km², and 2021 saw a further 20% increase over 2020 (Silva Junior et al. 2023). This trend can be mostly attributed to environmental setbacks that began with the 2012 changes to the Brazilian Forest Code, which included amnesty for deforesters and was followed by weakened enforcement of environmental policies and a gradual reduction in the governance capacity of environmental agencies (MMA 2023; Silva Junior et al. 2023). Additionally, there was a lack of policy coherence. While the national government developed PPCDAm and implemented a policy package to reduce deforestation, it simultaneously supported the expansion of large-scale commodity agriculture and large-scale infrastructure projects, with the Belo Monte Hydroelectric Power Plant, inaugurated in 2016, being one of the most emblematic examples. These issues were exacerbated after President Bolsonaro took office in January 2019 (Silva Junior et al. 2021, 2023).

16 The categories are as follows: (i) Embargoed municipalities are on the federal government's priority list, with the main focus on controlling deforestation and advancing the CAR to be removed from the list; (ii) Under pressure municipalities face high deforestation risks due to significant deforestation rates or proximity to large infrastructure projects, with strategies aimed at preventing or reducing deforestation to avoid their inclusion on the priority list and advancing the CAR; (iii) Monitored and under control municipalities have been removed from the federal priority list; they must have 80% of their area registered in the CAR and maintain deforestation below 40 km² over the last four years; (iv) Consolidated municipalities, characterized by medium deforestation risk with less than 60% vegetation cover and lower deforestation rates, focus on CAR registration and regularizing environmental liabilities; (v) Forest base municipalities have a low deforestation risk, with more than 60% of their area covered by vegetation and low deforestation rates, where the goal is to strengthen the forest economy and prevent illegal logging and forest degradation (Municípios Verdes 2023).

The Bolsonaro administration implemented several anti-environmental measures that include discontinuation of PPCDAm IV, weakening environmental and regulatory agencies, reducing enforcement capabilities, relaxing environmental policies, disregarding climate change policies and introducing bills that facilitated land grabbing and illegal mining (Ferrante and Fearnside 2019, 2020; Silva Junior et al. 2021, 2023). In 2019, during Bolsonaro's first year in office, the number of environmental fines decreased by over 30%, while deforestation rates went up by 30% (Brant and Watanabe 2020). Additionally, the number of IBAMA's surveillance personnel was 1,300 in 2010 but dropped to only 723 for the entire country by 2023 (MMA 2023). These setbacks have profoundly impacted Indigenous communities, leading to increased mining activities and CAR registries within Indigenous lands (Silva Junior et al. 2023).

On 1 January 2023, President Lula took office and renewed Brazil's deforestation policy. Recent data from DETER show a 38% decrease in deforestation alerts in the Amazon during the first half of 2024 compared to the same period in 2023, following a 50% reduction in deforestation in 2023 relative to 2022 (MMA 2024a). This decline is largely attributed to the reimplementation of PPCDAm V (2023–2027), reinstatement of enforcement actions primarily through IBAMA, the re-establishment of the Amazon Fund, and the relaunch of programmes like Bolsa Verde. Additionally, new policies and programmes focusing on forest restoration, promoting environmental services and fostering a bioeconomy are being developed. The government also plans to invest approximately USD 145 million in deforestation prevention initiatives across 70 Brazilian cities that accounted for nearly 80% of Amazon deforestation in 2022, as part of the Union of Municipalities programme – an updated version of the Critical Municipalities programme (MMA 2024b).

Despite these recent reductions, significant challenges remain. The government continues to implement incoherent policies that undermine deforestation reduction targets and climate goals. The most recent example is the auction of 19 oil exploration blocks in the Foz do Amazonas basin region, carried out despite strong opposition from Indigenous Peoples and civil society organizations (Satie 2025).

Land clearing for speculation on undesignated lands continues to be a major driver of deforestation (Alencar et al. 2021; Azevedo-Ramos et al. 2020; Carrero et al. 2022). By 2020, alleged owners had illegally registered 18.6 million hectares of undesignated public forests as private property in the CAR system (Alencar et al. 2021). The misuse of CAR has facilitated illegal deforestation, as the system – despite not being a land regularization instrument – enables access to financial resources from banks, which indirectly support deforestation and land grabbing (Alencar et al. 2021). There is an urgent need to review and cancel illegal CAR registrations on undesignated public forests, while advancing the demarcation of Indigenous lands, quilombola (Afro-Brazilian) territories and national forests designated for sustainable use, as well as strengthening the protection of these areas.

Brazil's anti-deforestation efforts have focused on integrating environmental regularization with various incentives, both positive and negative. However, in regions with unclear land tenure, the effectiveness of environmental registries like CAR for enforcing policies is limited unless ongoing efforts address land claim uncertainties. Without resolution, these unclear tenure situations may exacerbate inequalities, power dynamics and land conflicts (Londres et al. 2021)

Another challenge lies in how easily those involved in soy, beef and timber production can bypass government regulations and commodity supply chain agreements due to shortcomings in deforestation control (Carvalho et al. 2019). To address this, Carvalho et al. (2019) recommend strengthening Brazil's environmental agencies, enhancing monitoring technologies to assess the impact of deforestation reduction programmes, improving the integration of agrarian and environmental policies and coordinating environmental enforcement at federal, state and municipal levels. They also highlight the importance of increasing transparency in supply chains, like the Green Seal initiative in Pará, and raising consumer awareness to apply market pressure on producers to prevent further deforestation.

The lack of effective policies for sustainable productive activities for smallholders and communities is another important gap. Although sustainable activities were included in all phases of the PPCDAm, they received minimal emphasis during implementation and achieved the least success, as noted in evaluations conducted with international cooperation partners (West and Fearnside 2021). Implementation agencies frequently encounter logistical, resource and institutional capacity constraints that impede the effective promotion of these activities (West and Fearnside 2021). Another significant barrier is the extremely complex and costly process required to regulate smallholders' production so they can access formal markets. To address this issue, policies need to be made more accessible to smallholders, with simplified requirements that align with local realities. States also must adapt their legislation and ensure they have the necessary personnel to implement these activities effectively (Cromberg et al. 2022).

In response to this scenario, the plan for the fifth phase of PPCDAm (2023) has a significant emphasis on activities that support the development of the bioeconomy. Other key innovations of the current national government include the release of the National Bioeconomy Strategy (Decree 12.044 of 2024) and the National Programme of Productive Forests (Decree 12.087 of 2024). These policies hold promise for increased support for sustainable economic development through technical assistance, capacity building and easier access to credit. Nevertheless, to be effective, they need to be accompanied by agrarian reform and land tenure regularization, the strengthening of state technical assistance agencies with more personnel and resources to enable access to remote areas, norms aligned with the local context, appropriate credit lines, and the provision of basic infrastructure and services in rural areas.

5 Discussion and recommendations

5.1 How Brazilian policies are targeted to diverse forest archetypes

5.1.1 Deforestation area archetypes

To combat the alarming deforestation rates that were seen until the early 2000s, Brazil implemented a coordinated set of policies through PPCDAm. As a result, deforestation rates dropped by 80% between 2004 and 2012, a decline largely attributed to PPCDAm policies, combined with declining commodity prices during that period (Arima et al. 2014; Assunção et al. 2015; Hargrave and Kis-Katos 2013; Soares Filho et al. 2010).

While PPCDAm implemented a mix of different policies, compliance and enforcement policies – particularly those targeting deforestation area archetypes – are widely acknowledged as having played a pivotal role in reducing deforestation across the LAM (Arima et al. 2014; Assunção and Rocha 2019; Börner et al. 2015; Cisneros et al. 2015; Hargrave and Kis-Katos 2013; Koch et al. 2019). These measures included expanding protected areas to serve as barriers against advancing deforestation areas (Soares et al. 2010), and conducting field-based law enforcement operations in deforestation hotspots using the DETER system for real-time monitoring (Hargrave and Kis-Katos 2013). The establishment of the Critical Municipalities programme further strengthened these efforts by combining stricter monitoring and enforcement with credit restrictions and property embargoes on blacklisted municipalities. This approach incentivized states, municipalities, land users and other stakeholders to pursue alternatives to deforestation.

Numerous rigorous impact studies have highlighted significant reductions in deforestation within the listed municipalities (Arima et al. 2014; Assunção and Rocha 2019; Chagas and Andrade 2024; Cisneros et al. 2015; Gonçalves 2022; Koch et al. 2019). Arima et al. (2014) found that rates of deforestation in priority municipalities went down by 35% in comparison with non-priority municipalities. Similarly, a counterfactual evaluation found the policy decreased anticipated forest loss during 2008–2012 by 13–36% (Cisneros et al. 2015). Notably, the reduction in deforestation did not come at the expense of agricultural production; instead, it was associated with increased cattle production and productivity (Koch et al. 2019). This suggests that deforestation-control policies in the Brazilian Amazon can incentivize ranchers to adopt technology and intensification, particularly where there are significant yield gaps. The policy also generated positive spillover effects, as neighbouring areas experienced reduced deforestation following the blacklisting of municipalities (Assunção and Rocha 2019).

Two other key policies targeting deforestation area archetypes were the Rural Environmental Registry (CAR) and Central Bank Resolution 3545. The introduction of CAR provided a transparent mechanism for assessing compliance with the Forest Code and served as a foundation for various policies. Resolution 3545 leveraged the behavioural mechanism of maximizing material payoffs by linking credit access to Forest Code compliance, as verified through CAR. Assunção et al. (2013) estimated that this resolution helped prevent 2,700 km^2 of deforestation between 2009 and 2011.

However, the impact of CAR on forest conservation remains uncertain. While it influences landholder behaviour through its integration with multiple policies, it has also been misused to make illegal claims on public lands, resulting in deforestation and increased concentration of rural land ownership (Alencar et al. 2021; Azevedo-Ramos et al. 2020; Camara et al. 2023; Londres et al. 2021; Moutinho et al. 2023).

Alongside stricter monitoring and enforcement, sectoral agreements – like those for soy and cattle – played a significant role in targeted actions within listed municipalities. By restricting the purchase of commodities like soy and cattle from recently deforested lands, they helped reduce the economic incentives driving deforestation (Gibbs et al. 2016; Heilmayr et al. 2020; Levy et al. 2023; Nepstad et al. 2014). Research shows that these agreements were most effective in decreasing deforestation when combined with government enforcement and compliance mechanisms (Gibbs et al. 2016; Heilmayr et al. 2020; Svahn and Brunner 2018). However, during the third phase of PPCDAm, as environmental regulations weakened and government forest enforcement declined, deforestation rates began to rise again, even though these value chain agreements were still in place. This suggests that supply chain initiatives alone are insufficient for reducing deforestation without strong political support and effective enforcement of environmental laws at the federal level (Muradian et al. 2025).

By concentrating enforcement efforts on critical municipalities, the national government was able to narrow the focus of its anti-deforestation initiatives, thereby enhancing the intensity and effectiveness of monitoring and law enforcement in key deforestation hotspots (Massoca and Brondízio 2022). As part of PPCDAm, the strategic placement of protected areas was also used to help curb the expansion of the deforestation area. Rigorous impact studies have demonstrated that in areas with greater pressure (near cities or roads), protected areas have higher impact (Assunção and Gandour 2018; Pfaff et al. 2015a, 2015b). Similarly, a methodical review of counterfactual studies on the heterogeneous impacts of initiatives aimed at tropical forest conservation found these initiatives achieve greater conservation outcomes in areas where forests face the highest pressure (Carrilho and Chervier 2023) This suggests that prioritizing the protection of forests most at risk should be a key focus for conservation efforts (Carrilho and Chervier 2023).

At the subnational level, the government of Pará has targeted deforestation area archetypes by addressing the Critical Municipalities list and establishing new governance arrangements that promote inter-governmental and inter-institutional collaboration. The Green Municipalities programme in Paragominas exemplifies successful hybrid governance, integrating efforts across national, state and municipal levels, as well as engaging the private sector and NGOs to reduce deforestation (Viana et al. 2016). According to Massoca and Brondízio (2022), this collaboration between government agencies and organizations enables the alignment of additional policy measures tailored to local contexts, enhancing both incentives and disincentives for local agents and municipalities to address deforestation more effectively. Other initiatives led by Pará that target deforestation area archetypes include the Green Seal platform and a recent programme to microchip and tag cattle, ensuring transparent tracking throughout the entire supply chain.

5.1.2 Intact forest area and stable forest mosaic archetypes

In our sample, national policies that predominantly target intact forest area and stable forest mosaic archetypes include protected territories and forest concessions, as well as the Bolsa Verde, Community and Family Forests, and Floresta+ programmes. At subnational level, there are subprogrammes of SISA – they focus on targeting the development of socio-biodiversity value chains in forest-dependent communities, and on promoting Indigenous agroforestry agents.

Brazil has established an extensive network of protected areas as an effective strategy to prevent deforestation in intact forest areas and stable forest mosaics (Soares-Filho et al. 2010, 2023). Beyond preventing deforestation, these protected areas are vital for preserving cultural diversity and result from long-standing collective efforts to safeguard the forest and support local livelihoods.

When PPCDAm was introduced in 2004, approximately 38% of the Amazon biome was designated as protected, with 61 million hectares classified as protected areas and 98 million hectares set aside as Indigenous lands. In the decade that followed, protected areas nearly doubled, reaching a total of 113 million hectares, at the same time as Indigenous lands reached 107 million hectares. By 2014,

more than half of the Amazon biome was under some form of protection (Assunção and Gandour 2018). Before PPCDAm, biological and ecological factors were the main considerations for establishing these areas. Under PPCDAm, however, current and future deforestation risks were also considered when determining which areas to protect (Gandour 2021).

Numerous studies have demonstrated that protected areas and Indigenous lands have been effective at reducing deforestation within their boundaries, although their regional impact varies based on factors like governance type, period and local context (Anderson et al. 2016; Assunção and Gandour 2018; Herrera et al. 2019; Pfaff et al. 2014, 2015a, 2015b). According to a recent study by MapBiomas, the most well-preserved areas in Brazil are Indigenous lands, which cover 13% of the national territory. Between 1985 and 2023, these lands lost less than 1% of their native vegetation, compared to a 28% loss on privately owned lands (Mapbiomas 2024).

In addition to protected areas, Brazil has experience implementing maximization of material payoffs policies – like conditional cash payments – in intact forest areas and stable forest mosaics, where financial incentives can promote sustainable practices. At the national level, the Bolsa Verde programme is one prominent example, while the Bolsa Floresta programme is another relevant initiative which, in multiple-use reserves in the state of Amazonas, provides direct conditional payments alongside livelihood investments (Bakkegaard and Wunder 2014; Cisneros et al. 2022). A counterfactual evaluation of Bolsa Verde found that the programme reduced deforestation in threatened areas (Wong et al. 2023). Similarly, Cisneros et al. (2022) reported that the Bolsa Floresta programme achieved small but significant additional conservation effects, with relatively larger impacts in regions facing higher deforestation pressure and with greater agricultural potential. Conditional payments have also been used as incentives in deforestation areas, like the Proambiente programme and initiatives led by NGOs funded by the Amazon Fund, including the Sustainable Settlements in the Amazon Project (Cromberg et al. 2014; Simonet et al. 2019).

Efforts to promote competence and self-efficacy policies have targeted forest landscapes through national programmes like Community and Family Forest Management, and private forest concessions. However, the community forest programme was prematurely terminated, and the implementation of forest concessions has been slow. So far, there is no evidence in the literature showing their effectiveness in curbing deforestation in LAM.

At the subnational level, the government of Acre has implemented several programmes under the System of Incentives for Environmental Services (SISA) to enhance competence through training and technical assistance, aiming to improve the value chains for socio-biodiversity products, primarily in forested archetypes. One example is the Indigenous Agroforestry Agent, which focuses specifically on managing forest landscapes within Indigenous lands, thereby contributing to both `forest conservation and food security.

While in the deforestation archetypes, compliance and obedience mechanisms targeting cattle and agriculture expansion have been predominantly adopted and combined with other policies like credit restrictions. In intact forest area and stable forest mosaic archetypes, where deforestation pressure is lower and monitoring is more costly, policies based on material incentives (e.g., Bolsa Verde) and competence/self-efficacy mechanisms (e.g., Indigenous Agroforestry Agents, community forest initiatives) have been applied in addition to protected areas. However, incentive- and capacity-based policies have often lacked adequate scale, sustained investment and continuity. Many were prematurely discontinued or unevenly implemented. Ensuring sustained funding, policy continuity and strong local ownership is therefore essential to enhancing their effectiveness – not only in intact forest area and stable forest mosaic archetypes, but also among smallholders and collective territories in deforestation areas.

Hänggli et al. (2023) also highlight the uneven distribution of studies across the Amazon biome, which are predominantly concentrated on deforestation areas. In contrast, there is a lack of research on causal relationships between deforestation drivers and policy impacts in the central Amazon, for instance, where intact forest area and stable forest mosaic archetypes prevail. Although activities like mining, small-scale agriculture, infrastructure development, logging and fires may exert comparatively less pressure on forests than large-scale agricultural expansion, they remain insufficiently studied in the current literature (Hänggli et al. 2023).

5.2 Usefulness of the approach and recommendations

Given the vast size of the Brazilian Amazon, the heterogeneity of contexts and the diversity of policies applied at different scales, formally categorized spatio-temporal archetypes could potentially provide a more nuanced contextual analysis and better inform policy decisions for conservation and sustainable development. However, in the case of Brazil, a categorization based on tenure could be a useful addition to link these archetypes with relevant policies. Initially, maps should be created to assign each policy measure to a specific land tenure category, providing a spatial representation. These maps can then be overlaid with archetype maps to assess how policies are distributed. Although these analyses were initially planned, it was not possible during the current project due to limited funding.

Due to the absence of such maps, for this study, we conducted an interpretative assessment based on policy descriptions and available literature to assign each policy to its corresponding archetype. However, this analysis has its limitations. Combining tenure data with the archetype analysis would enable a more comprehensive observation of how deforestation dynamics and responses to policies vary across different contexts like settlements, protected areas, Indigenous lands, private land (small, medium and large properties), and public undesignated lands. As a second step we suggest carrying out spatial correlation analysis of selected past Brazilian policies, their dominating mechanisms and these combined archetypes (land use and tenure), to verify if there has been a tendency to place some programmes in certain archetypical sites.

To address the complexity and diversity of the Amazon region, Brazil has implemented overarching umbrella policies like PPCDAm, which integrate a range of approaches. These broader strategies are typically overseen by interministerial groups or multistakeholder forums. However, initiatives of this scale do not fit neatly within a single classification framework. For this exercise, we did not classify PPCDAm itself but rather its main policies. Similarly, jurisdictional initiatives and certain Brazilian policies encompass multiple mechanisms, making it challenging to categorize them under a single dominant attribute. This highlights the need for ongoing refinement of both the categories and methods used for classification.

The framework may be useful for building a database for analysing which policies were applied at each context, its main characteristics (actor target and mechanism) and links to counterfactual research on main results. However, it is important when using the framework to not analyse the policies in isolation; policies normally act synergistically and form a policy package. For example, when examined individually, CAR did not show a significant impact on reducing deforestation. However, CAR is crucial for ensuring compliance with the Forest Code and accessing other policy benefits. L'Roe et al. (2016) demonstrated that CAR was more effective in reducing deforestation when implemented alongside a land titling programme, where obtaining the title was contingent on compliance with environmental regulations. Similarly, in Brazil, the Amazon Soy Moratorium effectively curbed deforestation, but only when this was established in conjunction with CAR and forest monitoring (Heilmayr et al. 2020).

In this study, we considered a sample of broader anti-deforestation initiatives led by the government at the national and jurisdictional levels. However, there are many important initiatives emerging from collective action in different parts of the Amazon that create well-tailored responses to the local

context (Brondízio et al. 2021). The AGENT project (Amazonian Governance to Enable Transformation to Sustainability)[17] is currently mapping these initiatives and it could be very useful to use this policy typology and archetype analysis to categorize these initiatives. To govern a complex and heterogeneous region like the Amazon, it is important to identify and promote multiple levels of governance.

We recommend that future efforts to refine the diagnostic tool focus on integrating archetype analysis with a tenure typology to enable spatial correlation of policies with tenure situations and forest archetypes. Combined with an increased number of context-dependent policy impact studies on Legal Amazon (LAM) policies, this approach could become a valuable tool to enhance analysis and inform more effective policy decisions for forest conservation and sustainable development in the region.

17 https://agents.casel.indiana.edu/index.html

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Annexes

Table A1. Description of follow up land-use categories to describe the deforestation areas

Follow-up land use	Description
Tree plantation	Tree plantations, mainly oil palm and rubber
Forest regrowth	Tree cover regrowth (visible for at least 3 years) after full removal of tree cover that has remained for at least 2.5 years without trees growing back.
Water	Permanent and seasonal water
Cropland	Land covered with annual cropland that is sowed/planted and harvestable at least once within the 12 months after the sowing/planting date. The annual cropland produces an herbaceous cover and is sometimes combined with some tree or woody vegetation. Note that perennial woody crops will be classified as the appropriate tree cover or shrub land cover type.
Grassland	This class includes any geographic area dominated by natural herbaceous plants (plants without persistent aboveground stem or shoots and lacking definite firm structure) – like grasslands, prairies, steppes, savannahs and pastures – with a cover of 10% or more, irrespective of different human and/or animal activities – like grazing and selective fire management. Woody plants (trees and/or shrubs) can be present assuming their cover is less than 10%. Areas classed as grassland may also contain uncultivated cropland areas (without harvest or having periods of bare soil) in the reference year.
Urban/ built-up	Land covered by buildings, roads and other man-made structures like railroads. Buildings include both residential and industrial. Urban green areas (like parks and sport facilities) are not included in this class. Waste dump deposits and extraction sites are considered under the classification 'bare'.
Shrubland	This class includes any geographic area dominated by natural shrubs having a cover of 10% or more. Shrubs are defined as woody perennial plants with persistent and woody stems and without any defined main stem being less than 5 m tall. Trees can be present in scattered form if their cover is less than 10%. Herbaceous plants can also be present at any density. Shrub foliage can be either evergreen or deciduous.
Other / no data	Other land uses (e.g., bare, wetlands)

Table A2. Description of forest policies considered in deforestation diagnostics

Policy name	Description
Payments for ecosystem services (PES)	"Voluntary transactions between service users and service providers that are conditional on agreed rules of natural resource management for generating offsite services" (Wunder 2015). Encompasses both user- and government-financed PES.
Conservation ecotourism	"Ecotourism is a specific kind of tourism, distinguished from nature tourism and outdoor recreation by its conservation and development goals. Tourism, when designed and practiced as ecotourism, can benefit wildlife and biodiversity, create incentives to protect landscapes, and support local communities" (Stronza et al. 2019).
Certification schemes	Programmes that "accredit goods and services that have met defined process standards meant to protect the environment and social welfare in the places of origin" (Lambin et al. 2014). Generally associated with either a premium price or a preferred market access incentive. These schemes include private schemes like sustainable palm oil certification by the Roundtable for Sustainable Palm Oil (RSPO) or sustainable timber certified by the Forest Stewardship Council (FSC).
Conservation easements	"A negotiated, legally binding agreement between individuals who own property and a second-party organization (e.g., state agency or nongovernmental organization like a land trust). A conservation easement restricts specific activities on the property in order to meet the owner's goals and the organization's conservation objectives." (Farmer et al. 2011)
Avoid infrastructure development	Avoiding the construction of new road infrastructure or favouring the closing of existing roads to avoid deforestation or impact on biodiversity-rich areas (Angelsen 2010)
Integrated Conservation and Development Programmes (ICDPs)	"Initiatives that aim to manage and conserve natural resources including biodiversity with socioeconomic development components or goals" (Brandon and Wells 1992). Some have understood this as conservation approaches that include the use of socio-economic investment tools to achieve conservation objectives" (Minang and van Noordwijk 2013).
Conditional cash transfers	Transfer of income to poor households that is conditional on taking specific actions, usually related to education and health. "Conditional cash transfers aim to enhance human capital and thereby reduce the intergenerational transfer of poverty." (Ferraro and Simorangkir 2020)
Offsets/cap and trade	"Compensating for losses of biodiversity components at an impact site by generating (or attempting to generate) ecologically equivalent gains, or 'credits', elsewhere (i.e., an offset site). Offsets can be achieved in two main ways: (1) via averted loss from ongoing or anticipated impacts (e.g., avoided deforestation or degradation) at a site through the removal of threatening processes; and (2) by enhancement of a degraded site through restoration and rehabilitation ('restoration offsets')" (Maron et al. 2012). The Environmental Reserve Quotas (CRA) was conceived as an offset mechanism (Soares-Filho et al. 2016).
Government moratoria	Government measure aimed at imposing limitations on land-based development activities by enacting a temporary suspension of new land-related rights by public authorities. A prominent example is Indonesia's moratorium on new oil palm, timber and logging concessions (Busch et al. 2015).
Protected areas	"A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley 2008). "The term embraces a wide range of different management approaches, from highly protected sites where few if any people are allowed to enter, through parks where the emphasis is on conservation but visitors are welcome, to much less restrictive approaches where conservation is integrated into the traditional (and sometimes not so traditional) human lifestyles or even takes place alongside limited sustainable resource extraction. Some protected areas ban activities like food collecting, hunting or extraction of natural resources while for others it is an accepted and even a necessary part of management" (Dudley 2008).

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Table A2. Continued

Policy name	Description
Land-use zoning	"Land use zoning results from a spatial planning process that divides a territory into zones with different rules and regulations for land use, management practices, and land cover change. In and of itself, zoning does not promote sustainability but supports legal land use regulations for different units of a landscape" (Lambin et al. 2014). It includes setting the boundaries for forest estate.
Environmental education	"Encompasses approaches, tools, and programs that develop and support environmentally related attitudes, values, awareness, knowledge, and skills that prepare people to take informed action on behalf of the environment" (Ardoin et al. 2020). This targets numerous groups, including those that may be marginalized.
Conservation concessions	"Comprise public land of which the access, management and exclusion rights are granted to non-government actors for conservation purposes, typically for a specific period of time" (Schleicher 2018). Conservation concessions are generally associated with the prospect of direct payments made to keep the forest intact.
Tenure recognition	Policies that promote recognition of tenure rights. Recognition, in this context, implies a legal process aimed at formalizing, through law or de jure process, rights that are already being held through customary, informal or de facto mechanisms (Fitzpatrick 2005).
Community forest management	Forest management approaches where governance is devolved to local community groups or institutions, to varying degrees (Bowler et al. 2012).
Logging concessions	Scheme through which the state "gives a company the exclusive right to exploit timber resources over clearly-defined boundaries in its private domain for a specified period. In return, concessionaires must meet several requirements in terms of taxation or provision of public goods" (Lescuyer et al. 2012).
Family planning programmes	Interventions that promote the use of family planning in order to lower fertility rates (Sellers 2017).
Ecological fiscal transfers (EFT)	A scheme that "transfer[s] public revenue between governments within a country based on ecological indicators. Here, 'ecological' refers to ecological public functions of governments, which encompass both nature conservation and abatement of environmental pollution. EFT may transfer revenue 'vertically' from higher-level to lower-level governments or 'horizontally' between governments at the same level. EFT may be 'general-purpose' transfers to subnational government budgets that can be spent on any priority of recipient jurisdictions, whether ecological or non-ecological. Or they may be 'specific-purpose' transfers earmarked for a particular ecological use, for example, reforestation or water treatment" (Busch et al. 2021).
Conditional debt relief	"Debt to foreign countries and to international banks may encourage forest loss. Debt-for-nature swaps try to address this by reducing international debt, typically in exchange for establishing a conservation trust fund within the debtor nation" (Pfaff et al. 2013).
Conditional loan or oversee development aid	Conditional loans attach specific reforms – improved law enforcement, expanded parks areas, economic policy changes – to lending from governments and multilateral financial institutions (Pfaff et al. 2013).
Political decentralization	"Any political act in which a central government formally cedes powers to actors and institutions at lower levels in a political-administrative and territorial hierarchy" (Ribot et al. 2006). "Political decentralization involves the transfer of power to actors or institutions that are accountable to the population in their jurisdiction" (Ribot et al. 2006).

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Table A2. Continued

Policy name	Description
Anti-corruption policies	Policy reforms aimed at influencing the benefits and costs of corruption that are linked to the use of forests. In particular, policies that reduce opportunities to generate excessive private rents through bribes, and those that increase penalties and/or the likelihood of being discovered and punished (by increasing accountability and transparency) (Tacconi et al. 2009). In Brazil, exposing corrupt politicians by making financial results publicly available reduced their re-election chances (Ferraz and Finan 2008). Such policy reforms often need to take place outside the forest sector to regulate how political parties are financed, regulating lobbying, judicial reform, the establishment of anti-corruption commissions and free media (Tacconi et al. 2009).
Procurement policies	The criteria governments set for their purchases of forest-risk products (Brack 2013). One example is the EU Renewable Energy Directive (EU RED), according to which all biofuels used in the EU must comply with sustainability criteria (Walker et al. 2013).
Due diligence requirements on industry	"Requirements on industry, requiring companies to put in place procedures to minimize the chance of them handling illegal products, as in the EU Timber Regulation and the Australian Illegal Logging Prohibition Act" (Brack 2013).
Public disclosure initiatives	Initiatives, which involve public and/or private attempts to increase the availability of information on behaviours harmful to the environment (Tietenberg 1998). "Disclosure initiatives have been instituted by civil society, often with the backing of financial institutions (banks, pension funds, asset managers, insurance companies and foundations), to emphasise the importance of full information and disclosure throughout the supply chains" (Walker et al. 2013) and by governments (Cisneros et al. 2015).
Consumer/ social media campaigns/ boycotts	Marketing strategies aimed at changing consumption behaviours (i.e., reducing the consumption of deforestation-risk products, or increasing the consumption of forest-friendly products) by increasing consumers' awareness about environmental sustainability and informing them about the benefits and risks of products and services (Dangelico and Vocalelli 2017). This can lead to boycotts, i.e., an organization calling on consumers to avoid purchasing a particular product or brand (Walker et al. 2013).
Extension programmes to curb demand for timber products	Programmes aimed at enhancing the adoption of technologies and practices that reduce demand for timber, like cookstoves (Chan et al. 2015), or increase the supply of non-forest timber, like agroforestry (Minang et al. 2014).
Blended finance initiatives	A model that strategically directs public finance to de-risk and mobilize private or other sources of finance for sustainable development, concessional finance and green bonds. Such initiatives are tools that can be used to access the private capital needed to fund more sustainable agricultural practices (United Nations, Inter- agency Task Force on Financing for Development 2022).
Monitoring tools	Satellite-based system for real-time detection of deforestation. These free deforestation alerts reduce the cost to policymakers of monitoring forests, thereby reducing the cost of implementing deforestation policies (Moffette et al. 2021). The act of monitoring can encourage compliance with laws (Rasmussen and Jepsen 2018). It is therefore a key tool to support law enforcement activities in the Brazilian Amazon (Assunção et al. 2017).
Bilateral agreements	"Bilateral agreements between consumer and producer countries to establish licensing systems designed to ensure that only legal products enter trade between the two, and improve forest governance in the producer country, such as the voluntary partnership agreements currently being negotiated and implemented under the EU Forest Law Enforcement, Governance and Trade (FLEGT) initiative" (Brack 2013). Such a programme "is intended to reinforce producer-country government reforms that aim to improve forest governance" (Pfaff et al. 2013).

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Table A2. Continued

Policy name	Description
Multistakeholder forums	"Purposefully organized interactive processes that bring together stakeholders to participate in dialogue, decision-making and/or implementation regarding actions seeking to address a problem they hold in common or to achieve a goal for their common benefit" (Sarmiento Barletti et al. 2020).
Tax relief and environmental subsidies	Environmental subsidies are economic transfers by a legislator with the aim of reducing the costs of activities which contribute to protecting the environment or reducing the use and extraction of natural resources (European Union 2015). Tax relief are "arrangements and provisions in general tax schemes, with the explicit aim of providing positive financial incentives steering the taxpayers' behaviour in a more biodiversity-friendly direction" (Ring and Schröter-Schlaack 2011). "Usually applies reduced rates or exemptions conditional on certain 'biodiversity-friendly' requirements that the taxpayer should fulfil" (Ring and Schröter-Schlaack 2011).
Environmental tax, user fees and reduced subsidies	Tax levied on an agent causing an environmental externality (environmental damage) as an incentive to avert or mitigate such damage (Hansen and Lund 2018). This also includes tariffs, i.e., a tax to be paid on a particular class of imports or exports. In this category we also include both user fees (economic mechanisms which secure revenues from users of biodiversity and ecosystem services) and the reduction of subsidies (for agriculture in particular).
Conditional access to credit	Policy that makes the concession of rural credit conditional upon proof of compliance with legal requirements that contribute to protecting the environment. A prominent example is Resolution 3545 published by the Brazilian Central Bank in 2008 (Assunção et al. 2020).
Moratoria/ standards associated with market exclusion	"Moratoria are agreements, brokered by civil society, whereby a significant proportion of an industry agrees to avoid purchasing products arising from a particular area or from deforestation in a specific area" (Walker et al. 2013). "The soy moratorium in Brazil took shape shortly after an NGO report linking illegal deforestation to soy fed to chickens sold in major fast food chains" (Lambin et al. 2014).

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CIFOR-ICRAF Working Papers **contain preliminary or advanced research results on important tropical forest issues that need to be published in a timely manner to inform and promote discussion. This content has been internally reviewed but has not undergone external peer review.**

This report is part of a wider inquiry into the intertwined challenges of climate change, deforestation and policy design, where global environmental goals depend on highly local realities. Forest loss remains a major driver of emissions, but its causes and trajectories vary widely across regions, shaped by governance systems, economic pressures and social dynamics. Moving beyond generic prescriptions, this study adopts a context-sensitive perspective that asks not only what policies exist, but how and where they are likely to be effective. In Brazil, home to the largest share of the Amazon rainforest, deforestation has followed a striking trajectory—marked by rapid expansion, periods of strong decline, and more recent fluctuations—reflecting shifts in political priorities, enforcement capacity and market conditions. This variability makes Brazil a critical case for understanding how policy mixes perform over time and across changing contexts. The report applies a diagnostic framework that connects spatial patterns (archetypes) of forest change with the behavioural mechanisms that policies seek to influence, from strict enforcement and monitoring to incentives and supply chain pressures. By examining how these instruments interact with different deforestation contexts, it highlights why similar approaches can succeed or fail depending on where they are applied. Brazil's experience underscores both the power of coordinated policy action and the variation in outcomes over time, offering important lessons for designing more resilient and adaptive strategies to curb deforestation.

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