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## **Brazil's conservation reform and the reduction of deforestation in Amazonia**

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## **Brazil's conservation reform and the reduction of deforestation in Amazonia**

### **ABSTRACT**

The *Action Plan for the Prevention and Control of Deforestation in the Legal Amazon* (PPCDAm), launched in 2004, promoted a drastic conservation reform in Brazil. To date, the plan has been through four distinct phases: PPCDAm-I (2004–2008), II (2009–2011), III (2012–2015), and IV (2016–2020). A substantial decline from historically high deforestation rates in the Amazon occurred from 2004 to 2012, part of which (particularly after 2007) can be attributed to the PPCDAm, and part to economic factors such as commodity prices and the currency exchange rates that affect the profitability of agricultural exports. After 2012 deforestation has trended upward despite control efforts. The PPCDAm evolved through distinct phases, and deforestation patterns have also changed in the region. Here, we review the conservation instruments and strategies promoted under the PPCDAm umbrella and, whenever possible, provide estimates of their impacts on deforestation based on rigorous, counterfactual-based evaluations. While the literature emphasizes some of the most famous PPCDAm actions (e.g., improved satellite-based monitoring, the “blacklist” of municipalities, expansion of protected areas, land tenure regularization, credit access restrictions, and the moratoria), we call attention to a number of other PPCDAm activities that, along with the previous examples, are arguably also responsible for some share of the reduction of deforestation in Amazonia.

*Keywords:* PPCDAm; land-use change; governance; tropical forest conservation; Amazon

### **Introduction**

Brazil's Amazonian deforestation declined by  $\approx 80\%$  between 2004 and 2012, followed by an upward trend (Figure 1). Informing future deforestation-control measures requires understanding the role of the *Action Plan for the Prevention and Control of Deforestation in the Legal Amazon* (PPCDAm, the Portuguese-language acronym<sup>1</sup>), in the initial decline and subsequent surge in forest loss. However, the PPCDAm, launched in 2004, is a complex and still ongoing plan, currently in its fourth phase (2016–2020). It resulted from an inter-ministerial working group established by the federal government (Decree of July 3, 2003) with the objective of mitigating the rising trend of rainforest loss in the region in a coherent, integrated, and effective manner. In particular, the plan was a direct response to the June 2003 report from Brazil's *National Institute for Space Research* (INPE) indicating an increase of  $\approx 40\%$  in deforestation between July 2001 and August 2002 (Brazil, 2004). The plan was unique in the sense that it involved the collaboration of dozens of ministries and it was coordinated by the *Civil House of the Presidency* until March 2013, when coordination was transferred to the Ministry of Environment (Decree 7957). It has evolved significantly since its creation in response to changes in deforestation patterns, which can be (at least partially) attributed to the plan itself due to the promotion of a series of land planning activities, new forest-monitoring and law-enforcement systems, and sustainable development programs (Arima et al., 2014;

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<sup>1</sup> We adopted Brazilian acronyms throughout the text to refer to the initiatives promoted by the PPCDAm.

Assunção et al., 2015; Azevedo et al., 2017; Börner et al., 2015; Cisneros et al., 2015). While many have studied individual components of the plan, the literature still lacks a comprehensive review of the PPCDAm. Hence, the objective of this review is to fill this gap by examining the plan's four phases, emphasizing PPCDAm's evolution and achievements. We primarily summarize information from official government reports (over 1200 pages written in the Portuguese language, and only understood by a limited number of non-Brazilian researchers). We complement this review with findings from the peer-reviewed literature. While this study does not estimate the PPCDAm's impact on avoided deforestation, it discusses how the effectiveness of the plan has varied over time and argues that similar conservation reforms must be given high priority in efforts to stem the loss of tropical rainforests.

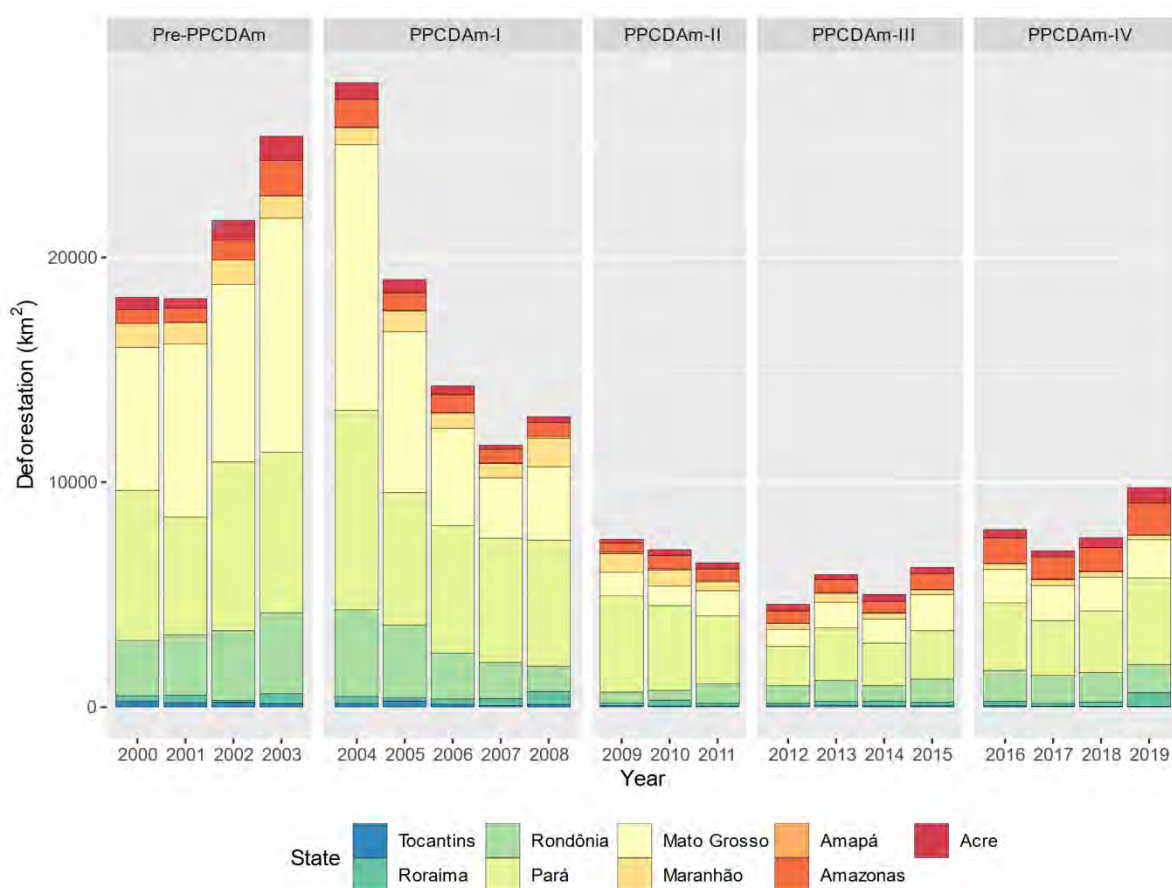


Figure 1. Brazilian Legal Amazon deforestation pre-PPCDAm and during PPCDAm-I, II, and III (INPE, 2020).

## 2. Evolution of Brazil's conservation reform in Amazonia

### 2.1 Pre-PPCDAm period (pre-2004)

Brazil's "Legal Amazon" (*Amazônia Legal*) region was defined in 1953 based on political criteria, with roughly 25% of its area originally occupied by *Cerrado* and other non-forest vegetation. In 2004, the *Brazilian Institute for Geography and Statistics* (IBGE) divided the country into six biomes on the basis of the predominant original vegetation. For Amazonia,

different government policies, laws, and statistics vary as to which definition of the region is used. The “Amazon biome” (*bioma Amazônia*) is contained entirely within the “Legal Amazon” except for a tiny area in the state of Maranhão. We use the terms “Brazilian Amazonia” or “Brazilian Amazon” when the distinction between the two is not important.

In the pre-2004 period, private land covered 24% of Brazil’s Legal Amazon region, protected areas and indigenous territories 29%, and another 47% was federal land (much of it “vacant,” or not assigned to any particular use, making it open to invasion in practice). Non-conformance with environmental regulations (e.g., the *Brazilian Forest Code* [Law 4771 of 1965], the *National Environmental Policy* [Law 6938 of 1981], and the *Environmental Crimes Law* [9605 of 1998]), was widespread during this period (pre-PPCDAm). Deforested areas in the region totaled about 680,000 km<sup>2</sup> ( $\approx$ 19% of the original forest area) by the time PPCDAm was launched in 2004 (Souza et al., 2013), out of which 25% was estimated to be abandoned or underused (Brazil, 2009). Grazing activities were responsible for  $\approx$ 80% of the Amazonian deforestation (Tyukavina et al., 2017), mainly associated with large- and medium-sized private landholdings (Godar et al., 2012). Soy plantations were expanding much more rapidly than other crops: 57% increase from 1999 to 2001 in contrast to 11% and 2% declines in rice and corn areas (Brazil, 2004). Deforestation was often associated with illegal land grabbing, unrestrained by a fragile land tenure system (Fearnside, 2005). Moreover, the opening of clandestine roads by illegal loggers in forests close to agricultural frontiers facilitated the encroachment of land grabbers, who clear forests in the pursuit of tenure (Busch and Ferretti-Gallon, 2017). The deforestation pattern prior to (but also during) the PPCDAm was also strongly correlated with the presence of infrastructure, e.g., nearly 95% of all deforestation occurred within 5.5 km of roads (Barber et al., 2014), and 82% was concentrated in three states: Mato Grosso (37%); Pará (31%), and; Rondônia (14%).

Since the 1970s, the Amazon region has been a priority target for colonization programs and the establishment of rural settlements (Caviglia-Harris and Harris, 2011; Yanai et al., 2017). Nevertheless, even though the government facilitated land access, most colonization projects lacked the infrastructure and local government support necessary to promote family agriculture (Fearnside, 2001). Poor conditions have historically driven many farmers to sell their lots and leave settlements in search of off-farm opportunities or new colonization programs. Often, these lots were (and still are) informally acquired by local merchants, loggers, or larger farmers, resulting in a process of land re-concentration, in contrast to the agrarian reform goals (Carrero and Fearnside, 2011). An average of 21,737 km<sup>2</sup> was lost every year from 2001 to 2003. Settlements, along with federal lands, had the highest rates of forest loss during that period (5579 and 6997 km<sup>2</sup> year<sup>-1</sup>, respectively) compared to indigenous lands (752 km<sup>2</sup> year<sup>-1</sup>) and protected areas (1749 km<sup>2</sup> year<sup>-1</sup>). On average, protected areas experienced 2.3% less deforestation during 2000–2004 when compared to non-protected areas with similar characteristics (Pfaff et al., 2015).

Many factors were identified by the government as responsible for the historically widespread illegal deforestation in the Amazon. Among them, the lack of timely detection of deforestation to assist on-the-ground law enforcement, lack of collaboration among federal, state, and municipal environmental agencies, inefficient use of previously deforested lands and forest resources, inefficient mechanisms to issue (legal) deforestation permits and to identify

compulsory conservation areas within private landholdings<sup>2</sup> (i.e., *Legal Reserves* and *Permanent-Protection Areas*), and lack of an effective land-tenure system (Brazil, 2004).

## 2.2 PPCDAm-I (2004-2008)

The first phase of PPCDAm was launched on March 15, 2004, prioritizing four thematic axes: (1) land planning, with a focus on land policy, expansion of the network of protected areas, and “homologation” (official recognition confirmed by a higher authority, in this case the President of the Republic) of indigenous lands; (2) monitoring and control, assisted by near real-time satellite-based detection of deforestation, environmental licensing and fining, and on-the-ground enforcement of the law; (3) promotion of sustainable land-use activities supported by rural credit policies, extension agencies, and scientific research, and; (4) sustainable infrastructure development<sup>3</sup>, with a focus on the transport and energy sectors (Brazil, 2013a, 2004). The activities promoted by PPCDAm-I primarily targeted the “Arc of Deforestation” region, and especially the area along the BR-163 highway connecting Santarém (Pará state) to Cuiabá (Mato Grosso state). The total PPCDAm-I budget was BRL 394 million (Table 1), with the majority of the funds (62%) allocated to land planning activities, followed by deforestation monitoring and control actions (21%), and the promotion of sustainable activities (17%; Brazil, 2004).

Table 1. PPCDAm-planned budget for phases I, II, III, and IV (BRL million).

PPCDAm Axis	PPCDAm-I	PPCDAm-II	PPCDAm-III	PPCDAm-IV
Land planning	224	338	213	–
Monitoring and control	83	454	425	–
Sustainable development	67	459	790	–
Total	394	1224	1428	–

Among the land planning achievements of PPCDAm-I (Axis 1) was the creation of 50 million ha of protected areas as part of the *Protected Areas Program* (ARPA) that had been established by Decree 4326 of 2002, mainly located along deforestation frontiers, the “homologation” of 10 million ha of indigenous territories, and declaring invalid ≈60,000 illegal land titles (Brazil, 2009). Also important was Mato Grosso’s State Law 343 of 2008, which established a land-tenure and environmental regularization program for rural landholdings in the state, the *Mato Grosso Legal*. The program influenced a similar initiative launched in the state of Pará in the same year (State Decree 1148 of 2008), establishing what would later result in the national *Rural Environmental Registry* (CAR) system, a spatially-explicit database for registering (legally and illegally) cleared areas in each landholding and determining forest

<sup>2</sup> According the 1965 Brazilian Forest Code as modified in 1996 (MP 1511, and subsequent provisional measures; see Gonçalves, 2018), 20% of the area of a private rural property in the Amazon biome can be legally deforestation; this threshold is increased to 65% for properties in the *Cerrado* biome. The 2012 Forest Code (Law 12,651 of 2012) maintains these percentages.

<sup>3</sup> The fourth thematic axis was removed from the original plan only one year after PPCDAm-I was launched, and integrated into the *Sustainable Amazon Plan* (Brazil, 2009).

restoration requirements (Roitman et al., 2018). A recent study reported that deforestation inside registered landholdings declined significantly during 2009–2011 (Azevedo et al., 2017).

As part of PPCDAm-I's monitoring efforts (Axis 2), the development of INPE's DETER product for near real-time detection of deforestation, based primarily on MODIS satellite imagery (6.25-ha resolution), enabled effective on-the-ground law enforcement in priority areas conducted with the participation of the army and the federal police (Diniz et al., 2015). These operations resulted in the seizure of illegal logs and heavy machinery used for deforestation, application of environmental fines and detention of  $\approx 600$  officials from environmental agencies involved in criminal activities (Brazil, 2009). In addition, INPE launched DEGRAD in 2007, a monitoring system for forest degradation detection (i.e., where forest cover was not completely removed), based on Landsat and CBERS satellite imagery and a Minimum Mapping Unit of 6.25 ha (Diniz et al., 2015).

The actions taken during PPCDAm-I were followed by significant declines in deforestation rates, from a peak of 27,772 km<sup>2</sup> in 2004 to 12,911 km<sup>2</sup> in 2008 (−53%) according to Brazil's official deforestation data from INPE's PRODES program for the annual mapping of Amazonian forest loss (which adopts a 6.25-ha Minimum Mapping Unit, mostly based on Landsat satellite imagery; Figure 1). An estimated 57,862 km<sup>2</sup> of the forest was lost during 2005–2008 (14,466 km<sup>2</sup> year<sup>−1</sup>), representing an average annual reduction of 22% compared to the historical 1988–2004 period. Between the 2001–2003 period and 2008, deforestation rates decreased by 42% in indigenous lands (−318 km<sup>2</sup>), 49% in rural settlements (−2723 km<sup>2</sup>), 57% in federal lands (−4015 km<sup>2</sup>), and 49% in protected areas (−861 km<sup>2</sup>; Figure 2). Despite these declines, protected areas experienced only 1.5–2% less deforestation than non-protected areas with similar characteristics during PPCDAm-I (Pfaff et al., 2015). Approximately 85% of the Amazonian deforestation remained located in the states of Pará (37%), Mato Grosso (34%), and Rondônia (14%). Still, despite overall declines, PRODES data identified an 11% increase in forest loss between 2007 and 2008 (from 11,633 to 12,911 km<sup>2</sup>), mostly driven by large- and medium-sized cattle ranches (Brazil, 2009). Grazing activities remained as the main driver of deforestation in the Amazon during PPCDAm-I (Tyukavina et al., 2017).

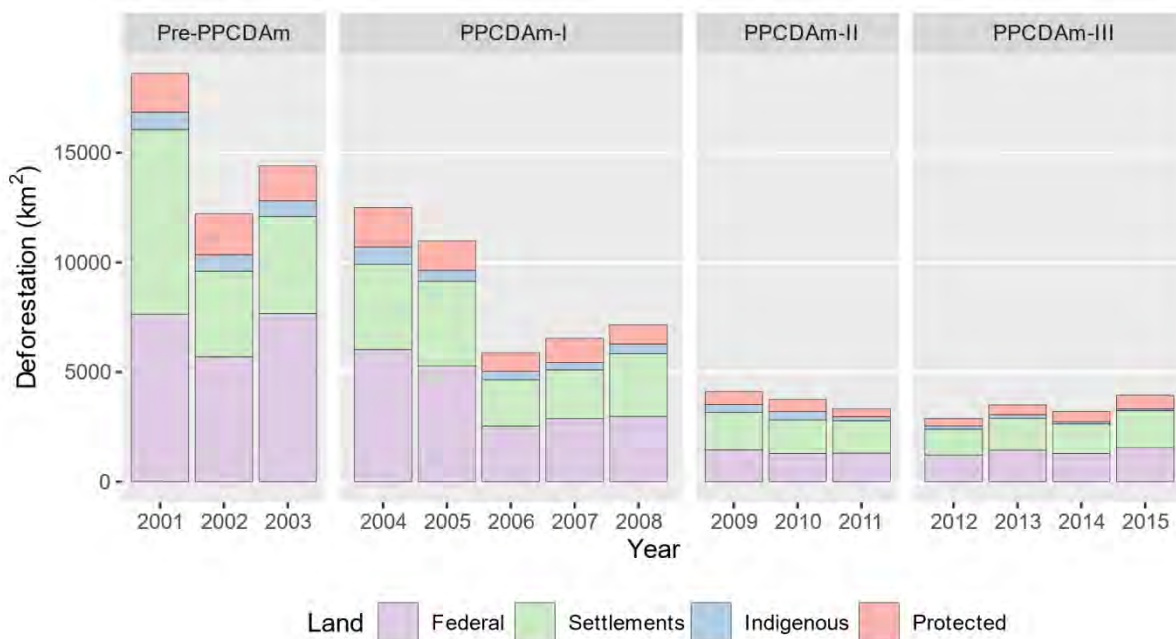


Figure 2. Location of the Brazilian Legal Amazon deforestation pre-PPCDAm and during PPCDAm-I, II, and III (INPE, 2020).

According to PRODES data, large deforestation patches (>100 ha) decreased substantially after 2004 (Figure 3). Large patches represented 50% of the total 2001–2003 deforestation, but only 21% by the end of PPCDAm-I. Large patches were replaced by “small” ones (<25 ha). The latter contribution to total deforestation increased from 26% (2001–2003 average) to 50% in 2008. We note that the “small” patch class includes both the activity of “small farmers” (traditionally defined in Brazilian Amazonia as having  $\leq 100$  ha of land) and larger actors, since clearing 25 ha in a single year is not within the capability of small farmers. These findings led to suggestions that agents of deforestation had adapted to DETER’s 25-ha Minimum Mapping Unit, leading to a new pattern of LUCC in the region (Kalamandeen et al., 2018; Rosa et al., 2012).

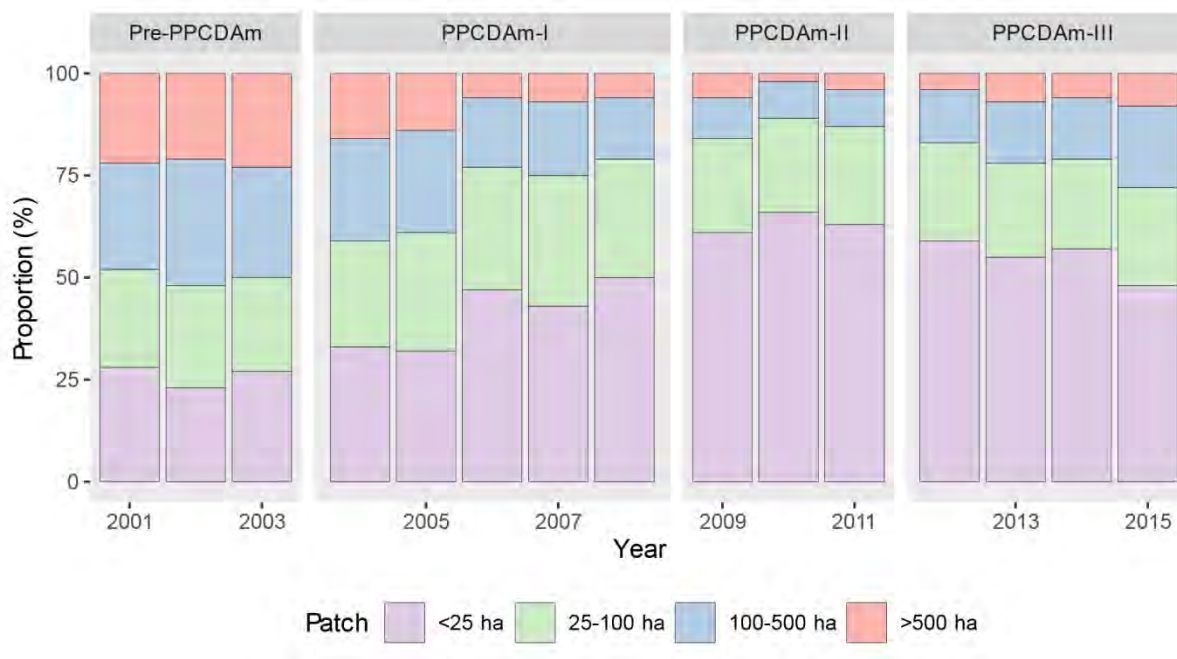


Figure 3. Size change in deforestation patches in the Brazilian Legal Amazon pre-PPCDAm and during PPCDAm-I, II, and III (INPE, 2020).

In response to apparently rising trends of forest loss between 2007 and 2008, in January of 2008, the government announced a “blacklist” of 36 municipalities (43 after March 2008) that together represented 46% of all Amazonian deforestation (Decree 6321 of 2007). The blacklisting criteria were based on (i) cumulative area of forest loss, (ii) area of forest loss in the last three years, and (iii) increases in deforestation rates in at least three of the last five years (Brazil, 2009). Blacklisted municipalities were subjected to more intense environmental surveillance, restrictions on the issuance of deforestation permits, embargo of illegally cleared areas, and limited access to credit and markets (Fearnside, 2017). According to the rules set by the Ministry of Environment (Ordinance 103 of 2009), in order to be removed from the next year’s list, blacklisted municipalities needed to (i) have at least 80% of their lots in the CAR system, (ii) deforestation  $\leq 40$  km<sup>2</sup> in 2008, and (iii) an average 2007–2008 deforestation  $< 60\%$  of the 2004–2006 average (Brazil, 2009). Evidence suggests that the blacklist policy was effective in stemming forest loss in the region (Arima et al., 2014). PRODES estimates showed deforestation rates in blacklisted municipalities declining from 5310 km<sup>2</sup> in 2007 to 4902 km<sup>2</sup> in 2008. This trend was confirmed by a counterfactual evaluation that found the policy to have reduced the expected 2008–2012 forest loss by 13–36% (Cisneros et al., 2015).

In addition to the blacklist, Decree 6514 of 2008, which altered the *Environmental Crimes Law* (Law 9605 of 1998), established new legal grounds for effective application and determination of environmental infractions and related administrative sanctions, while Resolution 3545 of 2008 of the *Brazilian Central Bank* and the *National Monetary Council* restricted credit access from public banks to rural landowners in non-conformance with environmental and land regulations (e.g., CAR registration). In that regard, three-fourths of the rural credit in Amazonia was concentrated in the states responsible for most of the deforestation in the region: Mato Grosso, Pará, and Rondônia (Figure 4). Despite the increase in credit

distributed across Amazonian states after 2008 (Figure 4), the credit policy reportedly reduced credit access for large and medium ranches and had a significant effect in lowering deforestation (Assunção et al., 2020).

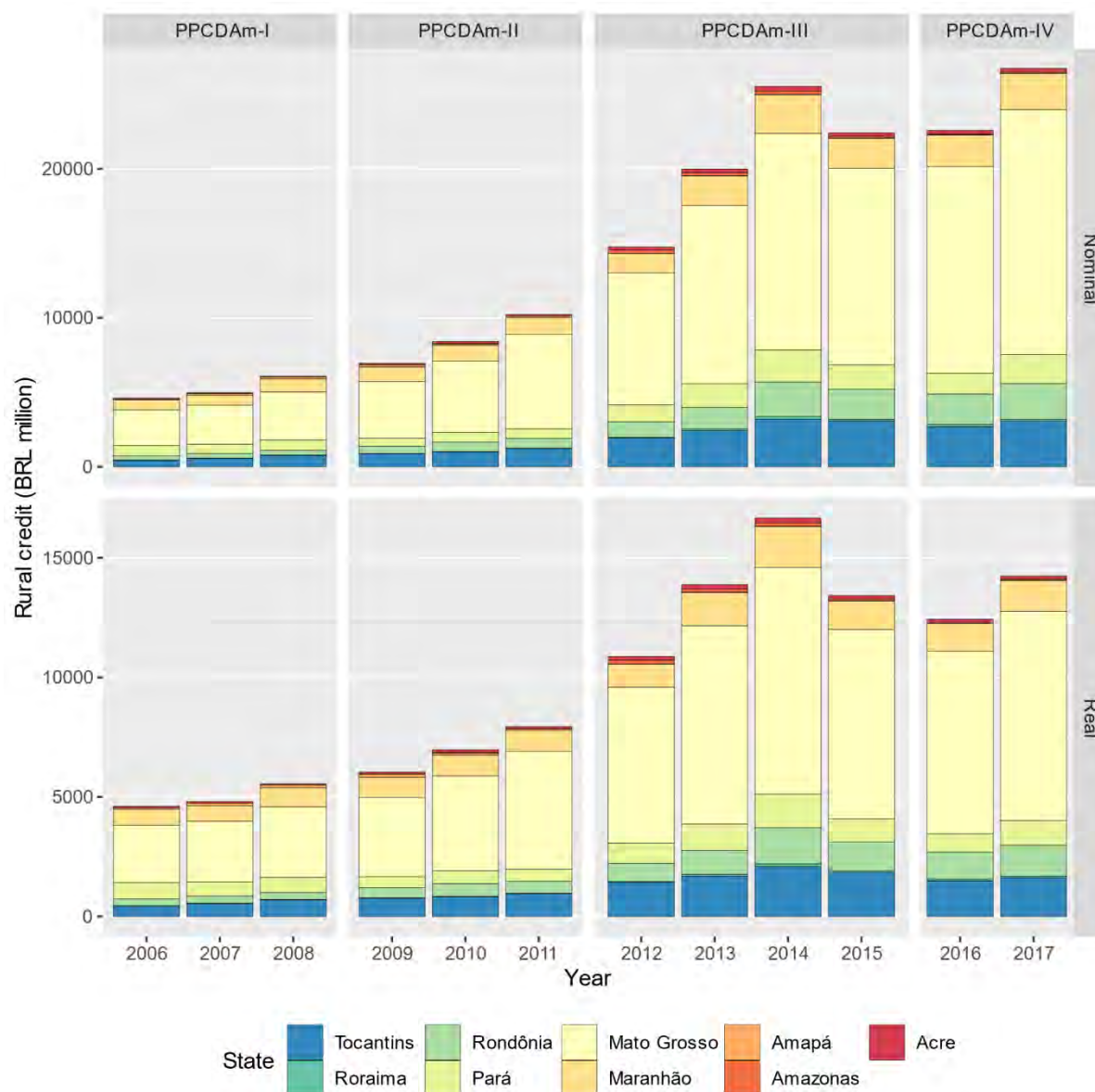


Figure 4. Rural credit granted to Amazonian states during PPCDAm-I, II, III, and IV: nominal and real values (Source: Ministry of Agriculture<sup>4</sup>).

While fines were reportedly effective in particular locations (Börner et al., 2015), less than 5% of them were reportedly paid in the early 2000s (Capobianco, 2019). Nevertheless, while no rigorous study has so far successfully disentangled the effects of the mix of policy instruments on deforestation enacted since 2008, PRODES data identified a significant decline

<sup>4</sup> Adapted from the *Statistics and Basic Data on Agricultural Economics* monthly reports. Real values adjusted for inflation based on Brazil's IPCA index (2006 base year).

in Amazonian forest loss rate, from 12,911 km<sup>2</sup> in 2008 to 7464 km<sup>2</sup> in 2009 (−42%), despite relatively steady real-prices for beef and soybeans and BRL/USD exchange rates in these years (Assunção et al., 2015; Hargrave and Kis-Katos, 2013).

PPCDAm-I also acknowledged the key role of voluntary supply-chain commitments and sectoral pacts among federal and state governments, companies, banks, and civil society organizations to inhibit illegal deforestation in the region (Brazil, 2009). In July 2006, the *Brazilian Association of Vegetable Oil Industries* (ABIOVE) and the *National Association of Cereal Exporters* (ANEC) committed not to commercialize soybeans from areas cleared after October 2006 in Amazonia (but not in the *Cerrado*); the cutoff was extended to 2008 in 2013 (Fearnside, 2017). This commitment became known as Brazil's *Soy Moratorium* (Gibbs et al., 2015). However, because land constraints imposed by the moratorium increased the value of pastures established before 2008 (i.e., in areas suitable for producing soybeans), studies suggest that much of the land devoted to grazing activities was replaced by soy crops (Kastens et al., 2017; Macedo et al., 2012). The new soy expansion pattern induced cattle ranchers to establish new pastures further into the forest, triggering an “indirect” LUCC process in the region (Arima et al., 2011; Barona et al., 2010; Richards et al., 2014). Further, despite the international attention gathered by the moratorium, a recent rigorous impact evaluation failed to find a different (“discontinuity”) effect of the intervention on the forest loss around the border between the Amazon and the *Cerrado* biomes (regions respectively affected and not affected by the moratorium), raising questions about the initiative's contribution to deforestation mitigation (Svahn and Brunner, 2018).

Similarly, in July 2008, the *Association of Timber Exporting Industries of Pará State* (AIMEX), the *Amazonia Group of Certified Forest Producers* (PFCA), along with government agencies, signed the *Legal Wood and Sustainable Development Pact* (Brazil, 2009). Organizations from the business sector committed to the pact agreed to only purchase wood products from legal and sustainable sources, as well as to help with the identification of supply-chain frauds. Unfortunately, no information about the effects of the pact are found in the literature. A year later, companies from Pará state signed additional legally binding agreements (TACs) to stop the purchase of beef products from farms linked to illegal deforestation. This example was later followed by the largest meatpacking companies in the country (Fearnside, 2017; Gibbs et al., 2016), referred to by some as the *Beef Moratorium* (Gollnow and Lakes, 2014). Nevertheless, studies suggested that the supply-chain commitment had little or no mitigatory effect on total forest loss (Alix-Garcia and Gibbs, 2017; Klingler et al., 2018).

Among the thematic areas, the promotion of sustainable land-use activities (Axis 3) received less attention during PPCDAm-I (IPEA-GIZ-CEPAL, 2011). The main achievements of Axis 3 were linked to (i) the *Public Forest Management Law* (Law 11,284 of 2006; emphasizing decentralization and the promotion of logging concessions), (ii) creation of the *Sustainable Forest District of BR-163* in 2006, focused on the promotion of public forest management, sustainable production, and engagement of social groups located along the highway, under high-deforestation pressure (Fearnside, 2007), and (iii) its influence on other policy programs, such as the *Sustainable Amazon Plan* launched in May 2008. The latter plan, signed by the president and by state governors, defined common goals and sustainable development guidelines for the Amazon region (Brazil, 2009). The first forest concession

contract was signed in 2008, covering an area of 96,400 ha inside the *Jamari National Forest* (Rondônia).

The *Amazon Fund* (Decree 6527 of 2008) was also launched as part of PPCDAm-I to raise donations for non-reimbursable investments in conservation, reforestation, deforestation monitoring and prevention, and sustainable use of forest resources—mainly through financial support of independent projects (Correa et al., 2019)—as well as the promotion of the ecological and economic zoning (EEZ) of the Amazon and land planning/regularization programs (Brazil, 2009). The fund creation was the result of a major donation offer from the Norwegian government that led to a bilateral “memorandum of understanding” between Norway and Brazil, signed in September 2008, involving a USD 1-billion and a results-based pledge for the reduction of Amazonian deforestation over a 5-year period (Angelsen, 2017). Donations are rewarded with certificates of carbon-emission reductions defined annually by the Brazilian Ministry of Environment based on deforestation reduction in previous years and certified by the *Technical Committee of the Amazon Fund*. Based on this information, Brazil’s *National Bank for Economic and Social Development* (BNDES) is authorized to raise donations in exchange for carbon emission reduction certificates, which are nominal, non-transferable, and do not generate rights or credits of any nature (Brazil, 2013a). Despite its name, up to 20% of the *Amazon Fund* can be used to develop forest control and monitoring systems in other Brazilian biomes, as well as in other tropical countries (Brazil, 2009).

By the end of PPCDAm-I, rising international concern about climate change and national mitigation commitments played a strong role in reshaping the plan, as 77% of the Brazilian greenhouse-gas (GHG) emissions by 2005 originated from LUCC (Brazil, 2010). The *National Climate Change Plan*, launched in 2008, presented four-year deforestation reduction targets for the Amazon (Brazil, 2008). The initial target set by the plan was to reduce the rate of forest loss by 40% during the 2006–2009 period as compared to the historical 1996–2005 average; a 30% reduction target was set for the two subsequent quadrennium periods (2010–2013 and 2014–2017) based on the previous four-year average (West et al., 2019).

### 2.3 PPCDAm-II (2009-2011)

PPCDAm-I addressed some of the major drivers of deforestation. However, addressing the remaining causes represented a much greater challenge for PPCDAm-II, mainly because it required tackling one of the roots of the problem: the lack of sustainable economic alternatives for the region. While there was a consensus among PPCDAm stakeholders that deforestation monitoring and control was the most successful thematic axis during PPCDAm-I, Axis 3 was reportedly the least effective due to planning issues, lack of collaboration among agencies, insufficient funds, and limited access to credit (IPEA-GIZ-CEPAL, 2011). As a result, PPCDAm-II focused on the promotion of a sustainable development agenda for Amazonia (Brazil, 2009). Among the main goals set by plan were (i) the macro EEZ of the region, (ii) continued expansion of protected areas and demarcation and “homologation” of indigenous lands (4 million ha), (iv) creation of the *Interministerial Commission to Combat Environmental Crimes* (CICCIA)<sup>5</sup>, along with the strengthening of existing environmental enforcement

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<sup>5</sup> Composed the army, federal police, federal highway police, and the National Public Security Force. During PPCDAm-II, CICCIA seized 864,000 m<sup>3</sup> of timber, embargoed 0.6 million ha, and arrest of ≈600 environmental offenders (Brazil, 2009).

agencies, (v) promotion of the CAR registry, particularly in blacklisted municipalities and settlements, (vi) new efforts towards decentralization of forest management, (vii) promotion of sustainable agriculture strategies, and (viii) improvement of credit instruments for conservation, reforestation, and recovery of degraded agricultural lands (Brazil, 2009). Other relevant development policies were implemented in the region, but were not directly linked to the PPCDAm, e.g., the federal *Growth Acceleration Program* (PAC).

To improve efficiency and implementation effectiveness, PPCDAm-II reduced the number of activities promoted by the program and adopted a new administrative structure based on priorities and project deadlines (Brazil, 2013a). An issue that undermined efficient administration of PPCDAm-I was the fact that the funds allocated to the plan's activities were largely diluted in the federal government's constitutional *Multi-Annual Investment Plan* for 2008–2011. As a result, it became very difficult to track all of the plan's costs to assess its cost-effectiveness.

There was overall agreement among government agencies and experts that land tenure regularization (Axis 1) was a key enabling factor for virtually all PPCDAm activities and needed to become a priority (IPEA-GIZ-CEPAL, 2011). The lack of well-defined land ownership was one of the main unresolved bottlenecks in the Amazon (Fearnside, 2017, 2001). Law 11,952 of 2009 (followed later by Law 13,465 of 2017) launched the *Terra Legal* program for georeferencing and tenure regularization of rural landholdings in Amazonia, initially focusing on the 43 blacklisted municipalities by that time. The initial goal of the program was to legalize the status of 67 million ha of ownership claims in public land in the region (IPEA-GIZ-CEPAL, 2011). In order to be regularized, land occupation had to have occurred peacefully, a portion of the land had to be under agriculture or ranching since 2004, land claimants needed to be Brazilian and could not own other lots or have previously benefited from other land-reform programs (Duchelle et al., 2014). The most controversial aspect of *Terra Legal* is that the program is not restricted to smallholders: under the 2009 law, up to 1500 ha could be legalized under a single taxpayer identification number (CPF), and this limit was increased to 2500 ha in 2017. The 2017 law, known as the “*grileiro's law*” (with reference to the large “land grabbers” who invade and illegally claim public land) also facilitates sale of land in the >3000 smallholder settlements recognized by the government, thus stimulating the ongoing trend of land concentration, where smallholder populations are replaced by medium and large ranches, ultimately creating new waves of landless farmers (Fearnside, 2017). Despite the efforts of the *Terra Legal* program, land regularization was slow during PPCDAm-II due to dispersed (and often conflicting) tenure information across the databases of state and federal agencies and land registry offices. Only 25,618 rural properties were georeferenced by the program by 2011 (Brazil, 2013a).

Creation of protected areas remained a key strategy in the plan's Axis 1 during PPCDAm-II. These areas were expanded by 6 million ha, mainly targeting the regions that were most threatened by deforestation. However, the expansion was sometimes criticized because of a slower implementation pace and smaller spatial scale as compared to PPCDAm-I (IPEA-GIZ-CEPAL, 2011). Further, close to 3 million ha of existing protected areas underwent significant downsizing and/or de-gazettement after 2008 (Bernard et al., 2014). Still, under Axis 1, the elaboration of the macro EEZ of the Legal Amazon during PPCDAm-II identified

zones suitable for conservation and agricultural, livestock, and timber production. The macro EEZ was completed in December 2010 as a result of issuing Decree 7378.

Regarding deforestation monitoring and control (Axis 2), PRODES identified a total of 20,882 km<sup>2</sup> of forest loss during PPCDAm-II (6961 km<sup>2</sup> year<sup>-1</sup>), representing a 52% reduction in the average annual loss compared to the 2005–2008 average (Figure 1). Pará state was responsible for 53% of Brazil's Amazonian deforestation, followed by Mato Grosso (15%) and Maranhão (9%), which surpassed Rondônia (8%). As compared to the 2001–2003 average, deforestation rates in 2011 had decreased by 76% in indigenous lands (–569 km<sup>2</sup>), 78% in protected areas (–1370 km<sup>2</sup>), 81% in federal lands (–5694 km<sup>2</sup>), and 74% in rural settlements (–4105 km<sup>2</sup>; Figure 2). Significant reductions in deforestation were also observed during PPCDAm-II for the 36 initially blacklisted municipalities (IPEA-GIZ-CEPAL, 2011).

A distinct shift in LUCC patterns was identified between the first and the second phases of PPCDAm (Godar et al., 2014; Kalamandeen et al., 2018; Rosa et al., 2012; Tyukavina et al., 2017). Between 2001 and 2011, the average size of deforestation patches went from 40 to 20 ha in Mato Grosso, 20 to 10 ha in Pará and Roraima, 30 to 10 ha in Maranhão, and 15 ha to 5 ha in Amapá. Patch size remained relatively constant in the other Amazonian states, with the exception of Acre, where the average area increased from 5 to 10 ha during the same period (Brazil, 2013a). Most importantly, PRODES data indicate that large patches (>100 ha) represented only 17% of the total deforestation by the end of PPCDAm-II, whereas small ones (<25 ha) contributed 63% (Figure 3). The size reduction of deforestation patches, and the increase in their spatial dispersion, increased the cost of on-site inspections, demanding new monitoring and mitigatory approaches (Brazil, 2013a). In 2011, INPE, in partnership with the *Brazilian Agricultural Research Corporation* (EMBRAPA), launched *TerraClass*, a post-deforestation land-use mapping product complementary to PRODES (Almeida et al., 2016). The current version of *TerraClass* allows to trace shifts among 10 land-use/cover categories across 2004, 2008, 2012, and 2016.

Under PPCDAm-II's Axis 2, the *Brazilian Institute of Environment and Renewable Natural Resources* (IBAMA) initiated technical cooperation with *Japan's Aerospace Exploration Agency* (JAXA) and *International Cooperation Agency* (JICA) in 2007 to use radar images from the ALOS satellite to map deforestation under cloud cover. The program, known as “INDICAR,” was short-lived but assisted command-and-control actions in the Amazon for 28 months (January 2009 to April 2011), until the end of the ALOS satellite's lifetime. Although the program was expected to resume when a new JAXA satellite became operational after 2013 (Brazil, 2013a), this has apparently not occurred. Despite the considerable improvement of deforestation monitoring, only 0.3% of the total value of fines issued by IBAMA from 2008 to 2010 was paid (Börner et al., 2015). Moreover, although deforestation information was publicly available during PPCDAm-I and II, it was reportedly rarely used by local governments. As a result, an independent assessment of the plan called for urgent integration among municipal-, state-, and federal-level agencies, with more transparent and shared databases (IPEA-GIZ-CEPAL, 2011).

During the 15<sup>th</sup> *Conference of the Parties* (COP) to the *United Nations Framework Convention on Climate Change* (UNFCCC) held in 2009 in Copenhagen, Brazil voluntarily committed to cut 36.1–38.9% of its 2020 projected GHG emissions (Law 12,187 of 2009). A year later, the government adjusted the original deforestation reduction targets set by the

*National Climate Change Plan* (Decree 7390 of 2010, revoked by Decree 9578 of 2018). The new goal aimed for an 80% reduction by 2020 in annual deforestation rates in the Legal Amazon in relation to the 1996–2005 average (i.e., from 19,625 to 3925 km<sup>2</sup> year<sup>-1</sup>), as well as a 40% reduction in the *Cerrado* biome rates compared to the 1999–2008 annual average (Brazil, 2013b). PPCDAm-II also highlighted the alignment between *Sectorial Plans* for climate change mitigation and conservation efforts, e.g., (i) the *Prevention and Control of Deforestation in the Cerrado* (PPCerrado) program, (ii) the *Decennial Energy Expansion Plan* (PEE) to increase electricity generation, (iii) the *Low-Carbon Agriculture Program* (ABC) to recover 15 million ha of degraded pastureland by 2020, promote integration between agriculture and forests (including agroforestry systems), promote forest plantations and reduce overall GHG emissions from agricultural practices, and (iv) the *Emission Reduction Plan for the Steel Industry* to reduce the illegal use of native trees for charcoal used in iron and steel production by expanding the biomass stock of planted forests (Brazil, 2013a). According to PRODES, a 50% reduction in Legal Amazon deforestation was observed between 2008 and 2011 (last years of PPCDAm-I and II, respectively).

During PPCDAm-II, the *Amazon Fund* received substantial donations from Norway (BRL 86 million), Germany (BRL 6.6 million) and Petrobras, a semi-public Brazilian petroleum corporation (BRL 7.3 million). In addition to the *Amazon Fund*, the *National Fund for Climate Change* was created during PPCDAm-II (Law 12,114 of 2009 and Decree 7343 of 2010, revised by Decree 9578 of 2018) to support projects and studies on climate change mitigation and adaptation, including avoided deforestation and degradation, sustainable supply chains, payments for environmental services, agroforestry systems and reforestation, as well to cover extraordinary forest monitoring costs.

A number of development initiatives (Axis 3) were promoted during PPCDAm-II, emphasizing (i) technical assistance and rural extension, (ii) support for extractivist and indigenous communities, (iii) scientific research and technological innovation to foster social development and sustainable-production strategies, and (iv) sectoral agreements (Brazil, 2009). One example was the *Community and Family Forest Management Program*, launched in 2009 to improve local livelihoods and combat illegal timber exploitation (IPEA-GIZ-CEPAL, 2011). However, not all initiatives were successful. For example, the initial forest concession plan, initially targeting 1 million ha of native forests for 2009–2010, was reduced to 260,000 ha during PPCDAm-II, mainly due to issues arising from unclear tenure status of the public forests (IPEA-GIZ-CEPAL, 2011). In addition to the *Jamari National Forest* concession, another concession contract for 48,900 ha in the *Saracá-Taquera National Forest* (Pará state) was signed in 2010.

Another notable effort from PPCDAm-II Axis 3 was the *Arco Verde* operation, which was included as part of PPCDAm in 2009 (Decree 7008 of 2009), but originally started in May 2008, with the objective of promoting sustainable land-based production models, particularly in blacklisted municipalities, in conjunction with the *Terra Legal* program (IPEA-GIZ-CEPAL, 2011). Specifically, *Arco Verde* assisted smallholders who, due to environmental infractions, lost their source of income, and it was linked to existing credit lines to promote the recovery of degraded lands.

The Ministry of Agriculture was also responsible for the creation of a number of conservation programs targeting the Amazon region and included as part of the PPCDAm. One

example was the proposed *Program for the Recovery of Degraded Areas in the Amazon* (PRADAM), which attempted to increase agricultural productivity and regional economic growth disassociated from deforestation. However, the initiative was criticized for the timid goals set for 2010 restricted to planning, resource acquisition, and identification of degraded areas, and even these limited agenda and activities were only 25% implemented during PPCDAm-II (IPEA-GIZ-CEPAL, 2011). Other examples of poorly executed initiatives proposed by the Ministry of Agriculture were the *Executive Plan for Sustainable Development of Agribusiness in the Legal Amazon* (PDSA), with the goal of promoting pilot projects based on the adoption of sustainable agricultural practices and capacity-building among extension agents, and the *Program for the Implementation of Good Livestock Practices*, both with 0% implementation rates by 2010 (IPEA-GIZ-CEPAL, 2011).

The volume of rural credit in the Amazon increased by 47% during PPCDAm-II, reaching BRL 10.2 billion in 2011 (Figure 4). Nonetheless, it was reported that despite the multiple credit lines and funding programs for the promotion of sustainable activities<sup>6</sup> in the region, the initial targets had to be reduced mainly due to the difficulties of smallholders in obtaining credit approval (IPEA-GIZ-CEPAL, 2011). Despite the initial intent of PPCDAm-II to focus on the promotion of sustainable activities, the total budget (BRL 1.2 billion; Table 1) was equally distributed between Axis 3 (37%) and the monitoring actions (Axis 2; 37%), followed by land planning activities (Axis 1; 27%; Brazil, 2009).

## 2.4 PPCDAm-III (2012–2015)

In response to the independent evaluation of the plan (IPEA-GIZ-CEPAL, 2011), PPCDAm-III adopted a new, decentralized and shared governance structure divided into executive, advisory, and transparency arms and grounded on partnerships between federal, state and municipal agencies to support the implementation of state plans to curb deforestation. In particular, PPCDAm-III's *modus operandi* focused on the promotion of cross-ministry activities, including the multi-level participation of governmental and non-governmental sectors intended to foster a new sustainable economic model for the Amazon. PPCDAm-III continued to prioritize blacklisted municipalities, but it also targeted other municipalities in the “Arc of Deforestation” region (Brazil, 2013a).

Among the proposed goals of PPCDAm-III were (i) the continuation of tenure regularization activities, (ii) drafting and approval of missing state-level EEZs, and (iii) designing a land planning framework that integrates state-level EEZs within the macro EEZ of the Amazon and the major infrastructure developments planned for the region (Brazil, 2013a). Nevertheless, arguably the most relevant land planning action taken during PPCDAm-III was the controversial revision of the Brazilian *Forest Code* in 2012 (Laws 12,651 and 12,727; Freitas et al., 2018). The new version of the law gained international attention and raised concerns over granting amnesty for the pre-2008 illegal deforestation, consequently reducing the total area previously required to be restored from 50 to 21 million ha (–58%), in addition

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<sup>6</sup> These activities targeted the promotion of agroforestry, agroecological or organic production systems, reduction of environmental impacts, sustainable use of forest resources, forest management plans, and maintenance and restoration of *Legal Reserves*, *Permanent Protected Areas*, and degraded areas supported through a series of credit lines, e.g., *National Program for Strengthening Family Agriculture* (PRONAF) *Forests*, *PRONAF Eco*, *PRONAF Agroecology*, *PROPFLORA*, *BNDES Forest*, *BNDES Forest Compensation*, *Program for the Recovery of Degraded Areas in the Amazon* (PRADAM), as well as *Constitutional Funds*.

to a total 88 million ha in private landholdings that can be legally cleared according to both the old and the new versions of the code (Soares-Filho et al., 2014). The expansion of the protected-area network also seemed to have stagnated after PPCDAm-II (Bernard et al., 2014). At the same time, construction of 18 “large” dams (i.e., with installed capacity >30 MW) in the Amazon was announced as a key strategic component of Brazil’s 10-year energy expansion plan for 2013–2022 (Fearnside, 2015).

According to PRODES, the annual rate of deforestation reached the lowest historical level in 2012 (4571 km<sup>2</sup>). During 2012–2015, 21,680 km<sup>2</sup> of forest was lost in the Amazon (5420 km<sup>2</sup> year<sup>-1</sup>), representing annual average reductions of 63% and 22% compared to the PPCDAm-I and II periods, respectively (Figure 1). Between the 2001–2003 and 2015, forest loss decreased by 90% in indigenous lands (–677 km<sup>2</sup>), 64% in protected areas (–1123 km<sup>2</sup>), 70% in rural settlements (–3887 km<sup>2</sup>), and 78% in federal lands (–5447 km<sup>2</sup>; Figure 2). About three-fourths of the Amazonian forest loss was again associated with the states of Pará (37%), Mato Grosso (21%), and Rondônia (16%). For the first time during a PPCDAm phase, deforestation rates ceased to decline and instead increased by 36%, from 4571 km<sup>2</sup> in 2012 to 6207 km<sup>2</sup> in 2015. In particular, deforestation in Mato Grosso more than doubled between those years (from 757 to 1601 km<sup>2</sup>). Data from PRODES also revealed an increase in the contribution of large patches (>100 ha) to the total deforestation during PPCDAm-III, from 17% in 2012 to 28% in 2015, whereas the participation of <25-ha patches decreased from 59% to 48% (Figure 3). The increasing trend in forest loss led many to suggest that the PPCDAm had reached its limit in halting deforestation.

There were significant efforts to improve forest monitoring (Axis 2) during PPCDAm-III. The Sino-Brazilian satellite CBERS-3 (20–80 m resolution) was lost during launch in December 2013, but its successor, CBERS-4, was successfully launched in the following year. Images from the new satellite helped improving the ongoing DETER and PRODES monitoring programs (Brazil, 2013a). Further, in 2014 the Brazilian government signed a cooperation agreement with the *Indian Space Research Organization* for the use of ResourceSat-2 satellite imagery (23.5–56 m resolution) for the same purpose. Complementary on-the-ground activities benefited from Decree 7957 of 2013, which established the *Permanent Office of Integrated Management for the Protection of the Environment*, composed of the *Institutional Security Office of the Presidency* and the Ministries of Environment, Defense, and Justice. This strengthened the participation of the army in environmental operations.

Promotion of sustainable activities (Axis 3) remained the priority during PPCDAm-III, mainly targeting 65 priority municipalities in the Amazon. A major objective was to facilitate farmers’ access to credit and other financial incentives (Brazil, 2013a). During phase III, the *Amazon Fund* received an additional BRL 2.36 billion from Norway, BRL 54 million from Germany, and BRL 5.9 million from Petrobras. In addition, the new version of the *Forest Code* introduced a financial mechanism to compensate private landholdings that exceed minimum forest-cover requirements: the *Environmental Reserve Quota* (CRA). This mechanism allows surpluses in the forest area to be tradable as a way to offset environmental debts (Soares-Filho et al., 2014). Once operational, the emerging CRA market in Brazil could encompass 4.2 million ha of forests with an estimated gross value of USD 8–10 billion (Soares-Filho et al., 2016).

The area of national forests allocated to logging concessioners also grew substantially during PPCDAm-III, from 145,000 ha to 1 million ha. Included in this total were areas in the following national forests: *Saracá-Taquera* (86,300 ha; Pará), *Jacundá* (87,800 ha; Rondônia), *Crepori* (194,000 ha; Pará), *Altamira* (379,000 ha; Pará), and *Caxiuanã* (176,600 ha; Pará)<sup>7</sup>.

Under Axis 3, Brazil's *National Institute of Colonization and Agrarian Reform* (INCRA) announced in 2012 the development of the *Plan for Prevention, Combat, and Alternatives to Illegal Deforestation in Amazon Settlements*, known as the *Green Settlements Program*. The initiative aimed to promote sustainable land-based activities, degraded land restoration, land regularization (i.e., CAR registration), and food security (Brazil, 2013a). Settlers also benefitted the most from the *Bolsa Verde* ("Green Stipend") program launched at the end of 2011 (Law 12,512), part of Brazil's social security efforts against poverty (Decree 7492 of 2011). The *Bolsa Verde* program targeted the rural population living in extreme poverty, estimated to represent 7.3% of the total Brazilian population during the previous PPCDAm period, providing them with quarterly payments of BRL 300 per family. It benefitted 44,388 families living in settlements and protected areas at a cost of BRL 69 million from 2011 to 2013 (Viana, 2014).

While the concept of "Reducing Emissions from Deforestation and forest Degradation," with recognition of the roles of conservation, sustainable forest management, and enhancement of carbon stocks, (REDD+) had been part of Brazil's *National Climate Change Plan* since 2008 (Brazil, 2008), these activities were only formally acknowledged as part of the PPCDAm during phase III<sup>8,9</sup> (Brazil, 2013a). REDD+ represents a funding opportunity to promote conservation and sustainable-development initiatives from bi- and multi-lateral agreements between Brazil and developed countries based on realized GHG reductions recognized by the UNFCCC (Angelsen, 2017), and largely associated with the PPCDAm activities. In 2014, Brazil submitted to the UNFCCC a *Forest Reference Emission Level* (FREL) for the Amazon biome in order to claim results-based REDD+ payments, in accordance to the *Bali Action Plan* (Decision 2/CP.13) and the country's climate change mitigation commitment, or *Nationally Determined Contribution* (NDC<sup>10</sup>), to the UNFCCC (Brazil, 2014). The average GHG emission from 1996 to 2005 presented in the FREL was 1.1 Pg CO<sub>2</sub> year<sup>-1</sup>. In 2014, Brazil submitted the first avoided-deforestation result for REDD+ compensation under the UNFCCC, pertaining to the 2006–2010 period, equivalent to 3 Pg CO<sub>2</sub> (FAO, 2019). One of the government's intended uses of REDD+ funds during PPCDAm-III was for the promotion of the *Low-Carbon Agriculture Program* (ABC), which aimed to increase farm productivity as a strategy to constrain agricultural expansion over forests (Brazil, 2013a).

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<sup>7</sup> However, the original bidding areas in the *Jacundá*, and *Crepori* national forests were 111,500 ha and 450,000 ha, respectively.

<sup>8</sup> Still, several decentralized, voluntary REDD+ projects have been implemented in the Brazilian Amazon since the late 2000s (West, 2016).

<sup>9</sup> The Ministry of Environment established the *REDD+ Working Group* for REDD+ readiness in 2011 (Brazil, 2016c).

<sup>10</sup> After Brazil ratified the Paris Agreement in September 2016 the INDC became the "NDC," or Nationally Determined Contribution.

The volume of rural credit increased again by half between 2012 (BRL 14.7 billion) and 2015 (BRL 22.4 billion; Figure 4) and a much larger budget was allocated for the implementation of the PPCDAm-III actions to combat deforestation compared to the previous phases (Table 1). The majority (55%) of the BRL 1.4 billion budget was allocated to the promotion of sustainable activities (Axis 3), while 15% was allocated to land planning (Axis 1), and 30% to the monitoring and control of deforestation (Axis 2; Brazil, 2013a).

## 2.5 PPCDAm-IV (2016–2020)

The current phase of the PPCDAm proposed a new thematic axis, in addition to the previous three. The new axis specifically focuses on the elaboration of norms and economic instruments for deforestation prevention and control (Brazil, 2016a). This phase of the plan also seems to place a stronger focus on climate change mitigation compared to PPCDAm-I–III; it is oriented to meeting the goals established by the *National Climate Change Plan* for 2020 under Brazil's NDC to the UNFCCC (Brazil, 2016b, 2015). During PPCDAm-IV, there was a revision of previous climate legislation (Laws 12,114 and 12,187 of 2009 and Decree 7343 of 2010, revised by Decree 9578 of 2018); the new regulation presents 3236 Gg CO<sub>2</sub> as the projected national GHG emission for 2020 (and the intended reduction target of 1168–1259 Gg CO<sub>2</sub> for the same year), out of which 43% corresponds to emissions from LUCC. Decree 9578 also reaffirms the country's commitment to reducing deforestation in the Amazon biome by 80% and in the *Cerrado* by 40% below the historical levels by 2020. As a result, higher importance was placed on the PPCerrado, in addition to the PPCDAm, since both programs are key instruments of the *National Climate Change Plan* and, consequently, paramount for the country meeting its GHG emission reduction targets.

Brazil signed the *Paris Agreement* at COP 21 (2015) of the UNFCCC (and ratified it in September 2016). Under the agreement (and the NDC), the country committed to achieving zero illegal deforestation in the Amazon by 2030 (Brazil, 2016b, 2015). Although the NDC acknowledged the country's intention to curb the loss of *Cerrado*, deforestation reduction was only legally binding for the Amazon biome, and only applies to the illegal portion of the deforestation. In addition, the NDC also included (i) reforestation of 12 million ha, (ii) promotion of sustainable forest management supply chains, based on georeferencing and traceability, to discourage illegal and unsustainable practices, (iii) restoration of 15 million ha of degraded pastures, and (iv) a 5 M-ha expansion of integrated crop-livestock-forest systems by 2030 (Brazil, 2016b). Advances in Brazil's REDD+ readiness (i.e., *National REDD+ Strategy*, or ENREDD+), also revisited the country's eligibility and its intention of benefiting from international REDD+ funds (Brazil, 2016c). ENREDD+ also stressed another challenging task ahead: the effective distinction between illegal and legal deforestation, to eliminate the former and promote policies that can reduce the latter, without prejudice to regional development (Brazil, 2016b). During PPCDAm-IV, Brazil submitted three other avoided deforestation results for REDD+ compensations under the UNFCCC (FAO, 2019). The first one, in 2017, was equivalent to 3.1 Pg CO<sub>2</sub> for the 2011–2015 period. The other two, both in 2019, were equivalent to 0.8 Pg CO<sub>2</sub> for the 2016–2017 period, and 1.3 Pg CO<sub>2</sub>, for the first time pertaining to avoided clearing in the *Cerrado* during 2011–2017. Also in 2019, Brazil became the first country in the world to be entitled a payment from the *Green Climate Fund's* REDD+ results-based payments pilot program (USD 96.5 million) for the 18.8 million Mg CO<sub>2</sub>

reductions in carbon emissions from deforestation (at USD 5 Mg CO<sub>2</sub><sup>-1</sup>) during 2014–2015, calculated by comparison with the 1996–2010 baseline period, i.e., Brazil’s reference emission level (FAO, 2019).

Land planning activities during PPCDAm-IV (Axis 1) are focused on the conclusion and validation of the CAR registry<sup>11</sup> and the continuation of the *Terra Legal* program, as the country’s main effort against land grabbing in Amazonia (Brazil, 2016a). In regard to deforestation monitoring and control (Axis 2), 32,505 km<sup>2</sup> of Amazonian forests were lost during PPCDAm-IV through 2019 (8126 km<sup>2</sup> year<sup>-1</sup>) according to PRODES, representing an average annual increase of 50% compared to PPCDAm-III (Figure 1). In particular, the state of Amazonas experienced a 98% increase in forest loss. Once again, 73% of the total Amazonian deforestation was associated with the states of Pará (37%), Mato Grosso (19%), and Rondônia (16%). Moreover, the 9741 km<sup>2</sup> of deforestation in 2019 was 148% above the annual target set by the *National Climate Change Plan* for 2020 (i.e., 3925 km<sup>2</sup>; Brazil 2013b). The numbers from PRODES also suggest an increase in the contribution of large patches (>100 ha) in the total deforestation by the end of PPCDAm-III (28%), compared to the previous period (17%), whereas the participation of <25-ha patches decreased from 59% to 48% (Figure 3).

Stopping illegal logging is also a priority of PPCDAm-IV, mainly due to the increasing area of degraded forests detected by INPE’s DEGRAD and DETER-B monitoring systems (Brancalion et al., 2018). In response, Resolution 474 of 2016 (revoking Resolution 411 of 2009) of the *National Council for the Environment* (CONAMA), reduced from 45% to 35% the coefficient used for the volume conversion of logwood to sawn timber because the larger value was found to overestimate total (legally approved) timber production. According to IBAMA, the original total timber surplus “credit” granted to forest companies was 1.3 million m<sup>3</sup>, which could be used to sell illegally exploited timber as if it had been legally harvested from approved forest-management sites (Brazil, 2016a). This kind of “fake legal logging” has reportedly been rampant in Brazilian Amazonia (Brancalion et al., 2018).

In regard to sustainable development (Axis 3), PPCDAm-IV maintains the focus on the promotion of sustainable agriculture, ranching, and forest management<sup>12</sup> (Brazil, 2016a). The *Amazon Fund* consolidated its role as a key enabling instrument for the implementation of PPCDAm-related activities (Correa et al., 2019). By 2016, the fund had played a central role in the promotion of the *State Plans for Prevention and Control of Deforestation* and funded 80 government-led projects from state and municipal governments in the Amazon, as well as federal agencies, universities, and civil society and international organizations (BRL 1.2 billion in total). Among the projects, 18 focused on the promotion of sustainable agricultural production in the region and nine benefited a total of 40 indigenous lands (Brazil, 2016a). However, in 2017, the Norwegian government cut its donations to the fund by half due to the recent increases in deforestation rates in the region (Rodrigues, 2017). So far during PPCDAm-IV, the *Amazon Fund* has received BRL 742 million from Norway, BRL 132 million from Germany, and BRL 4 million from Petrobras in donations.

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<sup>11</sup> The total amount spent on contracted work for the CAR initiative, inside and outside the Legal Amazon, was approximately BRL 330 million by 2016 (Brazil, 2016b).

<sup>12</sup> Note that the sustainability of approved forest-management projects, for example, is simply assumed, and that this sustainability is highly unlikely (Fearnside, 2018b).

More recently, a political upheaval after the change of Brazil's presidential administration on January 1, 2019, has raised major concerns about the future of conservation in Amazonia. The new far-right administration has openly questioned Brazil's participation in the *Paris Agreement* and signaled interest in expanding the regional infrastructure, as well as agricultural and mining operations in the Amazon, with little regard to indigenous rights and existing environmental regulations (Escobar, 2018; Fearnside, 2018a; Tollefson, 2018). President Jair Bolsonaro and the ministers he appointed have unleashed an unprecedented series of measures to effectively dismantle the country's environmental agencies and to undo the environmental licensing system and deforestation control programs that had been implemented over the preceding 40 years (Abessa et al., 2019; Ferrante and Fearnside, 2019). These actions seem at least partially responsible for the astonishing 30% jump in Amazonian deforestation from 2018 to 2019 (INPE, 2020).

### 3. Discussion and conclusions

We presented a comprehensive and, whenever possible, critical review of the conservation activities promoted by the PPCDAm in the Brazilian Legal Amazon since 2004. While we do not attempt to establish causal relations between those activities and the observed reduction in deforestation rates, we highlighted the findings of a number of rigorous impact evaluations that attempted to do so (e.g., Alix-Garcia and Gibbs, 2017; Arima et al., 2014, 2011; Azevedo et al., 2017; Börner et al., 2015; Cisneros et al., 2015; Svahn and Brunner, 2018). Other noticeable findings from this literature include the study by Assunção et al. (2015), which attributes 56% of the reduction in forest loss over the 2004–2009 period to the conservation policies implemented in Amazonia in 2004 and in 2008 after controlling for changes in agricultural prices (correlated with deforestation), and the study by BenYishay et al. (2017), which found that homologation of indigenous land in Brazil had no mitigatory effect on deforestation between 1982 and 2010. In contrast, Nolte et al. (2013) and Jusys (2018), investigating deforestation in protected areas, found indigenous lands to have avoided more forest losses between 2000 and 2010 when compared to those under strict protection and sustainable use. Jusys (2018) also highlights a shift during 2009–2014, when strictly-protected areas outpaced indigenous lands in terms of avoided deforestation.

The expansion of the protected areas network, promotion of the CAR registry, and tenure regularization through the *Terra Legal* program arguably represented the most important land planning activities (Axis 1) promoted during PPCDAm. The creation of protected areas was particularly efficient during PPCDAm-I when strong political support was present, but many of the new areas still lack management plans (IPEA-GIZ-CEPAL, 2011). While the expected number of CAR entries has been almost completed during PPCDAm-IV, it should also be noted that many Amazonian areas under the responsibility of the federal government<sup>13</sup> still lack effective planning and are often disregarded by state-level efforts against widespread land grabbing and illegal deforestation (Brazil, 2016a).

Grazing activities remain as the main driver of deforestation in the Amazon (Tyukavina et al., 2017), likely due to low labor requirements (even though labor is relatively cheap in the

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<sup>13</sup> Nevertheless, the *Technical Chamber for the Allocation and Regularization of Federal Public Lands* in the Legal Amazon facilitates the allocation of federal lands to federal agencies or states as an attempt to reduce deforestation and land conflicts.

region) and the availability of low-priced land (Fearnside, 2008). Further, average animal stocking in the region remains very low, often  $<1$  animal  $\text{ha}^{-1}$  (Martha et al., 2012). While low stocking is a recurrent problem throughout Brazil, incentives to increase the productivity of grazing and agricultural activities could result in positive spillover effects for conservation (Stevenson et al., 2013), but could also backfire in the absence of effective environmental regulations (Byerlee et al., 2014; Fearnside, 2002, 1987; Kaimowitz and Angelsen, 2008). Examples of increased returns to farming leading to agricultural expansion are reported in the literature, as in the postulated “Jevons paradox” (Hertel et al., 2019). Still, recent evidence from the literature suggests that reductions in deforestation in priority municipalities during 2004–2014 were paired with increases in cattle production and productivity, but there was no consistent relation between deforestation and dairy or crop outputs (Koch et al., 2019). These findings reinforce the theory that deforestation-control policies in the Brazilian Amazon can lead ranchers with large yield gaps to invest in technology and intensification instead of deforestation (Nascimento et al., 2019). Furthermore, simulation exercises suggest that a tax on cattle raised in conventional pasture, or a subsidy for cattle raised in semi-intensive pasture, could result in considerable forest conservation and abatement of GHG emissions (Cohn et al., 2014). This is of concern for Amazonian conservation and for Brazil’s NDC to the UNFCCC, since intensification represents a key PPCDAm strategy, particularly related to the *Low-Carbon Agriculture Program* (De Oliveira Silva et al., 2018).

Sustainable development activities (Axis 3) remains as the most important and challenging component of PPCDAm. On-the-ground implementation agencies often lack the proper logistics, resources, and institutional capacities to effectively promote these initiatives, in addition to the impediment of slow bureaucratic processes (IPEA-GIZ-CEPAL, 2011). A bottleneck for the development of good-practice guidelines and promotion of science-based activities for sustainable development programs in the Amazon is the limited number of national researchers based in the region: only 4% of the national total (IPEA-GIZ-CEPAL, 2011). Moreover, since there has been no effective transition from unsustainable to sustainable production models, it is unlikely that deforestation levels as low as observed during PPCDAm-III will be achieved under the new pro-agribusiness political scenario (Abessa et al., 2019; Escobar, 2018; Fearnside, 2018a). The new administration’s plans, actions, and anti-conservation discourse are already reflected in accelerated forest loss and increased GHG emissions, potentially jeopardizing the PPCDAm achievements to date.

The dynamic of LUCC in the Amazonian region is known to respond directly to political incentives and discourses (Pailler, 2018; Rodrigues-Filho et al., 2015), whereas the promotion of sustainable development activities rely on effective funding mechanisms. While the volume of credit distributed across the Amazonian states increased by almost six-fold between 2006 and 2017, small households still struggled to meet loan requirements set by the banks. At the same time, credit restrictions (i.e., Resolution 3545 of 2008) were estimated to have reduced counterfactual deforestation by  $\approx 60\%$  during 2009–2011 (Assunção et al., 2020).

Over the PPCDAm-III–IV period, the *Amazon Fund* became a key promoter of sustainable activities in the region. Norway has been the main donor of the fund, responsible for 94% of all donations, followed by Germany (5.6%), and Petrobras (0.5%)<sup>14</sup>. All donations

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<sup>14</sup> Numbers processed by the authors based on the *Amazon Fund* data.

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