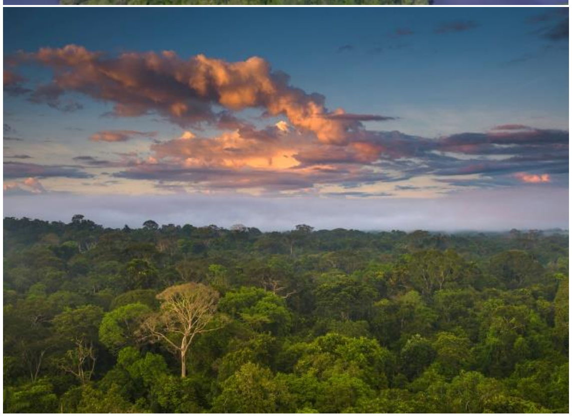
Role of Amazon protected areas, especially the conservation units supported by ARPA, in reducing deforestation






ARPA

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Britaldo Silveira Soares Filho
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1. Effectiveness. 2. Climate Change. 3. Ecosystem Services

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Abstract

Brazil has achieved an unprecedented success in reducing deforestation in the Amazon by 70% below the historical baseline. Of the wide set of policy interventions in place, the expansion and consolidation of protected areas (PAs) have played a major role in this reduction. Most of the Amazon PAs have proven effective in deterring deforestation. Moreover, the design of the newly designated PAs has established a new conservation paradigm that focuses not only on biodiversity hotspots but also seeks to set aside large blocks of forest to act as "green barriers" against deforestation. Fully implementing PAs in regions under immediate deforestation threat, however, requires prompt and predictable inflows of resources. In 2002, Brazil launched the Amazon Protected Areas Program (ARPA) to support a total of 60 million hectares of conservation units in the Brazilian Amazon, making it the largest initiative of tropical forest conservation worldwide. We assessed the effectiveness of Amazon PAs, especially the conservation units supported by ARPA, in locally deterring deforestation between 1997 and 2015. Results for major categories of PAs indicate increasing trends of effectiveness over time, with strictly protected conservation units being the most effective category followed by indigenous lands. Conservation units with ARPA support improved effectiveness after beginning support. They also show a stronger trend of increase in effectiveness in comparison with that of conservation units without ARPA support. In general, PAs are becoming more effective in deterring deforestation even as deforestation further declines across the Amazon. Hence, deforestation reduction within PAs between 2005 and 2015 contributed by 30±3% to the overall decrease in Amazon deforestation, sparing from 1.4 to 1.7 Gigatons of CO_2 emissions.

1. Introduction

Brazil has achieved an unprecedented success in reducing deforestation in the Amazon by 70% below the historical baseline for 1996-2005 period of 19,600 $km^2 year^{-1}$. This figure is tantamount to 5.5±0.5 Gigatons of CO_2 reduced since 2005[1]. The causes of this precipitous decline are various. Major policy interventions include an expansion of 61 million hectares (Mha) of conservation units in the Amazon (1) plus the demarcation of 25 Mha of indigenous lands between 2002 and 2016 (Fig. 1), more efficient satellite-driven enforcement campaigns by IBAMA (Brazil's environmental agency) on cracking down illegal deforestation (2) and logging (3), the role of public prosecutors in unveiling fraudulent schemes of environmental licenses and enforcing the industry to exclude deforesters from their supply chains (4), ban of credit for rural landowners in municipalities in the black list of top deforester (5), and moratorium on buying soy grown on recently-cleared lands (6). All these actions have created a synergy to sustain

[1] Difference from CO_2 emissions from historical rates and emission from running SimAmazonia-2 (1) under the baseline scenario of 19,600 km^2 of annual deforestation rate. Estimates of CO_2 emissions based on spatial variation in forest biomass according to Brazil's third communication on climate change (8).

further reductions in deforestation, disseminating an awareness among landowners that deforestation is a bad deal.

Most of the Amazon protected areas (PAs) have proven effective in deterring deforestation (1, 9); the expansion of PAs in the Brazilian Amazon was responsible for 37% of the region's total reduction in deforestation between 2004 and 2006 without provoking leakage (1). The design of the newly designated PAs has established a new conservation paradigm that focuses not only on biodiversity hotspots (10) but also seeks to set aside large blocks of forest to act as "green barriers" against deforestation (1). Today, this network, embracing three major PA categories, *i.e.* strictly protected and sustainable use conservation units plus indigenous lands, comprises 216 million hectares[2], the equivalent to 43% of the Brazilian Legal Amazon (Fig. 2). Hence, the strategy of expanding and consolidating Amazon PAs has enormous implications for conserving the vast array of ecosystem services the Amazon forests provide (11) and is crucial for mitigating global climate change (1). Meeting the challenge of fully implementing PAs in regions under immediate deforestation threat, however, requires prompt and predictable inflows of resources.

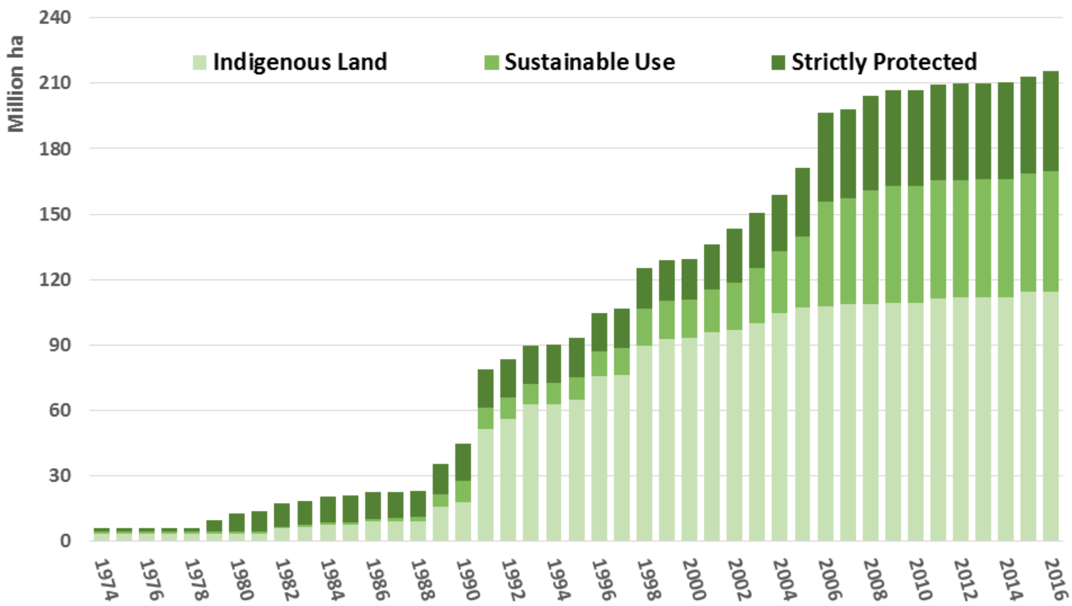

Fig. 1. Expansion of conservation units and indigenous lands in the Legal Amazon.

In 2002, Brazil launched the Amazon Protected Areas Program (ARPA) to support a total of 60 million hectares of conservation units in the Brazilian Amazon, making it the largest initiative of tropical forest conservation worldwide. The ARPA program under the administration of Fundo Brasileiro para Biodiversidade (Funbio) involves three implementation phases. The first between 2003 and 2010 with investments of USD 55.2 million established 46 new conservation units totaling 24 million hectares. The

[2] 115 million ha of indigenous lands plus 46 million ha of strictly protected and 55 million ha of sustainable use conservation units.

second phase, which began in 2010 and goes until 2017, has already invested USD 54.2 million in consolidating newly designated PAs. In addition, further donations totaling USD 123 million have been secured for the third phase that will last 25 years[3]. This phase aims to expand another 6 million hectares of new conservation units and to raise new funds in order to guarantee long-term financial support to ARPA entirely by the Amazon states and the federal government. Currently, ARPA supports 114 conservation units totaling 59.2 million hectares or 98.6% of the program's initial target (funbio.org.br/programaarpa) (Fig. 2).

Although previous studies have underlined the role of Amazon PAs as an essential component for a basin-wide conservation strategy (1, 7), it remains unclear what might be the relative contribution of the Amazon PAs, specifically over the last decade, towards Brazil's effort in reducing deforestation in the Amazon, given the interplay between the ample set of policy interventions in place. Here we shed light on this debate by assessing the effectiveness of Amazon PAs, especially the conservation units supported by ARPA, in locally deterring deforestation between 1997 and 2015 as well as their role in reducing overall deforestation rates in the Amazon between 2005 and 2015.

2. Results

We analysed the effectiveness of each of 632 Brazilian Amazon PAs[4] (Fig. 2) using wall-to-wall annual deforestation data from 1997 to 2015 (12) at a high spatial resolution (60 meters). Interior versus exterior comparison of deforestation may be biased because land characteristics in sampled areas are not the same due to the location of PAs, which are usually more remote and thus less likely to be deforested than their exterior. We overcame these limitations by applying a robust metric that accounts for PA location and size, as well as variation in the overall deforestation rate. The method, termed "adjusted odds ratio[5] of deforestation", compensates for differences in the probability of deforestation (1) in areas used for pairwise comparison (10 km inner and outer buffers) without needing to find matching samples (see methods). Odds ratio of deforestation are herein presented using logarithm notation; values above 0 mean an association with deforestation; negative values indicate a deterring effect, the lower the value the stronger is the effect (Fig. 3).

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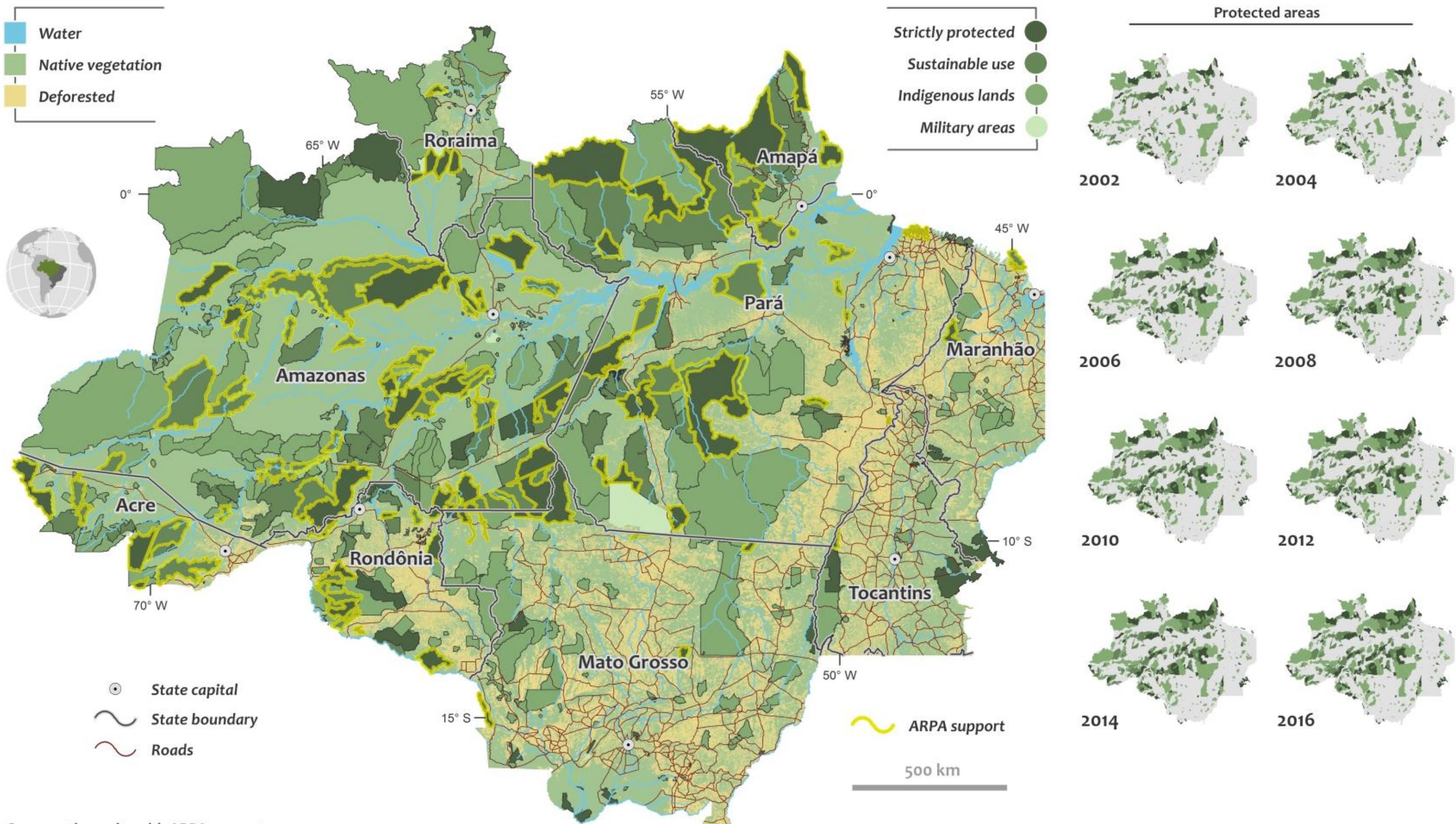
[3] Major donors are the German Federal Ministry for Economic Cooperation and Development (BMZ) via KfW Development Bank, The Amazon Fund via BNDES, Global Environmental Fund via World Bank, WWF-Brasil, Inter-American Development Bank, the Gordon and Betty Moore Foundation (GBMF), Anglo American Minério de Ferro Brasil, Natura, and O Boticário.

[4] In total, PAs analyzed comprise 98 strictly protected conservation units, 172 sustainable use, and 362 indigenous lands.

[5] Odds Ratios represents the odds (chances) that an outcome will occur given the presence of particular factor, compared to the odds of the outcome occurring in the absence of that factor.



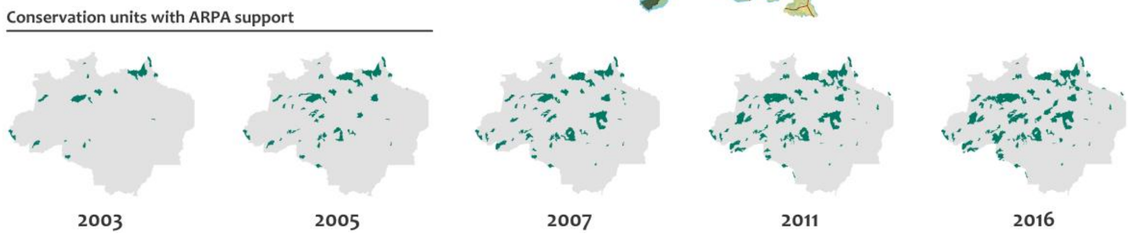


Fig. 2. Protected areas (plus military areas) in the Legal Amazon, highlighting conservation units supported by ARPA.

Results for major classes of PAs show trends of increase in effectiveness over time, with strictly protected conservation units being the most effective category followed by indigenous lands (Fig. 3). Comparison of mean effectiveness before and after designation indicates that effectiveness of strictly protected conservation units improved after designation ($p < 0.05$, Mann–Whitney U test), whereas for sustainable use and indigenous lands effectiveness kept the same (Table 1). Conservation units with ARPA support (n=114) show a stronger trend of increase in effectiveness than that of areas without support (n=156) (Fig. 4). In addition, comparison of mean odds ratios before and after ARPA support (constrained to only after designation) shows that effectiveness enhanced due to ARPA support ($p < 0.05$, Mann–Whitney U test) (Table 2). Furthermore, we estimate that deforestation reduction within PAs between 2005 and 2015 contributed by 30±3% to the overall decrease in Amazon deforestation below the historical baseline of 19,600 $km^2 year^{-2}$ (Fig. 5). This reduction spared about 1.4-1.7 Gigatons of CO_2, the equivalent of 30% of total emission reductions. Roughly 25% of reductions within PAs occurred in conservation units supported by ARPA after the beginning of this support. Areas with major reductions within PAs concentrate in Terra do Meio and along Br-163 in Pará, on the fringe of the consolidated frontier in Rondônia, Northern Mato Grosso and Park of Xingu in Mato Grosso, and within Indigenous lands in Maranhão (Fig. 6).

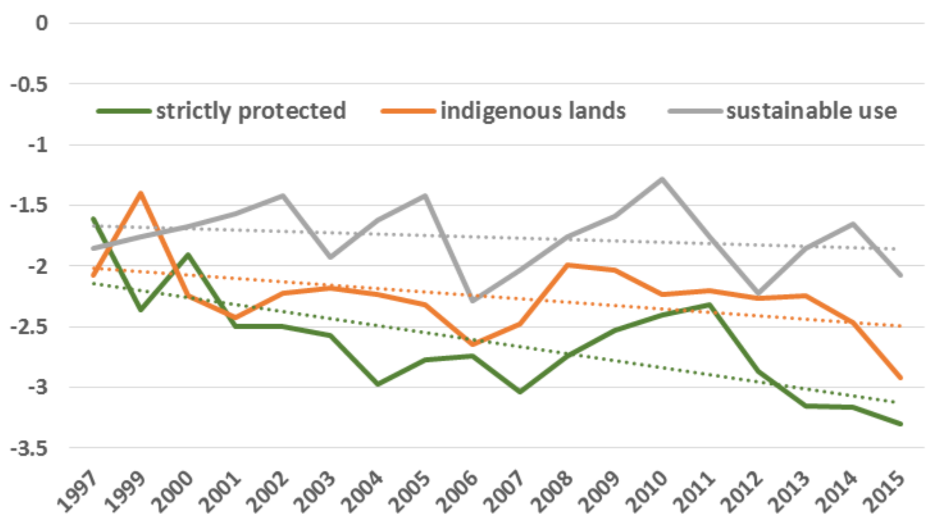


Fig. 3. Odds ratios of deforestation for the three major categories of protected areas (in logarithm notation). The lower the value, the stronger is the deterring effect.

Table 1. Mean odds ratios of deforestation (logarithm notation) for the three major categories of PAs before and after designation or demarcation.

	designation before	designation after	statistical significance
strictly protected	-2.12	-2.63	0.0002
sustainable use	-1.82	-1.76	*0.0620*
indigenous lands	-2.25	-2.30	*0.2208*

*italic values are not statistically significant

Table 2. Mean odds ratios of deforestation (logarithm notation) for conservation units after designation, and before and after ARPA support.

	before	after	statistical significance
ARPA support	-1.958	-2.325	0.001

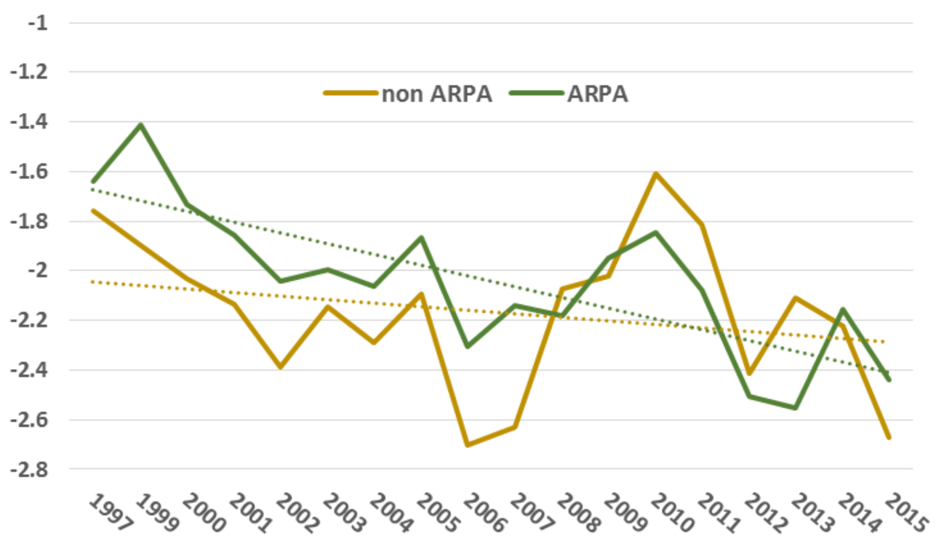


Fig. 4. Odds ratio of deforestation for conservation units with and without ARPA support (in logarithm notation). The lower the value, the stronger is the deterring effect.

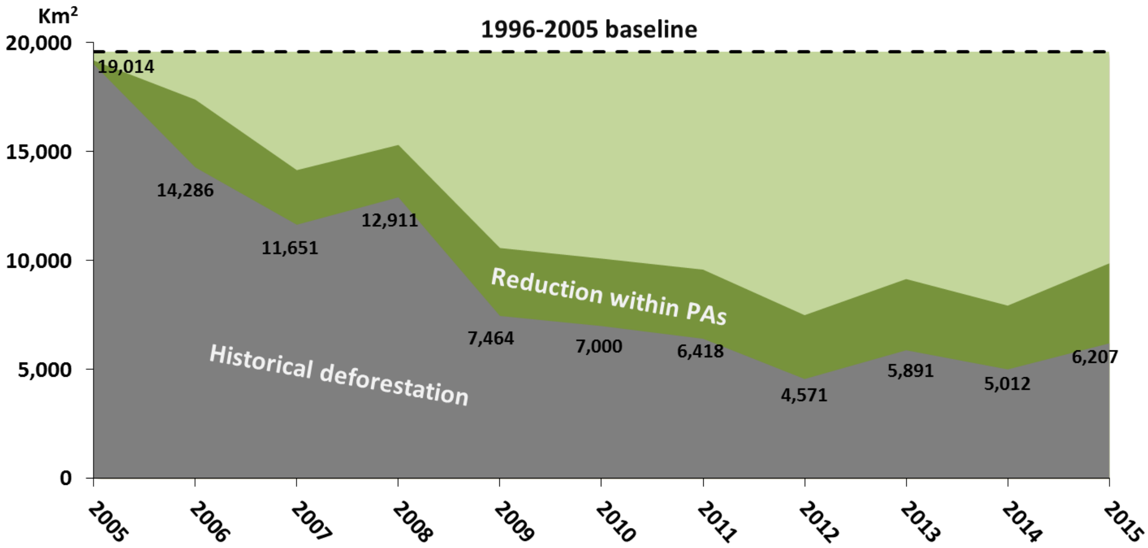


Fig. 5. Historical deforestation between 2005 and 2015 compared with the baseline. Reduction within PAs is depicted in dark green.

3. Conclusion

In general, PAs are becoming more effective in deterring deforestation even as deforestation further declines across the Amazon, given that deforestation was reduced even more inside PAs than in areas outside. This points out to the increasing contribution of PAs in reducing deforestation, and as such, in mitigating climate change. Nevertheless, the extent to which the PA mechanism plays a direct role in reducing deforestation, for example by removing land from the land grabbing market, or being a net beneficiary of other policy intervention remains unclear.

Consolidating Amazon PAs is central to help Brazil meet the ambitious target of its nationally determined contribution (NDC) that aims to reduce until 2030 greenhouse gas emissions by 43% in relation to 2005 (13). Amazon PAs not only reduce deforestation but also are major carbon sinks that sequester annually 0.24 Gigatons of CO_2 (14). In turn, ecosystem goods and services provided by Amazon PAs rely on tempering global climate change. The synergy between increasing drought frequency (15) and widespread fire events (16) driven by climate change may turn the Amazon forest from a carbon sink into a net source (15), deeply impoverishing the remaining forests with large socioeconomic and environmental consequences (17).

Despite the large geographic coverage of Amazon PAs, there is still opportunity to expand this network. There are 39 million hectares of undesignated lands in the Amazon (18) open for land grabbing and new settlement projects. To avoid this fate, those lands should become production forests under the logging concession regime run by the Brazilian Forest Service. But to put PAs to work, it is necessary to curb the unfair competition by illegal logging (19) and to upgrade extractive production chains in sustainable use reserves (20). However, protecting the Amazon only with PAs is not enough (1). A comprehensive conservation strategy should also focus on enforcing the environmental law on private lands, *i.e.* the Forest Code, providing economic incentives as well to landowners that conserve native vegetation beyond the legal obligation (21, 22).

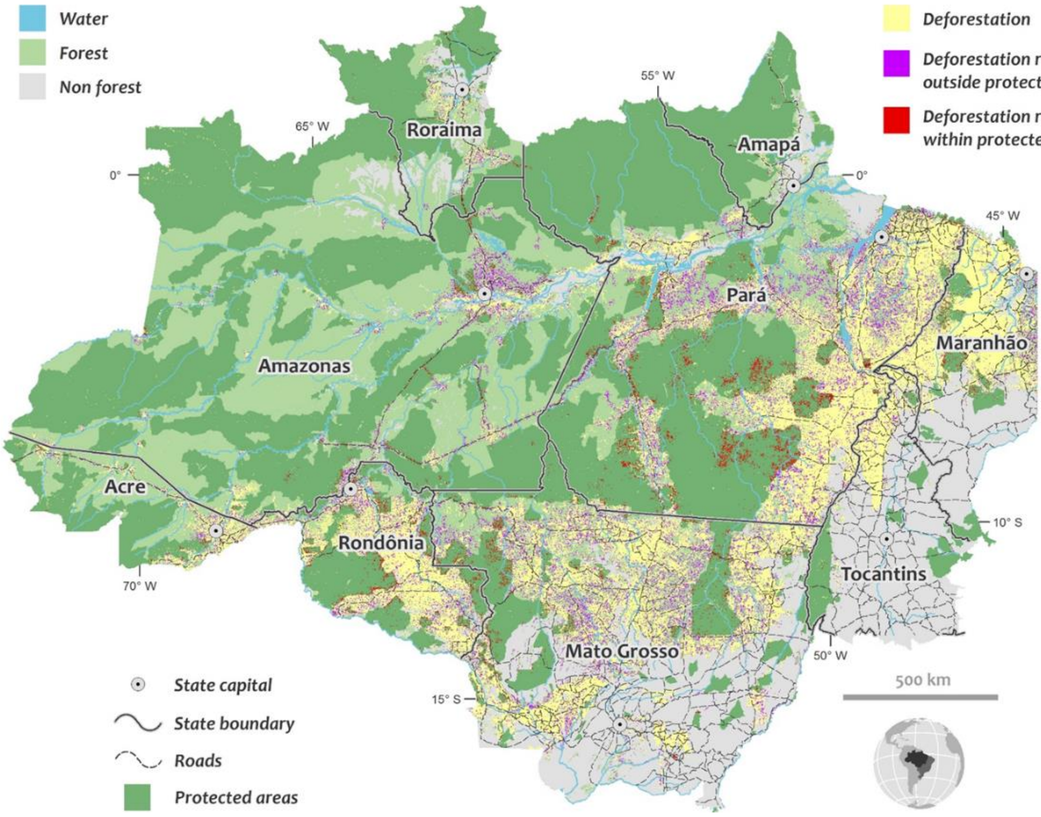


Fig. 6. Simulation of deforestation between 2005 and 2015 under the baseline scenario superimposed to historical deforestation to indicate areas where PAs helped reduce deforestation.

4. Methods

PA effectiveness

Adjacent internal and external 10 km buffer zones were derived specifically for each PA and overlaid with the map of deforestation, 1997, 1999, and annually from 2000 to 2015 from PRODES (11) (Fig. 7). To match landscape characteristics in internal and external buffers, we integrated the effects of a series of spatial determinants into a probability map of deforestation by using the Weights of Evidence method (1). Spatial determinants either represent proximate causes of deforestation (the opening or paving of a road) or are simply preferable, *e.g.* more fertile soil, low slope, or land use zoning, such as PAs. This Bayesian method takes into account the differential effects of spatial determinants on the spatial prediction of deforestation. Among the various factors that influence the location of deforestation in the Amazon (7), we chose the following variables: 1) distance to rivers, 2) distance to major roads, 3) maximum net present value from soy and cattle rents (1), 4) soil and terrain aptitude for mechanized crops (1), 5) elevation, 6) slope, and 7) attraction by urban centers.

The metric we used to assess the local effect of PAs on deforestation is the odds ratio of deforestation, which is defined as a ratio of the probability that an event will occur to the probability that it will not occur. We adapted this metric to account for differences in probability of deforestation in both forest and deforestation cells of the buffer zones used for pairwise comparison, and named this new metric "adjusted odds ratio". We determined the mean effect for a PA by selecting results from the 1997-2015 series of adjusted odds ratios only for the years after designation. We used the Mann-Whitney U test for checking difference in the population averages. This is a nonparametric test that two samples come from the same population against an alternative hypothesis that one of the populations tends to have larger values. It does not require the assumption of normal distributions.

PA contribution

Given the interplay between the policy interventions that reduced deforestation in the Amazon, translating effectiveness measures of PAs to their relative contribution to this reduction is very challenging. Synergy effects among policy interventions would require an ultimate model able to assess over time and space the combined effects of the major policy efforts in place in order to attempt to untangle their relative contributions. For example, PA role in reducing deforestation in the Amazon certainly benefitted from increase in law enforcement both inside and outside of PAs. Notwithstanding the other policy interventions, we designed a method to evaluate the direct reduction of deforestation within PAs. To do so, we applied SimAmazonia-2 (1) to spatially-explicit simulate deforestation under a baseline scenario of annual deforestation rates of 19,600 $km^2 year^{-1}$, *i.e.* the annual average between 1996 and 2005. The baseline scenario incorporates only PA designated by 2004 and their effectiveness (weights of evidence) prior to 2005. SimAmazonia-2 begins by regionalizing the overall annual rates using an econometric model; next, the rates are spatially-explicit allocated based on the influence of a set of spatial determinants as described above, including PAs. To calculate potential CO_2 reduction, the model annually sums the carbon stocks (8) of all PA cells that are deforested under the prescribed scenario, assuming that 85% of their forest carbon is released to the atmosphere with deforestation (23). To come up with the total emissions reduced by PAs, the model deducts the amount of emissions that occurred in PAs from observed deforestation (12) from emissions within PAs under the baseline scenario (Fig. 6). To account for spatial uncertainties, we ran SimAmazonia-2 50 times, recalculating each time the emissions figures. In this way, our approach considers which areas might be more vulnerable to deforestation if deforestation had continued unabated, and therefore presents a realistic picture of PA direct contribution. Spatial analyses and simulations were performed using Dinamica EGO freeware (www.csr.ufmg.br/dinamica).

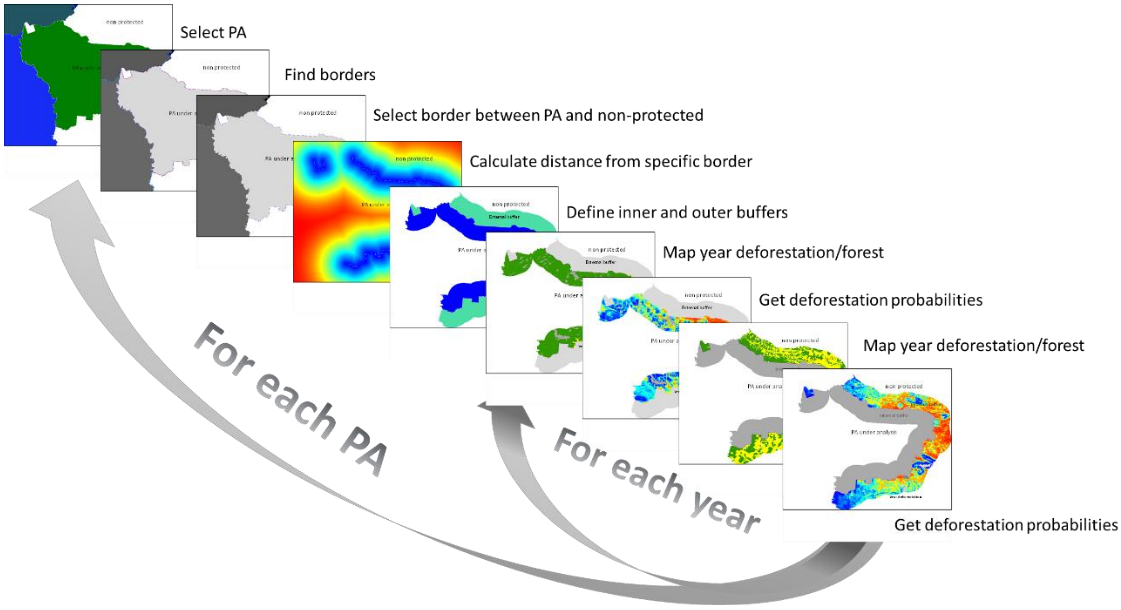


Fig. 7. Processing steps of the spatial analysis of deforestation rates within and without a specific protected area in order to derive the adjusted odds ratio of deforestation.

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