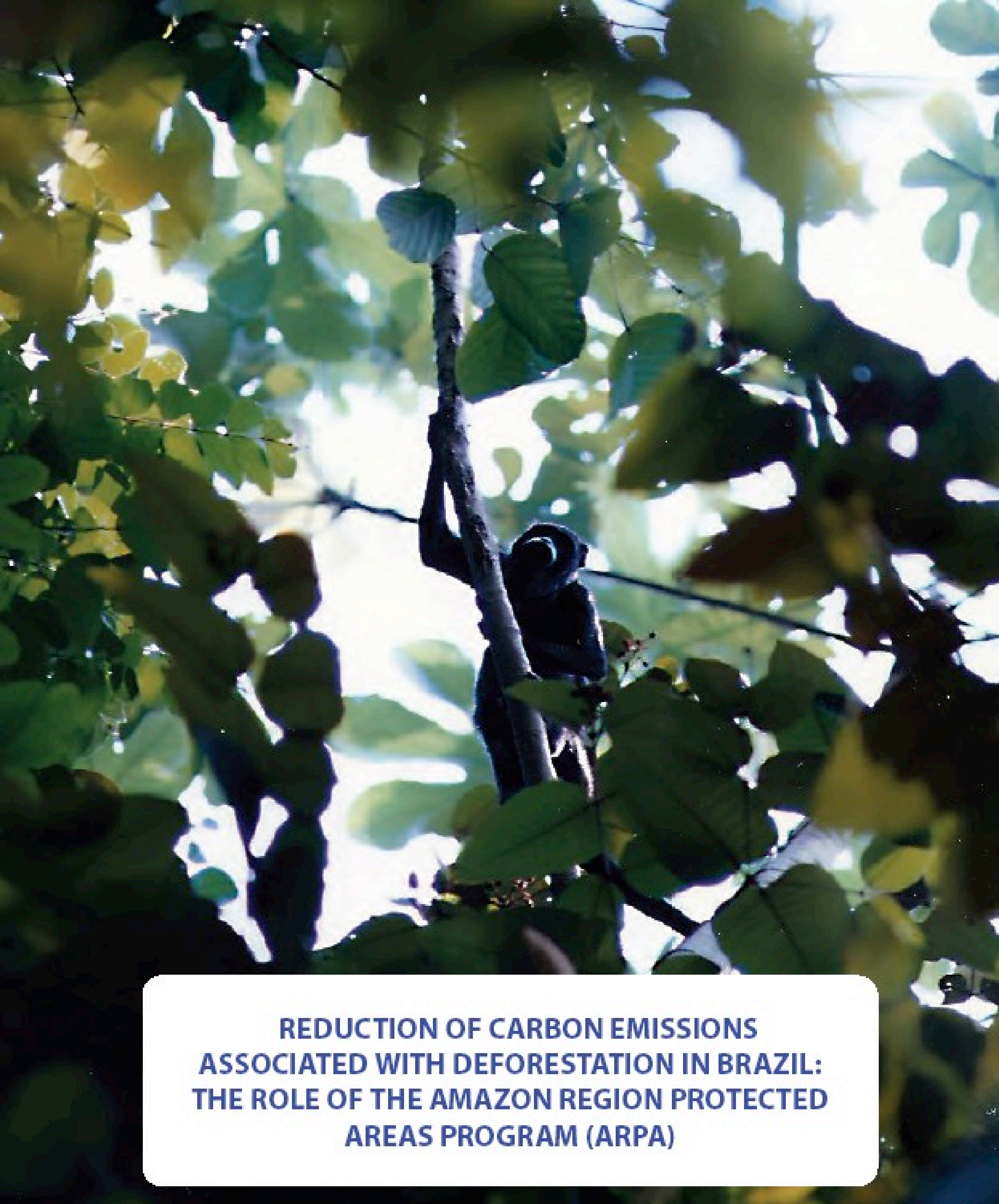

REDUCTION OF CARBON EMISSIONS ASSOCIATED WITH DEFORESTATION IN BRAZIL: THE ROLE OF THE AMAZON REGION PROTECTED AREAS PROGRAM (ARPA)

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The Woods Hole Research Center

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REDUCTION OF CARBON EMISSIONS ASSOCIATED WITH DEFORESTATION IN BRAZIL: THE ROLE OF THE AMAZON REGION PROTECTED AREAS PROGRAM (ARPA).

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ABSTRACT

The creation of protected areas in the Brazilian Amazon has been playing an important role in biological diversity conservation in the region and in the protection of extensive tropical forest areas. Approximately 50% of the remaining Amazon forests are protected areas. In light of this scenario, the most ambitious biodiversity conservation program is currently the Amazon Region Protected Areas Program (ARPA), which was created by the Brazilian Government in 2003. The program is related to the National Protected Area System (Sistema Nacional de Unidades de Conservação – SNUC) as part of a strategy for its implementation. Furthermore, it is an important mechanism for the implementation of various strategies and decisions of the Convention on Biological Diversity (CBD, 1992), especially the Programme of Work on Protected Areas (CBD Decision VII/28; CDB, 2004[1]) and the corresponding Brazilian National Strategic Plan on Protected Areas[2]. Over a 10-year period (2003–2013), the ARPA intends to protect 500 thousand km^2 of natural ecosystems, mainly forests. Despite its clear benefits to the conservation of biological diversity and protection of great forest carbon stocks, little is known about its role in the reduction of greenhouse gas – especially carbon dioxide (CO_2) resulting from Amazon deforestation. It is exactly this assessment of ARPA Program's contribution to the reduction of such emissions that is this study's central objective. By using analyses of historical deforestation rates between 1997 to 2007, and of estimated future rates obtained from modeling deforestation scenarios for 2050, it was possible to determine wthat, in general, the latu sensu protected areas3 in the Amazon not only work as great obstacles to the advancement of deforestation, but also yield the regional inhibition effect that consequently significantly contributes to the reduction of associated emissions of greenhouse gas. The results especially indicate that the 61 protected areas supported by ARPA are preserving a forest carbon stock of about 4.6 billion tons of carbon (18% of the total stock protected in the Amazon), which is almost twice the efforts for emissions reduction of the first commitment period of the Kyoto Protocol's if fully implemented. By using simulations of future deforestations, the protected areas (including those supported by the ARPA) created by the federal government between 2003 and 2008 will, until 2050, yield reduction of emissions resulting from deforestation by about 7±1 billion tons of carbon. From this expected reduction, 25% can be attributed to protected area created after ARPA Program was started and through its support (13 protected areas[4]). Notwithstanding, if the expansion of ARPA Program's protected area, which is expected to occur in 2008[5], actually takes place, an additional reduction of 1.1±0.2 billion tons of carbon can be expected by 2050. The recent and future contribution of protected areas in the Amazon and of the ARPA Program is therefore crucial for the reduction of deforestation patterns in the Amazon and of its associated carbon emissions and for the planet's biodiversity conservation. Such efforts shall be internationally acknowledged and valued, especially within the context of international negotiations in the scope of the Convention on Biological Diversity and the United Nations Framework Convention on Climate Change.

1. The Convention on Biological Diversity (CBD) considers that a great part of the world-wide advances in terms of new protected areas since the 2004 approval of the "CBD PoW PAs" has been attained by Brazil, and that great part of this achievement is a result of the ARPA Program (CBD-WGPA, 2008).
2. The National Strategic Plan for Protected Areas (Plano Estratégico Nacional de Áreas Protegidas - PNAP), according to Decree 5.758, of April 13, 2006.
3. Here includes strict preservation areas and sustainable use reserves, both stricto sensu nature protected areas, as well as indigenous people's lands and military areas.
4. Considering that the protected area that counted on ARPA Program support for their creation, but only as of 2003 when the Program was officially begun. Another parcel of protected areas supported by the ARPA are considered new (total of over 230 thousand km^2 since 2000) because they counted on support for their initial stages, including – in some cases – for their creation, even if this occurred during the Program's planning stages.
5. According ARPA Program's Annual Operations Plan for 2008, prepared by the governmental authorities.

The remaining Brazilian Amazon forests stretches over 3.3 million km² and holds a large carbon stock of approximately 47±9 billion tons (Saatchi *et al*., 2007, Nepstad *et al*., 2007). Nonetheless, the perturbation of such stocks by deforestation is resulting in substantial emissions of carbon dioxide – the gas which most contributes to global warming in addition to great biological diversity losses and reduction of its ecological function of regulating regional rainfall and global climate (Malhi *et al*., 2008).

The total deforested area in the Amazon is already of 616 thousand km² (15% of the domain) – an area that is larger than that of the French territory and twice the size of Germany. The concentration of deforestation is along the deforestation arc (Figure 1), which extends from northeastern Pará to the eastern region of Acre, and encompasses the world's largest expanding agricultural frontier (Morton *et al*., 2006).

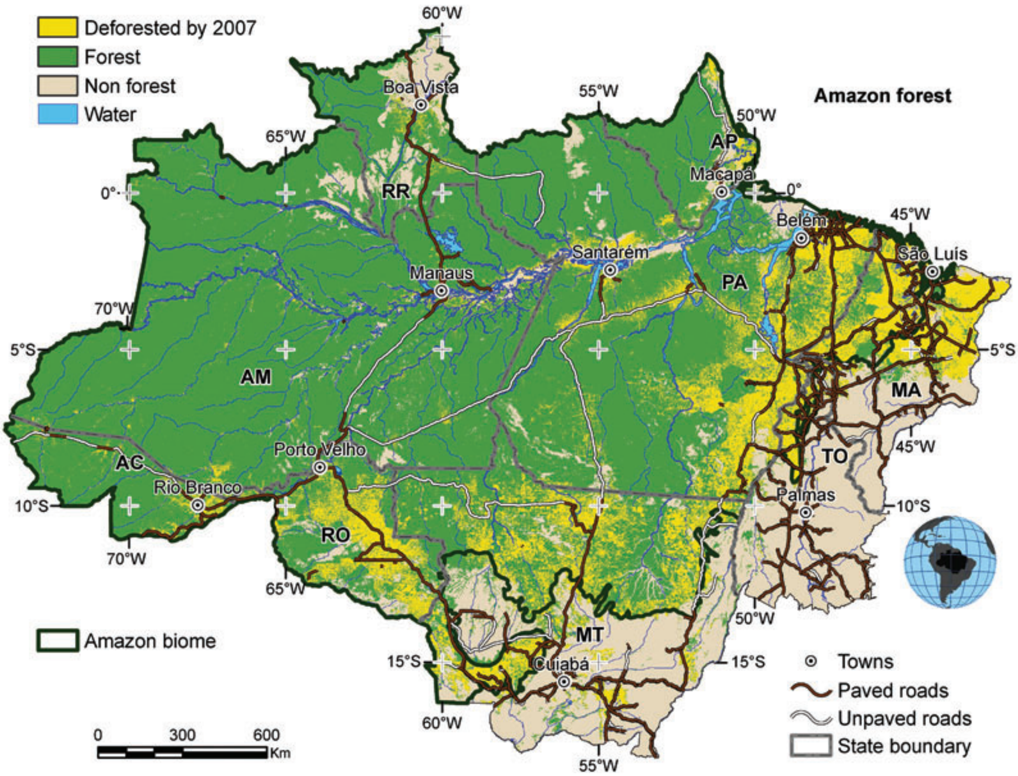


Figure 1. Brazilian Amazon. In yellow, areas deforested by 2007 forming the deforestation arc.

In the 1990's, annual deforestation rates were of around 17 thousand km^2, and corresponded to average annual emissions of 200 million tons of carbon[6]. Nonetheless, over the past two years, and after a period of intense deforestation rates in the early 2000 – which peaked to 27 thousand km^2 in 2004, the rates declined to approximately 13 thousand km^2 in 2007 (INPE, 2008) (Figure 2).

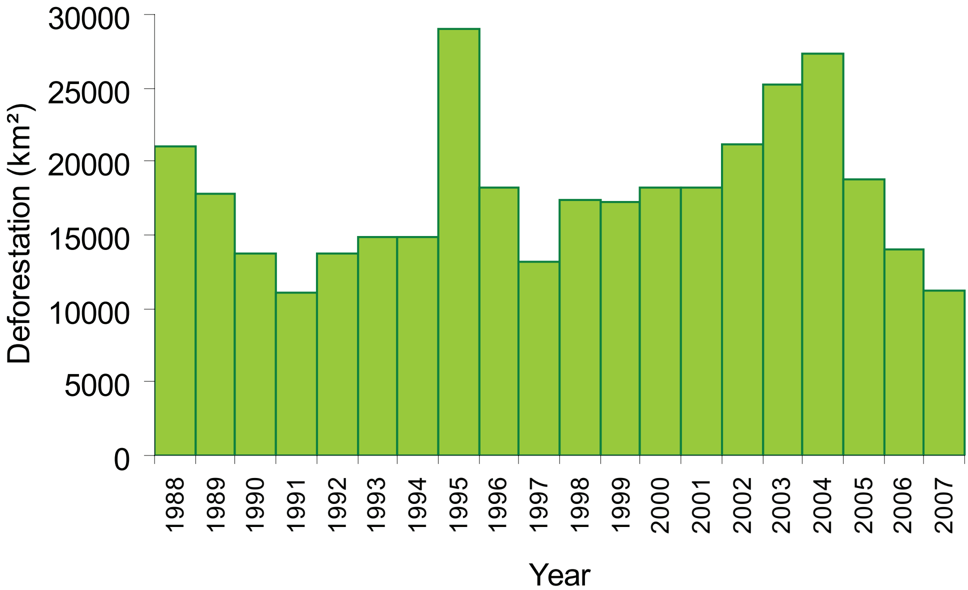


Figure 2. Annual deforestation rates in the Brazilian Amazon (INPE, 2008).

One of the main causes of deforestation in the Brazilian Amazon is the conversion of forests into extensive grazing land for cattle ranching (Margulis, 2003, Alencar *et al.*, 2004). Over 70% of deforestation in the Amazon results into pastures for cattle, most of which yields low productivity. More recently, the expansion of agribusiness and both expectation for paving and the actual paving of regional of roads has been contributing to the maintenance of high deforestation rates, because such infrastructure investments induce land speculation. Moreover, illegal market for land and timber, due to the government's difficulty to control criminal actions, further stimulates deforestation.

On the other hand, successive and recent decline of the Brazilian Amazon deforestation rates, summing 10 thousand km^2 over the past three years, demonstrates that governance in the Amazon frontier has been increasing. Despite the positive influence of external factors to the reduction of deforestation - e.g.: the decrease of international prices for soy and beef, and the depreciation of the US dollar against the Brazilian Real, which makes exporting more difficult, Brazil has demonstrated greater capacity to enforce and implement conservation policies in the Amazon forest. The creation of innumerous protected areas within the past years, summing a total of 622 thousand km^2 in 148 new protected areas created between 2003 and 2008, is a proof

6. Considering that one hectare holds an average of 120 tons of carbon (Nepstad *et al.*, 2007).

of such government efforts. However, this effort can be threatened by growing demands for agricultural products from national and international markets. If past trends of continuous agricultural expansion as well as extensive roads paving persist, 40% of the remaining Amazon forests may be eliminated by 2050 (Soares Filho *et al*., 2006). The quantity of carbon to be released into the atmosphere during this period can reach 32±8 billion tons – a quantity that is almost equivalent to three years of global CO2 emissions, at 2000 levels[7]. The impact of such potential deforestation on the Amazon biological diversity can be dramatic. As an example, it is estimated that ¼ of 382 Amazonian mammal species studied by Soares Filho *et al*. (2006) could suffer 40% loss of forest coverage or other natural ecosystems in their geographic distribution area. The evolvement of this trend would entirely hinder the possibilities for this region to attain significant advances towards the Convention on Biological Diversity goals that aim to deter a drastic decrease in biological diversity by 2010.

In addition to biodiversity losses, the evolvement of deforestation in the Amazon may lead to major changes in the regional climate regime, such as substantial decrease in rainfall (Sampaio *et al*., 2007) and the consequent increase of forest fire frequency, which in turn contributes to larger emissions of greenhouse gas (Nepstad *et al*., 1999, Nepstad *et al*., 2008). Only in 1998, Amazon carbon emissions to the atmosphere doubled due to the wide-spread fires resulting from a severe drought that affected the region, which was caused by the El Niño phenomenon. The simultaneous advance of deforestation and global warming can alter the Amazon climate in vicious cycle (Nepstad, 2007). Estimates point to 20-30% a reduction of regional rainfall (Nobre *et al*., 1991) and a 1.8 to 7.5°C increase of average temperatures during the dry season and of 1.6 to 6.0°C during the rainy season by 2080 (IPCC, 2007). Still if the increased frequency and intensity of El Niño due to global warming is added to this scenario (Nepstad *et al*., 1999), it is possible for the Amazon forest to enter an irreversible cycle of self-destruction (Nobre *et al*., 1996; Nepstad *et al*. 2007, Nepstad *et al,*2008).

One of the most promising mechanisms with which to interrupt massive destruction of the Amazon forest has been the creation of large blocks of protected areas. These areas have a role not only in protecting biological or forest diversity, but also in fostering social and cultural well-being as well as in providing economic alternatives to local populations, given that extractive reserves, sustainable development reserves and indigenous people's lands favor landscape protection and the maintenance of ecological processes and environmental services (Naughton-Treves *et al*., 2005; Maretti *et al*., 2003; Maretti *et al*., 2005; Peres, 2005; Schwartzman e Zimmerman, 2005). The innumerous benefits associated with protected areas include inhibition of land-squatting and consequently land-regulation chaos that facilitates irregular territorial occupation.

In general, management effectiveness models are considered for the protected areas. The main references for these models include International Union for Conservation of Nature (IUCN) guidelines, with methods that address, above all, its management and the implementation of its programs. The efficacy of protected areas with respect to deforestation has been assessed in several regions of the world. Generally speaking, findings state that deforestation rates within these areas are significantly lower when compared to areas that are not protected and areas in the vicinities of protected areas (Bruner *et al*., 2001; Naughton-Treves *et al*., 2005; Ferreira

7.33 billion CO^2 global emissions on the year 2000, which is approximately 9 billion tons of carbon. Climate Analysis Indicators Tool, WRI 2008.

et al., 2005; Soares-Filho *et al*., 2006, Nepstad *et al*., 2006). This large difference between deforestation rates within and outside protected areas is seen by some as a demonstration of their efficacy as a mechanism for the reduction of forest destruction, especially when these protected areas are properly implemented and, if possible, integrated with local social groups. Conversely, this interior versus exterior comparison has been seen as a demonstration that the protected areas strategy can foster deforestation in other regions and induce negligence as regards conservation of non-protected areas (Vandermeer, 1995; Cronon, 1995). Such statements are based on the argument that the establishment of a protected area can, at most, redistribute deforestation throughout a landscape and not decrease it in absolute values. Nonetheless, studies that quantify this effect on the redistribution of deforestation or its decrease are inexistent.

In order to advance toward greater understanding of the inhibitory effects of protected areas on tropical deforestation dynamics and, more specifically, in on its associated carbon emissions, this study assesses the role of the Brazilian Amazon protected areas in decreasing deforestation. For such, it analyzes historical deforestation rates (1997 to 2007) within and outside protected areas and also assess their effects of protected areas on future regional rates by 2050 under various economic and policy scenarios.

This study addresses protected areas in a more ample sense and includes protected areas (stricto sensu, for nature conservation), indigenous people's lands and military areas[8].

Brazilian protected areas are currently included in 12 categories of the National Protected Areas System (Sistema Nacional de Unidades de Conservação – SNUC, Law No. 9,985, of 2000)[9]. These categories are sustainable use reserves and strict preservation areas. The first group aims at conciliating conservation with the sustainable use of natural resources[10]. The second preponderantly aims at preserving biological diversity. In both cases, there is association with the remaining interests and benefits resulting from nature conservation as ecological processes, environmental services and others.

Indigenous people's lands are created to provide social and cultural protection to indigenous groups. In agreement with the decision of the Convention on Biological Diversity's Programme of Work on Protected Areas(CBD PoW PAs; Decision CBD VII/28) and as they play a positive role to the conservation of Amazonian biodiversity (Nepstad *et al.*, 2006), Brazilian indigenous people's lands can be considered as latu sensu protected areas for created and managed for other purposes, but contributing to nature conservation (Maretti, 2005).

In a similar manner, military areas can also play a relevant role in forest conservation – especially the Serra do Cachimbo Military Reserve (22.5 thousand km^2).

According to IBGE limits (2004), 43% of the Amazon domain are currently sheltered in latu sensu protected areas in the fore-mentioned categories and correspond to an extension of 1.8 million km^2 (Table 1). Among these protected areas, 54% are indigenous people's lands and 44% are stricto sensu nature protected areas.

Table 1 – Protected areas of the Amazon, their categories, area in km^2 and percentage of ARPA Program support.

Protected Areas		Number	Area (km^2)	Area (% of the domain)	Areas with ARPA Program Support (%)
Military area		6	26,235	0.6	0
Indigenous people's land		281	987,219	23.4	0
Strict preservation	State	44	137,385	3.3	22.5
	Federal	37	231,072	5.5	80.6
Sustainable use	State	72	201,918	4.8	13.2
	Federal	80	233,523	5.5	26.2
Total		520	1,817,355	43.0	16.8

8. Whether they are national or international, the definition of protected areas by both the most respected organizations (as the UICN) as well as official agencies (as for example the Convention on Human Heritage, CBD etc) tend to be somewhat associated with some elements as for example geographic delimitation, legal instruments for their institution, and nature conservation objectives that are more or less explicit) Notwithstanding, since the 2003 V World Parks Congress, promoted by the UICN in Durban, and above all the definitions of the Biological Diversity's Programme of Work on Protected Areas, approved by the COP7, held in Kuala Lampur in 2004, lato sensu protected areas are those that collaborate to biological diversity protection even if they have different objectives (as is the case of our indigenous people's lands that have social and cultural objectives) (Maretti, 2005).
9. Not considering the protected areas defined by the three governmental levels of Brazil (federal, state and municipal), which are not integrated with the SNUC.
10. The Environmental Protection Areas ("APA", in portuguese) were not included in this analysis as they are not of public domain and as they were not effective in terms of resistance to the current deforestation in the Brazilian Amazon.

Until 1997, most protected areas were of strict preservation. From 1998 on, there was not only great governmental effort with the enactment of innumerous indigenous people's lands, but also with the creation of over 300 thousand km² of sustainable use areas (Figure 3). Part of such effort counted on the technical and financial support of the ARPA Program, which was officially started in 2003. The efforts also include the expansions foreseen for 2008 and the years following ARPA Program's Annual Operations Plan for 2008.

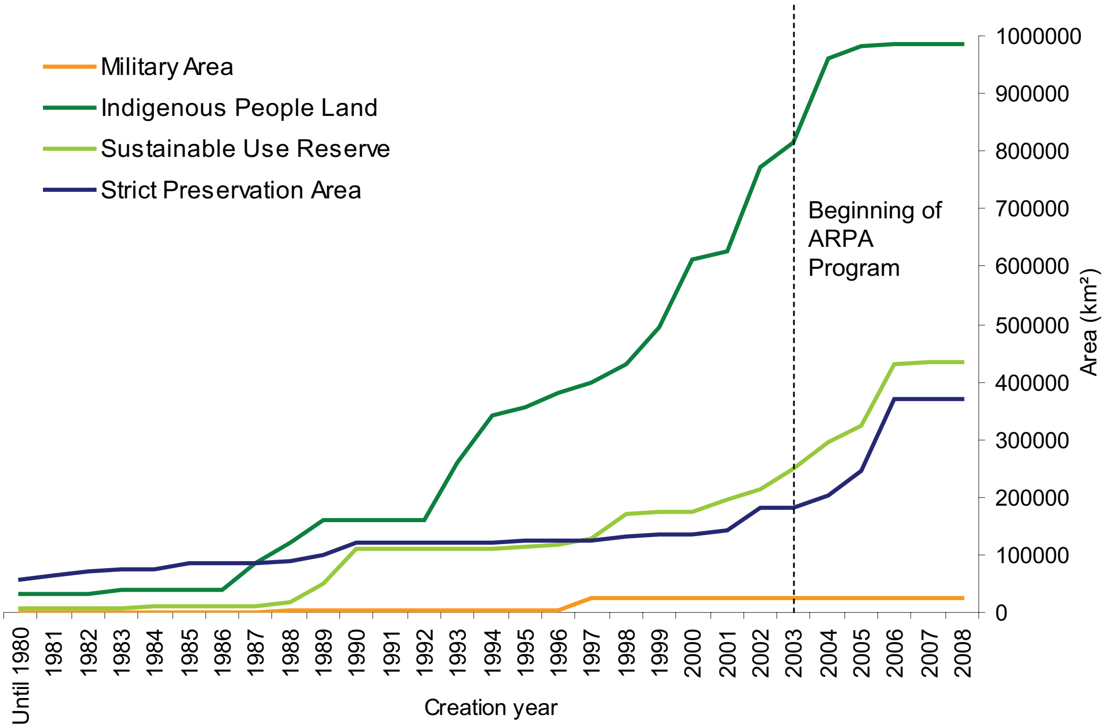


Figure 3. Timeline of the creation of protected areas and enactment of indigenous people's land in the Amazon domain.

The program was launched in 2002 and was officially started in 2003. ARPA is under federal government coordination, but now counts on support from several governmental and non-governmental institutions. The program aims at supporting the creation, implementation and consolidation of a total of 500 thousand km^2 of protected areas by 2013. Of this total, 375 thousand km^2 are for protected areas with creation support. The remaining 125 thousand km^2 will receive support for their consolidation and implementation.

ARPA Program partners[11] have committed to investing US$ 400 million during 10 years to this parcel of protected areas of the Amazon. The Protected Areas Fund (*Fundo de Áreas Protegidas – FAP*), a permanent capitalization fund[12], was created to ensure financial sustainability to protected areas that are created and consolidated through Program support. The resources received by means of donations are invested and earnings are employed to protected areas.

The ARPA does not provide support to all protected areas in the Amazon region. Its initial objective was to protect a sample of ecologically representative areas of the Brazilian Amazon in areas that were to be under better management. Furthermore, donations are limited and thus there are criteria to be fulfilled if an area is to receive Program support. Such criteria include the biological diversity representativeness, its level of threats ensuing from deforestation, the non-overlapping with indigenous people's lands and others. The protected area under Amazonian domain (IBGE, 2004) that are currently supported by the ARPA Program currently include:

From the group of strict preservation areas:
- Biological reserve (REBIO in Portuguese);
- Ecological station (ESEC in Portuguese); and
- National park (PARNA in Portuguese) or state park (PE in Portuguese);

From the group of sustainable use reserves:
- Sustainable Development Reserve (RDS in Portuguese); and
- Extractive Reserve (RESEX in Portuguese).

The areas are distributed throughout all states of the Amazon Region (Figure 4) and protect a total of 305 thousand km^2, of which 217 thousand km^2 are of strict preservation and 88 thousand km^2 are of sustainable use reserves[13].

11. Ministry for the Environment (MMA in Portuguese), Chico Mendes Institute for Biodiversity Conservation (ICMBio in Portuguese) – formerly the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA in Portuguese), state and municipal governments of the Amazon region, the Global Environment Fund (GEF), the World Bank, the German Cooperation Bank (KfW), the German Technical Cooperation Agency (GTZ), the WWF-Brasil, Brazilian Biodiversity Fund (FUNBIO in Portuguese). Among the partners, some collaborate with technical support, others with financial support, and some with both. Civil society organizations also participate in the management mechanisms as the Program's Committee, which decides about the allocation of financial resources.
12. Managed by the Brazilian Biodiversity Fund (FUNBIO).
13. For all of the calculations, overlaps were excluded so as to give priority to indigenous people's lands, followed by strict preservation areas, by sustainable use reserves, and finally by military areas.

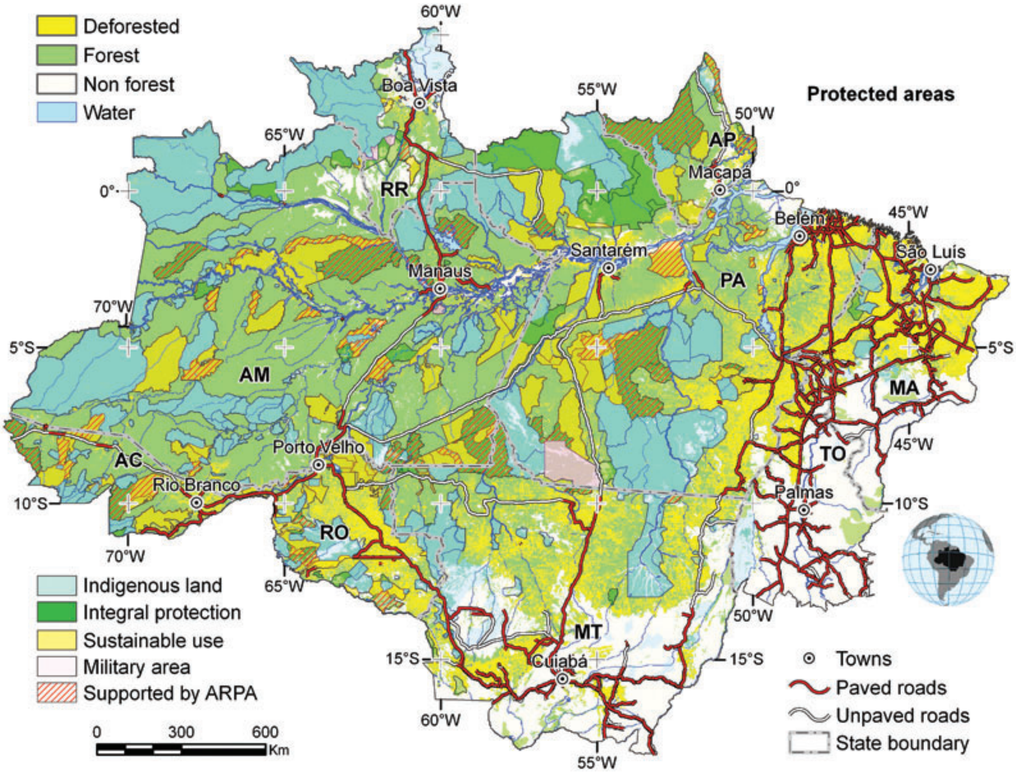


Figure 4. Protected areas of the Amazon domain, with emphasis on areas supported by the ARPA Program.

As previously mentioned, the central objective of this study is to analyze the influence of protected areas on deforestation reduction in the Amazon region. By overlaying the protected areas map (as defined in the previous section) with historical deforestation maps (1997 and 2007), obtained from PRODES (INPE, 2008), it was possible to assess the evolvement of deforestation both within and around protected areas[14]. For the analysis of the region surrounding the protected areas, buffer zones of 10, 20 and 20+ km were defined so as to establish the proximal effects of protected area. Furthermore, annual deforestation data were used to develop a Bayesian weights of evidence analysis, which calculates the *a posteriori* probabilities and the likelihood of events (deforestation), given a spatial pattern, which in this case is the presence or absence of a protected area (Bonham-Carter, 1994).

The first step of this analysis was to calculate the probability of deforestation within protected areas, 10, 20 and 20+ km buffer zones (see method details in the Annex). Deforestation data earlier than 2002 were not considered in the analysis due to the change in the PRODES method after 2001 (INPE, 2008).

Results show that protected areas in fact inhibit deforestation. Accumulated deforestation within the areas analyzed was relatively low (1.53% of the total protected area of the Brazilian Amazon), and totaled 28 thousand km^2 from 2002 to 2007. Accumulated deforestation throughout different protected area categories were of: 2.8 thousand km^2 (1% of the total protected area) in strict preservation areas; 13.1 thousand km^2 (3%) in sustainable use reserves; and 10.7 thousand km^2 (1.1%) in indigenous people's lands. This result is also confirmed by the comparison of deforestation probability in areas surrounding protected areas with the ones of the protected areas (Figure 5). The probability increases in places that are more distant from the protected areas, and the chances for deforestation in the vicinity areas are eight times higher than within the protected areas.

14. Analyses were carried out with spatial resolution of 60 meters.

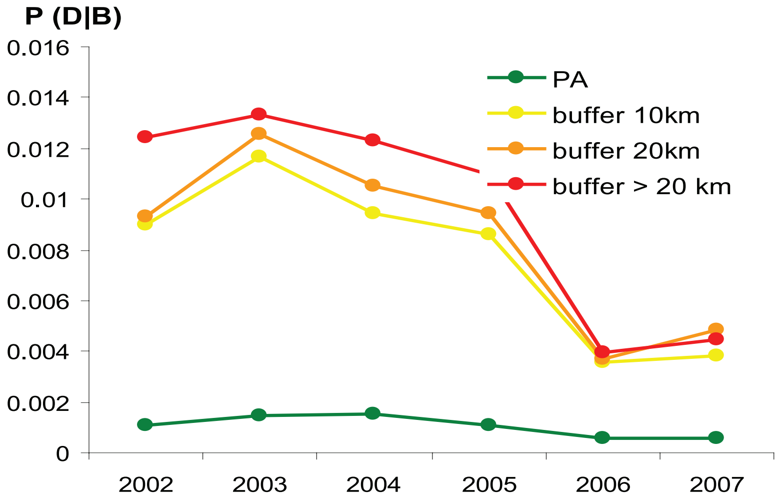


Figure 5. Probability of occurring deforestation within protected areas (total of 520 protected areas surveyed) and within areas within the 10 and 20 km buffer zones and in areas beyond the 20km buffer zones between 2002 and 2007.

This same analysis was individually employed for each protected area, through a sampling of 255 protected areas with records of historical deforestation. In this case, the analysis focused the contribution of each of these areas on the relative reduction of deforestation, regardless of the increasing or decreasing deforestation trajectories for the Amazon region as a whole. For the purpose of comparison, protected areas were grouped according to three types: indigenous people's lands, strict preservation areas, sustainable use reserves and military areas. The sustainable use and strict preservation areas were separated into areas without and with ARPA support. This analysis yielded the relative effectiveness of deforestation reduction for each protected area. Such index points out the degree of relative contribution that each area makes to deforestation reduction. This assessment compares deforestation rates between 2005 and 2007 with the rates between 1997 and 2004. From that analysis, it was possible to verify the contribution of different protected area categories to the deforestation reduction. The rates for relative effectiveness of deforestation reduction for each category were considered as described in Table 2. With respect to the areas that are not supported by the ARPA Program, it was observed that the reduction of relative effectiveness of deforestation is similar to those of sustainable use areas, strict protection areas and indigenous people's lands, and such fact confirms findings of other studies (Nepstad *et al*. 2006). Much lower values of relative effectiveness were only observed in military areas.

Table 2. Relative Effectiveness of Deforestation Reduction for the different categories of protected areas in the Brazilian Amazon with and without ARPA Program support. An elevated percentage points to greater effectiveness in deforestation reduction.

Type	ARPA	Non ARPA	P(T<=t)	Significant
Strict preservation area	25%	27%	0.3727	No
Sustainable use area	38%	21%	0.0011	Yes
Indigenous people's land	-	28%	-	-
Military area	-	12%	-	-

In comparing the relative effectiveness of deforestation reduction in protected areas supported by the ARPA Program, there was a considerable and statistically significant increase (test-t, n=105; $p<0.05$) of effectiveness of deforestation reduction in sustainable use areas supported by the Program (Table 2). In turn, for the strict preservation areas, the difference observed was not statistically significant (Table 2). One explanation for latter result is the time factor, as investments started by the ARPA Program require longer periods to mature.

The relative effectiveness of deforestation reduction in protected areas depends on their geographic location or, in other words, with their proximity to the deforestation arc. Such observation is valid for both sustainable use areas (Figure 6) as well as for strict preservation areas (Figure 7). The areas marked by darker colors correspond to protected areas in which there were greater decreases of deforestation from 1997-2004 to 2005-2007. Thus, some key areas supported by the ARPA Program are located in Terra do Meio, northeast of the Transamazônica Highway, Acre, northern Mato Grosso, and northeastern Rondônia.

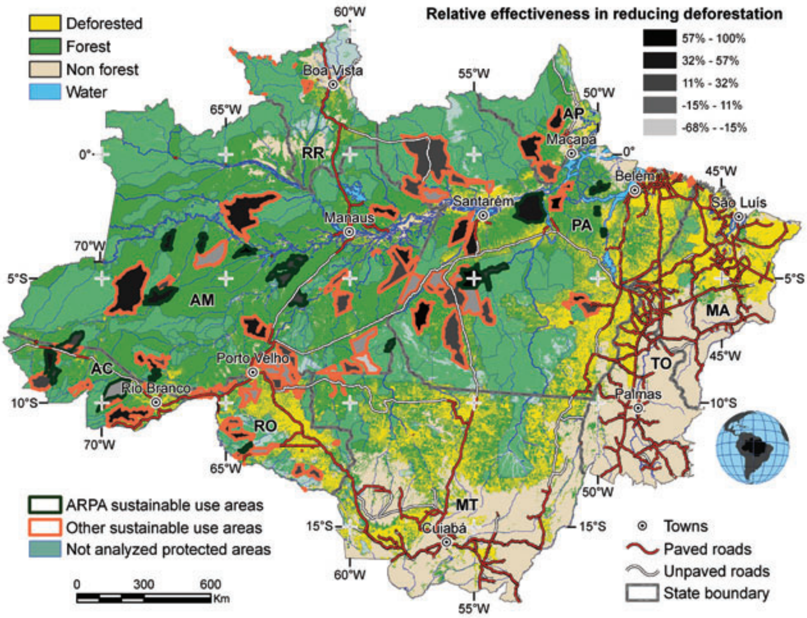


Figure 6 – Relative effectiveness of deforestation reduction for sustainable use areas. Note the key ARPA areas located in Terra do Meio (1), northeast of Transamazônica Highway (2), and in Acre (3).

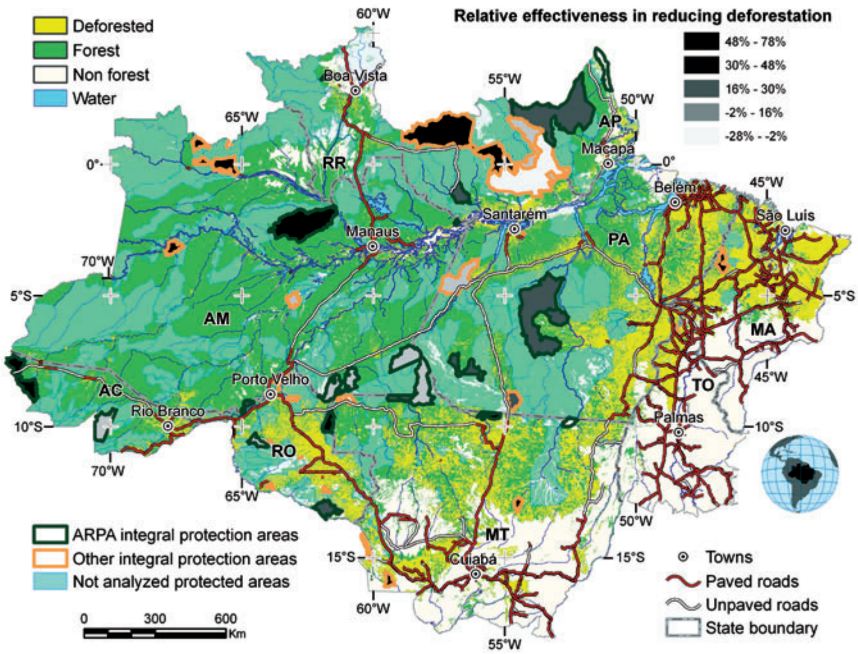


Figure 7 - Relative effectiveness in deforestation reduction for strict preservation areas. Note the key ARPA areas located in Terra do Meio (1), northern Mato Grosso (2), and northeastern Rondônia (3).

Recent studies show that deforestation in the Amazon region shall continue over the next decades if the region's occupation trend abides to the model adopted along the past 30 years (Soares-Filho *et al*. 2006, Nepstad *et al*., 2008). In great part, as it happened in the past, deforestation is pushed forth by the expansion of the network of paved highways and agricultural and ranching frontiers, which are fueled by the growing international demand for agricultural products. On the other hand, conservation initiatives reflecting the increasing social awareness against deforestation, greater law enforcement through command and control, and expansion of the network of protected areas are increasing. Investments in monitoring deforestation and logging, in promoting the new Brazilian forestry policies, in improving environmental licensing and implementing territorial zoning and measures that include conservation of forests located in private properties as legal reserves and permanent preservation areas are becoming more common. Among all of these measures, the massive creation of protected areas that was started in 2004 has been playing an important role and has ensued positive effects on reduction Amazon deforestation (see the previous section). Furthermore, these newly protected areas will exert a long-term effect on reducing future deforestation rates. Quantitative assessment of this role is still virtually unknown. Thus, this study incorporates analyses of these areas' roles in future deforestation. For such, we employed a deforestation simulation model developed under the auspices of the "Amazon Scenarios programm" led by the Amazon Institute for Environmental Research (IPAM in Portuguese), The Woods Hole Research Center and the Federal University of Minas Gerais.

The "Amazon Scenarios" allows the assessment of various scenarios of policies, regional economy, population mobility, and infrastructure development on future trajectories of Amazon deforestation (Soares-Filho *et al.,* 2006). The current version of this model "SimAmazonia-2" analyzes how the expansion and rentability of soy (Vera-Diaz *et al.,* 2008), cattle ranching (Merry *et al.,* in press), logging (Merry *et al.,* in press), interact to cause deforestation. In addition, SimAmazonia-2 takes into account public policies, as the creation and consolidation of protected areas and the implementation of the Forestry Code (*Código Florestal*) (Law No. 4,771, of 1965, with later amendments), on modeling future deforestation trajectories (*Soares et al.,* in press, see attachment for details about the method).

In the case of this study, the SimAmazonia-2 was used to assess the future role of protected areas recently created (between 2002 and 2008) and areas that are expected to be created under the ARPA Program.

SimAmazonia 2 models the future trajectory of deforestation in the Amazon region by pondering a series of conservation measures versus the deforestation drivers. As both show growing trajectories, this conflict becomes increasingly vigorous and sensitive to the speed and timing at which public policies are implemented. In this case, deforestation is a result of the expanding agricultural market and of regional infrastructure investments. In this sense, the effect of protected area in the future trajectory of deforestation is analyzed under two extreme scenarios – one (business as usual) of strong expansion of the agricultural frontier and the associated population mobility and extensive paving of roads and highways, and the other (governance) of moderate agricultural expansion and low population mobility and restricted paving of roads and highways. In each of these scenarios, All other variables were kept fixed to assess the effect of different protected area networks on the trajectory of deforestation until 2050. That is: only the extent and degree of protection of protected areas were changed. The effect of protected areas on the trajectory of future deforestation will thus be given by the mean value obtained from the two extreme scenarios, and its uncertainty will be the difference between the extreme values and the mean value.

To assess the role of protected areas on future deforestation, an initial simulation of deforestation in 2050 was made. This simulation excluded all protected areas, if they did not existed. This was done to establish the level of threat to the protected areas forests in case those areas had not been created. From this exercise, an index of level of threat by potential deforestation[15] was calculated. This index accounted not only for the chances of future deforestation, but also when it may occur, i.e. its suddenness (Figure 8).

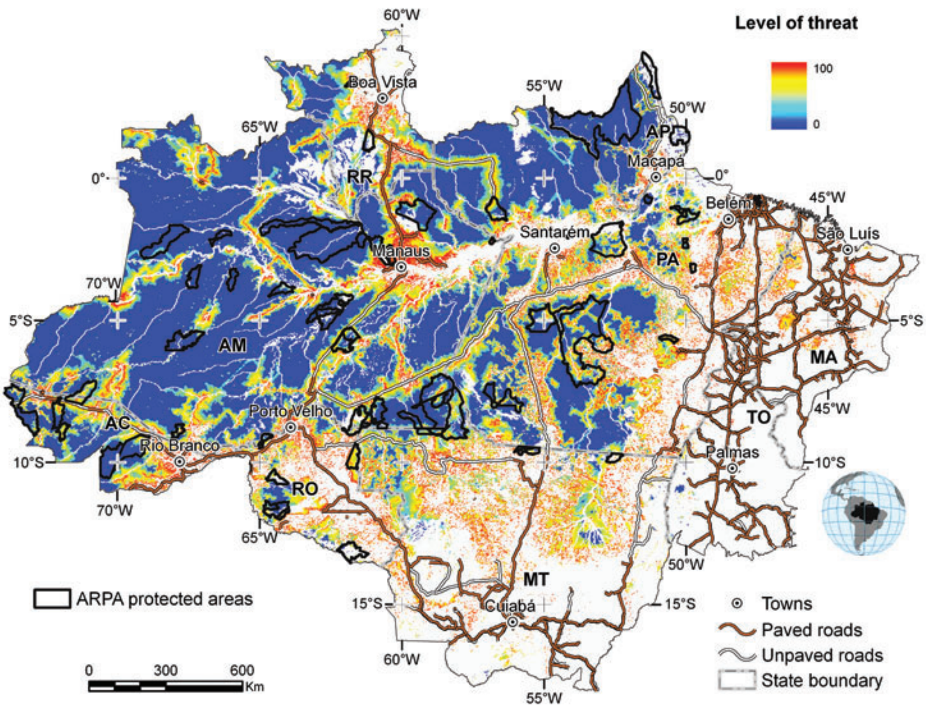


Figure 8 – Level of threat of deforestation. In this case, the future deforestation model disregards the existence of protected areas (see the text for additional details). ARPA Program areas are delineated in black lines.

15. Level of Threat corresponds to the year on which a parcel of the protected area will be deforested if it were not created and implemented: Threat = 100*(2050-year+1)/43).

The map of level of threat reflects the probability of deforestation to advance as a function of its main spatial determinants (proximity to paved highways, previously deforested areas, settlements and urban centers) as well as influenced by regional agricultural , cattle ranching, and population drivers.

The model then calculated the carbon stocks within each protected area supported by the ARPA Program and their respective emission potential in case such protected areas did not exist (Figure 9). by superposing the map of level of threat by 2050 on a map of forest's biomass (Saatchi *et al.,* 2007) and considering that 85% of forest carbon is released into the atmosphere during and after deforestation (Hougthon *et al.,* 2005).

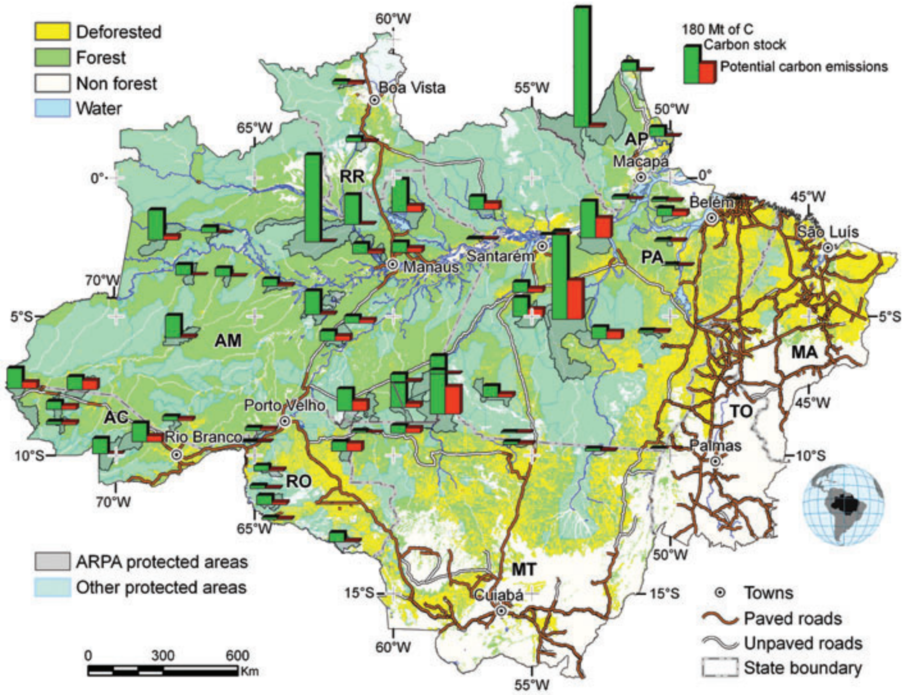


Figure 9 – Carbon stocks and potential emissions for ARPA areas.

The 61 units that are currently supported by the ARPA Program hold 4.6 billion tons of forest carbon. Such amount corresponds to 18% of forest carbon in protected areas of the Brazilian Amazon. With respect to the potential emission by deforestation in these areas, the analysis on the level of threat shows that these areas have a direct potential in reducing emissions of 1.1 billion tons of carbon – a total that is equivalent to what would be released by future deforestation by 2050 in case they did not exist

The next step of the analysis consisted in modeling the direct and indirect impacts of the existence of protected areas in different scenarios. In other words, this analysis assesses the influence of protected areas on inhibiting deforestation both within as well as around them. By keeping unaltered the set parameters of the extreme-case scenarios and by altering the configuration of protected areas, six additional scenarios were modeled:

1. By 2002 protected areas. Areas created only until the end of 2002: this scenario works as a baseline and allows for comparisons to be made on the reduction of emissions as the protected areas network is expanded;

2. By 2008 without the ARPA Program – areas created until April of 2008, except those areas that counted on ARPA support for their creation between 2003 and 2008 (13 protected areas[16]);

3. By 2008 – all protected areas created until April of 2008;

4. 2008 plus new areas proposed – all current protected areas plus the expansion planned for the future years according to the ARPA Program.

5. BY 2008 impervious – all current protected areas, but with the complete impediment of deforestation within them or, in other words, maximum effectiveness in reducing deforestation;

6. 2008 plus proposals impervious – all current protected areas plus the expansion foreseen for the following years and with complete impediment for deforestation within them.

Therefore, the latter two scenarios represent variants of the third and fourth in which the probability of deforestation within the protected areas are adjusted to zero, thus making them 100% impervious to deforestation.

16. ARPA Program support was considered, as was the creation of protected areas from the Program's official beginning in 2003.

Figure 10 shows the deforestation trajectories simulated for the six aforementioned protected areas scenarios within a BAU scenario The average effect on reducing the deforestation trajectory can be calculated by using the base line scenario of 2002 protected areas as reference (Figure 11).

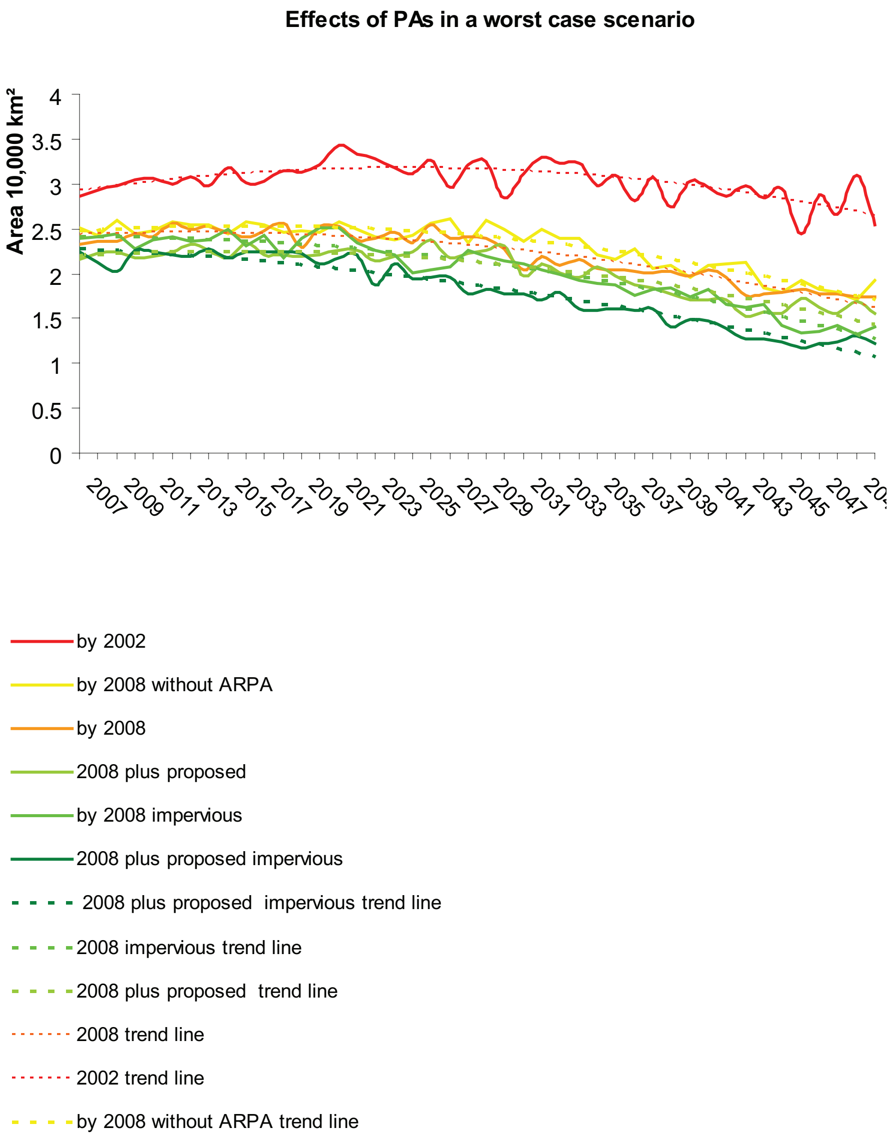
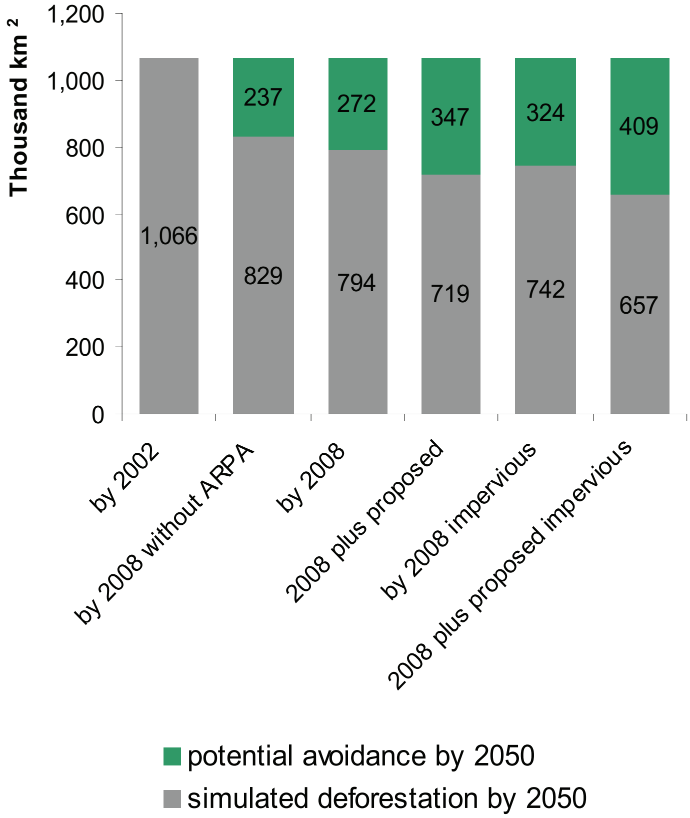
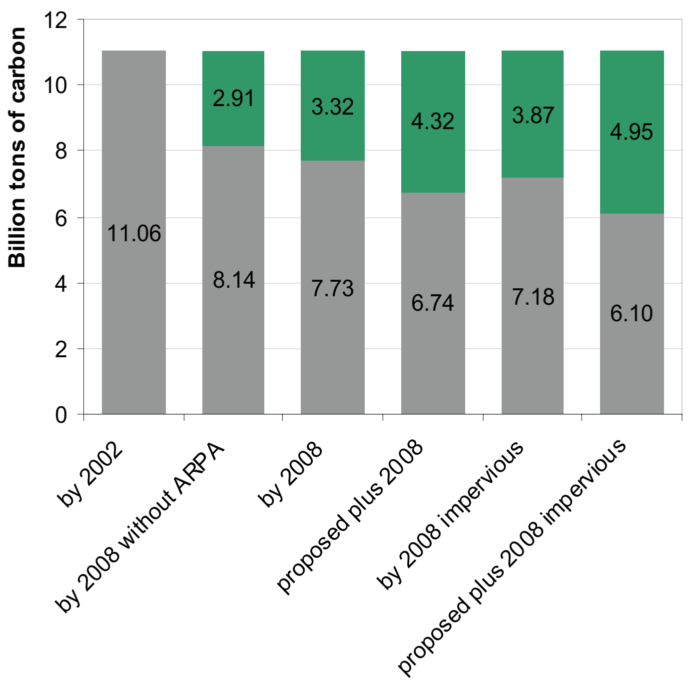


Figure 10. Modeled trajectories of deforestation in the Brazilian Amazon under various categories of protected area networks scenarios and degree of implementation.

Figure 11 – Simulated deforestation and associated carbon emissions. Potential avoidance is calculated using the 2002 PA network scenario as a baseline.





Only the expansion of protected areas between 2002 and 2008 will allow for a 237±180 thousand km^2 reduction of deforestation that could expected for 2050, which is, in other words, equivalent to a reduction of 3.3±1.1 billion tons of carbon emissions. Twenty-five percent (25%) of this global reduction can be attributed to the ARPA Program, which supported the creation of 13 protected areas during this time period. Moreover, the expansion of 210 thousand km^2 planned by the ARPA Program for 2008 and 2009 could increase this reduction to 350±170 and 409±137 thousand km^2 respectively, number that is equivalent to a reduction in carbon emissions of 3.9±1.3 to 4.9±1.5 billion tons of carbon. For a figure of comparison, this latter value corresponds to almost 50% of annual global anthropogenic emissions CO_2 emissions[17].

17. 33 billion CO2 global emissions on the year 2000, which is approximately 9 billion tons of carbon. Climate Analysis Indicators Tool, WRI 2008

Nearly 50% of remaining Amazon forests is under some type of protected area designation. Of this total, 16.8% are supported by the ARPA Program. Historically speaking, protected areas have played a fundamental role in deforestation reduction and are, consequently, a barrier to the advancing agricultural frontier that, when uncontrolled, illegally and predatorily destroys the Amazon forest.

Our empirical analysis has shown that protected areas not only inhibit deforestation within their lands, but also show an inhibitory effect on reducing deforestation in their surroundings. Notably, this inhibitory effect has been augmenting over time, as shown by the analysis of the effectiveness of protected areas in impeding deforestation, especially is the case of sustainable use areas supported by the ARPA Program.

Mosaics, corridors or networks of protected areas play a fundamental role in conserving biological diversity, protecting habitats, maintaining hydrological regimes, as well as in the stability of regional climate. Nowadays, the protected areas of the Brazilian Amazon hold nearly 50% of the remaining forest carbon stocks. Only the areas supported by the ARPA Program alone can reduce potential emissions from deforestation by 2050 in nearly 1.1 billion tons of carbon.

Nevertheless, the consolidation of these extensive protected area network represents a great challenge to the Brazilian nation, especially in areas located along the active deforestation front, where innumerous land conflicts and other illegal activities threats the social and natural environment,. This challenge tends to grow in the near future due to increasing demands for agricultural commodities.

Thus, those areas located along the deforestation front face greater threats and present the greatest potential for carbon emissions. On the other hands, if efficiently implemented, these same areas also represent the greatest potential for the reduction of carbon emissions. For these reasons they deserve special attention from conservation investment outlook, although their higher risks compared to traditional conservation approaches that prioritize protection areas according to their high biological diversity and low levels of anthropic threats. In our view, the best strategy consists in encompassing both strategies. In other words, it is necessary to give priority in protecting key areas against the advance of the deforestation frontier, targeting at the same time higly representative biodiversity samples of the Amazon domain as a whole.

Thus, the ARPA Program not only presents positive results regarding the protection of ecologically representative biological diversity, but it also meets the priorities of the Convention on Biological Diversity, including the Programme of Work on Protected Areas, Ecosystemic Approach, Programme of Work on Flora and other elements that will be decided during the 9th Conference of the Parties, such as the matters pertaining to forest biodiversity. Furthermore, the ARPA is also an important element in the reduction of emissions associated with deforestation and therefore collaborates with the implementation of the United Nations Framework Convention on Climate Change.

In addition to continuing to expanding of the Amazon protected network, a substantial allocation of resources is vital to the success of this innovative conservation strategy that aims the creation and consolidation of protected areas along regions of extreme land use dynamics.

Therefore, quantifying reductions of deforestation and associated carbon emissions through the implementation and consolidation of protected areas – especially under the ARPA Program, is an important contribution to the international debate.

In the scope of the United Nations Framework Convention on Climate Change, this work brings major contribution to the decisions[18] made by the Conference of the Parties, held in December of 2007 in Bali. The Bali Action Plan (Decision UCFCCC 1/COP13), which addresses measures and proposals with the objective of increasing the implementation of national and international mitigation, specifically refers to the development of policy approaches and positive incentives on issues relating to reducing emissions from deforestation in developing countries.

In a specific decision concerning deforestation (Decision UNFCCC 2/CP 13), it is noted that sustainable reductions of emissions resulting from deforestation in developing countries require stable and predictable resources. It is also acknowledged that reducing emissions from deforestation in developing countries can foster co-benefits and complement the objectives of other relevant conventions [19].

Thus, the estimation of the reduction of emissions resulting from deforestation under various scenarios allow us to conclude that the strategy for the implementation and consolidation of protected areas, especially the ARPA Program, can be classified as a demonstration activity for reducing emissions from deforestation in Brazil.

As highlighted by the parties, the huge efforts for conservation and reduction of deforestation emissions require stable and predictable availability of resources. It is imperative that the efforts made until the present moment be ensured and continued. The ARPA Program is ready to become integrated with future formal and/or volunteer mechanism of positive incentives towards reducing emissions from deforestation.

18. Report of Conference of Parties on its thirteenth session, held in Bali from 3 to 15 December 2007 – FCCC/CP/2007/6/Add.1 in http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf#page=8

19. The decision explains the need for developing countries to estimate possible reductions, as well as to explore a series of measures, identify options and undertake efforts, including that of demonstration activities, to address factors that are relevant to deforestation in national circumstances with the intention of reducing deforestation emissions and forestry degradation. In the guidelines resulting from the decision, emphasis is placed for deforestation assessments to adopt national approaches, and that sub-national demonstration activities shall be assessed within the limit used for demonstration and assessed as regards of associated displacement of emissions and that, when employed towards sub-national approaches, they should be a step towards the development of national approaches, reference levels and estimates and the reductions ensued from demonstration activities shall be based on historic emissions and account for national circumstances.

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DETAILS OF METHODS USED

The *a posteriori* probability accounts for the global deforestation rate and thus mirrors the decrease of this rate in probability values. In turn, the weights of evidence analysis does not depend on this effect as W+ corresponds to the natural logarithm of likelihood to find a deforested protected area versus the contrary. Positive W+ values favor an association whereas negative values point to refraction. In this case, the weight of evidence analysis shows the level of refraction of protected areas in relation to its surrounding areas, independently from the global deforestation rates. For such, the weights of evidence for the protected areas were calculated considering the occurrence of deforestation both within and around them. As a result, values under -1.5 were observed for protected areas, whereas the W+ for surrounding areas is of around 0.5. Table 3 shows a comparison among the protected area groups and the result of the test-t for the comparison among areas that are and are not supported by the ARPA Program.

Table 3 – Mean Minimum W+ (2005-2007)

Type	ARPA	Non-ARPA	P(T<=t)	Significant
Strict preservation area	-1.94137	-1.558657	0.306192	no
Sustainable use reserve	-2.74377	-1.215156	0.000183	yes
Indigenous people's land	-	-2.331827	-	-
Military area	-	-0.001108	-	-

The relative effectiveness rate for deforestation reduction points to the degree of refraction of the protected area to deforestation, as well as the difference between the minimum for this period and the maximum observed between 1997 and 2004. This last value was further normalized by being divided by the greatest difference obtained. Through this analysis, only protected areas in which there is occurrence of deforestation both within the initial and ending periods were considered due to flaws of PRODES data (355 samples of a total of 520).

The data obtained through the historic analysis was used to calibrate the deforestation simulation model. In addition to the Bayesian analysis that was previously presented, it is demonstrated that a fraction of the protected area is the only variable that presents a negative correlation with deforestation rates. Table 4 shows the results of a spatial lag regression obtained through social-economic and infrastructure data, percentage of protected area versus deforestation rates between 1997 and 2001 of 399 municipalities of the Amazon region. Of the five variables that have significant effect on deforestation rates, the fraction of protected areas is the only one that presents a negative effect on deforestation rates. Therefore, the extension of protected areas not only affects the location of deforestation, but also its global rate.

Table 4 - Spatial lag regression analysis of 1997-2001 deforestation per Amazon municipality.

Technique	**Maximum Likelihood**			
Multiple R		0,8021		
R^2		0,6434		
Observations		399		
Model OLS		**ML**		
	Coefficients	**S.D.**	**z**	**Prob.**
Constant	0.01703	0.0024	7.1499	0.0000
Mean proximity to paved roads	0.00003	0.0000	-2.4317	0.0150
Increase in cattle heads per Km^2	0.00053	0.0001	7.3599	0.0000
% Increase in crop areas	0.09547	0.0456	2.0930	0.0363
Migration net rate (1995/2000)	0.01412	0.0055	2.5815	0.0098
% of protected area	-0.0002	0.0001	-3.9195	0.0001
Positive outlier	0.07978	0.005	15.3247	0.0000
Negative outlier	-0.0474	0.015	-3.1092	0.0019
Spatial lag (r)	0.48948	0.041	11.8227	0.0000

This ration was obtained by means of a spatial lag regression with data collected between 1997 and 2001 and was used to calibrate the model for deforestation projection at the municipal level. The 2002-2006 time period was used for its validation (Figure 12). It is important to note that the fore-said deforestation projection accompanies both the rise and fall of deforestation (PRODES), due to the fluctuation of agricultural markets (negatively to production and export) and the recent expansion of protected areas.

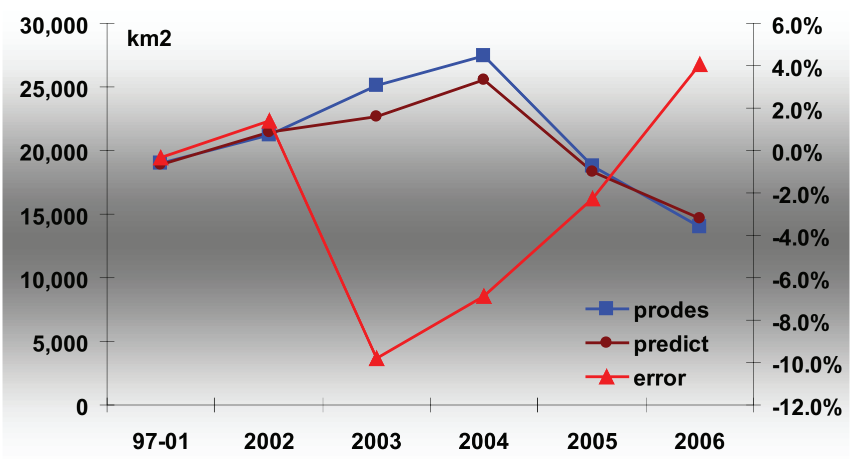

Figure 12 – Validation of temporal prediction of Amazon deforestation by SimAmazonia-2 model.