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# DETERring Deforestation in the Brazilian Amazon: Environmental Monitoring and Law Enforcement

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Executive Summary

## Descriptors

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## About the Executive Summary

This document presents the main findings of “DETERring Deforestation in the Brazilian Amazon: Environmental Monitoring and Law Enforcement” by Assunção et al. (2013). Please refer to the paper for a comprehensive discussion of the study.

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## About CPI

**Climate Policy Initiative** is a global policy effectiveness analysis and advisory organization. Its mission is to assess, diagnose, and support nations’ efforts to achieve low-carbon growth. An independent, not-for-profit organization supported by a grant from the Open Society Foundations, CPI’s headquarters are in the U.S., with offices and programs in Brazil, China, Europe, India, and Indonesia.



## Executive Summary

The Amazon is the world's largest rainforest. In Brazil, the forest originally occupied over four million km<sup>2</sup> – an area equivalent to almost half of continental Europe. Around 80% of the Brazilian Amazon remains covered by native vegetation, making it an important carbon sink. Moreover, the Brazilian Amazon holds unique biodiversity and 20% of the planet's fresh water (MMA [2012]). Amazon deforestation rates escalated in the early 2000s, peaking at over 27,000 km<sup>2</sup> in 2004, but fell sharply to about 5,000 km<sup>2</sup> in 2011 (INPE [2012]). Empirical evidence presented in previous CPI/PUC-Rio studies suggest that changes in Brazilian conservation policies helped address the challenge of protecting this immense area and significantly contributed to the recent deforestation slowdown.

In this study, we take a step further and answer the question: Which specific policy efforts contributed most to the reduction in Amazon deforestation? Our analysis reveals that the implementation of the Real Time System for Detection of Deforestation (DETER), a satellite-based system that enables frequent and quick identification of deforestation hot spots, was the main driver of the 2000s deforestation slowdown. Since its activation, DETER has served as the basis for targeting monitoring and law enforcement activity in the Amazon.

**We estimate that DETER-based environmental monitoring and law enforcement policies prevented the clearing of over 59,500 km<sup>2</sup> of Amazon forest area from 2007 through 2011. Deforestation observed**

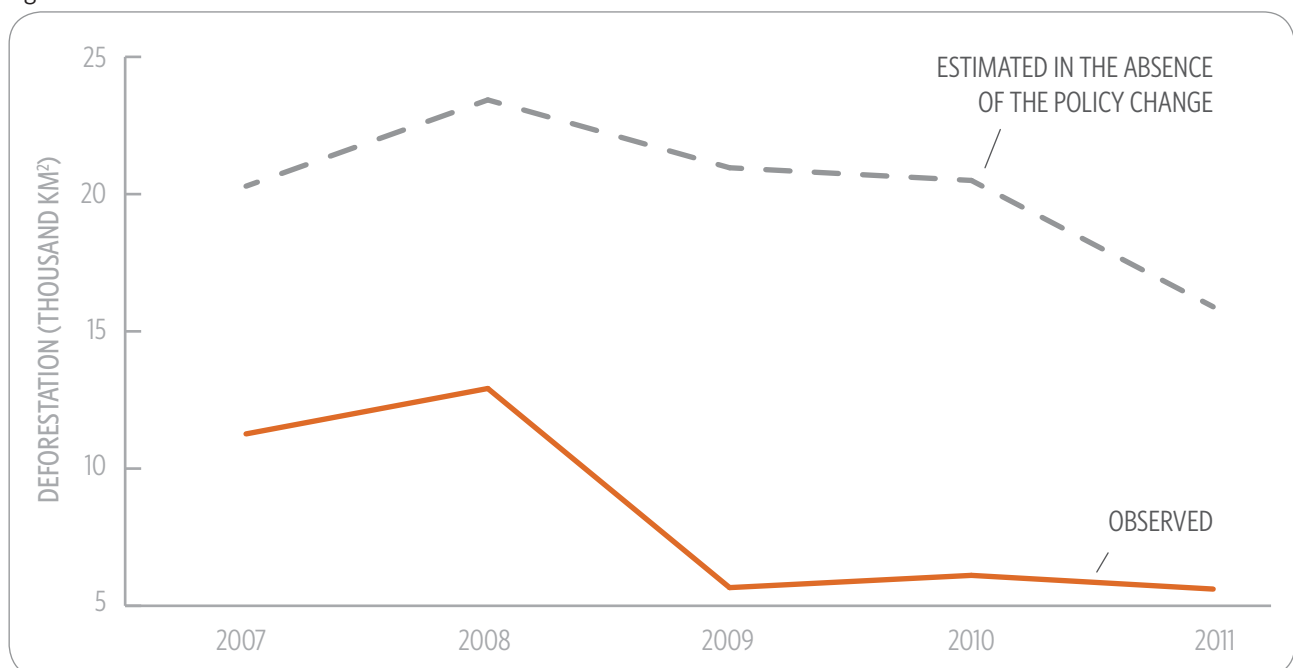
**during this period totaled 41,500 km<sup>2</sup> – 59% less than in the absence of the policy change. We also find that the policy change had no impact on agricultural production.**

## Improving Monitoring and Law Enforcement in the Amazon

The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) was the pivotal conservation policy effort of the 2000s. One of the main changes it introduced was a major leap forward in remote sensing-based Amazon monitoring capacity brought about by the implementation of DETER. Developed by the National Institute for Space Research (INPE), DETER is a satellite-based system that captures and processes georeferenced imagery on forest cover in 15-day intervals.

Figure 2 shows how deforestation is captured by DETER. The system, capable of detecting deforested areas larger than 25 hectares, portrays deforested areas in purple and forest areas in green. For any given location, recent images are compared with older ones to identify changes in forest cover. This procedure is used to locate deforestation hot spots and issue alerts signaling areas in need of immediate attention. The Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), which operates as the national environmental police and law enforcement authority, targets law enforcement activities in the Amazon based on these alerts.

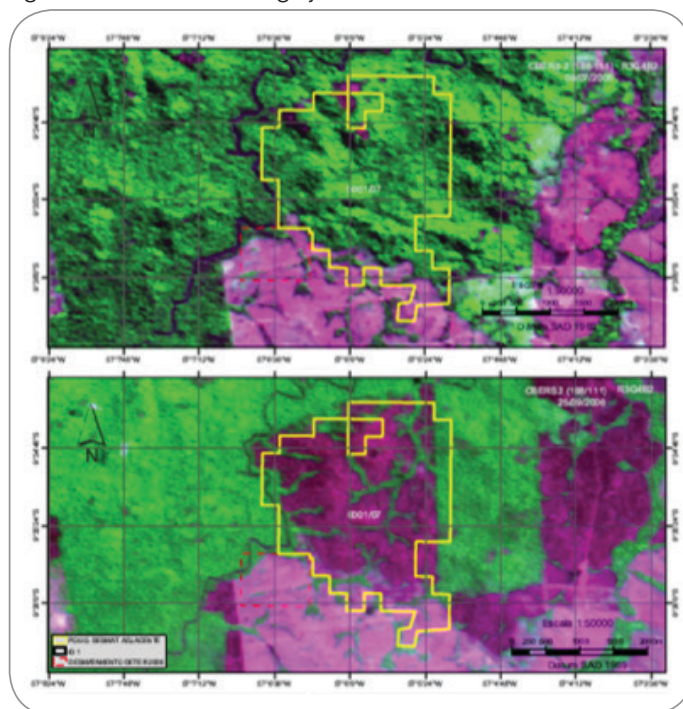
Figure 1: Deforestation in the Amazon Biome



Prior to the activation of DETER, Amazon monitoring depended on voluntary and anonymous reports of threatened areas, making it difficult for Ibama to identify and access deforestation hot spots in a timely manner. With the adoption of the new remote sensing system, Ibama was able to better identify, more closely monitor, and more quickly act upon areas with illegal deforestation activity.

The PPCDAm also promoted institutional changes that enhanced command and control capabilities in the Amazon. These changes increased the number and qualification of law enforcement personnel, and brought greater regulatory stability to the investigation of environmental crimes and application of sanctions. In particular, they regulated the use of legal instruments for the punishment of environmental crimes. These instruments included, but were not limited to, fines, embargoes, seizure of production goods, tools and material, and arrest. The policy changes also established the legal basis for singling out municipalities with very high deforestation rates – known as priority municipalities – and taking differentiated action towards them.

Figure 2: DETER Satellite Imagery



### A Word on Methodology

Estimating the impact of monitoring and law enforcement on illegal deforestation is a challenging task. Because the allocation of law enforcement teams typically targets areas under greater risk of deforestation, the correlation between the presence of the enforcers and forest clearings is jointly determined by the risk-based targeting strategy and the deterrent effect of monitoring and law enforcement. Estimation of the causal effect of monitoring and law enforcement on deforestation therefore hinges on successfully disentangling the impact of the two determinants. To do this within the context of the Brazilian Amazon, we must identify a source of variation in the allocation of Ibama resources that is not associated with deforestation.

Bearing this in mind, we exploit a key characteristic of the DETER system in our empirical strategy. DETER is incapable of detecting land cover patterns in areas covered by clouds, so no deforestation activity is captured and no deforestation alerts are issued in these areas. Ultimately, this reduces the probability of monitoring personnel being allocated to such areas. It is therefore likely that monitoring and law enforcement in the Amazon are directly affected by DETER cloud coverage.

We derive an empirical strategy that uses average annual DETER cloud coverage for a municipality as a source of variation in the allocation of Ibama resources that is not driven by deforestation activity. Our analysis is based on a two-step procedure. First, we show that DETER cloud coverage systematically affects Ibama presence, as measured by the annual number of environmental fines applied at the municipality level. A greater number of fines is regarded as indicative of more stringent monitoring and law enforcement. Second, we quantify the deterrent impact of the presence of Ibama on deforestation.

In a nutshell, we show that Ibama is systematically less present in municipalities with greater cloud cover in any given year, and that these municipalities exhibit higher deforestation the following year.

Table 1: Observed and Estimated Deforestation in the Amazon Biome (km<sup>2</sup>)

YEAR	OBSERVED DEFORESTATION	HYPOTHETICAL SCENARIO 1 (NUMBER OF FINES FROM 2007 THROUGH 2011 EQUAL TO NUMBER OF FINES RECORDED IN 2003)		HYPOTHETICAL SCENARIO 2 (NUMBER OF FINES FROM 2007 THROUGH 2011 EQUAL TO ZERO)	
		ESTIMATED DEFORESTATION	DIFFERENCE: ESTIMATED - OBSERVED	ESTIMATED DEFORESTATION	DIFFERENCE: ESTIMATED - OBSERVED
2007	11,263	20,289	9,026	32,933	21,669
2008	12,918	23,432	10,514	36,075	23,157
2009	5,663	20,960	15,297	33,603	27,940
2010	6,109	20,498	14,389	33,141	27,032
2011	5,610	15,895	10,285	28,538	22,928
<b>Total 2007-2011</b>	<b>41,563</b>	<b>101,073</b>	<b>59,511</b>	<b>164,290</b>	<b>122,727</b>

## The Effect on Deforestation

Our results indicate that the presence of Ibama, captured by the number of environmental fines applied in a municipality in a given year, significantly reduces deforestation the following year. This suggests that effective monitoring and law enforcement can curb deforestation.

To better understand the magnitude of this effect, we conduct two simulations to estimate total deforestation in hypothetical scenarios that differ from the observed reality. In the first scenario, we assume that the annual number of fines in each municipality from 2007 through 2011 was equal to that observed in 2003, the year immediately preceding the launch of the PPCDAm. In doing so, we recreate a scenario in which monitoring and law enforcement policy stringency remained unchanged after the implementation of the PPCDAm. We then estimate the deforestation trend for this hypothetical scenario. Table 1 presents both observed and estimated annual deforestation. Our analysis shows that, had command and control policy remained unchanged, the Amazon Biome would have seen over 101,000 km<sup>2</sup> of deforestation from 2007 through 2011. Compared to the 41,500 km<sup>2</sup> of deforestation actually observed during this period, results suggest that the more stringent monitoring and law enforcement policies preserved over 59,500 km<sup>2</sup> of forest area.

In the second simulation, we assume that no fines were applied in all Amazon Biome municipalities from 2007 through 2011. This scenario captures the complete absence of monitoring and law enforcement in the Amazon. Table 1 again presents both observed and estimated deforestation. We calculate that, without monitoring and law enforcement activities, over 164,200 km<sup>2</sup> of forest would have been cleared in the 2007 through 2011 period. Compared to observed deforestation,

results indicate that such activities preserved more than 122,700 km<sup>2</sup> of forest area.

## Costs and Benefits of Monitoring and Law Enforcement: Worth It?

We now show a simple calculation of the costs and benefits of monitoring and law enforcement in the Brazilian Amazon. In this simplified cost-benefit analysis, we compare the sum of Ibama's and INPE's annual budgets with the estimated monetary benefits of preserving forest areas and thereby avoiding carbon dioxide emissions. In this exercise, we use the avoided deforestation results from our second simulation to account for the deterrent effect of monitoring and law enforcement as a whole, and not only that of the policy change.

Ibama's 2011 budget was USD 560 million, while INPE's 2010 budget was USD 125 million. According to our simulation, command and control efforts preserved an average of 24,500 km<sup>2</sup> of forest area per year in the 2007 through 2011 period. This area is equivalent to approximately 900 million tCO<sub>2</sub>.<sup>1</sup> Therefore, any price of carbon set above 0.76 USD/tCO<sub>2</sub> would more than compensate the cost of environmental monitoring and law enforcement in the Amazon. Compared to the price of 5.00 USD/tCO<sub>2</sub> commonly used in current applications, these figures suggest that the presence of an active monitoring and law enforcement authority in the Amazon has the potential to yield significant net monetary gains. Indeed, our estimates capture the lower bound of this potential gain. Considering that, in reality, only a share of Ibama's and INPE's budgets is used for Amazon monitoring and law enforcement, our cost-benefit comparison becomes even more striking.

1 Estimations are based on a conversion factor of 10,000 tC/km<sup>2</sup> (36,700 tCO<sub>2</sub>/km<sup>2</sup>), as established in MMA/DPCD (2011).

## The Effect on Agricultural Production

There is an ongoing debate about how conservation policies and economic growth interact. While some worry that the preservation of natural resources can only be achieved at the expense of economic growth, many posit that society can – and should – jointly pursue the two goals. In particular, some argue that agricultural producers could increase output by boosting productivity, instead of expanding production into new – often forested – areas. This productivity growth could more than compensate potential costs of conservation efforts.

We address this debate by investigating whether the change in monitoring and law enforcement policies had an impact on local agricultural production. We find that the number of fines applied by Ibama in a given municipality had no effect on agricultural production.

Our results show that DETER-based monitoring and law enforcement played a crucial role in curbing Amazon deforestation, and thereby containing carbon dioxide emissions, without adversely affecting agricultural production. This suggests that it is possible to protect the native forest without significantly interfering with local agricultural production.

## Policy Implications

Our analysis shows that the adoption of a satellite-based system for real-time monitoring of deforestation and better targeting of law enforcement activities effectively reduced deforestation in the Brazilian Amazon. This yields two main policy implications.

1. **Maintain monitoring and law enforcement activities in the Brazilian Amazon.** In addition to showing that more stringent monitoring and law enforcement policies reduced deforestation, our results highlight the quantitative relevance of these policies' deterrent effect. We find that the total amount of avoided deforestation attributed to the policies in a five-year period is almost as large as the impact of a whole set of conservation policies introduced in the second half of the 2000s (see Assunção et al. [2012]). Although in this study we estimate avoided deforestation in a slightly different five-year window from the one used in the previous CPI/PUC-Rio study, the sheer magnitude of the forest area that was preserved indicates that the relative impact of DETER-based monitoring and law enforcement was far greater than that of other conservation policies implemented under the PPCDAm framework. This does not in any way imply that other policies should not be used to

combat deforestation. Rather, it suggests that such policies are complementary to monitoring and law enforcement efforts, effectively deterring forest clearings at the margin, while monitoring and law enforcement contain the bulk of deforestation.

Additionally, our findings show that the policy change had no effect on agricultural production. This finding reinforces the case for relying on monitoring and law enforcement to protect the Amazon. Moreover, it indicates that, in the Amazon region, both preservation and economic growth can happen simultaneously, contrary to any perceived dichotomy between these two goals.

2. **Improve monitoring technology.** Our results also suggest that better monitoring technology could further increase the effectiveness of Amazon law enforcement activities. Overcoming DETER's incapacity to see through clouds and obtaining land cover imagery in higher resolutions are two examples of technological advances that could enhance law enforcement targeting capability and add significant value to Brazil's conservation efforts.

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