

Research Article

Brazil's Success in Reducing Deforestation

Doug Boucher¹, Sarah Roquemore¹ and Estrellita Fitzhugh¹

¹Tropical Forests and Climate Initiative, Union of Concerned Scientists, 1825 K Street, NW Suite 800, Washington, DC 20006-1232, USA.

Email: dboucher@ucsusa.org

Abstract

Over the past several years, the rate of deforestation in the Brazilian Amazon has dropped by more than two-thirds. This reduction has been achieved despite high beef and soy prices, which in previous years had pushed deforestation upward, and during the same time that Brazil made important social progress in reducing poverty, hunger and inequality. The reduction in global warming pollution that this represents is the largest contribution so far by any country, rich or poor. Several factors are responsible for this accomplishment. They include: government policies and enforcement actions by prosecutors, on both the federal and state levels; the incentive created by Norway's pledge of up to \$1 billion in results-based compensation through the Amazon Fund; the strong and concerted pressure exerted by Brazilian civil society on the government and the soy and beef industries; and the positive response by those industries, resulting in the 2006 soy and 2009 beef moratoria. Political leaders, such as President Luis Inácio Lula da Silva and especially Minister of the Environment/2010 Green Party presidential candidate Marina Silva, can also claim an important share of the credit. While success is by no means assured, what has been achieved so far is already quite impressive, and makes it possible to envision the reduction of Amazon deforestation and forest degradation to zero within the next decade.

Key Words: Brazil, deforestation, REDD+, civil society, global warming, climate, emissions

Received: 17 August 2011; Accepted: 30 August, 2012; Published: 19 August 2013.

Copyright: © Doug Boucher, Sarah Roquemore and Estrellita Fitzhugh. This is an open access paper. We use the Creative Commons Attribution 3.0 license <http://creativecommons.org/licenses/by/3.0/> - The license permits any user to download, print out, extract, archive, and distribute the article, so long as appropriate credit is given to the authors and source of the work. The license ensures that the published article will be as widely available as possible and that the article can be included in any scientific archive. Open Access authors retain the copyrights of their papers. Open access is a property of individual works, not necessarily journals or publishers.

Cite this paper as: Boucher, D., Roquemore, S. and Fitzhugh, E. 2013. Brazil's success in reducing deforestation. *Tropical Conservation Science*. Special Issue Vol. 6(3):426-445. Available online: www.tropicalconservationscience.org

Introduction

The Amazon, with about 5 million square kilometers of forest, is the largest tropical forest in the world, both in area and in terms of carbon stock [1-2]. Unlike the Congo Basin and Southeast Asia, the other two main tropical rainforest areas, about 80% of its forest is intact, although substantial areas have been selectively logged [3]. Brazil contains about 3.4 million square kilometers of the Amazon forest [1], making it the largest tropical forest nation, and at the peak of its deforestation in 2004, it accounted for about 5% of global emissions. In size alone, deforestation and forest degradation in Brazil are vital to the future of global biodiversity and have a crucial impact on climate change.

Since 2005, with relatively little notice worldwide, a dramatic transformation has occurred in the Brazilian Amazon. The forces driving deforestation— above all, the soybean and beef cattle industries — have in a few short years been turned in a new direction. They continue to expand economically, but far less at the expense of the rainforest. Effective protection has been extended to indigenous reserves and other protected areas, which now make up over half of the area of Amazonian Brazil [4]. (In this paper, we generally use Brazil's "Legal Amazon" definition based on state boundaries; this is not exactly the same as the Amazon biome but corresponds fairly closely.) Responding to the pressure of organized civil society, governments and industries have put in place new policies and enforcement actions that have effectively countered the economic pressure of rising world food prices. And the government of Norway, by pledging up to \$1 billion in compensation for Brazil if it reduced its emissions from deforestation, has offered an important incentive in the form of concrete economic rewards for environmental success.

This paper examines the reasons that underlie the rapid reduction in deforestation in Brazil, assessing which actors and what forces are responsible for this historic advance. Many people and organizations can claim a share of the credit, and some of the features of Brazil's success are probably unique to that country and its changing political and economic dynamics. However, others can be replicated in many other tropical countries. If so, most of us who are living today could witness the end of thousands of years of deforestation — until the twentieth century mostly in temperate countries, but now mostly in the tropics — in our lifetimes.

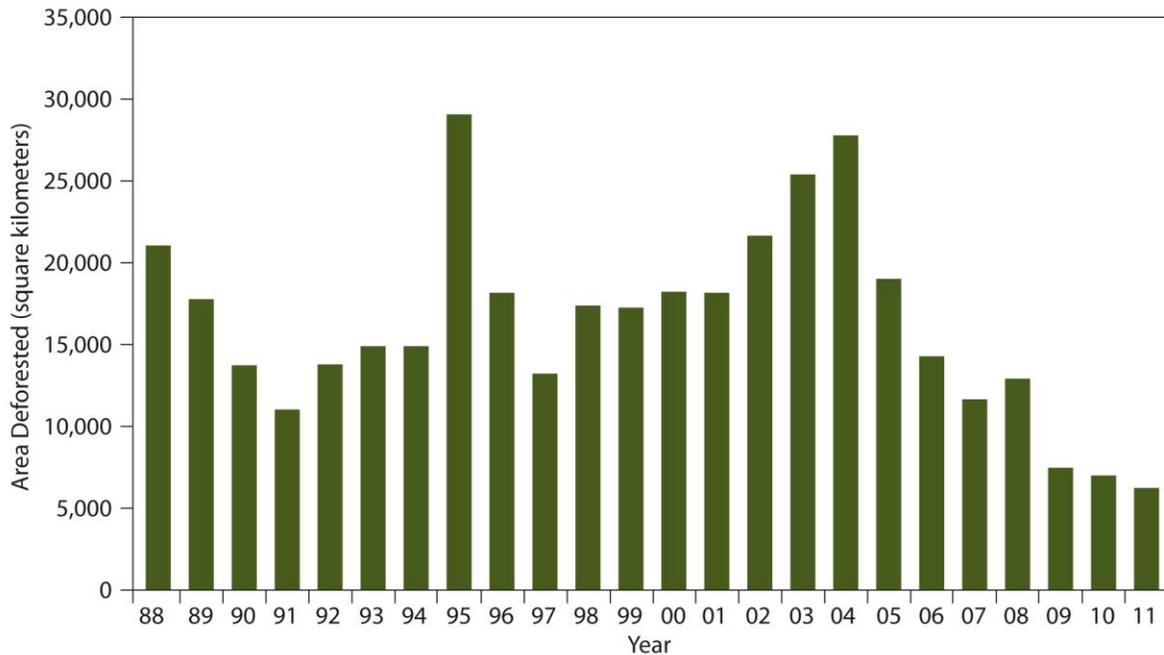
The Evidence

The first question to consider is, how sure are we that the reduction in deforestation has really occurred? We can be quite certain, because we can see the change in satellite photos visible to anyone with a computer and a connection to the Internet. The annual data (Fig. 1) from Brazil's INPE (Instituto Nacional de Pesquisas Nacionais = National Institute of Space Research; www.inpe.br) show a clear downward trend over the past seven years (2004 to 2011), bringing deforestation well below the level of the 1990s and early 2000s (INPE's definition of deforestation for its PRODES data includes clearing of forest areas of 6.25 ha or more). INPE, a well-respected research institution that just celebrated its 50th anniversary, makes available publically on its Web site not only the numbers, but also the methods and the satellite images on which the numbers are based. Other researchers around the world can therefore check their results. And they do: in particular, the non-governmental organization IMAZON (Instituto do Homem e Meio Ambiente da Amazônia = Amazon Institute of People and the Environment; www.imazon.org.br) does independent analyses on a monthly basis. This transparency is an important feature in giving outside observers high confidence in the reality of the reduction.

As Figure 1 shows, there was substantial variation from year to year through the 1990s and early 2000s. Part of this variability related to changes in the economic factors driving deforestation, e.g., recessions,

prices for commodities such as beef and soybeans, and the exchange rate of the Brazilian *real* relative to the dollar and the euro [5]. Variation in weather from year-to-year had an impact also, since most deforestation occurs during the southern-hemisphere dry season (roughly June to October), when forests can be cut down and burned most easily. Thus, weather events such as the “hundred-year” Amazon droughts seen in 2005 and 2010 [6], by deepening and lengthening the dry season, may lead to spikes in deforestation.

Declining Deforestation in the Brazilian Amazon



Deforestation in the Brazilian Amazon, although varying a lot from year to year, has declined greatly—by over 2/3 from the 1996–2005 average—over the past six years.

Source: INPE 2011

Fig. 1. Annual Amazon deforestation in Brazil from 1988 to 2011, in square kilometers, from the data of INPE (http://www.inpe.br/ingles/news/news.php?Cod_Noticia=271).

Month-to-month data, published by INPE through its programs DETER (for deforestation) and DEGRAD (for forest degradation) are even more variable, and INPE makes it clear that this analysis is done in order to be able to react quickly to deforestation events and hotspots, not to assess whether overall deforestation is increasing or decreasing. The monthly data are often affected substantially by cloud cover, especially during wet-season months, which can make large areas of the Amazon unavailable to remote sensing analysis. Increases or decreases in the monthly deforestation numbers may simply reflect how much land could be seen in the satellite images. Thus, particularly now that deforestation rates are low, there can be large *percentage* changes in the monthly data both upward and downward.

When the annual figures including corrections for cloud cover are published, these fluctuations may seem to signal a trend, but they may also prove simply to have been random variation.

For example, in 2011, a lot of attention was paid to such month-to-month variation, particularly to a large spike – described as “almost sixfold” by the BBC [7] – in April and May 2011 and before that, to another spike in December 2010. Both of these fluctuations turned out to be temporary, and the total area deforested in the 2010-2011 year ended up 11% lower than in 2009-2010 [8].

As Figure 1 shows, in comparison to the situation even half a decade ago, the reduction represents enormous progress. It means that deforestation has been reduced by over two-thirds from its average level in the decade from 1996 to 2005, and by nearly three-fourths from its high point in the mid-2000s. Whether there is continued progress, and even an end to Amazon deforestation by 2015 as civil society organizations have called for, is still very much in doubt. In particular, the President’s partial veto of the bill to weaken the Forest Code, although averting a possible disaster, leaves the legal situation quite murky [9]. But there is no denying the achievement so far. How has it been accomplished?

The Pressures Driving Deforestation

The major reduction in deforestation in recent years has taken place despite significant pressures in the opposite direction. The rapid growth of Brazil’s soybean and cattle industries in the first decade of the twenty-first century, stimulated by high international prices, export demand, and the availability of cheap land in the Amazon, would normally have been expected to cause a sharp increase in deforestation, not a decrease [10-13]. Furthermore, this was a time of important progress in reducing poverty and hunger (see below, “Environmental Success and Socioeconomic Progress”). Such social development is sometimes thought to be contradictory to the goal of environmental protection (“jobs vs. environment”). Brazil has managed to reduce deforestation even with these persisting pressures (or supposed pressures) pushing in the opposite direction.

Soybean Expansion and the Moratorium

The expansion of soybeans in South America is a quite recent phenomenon. Up until the 1970s the crop was grown mostly in the cooler, temperate parts of the continent in southern Brazil and Argentina, and mostly in natural grasslands or in areas previously cleared for cattle pasture. But with the growth of meat consumption and the collapse of the Peruvian anchovy fishery (previously an important source of fish meal for livestock feed), the world demand for alternate sources of protein meal to feed livestock made soy a profitable crop in the global market. In response, Brazilian soybean production expanded, pushing northward into the *cerrado* [14].

Initially, it was not clear whether soy production would continue moving to the north from the *cerrado* into the Amazon rainforest. But in the late 1990s, using new, humid-tropic-adapted varieties, soybean cultivation began to enter the Amazon forest in earnest, where it grew by 15 percent a year for several years [13]. Large farms were cut out of forested areas, often using heavy machinery such as bulldozers for rapid clearing, and were put into production with substantial inputs of fertilizers and pesticides.

While the phrase “growing exponentially” is often misused to mean simply “rapidly,” in this case it does apply: from just 9.7 million hectares in 1990, Brazil’s soybean area grew to 13.9 million hectares in 2000 and 24.2 million hectares in 2010 [15]. Production grew even faster, from 15.8 million tons in 1990 to 39.5 million tons in 2000 to 67.5 million tons in 2010. As a result, Brazil not only increased its livestock production and its per capita meat consumption, but also quickly became a major player in the world

oilseed trade. Soy exports grew more than tenfold in twenty years, from 2.5 million tons in 1990 to 31.4 million tons by 2010 [15].

This rapid growth changed the dynamics of deforestation in the southern Amazon in a fundamental way. For several decades, deforestation in the Amazon had occurred mostly to create cattle pasture, but when deforestation rates peaked in the early 2000s, soybean expansion was responsible for nearly one-fourth of forest clearing [12]. Additionally, there was the pressure of indirect land use change (ILUC), so that as soybean expansion took over *cerrado* lands farther south, it pushed cattle pastures northward into the rainforest in the state of Mato Grosso [16-17].

The new soybean farms were large, with some reaching tens of thousands of hectares in size. Soybean expansion was heavily concentrated in the state of Mato Grosso, where clearings for soybean planting were more than twice as large as those for pasture [12]. Soybean producers were heavily capitalized, using bulldozers to clear land and tractors and combines to cultivate it.

Although soybeans can be produced successfully in the tropics by small farmers, in the Amazon soybeans were overwhelmingly grown by large capital-intensive producers. As one would expect with the expansion of such a highly commercialized business into the forest, deforestation trends followed price fluctuations. Over several years, Brazilian deforestation mirrored the swings in world soy prices, with rapid deforestation in years such as 2003 and 2004 when prices were high [13]. Events in Europe also had an impact on soy production. For one, the ban on feeding animal parts to livestock because of mad cow disease increased demand for Brazilian soy. Also, the E.U.'s demand for non-genetically-modified soybeans initially favored soy from Brazil, although this is no longer the case now that GM soy has been approved for use in Brazil and has taken over a large proportion of the market. Transportation was also important, with new highways connecting soybean farms to domestic markets in southern Brazil and to the new deep-water ports of Itacoatiara and Santarém on the lower Amazon River [1, 13]. In fact, expansion of soy production provided the justification for highway construction, especially the new north-south highway BR-163 leading from the south of Brazil, which had already undergone large-scale deforestation, to Santarém. Deforestation in the Amazon became "teleconnected," through globalized markets, with expanding chicken, pork, and beef production in Europe and China [12-13]. By 2005, Brazil had become the largest soybean exporter in the world.

As soybean production expanded, academics and environmentalists began to point out the growing threat to the rainforest [14-18]. Initially there was little response, and forest clearing continued unabated, reaching record clearance rates (27,329 square kilometers annually) in the 2003/2004 crop year (Figure 1). But over time, there was growing criticism, both in and beyond Brazil, of the policies and institutions that were promoting soybean expansion at the expense of biodiversity, equitable development, and the earth's climate.

A critical turning point came in early 2006, with the release of Greenpeace's report *Eating Up the Amazon* [19]. The report linked the soybean industry to deforestation, global warming, water pollution, and even the use of slave labor to clear land. It focused particularly on two multi-national companies: the giant grain trader and exporter Cargill and the world's largest fast food chain, McDonald's. Cargill issued a five-page defense of its business practices, but also announced that, "In a groundbreaking move, we have informed our suppliers and local officials that, beginning with the next crop, Cargill will only purchase soy from those producers who are in compliance with the Forest Code [which requires farmers to maintain 80 percent of their land in forest if they are in the Amazon basin] or

actively working toward full compliance” [20]. McDonald’s, its reputation still damaged by the “McLibel” trial in Great Britain, in which it had sued some of its critics and lost, was similarly motivated to try to resolve the issue rapidly.

Action came within weeks. The two associations that bring together nearly all soybean processors and exporters in Brazil, the Brazilian Association of Vegetable Oil Industries (ABIOVE) and the National Association of Cereal Exporters (ANEC), announced a moratorium on deforestation. Their members would not buy any soybeans produced on Amazon farmland deforested after June 24, 2006. Initially the moratorium was temporary, but it has been renewed each year since, and its enforcement has been improved by overlaying detailed satellite images of areas cleared of forest with those of new soybean fields [21].

Now that it has been in place for six years, there are data to show that the moratorium has been remarkably successful. Although questions have been raised about Cargill’s performance and indirect land-use change effects of soy on pasture expansion [17], satellite data makes it clear that the clearing of forest for soybeans has been reduced practically to zero. By comparing the satellite images showing deforestation with views of the same areas in subsequent years, Rudorff et al. [21] found that by the 2009/2010 crop year, only 0.25 percent of land with soybean crops had been planted in deforested areas since the moratorium began. These fields represented only 0.04 percent of the total soybean area in Brazil.

Macedo et al.’s recent detailed examination of soybean production and deforestation in Mato Grosso [22], where the industry’s expansion has been concentrated, reinforces these conclusions and provides evidence that the link between soy and deforestation, which until recently remained strong [1,13] has now been broken. Despite the rise of soy prices to record high levels since 2007 [15], tropical forest clearing for soybeans has declined to very low levels in Mato Grosso. Furthermore, there does not seem to have been substantial “leakage” in the cerrado, where deforestation has also been substantially reduced [22].

Beef, Pasture and another Moratorium

Beef cattle have a much longer history in Brazil than soybeans. But their stories show some parallels, in that the most dramatic changes have occurred in just the past few decades.

Under the military dictatorship in the 1960s and 1970s, the Brazilian government promoted and subsidized the development of the Amazon, and the cattle industry began to penetrate into the region. During the 1990s, a significant boom in cattle ranching occurred, driven by growth in cattle product exports [11-13]. This was favored by changes in currency exchange rates and then in the 2000s by the elimination of foot-and-mouth disease in the Amazon, which had formerly prevented beef from Amazon states from being shipped overseas [23]. While domestic beef consumption grew slightly, the big jump was in exports, which increased seven-fold in a decade. A fourth of Brazil’s beef production now comes from the Amazon, and the country is the biggest beef exporter in the world [24].

In fact, as new land was cleared for pasture in the Amazon, in the south of Brazil pastures were converted to crops or abandoned. The economic advantage of the move northwards was not that the Amazon lands were better pastures – in fact, cattle productivity (carcass weight/hectare/year) in the Amazon was over 40% less than the national average in 1996, and still 30% less a decade later [24]. But

since the cost of land was much lower in the north, it still made economic sense to expand pastures there [23].

While previously cattle pastures had taken over savannas, temperate grasslands or long-deforested areas in southern Brazil, in the Amazon standing forest was in the way. Usually the rainforest was cleared and burned, with very little of the timber being used [20]. The point was to clear the land, and the trees were an obstacle to be removed. With clearing of forest increasing the value of the land by five to ten-fold, cattle ranching in the Amazon could be profitable despite its low productivity [11]. In fact, land speculation – the ability to capture increases in land values – has provided a substantial part of the economic incentive for deforestation by cattle ranches [25].

The result was widespread deforestation as the industry moved into the rainforest. At both the state and municipal levels, deforestation rates correlated with the growth of the cattle herd. Although soy became an important deforestation driver for a certain number of years, pasture was by far the predominant new land use in the deforested region, occupying over 85% of the agricultural land in the Amazon [23].

While the Brazilian cattle industry showed the same pattern of rapid export-driven expansion northward into the Amazon as the soybean industry, the industry was quite different in some important ways. Unlike soy, cattle production was extensive rather than intensive, with low levels of investment per hectare, frequent abandonment of the cleared land, and a low level of productivity. In fact, as soybean production entered an area it would often displace cattle ranching farther into the forest, since the potential profits from soy were considerably greater for those who could make the necessary investments [16-17; for a more detailed analysis of the changes in the Brazilian cattle industry, see the article by Walker *et al.* in this issue].

Amazon cattle ranchers used the land profligately, even compared to their compatriots further south. Stocking rates (animals per hectare) were low, and slow growth rates of the animals led to low rates of meat production per year as well as per hectare [11]. With high rates of abandonment prevailing in the 1990s, barely half of the cleared land would remain in production in the long term [24]. Employment levels in ranching were low as well, and ownership was highly concentrated. All in all, the expansion of the cattle industry was based on using small amounts of capital and labor combined with the large extensions of cheap land that could be obtained by clearing the forest. This business model, in addition to the rapid growth of export demand, was enough to make the expansion of the cattle industry profitable.

Because of the growth of the environmental and social movements in Brazil in the 2000s and the commitment of the new government of Luis Inácio Lula da Silva (known to Brazilians simply as “Lula”) to reducing deforestation rates, a more skeptical view of the industry that was the principal deforestation agent was inevitable. However, for the first several years of Lula’s administration (beginning in 2003) actions aimed at reducing deforestation emphasized the creation of protected areas and declaration of indigenous lands, as well as enforcement actions against illegal logging – and these steps did in fact begin to bring down deforestation rates [4]. But the rising Brazilian environmental movement pushed not only for strong government action, but also for direct steps by the cattle industry, along its entire supply chain.

With the publication of two widely publicized reports by Brazilian NGOs in April and June 2009, the pressure became insurmountable. These reports, Amigos da Terra Amazônia Brasileira's *Time to Pay the Bill* and Greenpeace's *Slaughtering the Amazon* [26-27] showed the overwhelming role of cattle pasture in destroying the Amazon forest, and placed the responsibility not only on the ranchers, but on the banks that financed forest clearing for pastures, the slaughterhouses that bought the meat, the exporters that shipped it abroad, and the government policies that directly and indirectly subsidized the entire process. As with the soybean industry three years before [19], NGOs and civil society demanded a moratorium on deforestation.

While ranchers objected loudly, the other parts of the export supply chain, recognizing their vulnerability to bad publicity, soon realized that they needed to deal with the controversy. The action of the International Finance Corporation (part of the World Bank group), which quickly canceled its loan for expansion in the Amazon by Bertin, S.A. – Brazil's largest beef exporter and the second largest in the world – showed the financial risk these enterprises were running. And within days, major supermarket chains in Brazil announced that they were suspending purchases of beef from Bertin.

The concentration of the slaughtering, packing, distribution and exporting in the hands of a small number of large businesses meant that they had the power to stop deforestation for creation of cattle pasture through their supply chain management. So in July 2009, the major slaughterhouses and distributors announced that they would refuse to buy cattle from any ranch that expanded its pasture at the expense of the forest.

Enforcement was to be based on overlaying the boundaries of each ranch (its "polygon") with the satellite photos showing deforestation published on the Web by INPE. Either a ranch would have to provide the polygon information to the slaughterhouse, or else (since boundaries of some ranches are poorly delimited, and ranchers are often reluctant to share this information, for fear of government action against them under the Forest Code) they would need to demonstrate that their ranch location was at least 10 km away from any area of recent forest clearing.

At this point, it is too early to assess the success of the beef moratorium, which only went into effect three years ago. Peer-reviewed studies based on satellite images have yet to be published, as they have with soybean [21-22], to allow a quantitative assessment of the moratorium's impact. (For an initial analysis of recent changes in the cattle supply chain in Brazil, see the article by Walker et al. in this issue.) Nonetheless the success of the soy moratorium, operating in the same region and enforced using similar satellite technology, is an indication that the same approach can work for the cattle industry. And since deforestation in the Amazon in the last decade has been overwhelmingly for expansion of pasture [23], the decline in deforestation overall clearly implies that there has also been a decline in pasture-caused deforestation.

Environmental Success and Socioeconomic Progress

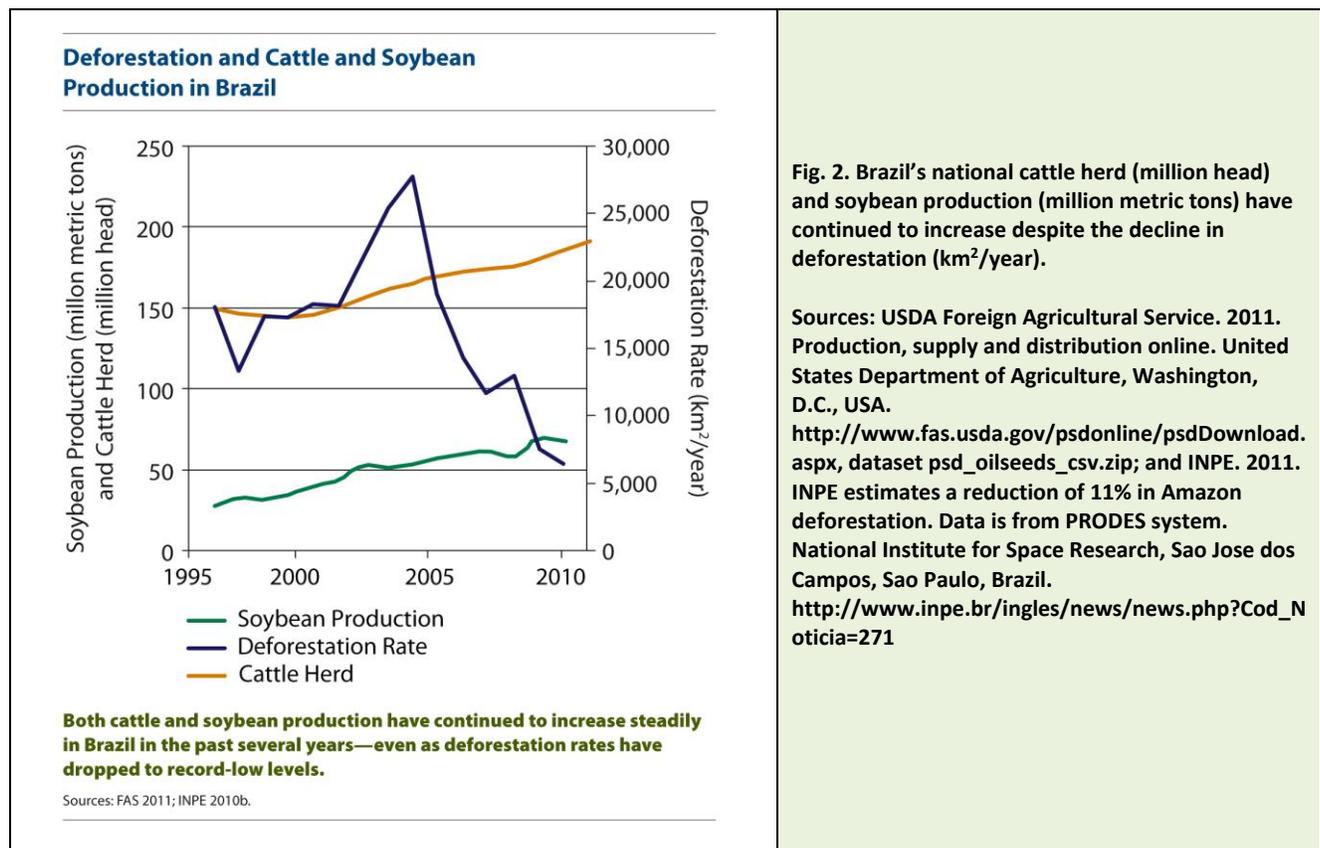
Although estimates of emissions due to deforestation have been controversial in the past, the climate benefits of Brazil's reduction in deforestation rates are clearly very large. Brazil's emissions reduction to 2011 represents a drop (in km²/year deforested) of 62% compared to emissions in the 1990s. Taking the range of 0.7 to 1.4 GtCO₂/year for estimated emissions in the 1990s [1] would mean that Brazil's reduced deforestation has cut emissions by between 435 million and 870 million tons of CO₂ annually.

(These figures correspond very well to the new estimates of Aguiar et al.[28], which give reductions of either 480 or 840 million tons of CO₂ depending on which emissions model is used).

In terms of global warming pollution, such a reduction is the equivalent of removing 100 to 200 million cars from the road in the United States. (Brazil's automobiles are mostly fueled with sugar cane-ethanol rather than imported oil, creating fewer direct greenhouse gas emissions).

What Brazil has already accomplished, in helping avert the worst consequences of global warming, is on the same scale as what the world's wealthiest nations have only promised to accomplish – by the year 2020. For example, the United States has promised a 17 percent reduction from its 2005 level, which amounts to 1,200 million tons. The European Union has promised a 20 percent reduction from its 1990 level, which amounts to about 850 million tons.

Often it is said that development and the environment are in conflict – that protecting nature inevitably leads to slower economic growth and makes social progress more difficult. But Brazil's reduction of deforestation by two-thirds occurred at the same time that it saw strong economic growth and a significant advance in social justice. The country's GDP increased at a rapid rate during the 2000s. It stagnated in just one year, 2009, because of the worldwide recession, but otherwise Brazil's growth rate ranged from over 3% to over 7% annually for nearly a decade [31-32]. The two industries previously most responsible for Amazon deforestation, beef and soy, both showed continued healthy growth at the national level, with production, exports and the size of the cattle herd continuing to increase steadily even as deforestation dropped (Fig. 2) [15].



While the first few years of decline were partly connected to the economic slowdown and lower commodity prices [1, 10, 13], more recent data show that the continuing reduction in deforestation rates has not been due to economic recession. Both before and after the recession of 2008-2009, and through the recent period of record agricultural prices, deforestation rates have continued to fall (Figure 1).

The continuation of this trend has been confirmed by the PRODES data for 2011-2012, the most recent full year for which data is available, which indicate a further reduction in deforestation of 27% from the previous year [29]. IMAZON's independent evaluation for the same year [30] indicated similar or larger reductions – 36% in deforestation, 69% in forest degradation, and 14% in emissions. This continued progress, well after the economy has rebounded from the 2008–2009 recession, makes clear that the reduction in deforestation cannot be attributed to poor economic growth; it has now continued for eight years, most of which showed healthy growth rates [31-32].

For the people of Brazil, more important than macroeconomic growth itself was the fact that because of the policies of Lula's Workers Party government, this progress was widely shared. Through social programs such as Fome Zero (Zero Hunger) and Bolsa Familia (Family Allowances), Brazil reduced its poverty rate from over 34% to less than 23%, and 29 million citizens transitioned into the middle class [33]. Hunger and malnutrition rates dropped substantially, and important advances were made in reducing economic inequality [34-35]. Brazil has shown that it is possible to make progress and still maintain forests.

How It Was Done

Brazil's accomplishment is a result of the work of many actors, including governments (both at the federal and state levels, and including those of other countries such as Norway), as well as businesses, indigenous peoples and NGOs. Although many of the steps have been taken by governments and corporations, the incentive created by Norway's support, the threats of prosecution against slaughterhouses and supermarkets, and the political pressure generated by civil society, predominantly from within Brazil, have been vital elements of the process.

Establishing a Framework

Brazil's reduction in deforestation is part of the Brazilian federal government's National Climate Change Plan, which includes the goal of reducing its emissions from deforestation by 80% by 2020. This objective grew out of the historic Plan for the Prevention and Combating of Deforestation in the Amazon (PPCDAM), instituted by the Lula government in 2004. It was not originally motivated by climate change, but rather by other environmental and socioeconomic concerns. But as international climate negotiations in Montreal (2005) and Bali (2007) connected deforestation to climate mitigation and offered the possibility of international funding for reducing emissions, the PPCDAM has grown and been transformed, and its efforts are now a key element of the National Climate Change Plan.

Under this plan, reductions are to be achieved in several steps, with the average yearly emissions over the ten-year period from 1996 through 2005 as the "reference level" – the starting point from which reductions will be measured. Using such a long-term average as a baseline is important because it prevents distortion by year-to-year fluctuations in economics or weather. An important feature of Brazil's baseline is that it is calculated at the Amazon biome level (and separately for the *cerrado* biome), not just for a particular state or project area. Such biome-wide baselines help deal with the problems of

“leakage” and “non-additionality,” which can be significant when the reference level is calculated over only a small area.

Leakage refers to the possibility that deforestation is not reduced overall, but simply shifted from one area to another. If this happened, measuring emissions compared to a baseline for just the area where the project occurred would indicate that it had successfully reduced emissions, but calculating emissions with respect to a national baseline would show that no overall reduction had occurred. Use of the Amazon-wide reference level will pick up both the reductions in one area and the increases in another, and thus correctly calculate how much emissions have been reduced overall.

Non-additionality refers to the difficulty of knowing, when a project is implemented in a limited area, whether deforestation rates would have decreased in that area even without the project. The smaller the project area is, the more uncertainty there is, and the greater the need for sophisticated statistical modeling to deal with it. With an Amazon-wide reference level, this uncertainty is reduced. It is not necessary to estimate what would have occurred in any particular area in the absence of a project; one simply looks at the overall reductions over the whole region compared to past years.

For these two reasons, both the national framework established by the National Climate Change Plan, and the Amazon-level accounting of emissions reductions that it incorporated were important contributions to meaningful reduction in rates of forest clearing. Even though many of the actions implemented in the plan were performed by actors at lower levels – state governments, indigenous groups, trade associations and corporations and NGOs – the national plan created a framework to verify that all these actions, taken together, really did reduce Brazil’s emissions. They also enabled the compensation mechanism negotiated with Norway (see below) so that Brazil could benefit financially from its emission reduction efforts.

Brazil showed the seriousness of its commitment to combating deforestation by putting it into legislation at the end of December 2009. The Climate Change Law [36] inscribes the commitment to reduce overall emissions by between 36.1% and 38.9%, relative to business as usual, by the year 2020. This is equivalent to a 20% reduction from Brazil’s 2005 level.

These high-level actions have been complemented by on-the-ground steps to strengthen enforcement of existing laws, for example against illegal logging. The data made available by INPE on a monthly basis have made it possible to crack down quickly in areas of new deforestation identified through the DETER and DEGRAD satellite monitoring programs [1]. Steps taken include the closing of illegal sawmills and jailing of the perpetrators, including government officials who had been taking bribes to look the other way. Although such enforcement campaigns are often episodic and occur in response to media coverage – which in turn is often generated by new monthly data on deforestation or burning – they do have a cumulative effect of indicating that deforesting is no longer a risk-free activity.

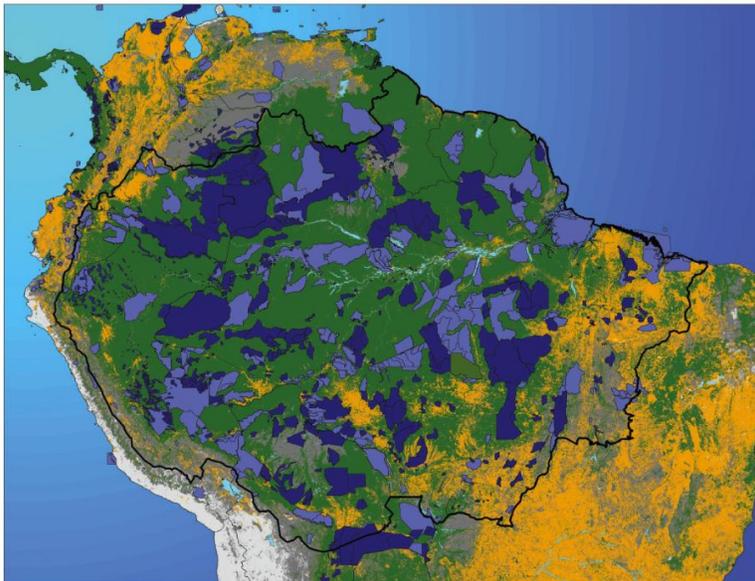
Indigenous Lands and Protected Areas

Much of the success in reducing deforestation has come from establishing – and effectively protecting – an extensive network of indigenous lands and protected areas across the Amazon since 2002 (Fig. 3). They are estimated to contain more than 25 billion tons of carbon – over half of the total carbon in the region [4, 10]. All in all, just over half of the forest in the Brazilian Amazon is protected in some form, with nearly half of this area reserved for indigenous peoples, about a fifth under strict protection, and about a fourth designated for sustainable development [10]. Some of the protected areas follow the model of state and federal preserves in developed countries. However, the protection of indigenous peoples’ territories is distinctive and plays a critical role in conservation of the Amazon rainforest.

Legally, the indigenous lands are not off-limits to cutting trees. The collective tenure of these lands by indigenous peoples, legally confirmed and enforced by the Brazilian government, gives them the right to use them for sustainable forest management and the exploitation of timber and non-timber forest resources. In practice, they have generally chosen to keep almost all of their lands in forest, and studies of Brazil's reserves have found that they have reduced the rate of emissions from deforestation by about ten-fold compared to neighboring areas [4].

Furthermore, they make an important contribution to sustainable development and social justice. They represent the tangible recognition of indigenous peoples' rights after many decades of denial. Thus, beyond their role in reducing emissions and protecting the climate, they also show the possibility of an alternative mode of development of tropical forests without deforestation.

Map of Amazon Indigenous Lands and the Protected Areas Network



This map of the Amazon basin (within the black line), shows indigenous reserves (dark blue) and other protected areas (light blue). Deforested areas are shown in yellow.

Source: Lefebvre 2011, Woods Hole Research Center.

Fig. 3. Lands reserved for indigenous peoples (dark purple), or protected by federal and state governments (pink and light purple), now cover over half of the Amazon Basin of Brazil.

Source: Ricketts, T.H., Soares-Filho, B., da Fonseca, G. A. B., Nepstad, D., Pfaff, A., Peterson, A., Anderson, A., Boucher, D., Cattaneo, A., Conte, M., Creighton, K., Linden, L., Maretti, C., Moutinho, P., Ullman, R. and Victurine, R. 2010. Indigenous lands, protected areas, and slowing climate change. *PLoS Biology* 8: e1000331

State Actions

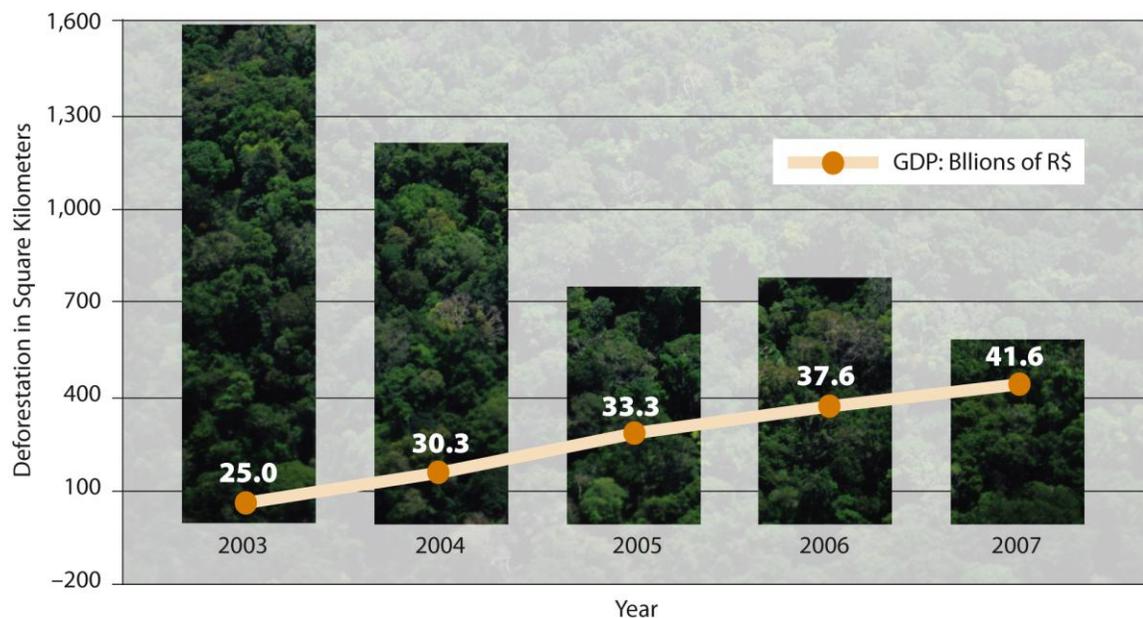
The Brazilian states have been responsible for a substantial part of the country's success in reducing deforestation. Brazil has a federal system in which the states share responsibility for land use policies with the national government in Brasilia. Deforestation is heavily concentrated in just a few states, especially Mato Grosso and Pará, and state governors have both acted themselves and pushed the federal government for stronger anti-deforestation policies. These actions have produced substantial

decreases in emissions from deforestation in these states, which account for the majority of Brazil's deforestation, over the past several years [22] – a point of pride for their political leaders.

Another example is the state of Amazonas, which is Brazil's largest – as big as Alaska, and over twice the size of Texas. It contains fully half of the carbon stock of the Brazilian Amazon. Although its reduction of its deforestation rate by 70% from 2002 to 2008 was from an initially low level, and thus not a major contribution to emissions reductions, its ability to maintain a rapid rate of economic growth while achieving this reduction – an increase of 65% in GDP in half a decade – showed how tropical forest regions can move to growth driven by urban sectors rather than by deforestation, and develop rapidly in the process (Figure 4).

As Virgilio Viana, the State Secretary who developed Amazonas' successful "Bolsa Floresta" plan, has explained, it was a true paradigm shift – the government went from its previous practice of giving away chainsaws to deciding that forests were more valuable standing than cut (personal communication, 2010). Through an innovative combination of policies – payments to villages that conserved forests, support for sustainable development projects, payments to families through debit cards, supporting education, health, transport and communications in rural areas, and above all the concentration of the state's development in the urban area of Manaus rather than in rural sections, Amazonas has reduced deforestation to a very low level, with 98% of its forest still standing.

GDP Growth and Deforestation in the Brazilian state of Amazonas, 2003–2007



In Amazonas, the largest state in the Brazilian Amazon, the economy has continued to grow rapidly while deforestation was being reduced to low levels.

Source: Virgilio Viana, Fundação Amazonas Sustentável.

Fig. 4. In the state of Amazonas, which includes half of the Brazilian Amazon, the deforestation rate (km²) has declined to very low levels even as the state's gross domestic product has steadily increased. Source: Virgilio Viana, Fundação Amazonas Sustentável

Norway's Support

In 2007, at the United Nations Framework Convention on Climate Change (UNFCCC) meeting in Bali, Indonesia, an agreement was reached that gave the green light to early action on Reducing Emissions from Deforestation and Degradation and related pro-forest actions (REDD+) ahead of the anticipated new international climate treaty. At the same meeting, Norway's Prime Minister Jens Stoltenberg announced Norway's commitment to protecting tropical forests and offered \$2.5 billion dollars during the next five years (\$500 million per year) to finance REDD+ programs around the world through the Norwegian International Climate and Forest Initiative.

Through this initiative, Norway emerged as a leader in tropical forest conservation. Through the UN-REDD program, the World Bank's Forest Carbon Partnership Facility and Forest Investment Program, regional development institutions like the Congo Basin Forest Fund, and bilateral agreements made directly with tropical countries, Norway is using its funding to support REDD+ programs around the globe. One of the most notable pledges by the Norwegian Climate and Forest Initiative was the promise of up to \$1 billion for Brazil's Amazon Fund.

This contribution to the Amazon Fund is part of a climate policy cooperation agreement made between Norway and Brazil in September of 2008. In order to receive the funds beginning in 2009, Brazil had to show that it had made progress. There had to be clear documentation that it was not merely trying to reduce deforestation, but that it had done so successfully. This is what is called "results-based financing" or "pay for performance;" the money flows not on the basis of efforts, promises or attempts to reduce deforestation, but as the goal is met.

The Norwegian International Climate and Forest Initiative is a fairly simple and pragmatic system. Norwegian diplomats have explained (personal communication) that as a small country with a very limited diplomatic corps, Norway could not micro-manage a complicated foreign aid program even if it wanted to. The entire country has only about 4.7 million people; New York City alone has more than 8 million.

The system Norway negotiated with Brazil to calculate compensation is simple and straightforward. The rate of compensation for reductions (the "carbon price") is \$5.00/ton of CO₂. Each hectare of tropical forest is assumed to emit 100 tons of carbon when cleared, which is equivalent to 367 tons of CO₂. The reduction in area deforested is calculated in comparison to the average from 1996 through 2005, which was 19,500 km² per year over all of the Brazilian Amazon.

Since typical carbon prices in the European ETS (cap-and-trade) carbon market were in the range of \$20 to \$30 per ton when the payment was negotiated, and Brazil's Amazon forests have carbon densities closer to 150 tons carbon per hectare rather than 100 [10], the compensation system is conservative. It is set up to avoid any possibility of Brazil being paid for more than it has really accomplished. In effect, Brazil is absorbing the majority of the opportunity costs of reducing its deforestation without being compensated, as its own contribution to the worldwide effort to slow global warming.

As REDD+ is often identified, erroneously, with offset-based carbon-market financing, it is important to point out that the Norway-Brazil program – by far the world's largest (it covers over one fourth of the world's tropical forests by itself) and the most successful – is strictly a non-market, non-offset program. Norway does not get the right to emit a single ton more of CO₂ because it is funding Brazil's reductions in emissions. Thus the amount of the Brazilian reductions is also the amount of the global reductions;

there are no offsetting emissions from the fossil fuel sector that need to be subtracted from them to get the net global impact.

No other country has committed to funding for REDD+ at a level close to that coming from Norway, even though there are many other developed nations that would be able to finance such work at a comparable level. The Norwegian contribution to REDD+ efforts worldwide in the initial period (\$2.5 billion over 5 years) amounted to about \$100 annually for each of its citizens. In comparison, the United States' REDD+ pledge in Copenhagen (\$1 billion over 3 years) added up to only about \$1 annually for every American.

The Threat of Prosecution

The Norwegian money was valuable as a carrot, but the stick wielded by federal public prosecutors, particular in the key states of Pará and Mato Grosso, has been equally important [37]. The statements from the slaughterhouses and supermarkets that they would buy only non-deforestation beef have been enforced by strong threats from the public prosecutors in those two states. First in Pará and then in Mato Grosso, the slaughterhouses signed agreements under which ranchers were required to provide the GPS coordinates of their property boundaries in order to sell to them. This in turn makes it possible to use remote sensing data not only to detect deforestation, but to know on which ranch it is taking place and to take action against it. The prosecutors' warnings to supermarkets that they too would be held responsible for the sale of beef produced in violation of environmental laws, combined with the new ability to enforce them using GPS data, have effectively made the supply chain a part of the system through which ranchers are pressured, both economically and legally, to end deforestation.

Civil Society and the Changing Political Dynamic

Governments – including federal and state-level agencies in Brazil, and governments from other countries, such as Norway – have taken important steps: designing plans to reduce deforestation rates, carrying them out, and making them economically and politically rewarding through international compensation. However, they did not take these actions simply because they wanted to do the right thing. Instead, the political pressure generated by organized civil society, serving as a counter-force to the pressure of the drivers of deforestation, played a key part in convincing government institutions to act.

The Broad Movement for Zero Deforestation

Brazil's citizens have played a critical role, pushing their governments to act and exerting pressure on the businesses that constitute the main deforestation agents. The Zero Deforestation campaign, launched in 2008 by a broad coalition of non-governmental organizations including environmental, indigenous, rubber-tapper, human rights, and other groups, exerted strong pressure on the federal government. As described above, NGOs were the key actors in the widely publicized 2006 and 2009 exposés of the role that the soybean and beef industries have played in deforesting the Amazon, and in negotiating deforestation moratoria with those industries. The Zero Deforestation campaign proposed what became the Amazon Fund and its management by the Brazilian national development bank BNDES (Banco Nacional do Desenvolvimento), and members of the campaign participate in the Fund's steering committee as important stakeholders. Additionally, research institutes such as IPAM (Instituto de Pesquisa Ambiental da Amazônia) and IMAZON (Instituto do Homem e Meio Ambiente da Amazônia) have been important in monitoring progress and showing how ranchers, farmers, and loggers can

increase their productivity in ways that make deforestation unnecessary. Now, since the national plan to reduce the incidence of deforestation by 80% by 2020 is clearly ahead of schedule, the Zero Deforestation campaign is pushing for a new goal of zero deforestation by 2015.

As seen in the soy and beef moratorium efforts, the movement was both political and economic, pressuring not only governments but also the industries that were the major drivers of deforestation. Although the threat of an international consumer boycott was always present as an overtone of the debate, the political strategy emphasized pressure on businesses all along the deforestation-related supply chain, not just the market pressure of individual consumers' shopping decisions. All the businesses involved – not just the farmers and ranchers producing soy and cattle, but also the banks financing them, the slaughterhouses buying their cattle, the exporters shipping their products overseas, and the intermediaries and supermarket chains distributing them domestically, were targets of the campaigning. Indeed, the concentration of market power at particular points in the supply chains, such as the vegetable oil trade association (ABIOVE) and major slaughterhouses, was one of the reasons that the industries could respond rapidly to pressure and agree to moratoria. The point of the campaigning was not to persuade individual consumers to change their behavior, but to force action by businesses that were critical links in the supply chain.

In and Out of Government

The political leadership that contributed to the progress in reducing deforestation had a long history of engagement with civil society, before and after as well as during the leaders' time in government. A key figure, of course, is Lula himself, not only during his two terms as President (2003–2010) but also during his previous decades of organizing and building the social movement and the Workers' Party (PT) through which he was eventually elected President on the fourth try. Based in the trade union and landless peasants' movements, but also with ties to forest peoples' organizations such as those of indigenous peoples and the rubber tappers, the PT provided a model for a broad-based coalition that focused on social, economic and environmental transformation, not just on taking the reins of government. PT members also developed useful experience in pressuring both businesses and governments – including Lula's own government after he was elected.

At least as important was the role of Marina Silva, Lula's first Minister of the Environment. Her activism aimed at curtailing the rate of forest clearing went back to her early experience in Acre, working with Chico Mendes to organize the rubber tappers union and the PT. As Minister she was responsible for implementing the government's actions to reduce deforestation, often in conflict with other Ministries' plans for development and economic growth. Equally significantly, after several years she resigned from Lula's cabinet in protest against the inadequate pace of action on deforestation, and became the Green Party's candidate for President in the race to succeed Lula in late 2010.

Quite unexpectedly, Silva won nearly 20% of the vote in the first round [38]. This both showed the strength of the popular commitment to ending deforestation, and exerted pressure on the PT and its candidate Dilma Rousseff (Lula's former Energy Minister and then Chief of Staff) to commit to continued environmental progress. Indeed, Lula himself agreed before leaving office to move the deadline for Brazil's target to reduce deforestation rates by 80% up to 2016 from 2020 (as mentioned, the Zero Deforestation Campaign is pushing for an end to deforestation by 2015). Rousseff's partial veto in 2012 of the amendments to the Forest Code that would have given amnesty for past illegal deforestation reflects the new political dynamic that has emerged, at least in part through Silva's electoral success.

Implications for Conservation

The story is certainly not over, and undoubtedly there will be both ups and downs in the years to come. With the 2012 Forest Code changes, continued progress is not at all certain. Simply looking at the variability of deforestation rates over previous decades (Figure 1) shows large fluctuations are the norm. Deforestation responds to a wide range of factors, from the exchange rate of the Brazilian *real* to the intensity of the dry season to the buying policies of slaughterhouses, so predicting its future course is extremely risky. Nonetheless, there are some conclusions that can be drawn from the success so far:

- **REDD+ can succeed.** Brazil's experience shows that a large reduction in deforestation is possible. Indeed, the speed with which it happened indicates that the global ambition for ending deforestation – as expressed, for example, in the E.U. goal of cutting emissions from deforestation and forest degradation in half by 2020 and to zero by 2030 – perhaps should be raised. Brazil is politically unique, and one can rightly point out that in many countries, forest policy and decisions on management of rural areas are dominated by rich elites with strong ties to government and that corruption and governance problems are often pervasive obstacles to change. However, not that long ago, one would have said the same things about Brazil. Reaching zero deforestation by 2020 now seems to be a feasible global goal.
- **Economics matters – but not all the costs have to be paid.** Norway's compensation, based on results, has been both politically and economically important to the success of Brazil's national REDD+ strategy. It has now amounted to \$ 670 million [39] – enough to be both economically and politically significant. However, as pointed out above, it will not cover even half of the cost being incurred by Brazil. And Brazil is not compensating the major agents of deforestation, the soy and beef industries. Quite the contrary, they are being forced, by both government policy and civil society pressure, to absorb the opportunity costs – and in light of their continued expansion, seem to be quite able to do so (Figure 2). Middle-income developing countries such as Brazil may be willing to absorb a substantial proportion of the cost of ending deforestation, due to their own internal political dynamics. This can reduce the necessary global financing for REDD+ very substantially, and allow it to be targeted to the poorer tropical countries where both equity and effectiveness will require 100% compensation.
- **A national approach makes subnational efforts more effective.** Although states, indigenous peoples and other subnational actors have been very important to success on the ground, the framework established by the National Plan and the national moratoria were critical to their success. They very substantially reduced the threat of leakage – that success in one area would simply lead to the industries responsible for deforestation moving to other parts of the Amazon, so that overall deforestation would not be reduced but simply shifted around [5, 40]. The Amazon-scale data from INPE and IMAZON made this publicly visible, reinforcing credibility and helping build a positive feedback between success and increased political support.
- **The drivers of deforestation can be stopped.** The overwhelming role of soy and beef as causes of Amazon deforestation meant that successful civil society pressure on key elements of these industries' supply chains could lead to rapid reductions in deforestation. Ironically, their enormous economic power did not prevent progress, but made it possible for it to happen quickly once the campaigns against them were successful. The biblical tale of David and Goliath is perhaps relevant here.
- **Civil society is key.** Organized social movements have been crucial to success, in paving the way for Lula's government, in creating the societal context in which deforestation became an important issue for the political leadership, and as agents of continuing pressure on both government and businesses to carry out their plans to reduce deforestation. They extended far

beyond the environmental NGOs, to include other interest groups such as unions, indigenous peoples' organizations, and rural and forest workers as well as political parties. The rapid progress in the second half of the decade of the 2000s, rested on a foundation constructed by tireless organizing – often unrelated to environmental issues – over many decades.

Reducing deforestation in other countries will take longer, and even reaching the goal of zero deforestation in Brazil will take strenuous effort. However, the accomplishments already are a very important contribution to preserving biodiversity, defending the rights of indigenous peoples, and avoiding the worst consequences of global warming. They show the world that development without deforestation can and should be an integral part of our global future.

Acknowledgements

We sincerely thank the students of the Yale School of Forestry and Environmental Studies for the invitation to present this work at the 2011 Annual Conference of the Yale ISTF chapter; and Nathalie Unterstell, Tina Schneider and two other reviewers for insightful criticisms which measurably improved the manuscript and helped us avoid a number of errors of fact and interpretation.

References

- [1] Nepstad, D., Soares-Filho, B., Merry, F., Lima, A., Moutinho, P., Carter, J., Bowman, M., Cattaneo, A., Rodrigues, H., Schwartzman, S., McGrath, D. G., Stickler, C. M., Lubowski, R., Piris-Cabezas, P., Rivero, S., Alencar, A., Almeida, O., and Stella, O.. 2009. The end of deforestation in the Brazilian Amazon. *Science* 326: 1350-1351
- [2] Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., Phillips, O. L. Shvidenko, A., Lewis, S. L., Canadell, J. G., Ciais, P., Jackson, R. B., Pacala, S., McGuire, A. D., Piao, S., Rautiainen, A., Sitch, S. and Hayes, D. 2011. A large and persistent carbon sink in the world's forests. *Science* 333:988-993
- [3] FAO-ITTO. 2011. *The State of Forests in the Amazon Basin, Congo Basin and Southeast Asia*. Food and Agriculture Organization, Rome, Italy. <http://www.fao.org/docrep/014/i2247e/i2247e00.pdf>
- [4] Ricketts, T.H., Soares-Filho, B., da Fonseca, G. A. B., Nepstad, D., Pfaff, A., Peterson, A., Anderson, A., Boucher, D., Cattaneo, A., Conte, M., Creighton, K., Linden, L., Maretti, C., Moutinho, P., Ullman, R. and Victurine, R. 2010. Indigenous lands, protected areas, and slowing climate change. *PLoS Biology* 8: e1000331
- [5] Boucher, D., Elias, P., Lininger, K., May-Tobin, C., Roquemore, S. and Saxon, E. 2011. *The Root of the Problem: What's Driving Tropical Deforestation Today?* Union of Concerned Scientists, Cambridge, MA, USA. www.ucsusa.org/whatsdrivingdeforestation
- [6] Lewis, S. L., Brando, P. M., Phillips, O. L., van der Heijden, G. M. F and Nepstad, D. 2011. The 2010 Amazon drought. *Science* 331:554
- [7] BBC. 2011. Brazil: Amazon rainforest deforestation rises sharply. BBC News, London, UK. 19 May 2011. <http://www.bbc.co.uk/news/world-latin-america-13449792>
- [8] INPE. 2011. INPE estimates a reduction of 11% in Amazon deforestation. Data is from PRODES system. National Institute for Space Research, Sao Jose dos Campos, Sao Paulo, Brazil. http://www.inpe.br/ingles/news/news.php?Cod_Noticia=271
- [9] Tollefson, J. 2012. Updated: Brazilian president vetoes parts – but not all – of controversial forestry bill. *Nature Newsblog*, 25 May 2012. <http://blogs.nature.com/news/2012/05/brazilian-president-vetoes-part-but-not-all-of-controversial-forestry-bill.html>

- [10] Soares-Filho, B., Moutinho, P., Nepstad, D., Anderson, A., Rodrigues, H., Garcia, R., Dietzsch, L., Merry, F., Bowman, M., Hissa, L., Silvestrini, R. and Maretti, C. 2010. Role of Brazilian Amazon protected areas in climate change mitigation. *Proceedings of the National Academy of Sciences* 107:10821-10826
- [11] McAlpine, C. A., Etter, A., Fearnside, P. M., Seabrook, L. and Laurance, W. F. 2009. Increasing world consumption of beef as a driver of regional and global change: A call for policy action based on evidence from Queensland (Australia), Colombia and Brazil. *Global Environmental Change* 19: 21-33
- [12] Morton, D. C., DeFries, R.S., Shimabukuro, Y.E., Anderson, L.O., Arai, E., del Bon Espirito-Santo, F., Freitas, R. and Morissette, J. 2006. Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proceedings of the National Academy of Sciences* 103:14637–14641
- [13] Nepstad, D. C., Stickler, C. M. and Almeida, O. T. 2006. Globalization of the Amazon soy and beef industries: Opportunities for conservation. *Conservation Biology* 20:1595–1603
- [14] Fearnside, P. M. 2001. Soybean cultivation as a threat to the environment in Brazil. *Environmental Conservation* 28: 23-38
- [15] USDA Foreign Agricultural Service. 2011. Production, supply and distribution online. United States Department of Agriculture, Washington, D.C., USA.
http://www.fas.usda.gov/psdonline/psdDownload.aspx; dataset psd_oilseeds_csv.zip
- [16] Barona, E., Ramankutty, N., Hyman, G. and Coomes, O.T. 2010. The role of pasture and soybean in deforestation of the Brazilian Amazon. *Environmental Research Letters* 5:024002
- [17] Arima, E. Y., Richards, P., Walker, R. and Caldas, M. M. 2011. Statistical confirmation of indirect land use change in the Brazilian Amazon. *Environmental Research Letters* 6:024010
- [18] Carvalho, R. 1999. A Amazônia rumo ao ‘ciclo da soja’. *Amazônia Papers # 2*. Amigos da Terra, Programa Amazonia, São Paulo, Brazil. <http://www.amazonia.org.br>
- [19] Greenpeace International. 2006. *Eating Up the Amazon*. Greenpeace International, Amsterdam, Netherlands, April 2006. <http://www.greenpeace.org/forests>
- [20] Cargill. 2006. Cargill’s View on the Greenpeace Report: “Eating Up the Amazon”. May 2006. www.brazilink.org/tiki-download_file.php?fileId=194
- [21] Rudorff, B. F. T., Adami, M., Alves Aguilar, D., Alves Moreira, M., Pupin Mello, M., Fabiani, L., Amaral, D. and Machado Pires, B. 2011. The soy moratorium in the Amazon biome monitored by remote sensing images. *Remote Sensing* 3: 185-202
- [22] Macedo, M. N, Defries, R. S., Morton, D. C., Stickler, C. M., Galford, G. L., and Shimabukuro, Y. E. Decoupling of deforestation and soy production in the southern Amazon during the late 2000s. *Proceedings of the National Academy of Sciences* 109: 1341-1346
- [23] Kaimowitz, D., Mertens, B., Wunder, S. and Pacheco, P. 2004. Hamburger connection fuels Amazon destruction: cattle ranching and deforestation in Brazil’s Amazon. CIFOR Report. Center for International Forestry Research, Bogor, Indonesia.
http://www.cifor.cgiar.org/publications/pdf_files/media/Amazon.pdf
- [24] Cederberg, C., Persson, U. M., Neovius, K. Molander, S. and Clift, R. 2011. Including carbon emissions from deforestation in the carbon footprint of Brazilian land. *Environmental Science and Technology* 45:1773–1779
- [25] Bowman, M. S., Soares-Filho, B. S., Merry, F. D., Nepstad, D. C., Rodrigues, H. and Almeida, O. T. 2012. Persistence of cattle ranching in the Brazilian Amazon: A spatial analysis of the rationale for beef production. *Land Use Policy* 29: 558-568
- [26] Amigos da Terra – Amazônia Brasileira. 2009. *A Hora da Conta - Time to Pay the Bill*. Friends of the Earth-Brazilian Amazon, São Paulo, April 2009.
http://www.amazonia.org.br/guia/detalhes.cfm?id=313449&tipo=6&cat_id=85&subcat_id=413

- [27] Greenpeace International. 2009. *Slaughtering the Amazon*. Greenpeace International, Amsterdam, June 2009. <http://www.greenpeace.org/international/en/publications/reports/slaughtering-the-amazon/>
- [28] Aguiar, A. P. D., Ometto, J. P., Nobre, C., Lapola, D. M., Almeida, C., Vieira, I. C., Soares, J. V., Alvares, R., Saatchi, S., Valeriano, D., & Castilla-Rubio, J. C. (2012). Modeling the spatial and temporal heterogeneity of deforestation-driven carbon emissions: the INPE-EM framework applied to the Brazilian Amazon. *Global Change Biology*, 18, 3346-3366
- [29] Butler, R. 2012. Brazil's deforestation rate still on decline in 2012? Mongabay.com, 2 August 2012. <http://news.mongabay.com/2012/0802-brazil-deter-2012.html>
- [30] Martins, H., Fonseca, A., Souza Jr., C., Sales, M. and Verissimo, A.. Boletim de Desmatamento (SAD) – Julho de 2012. IMAZON. July 2012. <http://www.imazon.org.br/publicacoes/transparencia-florestal/transparencia-florestal-amazonia-legal/boletim-do-desmatamento-sad-julho-de-2012>
- [31] World Bank. 2011. Data – GDP growth (annual %). <http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG>
- [32] Organisation for Economic Cooperation and Development. 2011. *Country Statistical Profile: Brazil*. http://www.oecd-ilibrary.org/economics/country-statistical-profile-brazil_csp-bra-table-en
- [33] Throssell, L. 2010. Lula's legacy for Brazil's next president. *BBC News – Latin America & Caribbean*, 30 September 2010. <http://www.bbc.co.uk/news/world-latin-america-11414276?print=true>
- [34] Rocha, C. 2009. Developments in national policies for food and nutrition security in Brazil. *Development Policy Review* 27: 51–66.
- [35] Chappell, M. J. and LaValle, L.A. 2010. Food security and biodiversity: Can we have both? An agroecological analysis. *Agriculture and Human Values* 28:3-26
- [36] Government of Brazil. 2009. Law #12.187 of 29 December 2009. *Diario Oficial da União*, #248-A, Secciao 1, 109–110. Brasilia, Brazil.
- [37] Walker, N., Bramble, B., and Patel, S. 2010. From major driver of deforestation and greenhouse gas emissions to forest guardians? New developments in Brazil's Amazon cattle industry. National Wildlife Federation, Washington, DC. <http://www.nwf.org/Global-Warming/Policy-Solutions/~media/4878226C49BF48EB9EB54C1B7C616327.ashx>
- [38] Phillips, T. 2010. Brazil election sees breakthrough for greens and environmental agenda. *The Guardian*, 4 October 2010. <http://www.guardian.co.uk/world/2010/oct/04/brazil-election-breakthrough-greens>
- [39] Mongabay.com. 2012. Norway payments to Brazil for reducing deforestation reach \$ 670 million. Mongabay.com, 6 December 2012. <http://news.mongabay.com/2012/1206-norway-brazil-payment.html>
- [40] Union of Concerned Scientists. 2011. *Drivers of Deforestation: How "Leakage" Shifts Tropical Deforestation around the Globe*. Union of Concerned Scientists, Washington, D.C., USA. July 2011. http://www.ucsusa.org/assets/documents/global_warming/DriversofDeforestation_Factsheet_Leakage.pdf