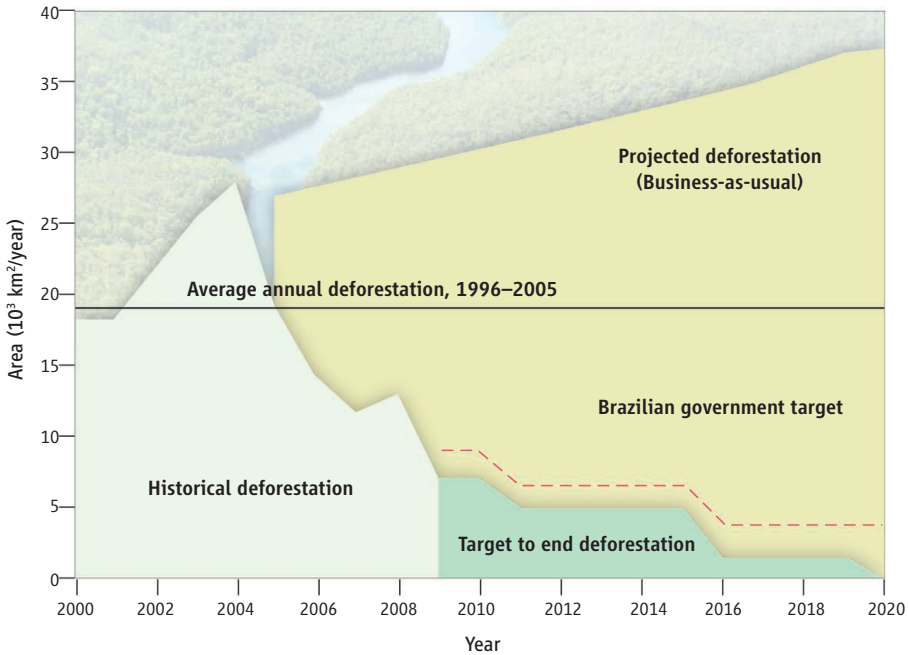
ENVIRONMENT

# The End of Deforestation in the Brazilian Amazon

Government commitments and market transitions lay the foundation for an effort to save the forest and reduce carbon emission.

Daniel Nepstad,[1,2‡] Britaldo S. Soares-Filho,[3‡] Frank Merry,[1,2*] André Lima,[2] Paulo Moutinho,[1,2] John Carter,[4] Maria Bowman,[1,2†] Andrea Cattaneo,[1] Hermann Rodrigues,[3] Stephan Schwartzman,[5] David G. McGrath,[1,2,6‡] Claudia M. Stickler,[1,2,7] Ruben Lubowski,[5] Pedro Piris-Cabezas,[5,8] Sergio Rivero,[6] Ane Alencar,[2,7] Oriana Almeida,[2,6] Osvaldo Stella[2]

Brazil has two major opportunities to end the clearing of its Amazon forest and to reduce global greenhouse gas emissions substantially. The first is its formal announcement within United Nations climate treaty negotiations in 2008 of an Amazon deforestation reduction target, which prompted Norway to commit $1 billion if it sustains progress toward this target (*1*). The second is a widespread marketplace transition within the beef and soy industries, the main drivers of deforestation, to exclude Amazon deforesters from their supply chains (*2*) [supplementary online material (SOM), section (§) 4]. According to our analysis, these recent developments finally make feasible the end of deforestation in the Brazilian Amazon, which could result in a 2 to 5% reduction in global carbon emissions. The $7 to $18 billion beyond Brazil's current budget outlays that may be needed to stop the clearing [a range intermediate to previous cost estimates (*3*, *4*)] could be provided by the REDD (Reducing Emissions from Deforestation and Forest Degradation) mechanism for compensating deforestation reduction that is under negotiation within the UN climate treaty (*5*), or by payments for tropical forest carbon credits under a U.S. cap-and-trade system (*6*).




**Historical deforestation in the Brazilian Amazon and future deforestation under three scenarios.** The first scenario simulates deforestation from 2005 into the future under business-as-usual conditions that assume economic trends and governance levels through 2003 (*14*). The intermediate curve is the current deforestation reduction target of the Brazilian government (*8*), and the lower curve, which ends deforestation in 2020, is the scenario analyzed here (SOM, § 2).

## Deforestation History

Brazil has been the world leader in tropical deforestation, clearing an average of 19,500 km$^2$/year from 1996 to 2005. This forest conversion to pasture and farmland released 0.7 to 1.4 Gt$CO_2$e (billion tons of $CO_2$ equivalents) per year to the atmosphere (*7*) (SOM, § 1). In 2008, the Brazilian government committed to reducing deforestation to 20% of the historical (1996–2005) rate by 2020 (*8*) (SOM, § 2), motivated by plummeting rates of forest clearing. From July 2005 to July 2009, deforestation declined to 36% of its historical levels (see figure, above). To help achieve this reduction, Brazil expanded the network of Amazon protected areas from 1.26 to 1.82 million km$^2$; the network now contains 51% of the region's remaining forest area (*9*) (table S4). Federal campaigns to publicize and cancel credit for illegal land holdings, to pressure buyers of Amazon products, and to imprison illegal operators may have contributed to the decline, as did a retraction of the region's cattle and soy industries (SOM, § 3, and fig. S1).

## Steps to End Deforestation

For Brazil to build upon its success and end deforestation, even if the profitability of Amazon cattle ranching and soy farming soar in the coming years, it must support low-deforestation livelihoods for forest peoples and smallholder farmers, expand the law-abiding "responsible" fraction of the cattle and soy sectors, improve law enforcement, and effectively manage protected areas.

Indigenous groups and traditional forest communities, totaling 420,000 people, have defended their perimeters from incursions by deforesters (*9*, *10*), but have never received compensation for this enforcement service. There are also 400,000 smallholder farms (up to 100 ha) (*11*) established in forested or marginal lands that could shift to low-deforestation production systems.

Cattle ranching, associated with four-fifths of Amazon deforestation, must stabilize and intensify on a diminishing area of pastureland, ceding space to a modest expansion of relatively lucrative soy production (SOM, § 3). Support within the cattle and soy sectors for declining deforestation could be strengthened by identifying, rewarding, and expanding

[1]Woods Hole Research Center, Falmouth, MA 02540, USA. [2]Instituto de Pesquisa Ambiental da Amazonia, Brasília-DF 71.503-505, Brazil. [3]Universidade Federal de Minas Gerais, Belo Horizonte, MG 31270-901, Brazil. [4]Aliança da Terra, Goiânia, GO 74.670-600, Brazil. [5]Environmental Defense Fund, Washington, DC 20009, USA. [6]University of Florida, Gainesville, FL 32611–7315, USA. [7]Universidad Rey Juan Carlos, Tulipán s/n, 28933, Móstoles, Spain. [8]Universidade Federal do Pará, 66.075-110, Belém, Pará, Brazil.

*Present address: Gordon and Betty Moore Foundation, Palo Alto, CA 94304, USA.
†Present address: University of California, Berkeley, Berkeley, CA 94720, USA.
‡Authors for correspondence. E-mail: dnepstad@whrc.org and britaldo@csr.ufmg.br







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the pool of "responsible" producers striving to comply with the law and to practice good land stewardship. Legal compliance could be facilitated through approval and implementation of land-use zoning plans, which lower the legal forest reserve requirement on private properties in farming and ranching regions (*12*). This requirement was abruptly raised from 50 to 80% of each property in 1996 without effective mechanisms for facilitating compliance (*2*) (SOM, § 6). The substantial flow of federal farm credit could be redirected toward the intensification of cattle production and support for forest-based economies (SOM, § 7). Market exclusion of deforesters (*2*) could be strengthened through government measures that penalize companies and banks that indiscriminately do business with Amazon farmers and cattle ranchers.

Some farmers and ranchers will need compensation for the opportunity costs incurred in maintaining private forests. Five landholder compensation qualification criteria could be used, including forest cover beyond 50% of the property (SOM, § 6).

### What Will It Cost and Who Will Pay?

We estimated the potential cost of a 10-year program for ending deforestation (see figure, page1350). Using spatially explicit economic models and programmatic estimates, we assess budgetary costs of ending deforestation assuming that the benefits of reduced deforestation outweigh the opportunity costs to society. These benefits include reduced forest fire, air pollution, flooding, biodiversity loss, soil erosion, and, perhaps, rainfall inhibition (*3*, *13*). They are difficult to quantify and are largely untreated in most economic models (*4*), even though they lower the net costs of reducing deforestation.

Annual investments in community forest-based economic activities, health, education, and cultural preservation for the region's indigenous and traditional forest peoples and smallholder farmers would total $3.6 to $7.2 billion from 2010 to 2020 (see table, below and SOM, § 5). The total opportunity cost potentially incurred by landholders is estimated at $14 billion (table S3 and fig. S9), or $26 billion if a minimum forest cover of 60% is imposed for each Amazon state to avoid rainfall inhibition (*13*) (SOM § 8). However, our estimate includes only those private forests that would qualify for compensation, which represent only 10 to 15% of potential opportunity costs (see table, below, and SOM, § 6).

Combining these costs with additional investments in law enforcement and protected area management gives a total budget of $7 to $18 billion (see table, below, and SOM, § 9). Already initiated by the Norway commitment, this investment could reduce carbon emissions from 2010 to 2020 by ~6 $GtCO_2e$ below the historical baseline and by 12 $GtCO_2e$ below projected emissions (see figure, page 1350) (*14*), culminating in annual emissions reductions that are 2 to 5% of global emissions rates in 2000–2006 (SOM, § 2). Under a REDD system, as designed in the American Clean Energy Security Act passed by the U.S. House of Representatives, reductions under Brazil's deforestation target could generate revenues valued from $37 billion to $111 billion between 2013 and 2020 (*6*) (SOM, § 10), providing a margin for expanding the program to end deforestation.

Ending deforestation in the Brazilian Amazon in 2020 with less than 20% of the forest cleared (table S4) would be an extraordinary and extremely difficult achievement, perhaps unique in the history of frontier expansion. The likelihood of success, however, is greatly enhanced by state-level programs that link zoning and property registries with statewide deforestation reduction targets (SOM § 11). The Governors' Climate and Forests Task Force is working to connect these Amazon state programs with international emissions offset programs under development for California and other U.S. states (*15*). State-level programs must also eventually link up with the federal "Amazon Fund," where the Norwegian commitment resides (*1*). Most tropical nations will require time to develop Brazil's institutional capacity, civil society organization, and legal framework (*16*). Ending deforestation in the Brazilian Amazon and reducing it elsewhere in the tropics is a cost-effective approach to climate change mitigation with multiple benefits (*13*, *16*).

**Estimated costs of a program to end deforestation in the Brazilian Amazon**

| Region or state | Forest peoples' fund ($10^6$ U.S. $) | | Enforcement and landholder compensation ($10^6$ U.S. $) | | Protected area management ($10^6$ U.S. $) | | Total cost ($10^6$ U.S. $) | |
|---|---|---|---|---|---|---|---|---|
| | Low | High | Low | High | Low | High | Low | High |
| Brazilian Amazon | 3,606 | 7,213 | 1,459 | 6,502 | 1,456 | 4,368 | 6,521 | 18,082 |
| Acre | 252 | 503 | 106 | 147 | 54 | 163 | 412 | 813 |
| Amapá | 68 | 135 | 13 | 12 | 56 | 168 | 136 | 315 |
| Amazonas | 565 | 1,129 | 229 | 116 | 546 | 1,639 | 1,340 | 2,884 |
| Maranhão | 189 | 377 | 13 | 248 | 10 | 31 | 212 | 656 |
| Mato Grosso | 335 | 669 | 693 | 4,135 | 80 | 240 | 1,107 | 5,044 |
| Pará | 1,357 | 2,715 | 280 | 639 | 488 | 1,464 | 2,125 | 4,818 |
| Rondônia | 580 | 1,159 | 94 | 1,127 | 79 | 238 | 752 | 2,524 |
| Roraima | 116 | 231 | 27 | 19 | 90 | 271 | 233 | 522 |
| Tocantins | 147 | 293 | 4 | 60 | 51 | 154 | 202 | 507 |

**Ending deforestation in the Brazilian Amazon by 2020.** These estimates for costs incurred from 2010 to 2020 assume that current budgetary outlays from the Brazilian government continue. (SOM § 9)


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### Supporting Online Material

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