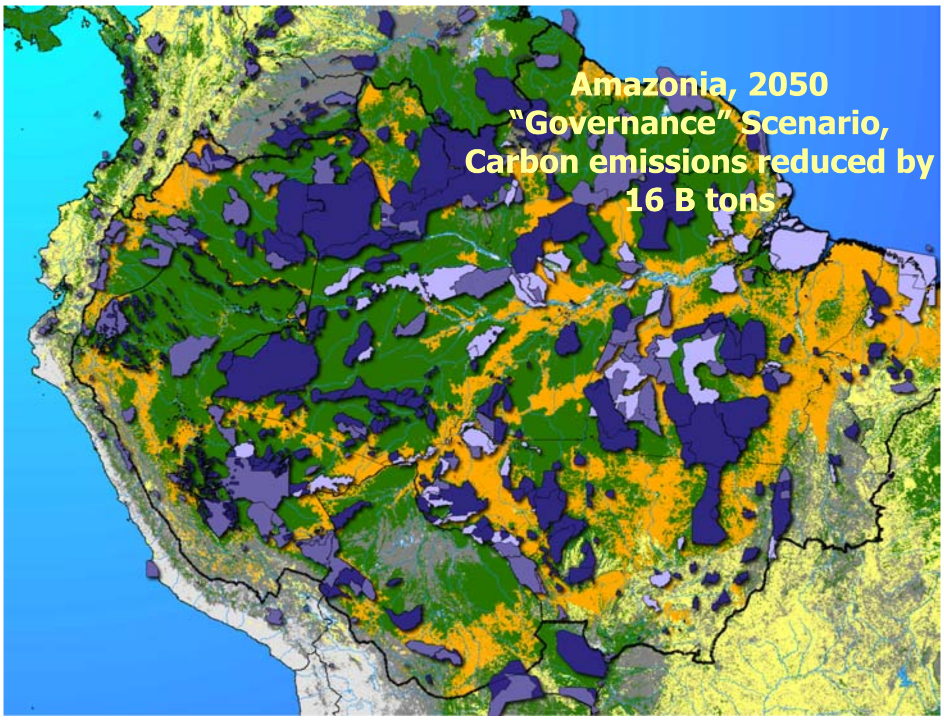
The Amazon in a Changing Climate:
Large-Scale Reductions of Carbon Emissions from Deforestation and Forest Impoverishment



This report is a joint project of the Amazon Institute for Environmental Research (Instituto de Pesquisa Ambiental da Amazônia—IPAM), the Woods Hole Research Center (WHRC), and the Federal University of Minas Gerais (Universidade Federal de Minas Gerais—UFMG). It is supported by grants from the Conselho Nacional de Pesquisa (PPG7), David and Lucille Packard Foundation, the Gordon and Betty Moore Foundation, the Blue Moon Foundation, the William and Flora Hewlett Foundation, the US Agency for International Development, the National Science Foundation, and the Brazilian Large-Scale Biosphere Atmosphere Experiment (through a grant from the National Aeronautics and Space Administration)

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1. Tropical forests are a giant, volatile reservoir of carbon that must remain largely intact if we are to bring global warming under control. They also are an enormous "air conditioner", transforming the sun's energy into water vapor.

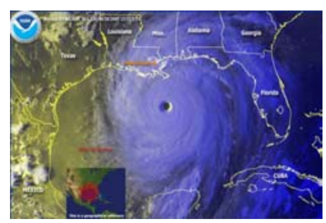
The tree trunks, branches and roots of these magnificent species-rich ecosystems store about fifty years' worth of today's global carbon emissions (~430 billion tons[1]), and this carbon is being released to the atmosphere at the rate of approximately 0.8 to 2.4 billion tons per year through deforestation and forest thinning[2]. (By contrast, fossil fuel combustion releases a little more than 7 billion tons per year worldwide). Beyond the role of tropical forests in carbon storage, climate models demonstrate that rainfall patterns in agricultural regions of the temperate zone may depend upon tropical forests.

[1] Prentice I.C., Farquhar, G.D., Fasham, M.J.R., Goulden, M.L., Heimann, M., et al.. 2001. The carbon cycle and atmospheric carbon dioxide. In: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change, J.T. Houghton, et al. (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 183-237.

[2] Reviewed in Houghton, R. 2005. Tropical deforestation as a source of greenhouse gases. In "Tropical Deforestation and Climate Change" Edited by P. Moutinho and S. Schwartzman. Instituto de Pesquisa Ambiental da Amazônia (IPAM) e Environmental Defense (ED). www.ipam.org.br

2. Forest fire and tree mortality can double carbon emissions from tropical forests during dry years, such as those associated with El Niño events and the 2005 warming of the tropical North Atlantic. Some evidence suggests that El Niño events will become more common in a warming world.

When El Niño events interrupt tropical rains, emissions from tropical forests can increase abruptly. In 1998, when El Niño triggered severe droughts in the Amazon and SE Asia, 0.8 to 2.6 billion extra tons of carbon were released to the atmosphere through accidental fire in SE Asian peat forests[3] while Amazon fires killed trees containing 0.1 to 0.3 billion tons of biomass[4]. This drought also killed rainforest trees. We simply don't know how much carbon was released because of tree mortality in 1998 or in the great Amazon drought of 2005—a drought triggered by the same anomalous heating of the tropical North Atlantic that gave North America a particularly brutal series of hurricanes, including Katrina. There is little that humanity can do to prevent severe droughts. But tropical forest fires are started by people and can be stopped by people as well.



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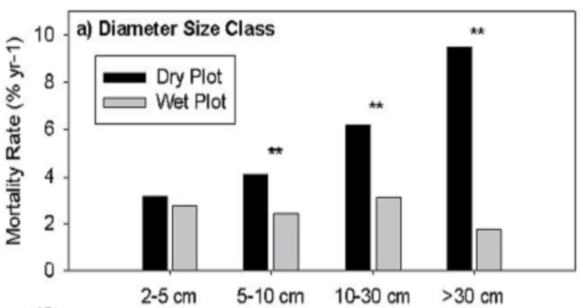
[3] Page SE, Siegert F, Rieley JO, Boehm H-DV, Jaya A, Limin S (2002) The amount of carbon released during peat and forest fires in Indonesia during 1997. Nature 420:61-65.

[4] Alencar A, Nepstad D, Vera Diaz MdC. 2006 Forest understory fire in the Brazilian Amazon in ENSO and non-ENSO Years: Area burned and committed carbon emissions. Earth Applications 10, Paper No. 6, 1-17.

3. Evidence from around the world has shown that severe natural drought kills rainforest trees. Experimental evidence from the Amazon indicates that <u>severe drought kills large canopy trees more than small understory trees</u>[5]. This is important because canopy trees protect the forest interior from sunlight, increasing forest resistance to fire.

Amazon tree death by drought



In the world's largest tropical rainforest drought experiment, 5,600 plastic panels were installed in the understory of a one-hectare forest plot in the east-central Amazon (Tapjos National Forest) and compared with a plot without panels, simulating a 50% reduction of rainfall. During the third year of drought, soil moisture was depleted to a depth of 11 meters and trees began to die. We were surprised to learn that the largest trees (trunk diameter greater than 30 centimeters) died more than smaller trees, opening the forest to the ravages of fire. Although Amazon forests are very tolerant of drought, they have their limits.

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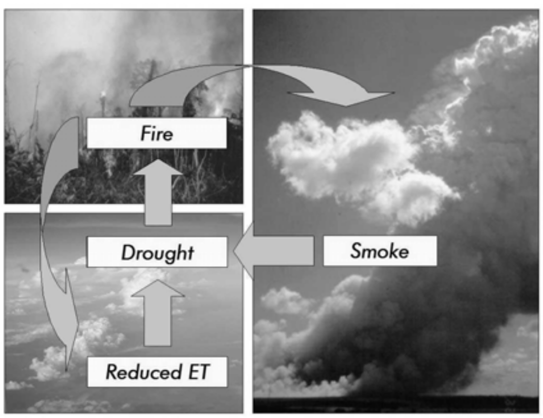
[5] For more information about the drought experiment: Nepstad DC, Moutinho PRdS, Dias-Filho MB, Davidson EA, Cardinot G, et al. (2002) The effects of rainfall exclusion on canopy processes and biogeochemistry of an Amazon forest. Journal of Geophysical Research 107:53, 1-18.; Tohver I, Ray D, Nepstad D, Moutinho P, Cardinot G (accepted) Long-term experimental drought effects on stem mortality, forest structure, and dead biomass pools in an Eastern-Central Amazonian forest. Ecology.

4. Once a rainforest burns, it is likely that it will burn again; selective logging also increases fire susceptibility[6]. The dense smoke from fire can inhibit rainfall for weeks, increasing the likelihood of further burning[7]. Forest substitution with cattle pasture and soy fields can also reduce rainfall by lowering evapotranspiration (ET) and increasing light reflection (albedo)[8]. This vicious cycle of fire and drought could help to transform 1/3 or more of the Amazon forest into fire-prone scrub vegetation over the coming decades, well in advance of the major biome shifts associated with global warming. The Amazon forest, alone, contains 100-140 billion tons of carbon[9].

Two of the "positive feedback" loops between Amazon forest fire and drought.



[6]Nepstad DC, Veríssimo A, Alencar A, Nobre CA, Lima E, Lefebvre PA, Schlesinger P, Potter C, Moutinho PRdS, Mendoza E, Cochrane MA, Brooks V (1999) Large-scale impoverishment of Amazonian forests by logging and fire. Nature 398:505-508. ; Nepstad DC, Carvalho GO, Barros AC, Alencar A, Capobianco JP, Bishop J, Moutinho P, Lefebvre PA, Silva UL, Prins E (2001) Road paving, fire regime feedbacks, and the future of Amazon forests. Forest Ecology and Management 154:395-407.

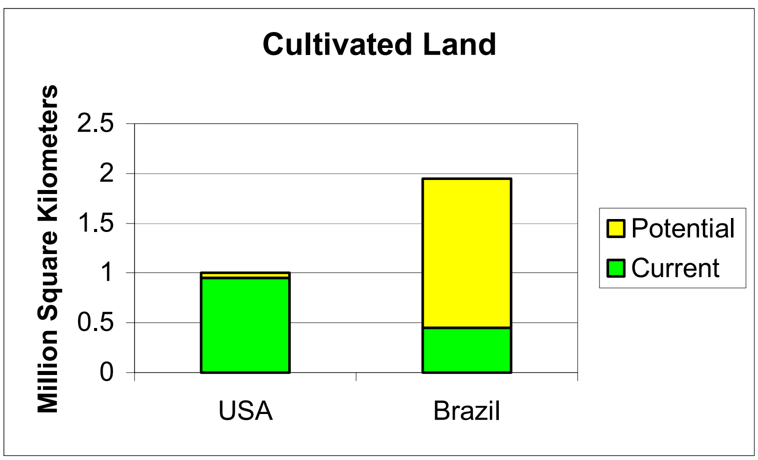
[7] Andreae MO, Rosenfeld D, Artaxo P, Costa AA, Frank GP, Longo KM, Silva-Dias MAF (2004) Smoking rain clouds over the Amazon. Science 303:1337-1342.

[8] Silva Dias, M. A. F., S. Rutledge, P. Kabat, P. L. Silva, C. Nobre, et al. 2002. Cloud and rain processes in a biosphere-atmosphere interaction context in the Amazon region. J. Geophysical Research 107, D20, 8072.

[9] Soares-Filho, B.S., D.C. Nepstad, L.M. Curran, G.C. Cerqueira1, R.A. Garcia, C.A. Ramos, E. Voll, A. McDonald, P. Lefebvre, and P. Schlesinger. (2006) Modeling conservation in the Amazon basin. Nature 440(7083):520-523.

<u>5. Tropical deforestation will likely increase in the coming decades</u> because the US, Europe, and Asia have very little land available for agricultural expansion, and because of urbanization (particularly in China). Much of the future expansion of cultivated land and planted pasture will be in South America and, soon thereafter, Africa. The expansion of agricultural commodity production in tropical forest regions is accelerated by growing demands for biofuels and animal ration. The emerging economies such as China are also "emerging meat-eating nations", consuming poultry, pork, and beef fed with imported soymeal, increasing the land area necessary to provide protein and calories for the world population[10].

Current and potential area of agricultural cultivation in the US and Brazil



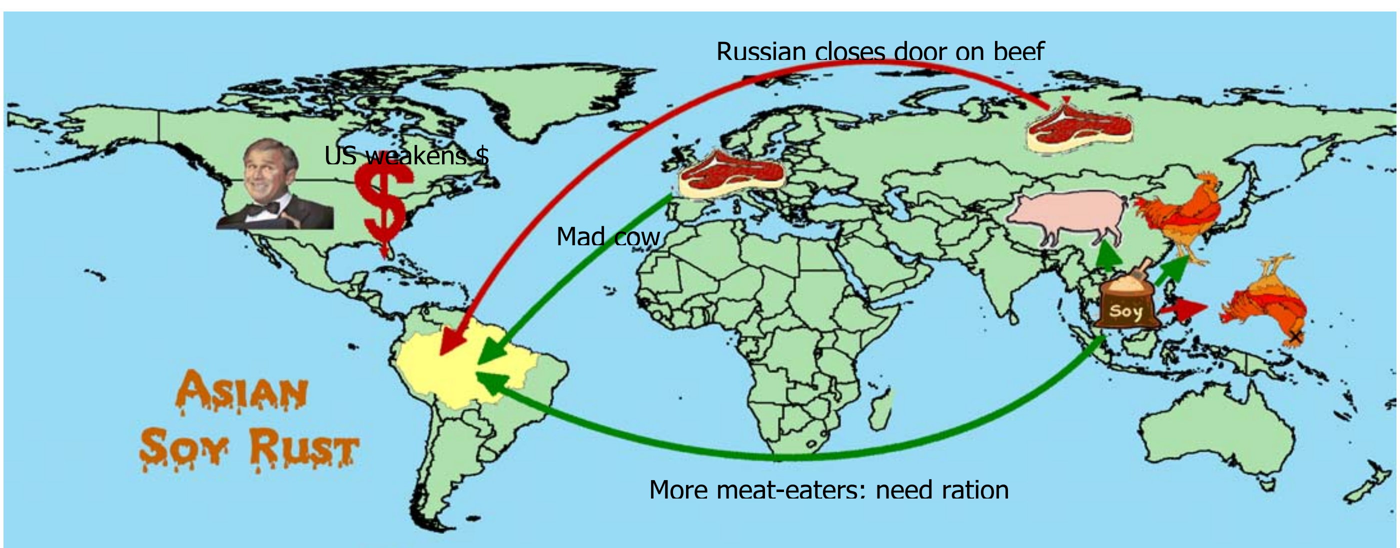
USDA-FAS 2003[11]; Michael Shean, USDA/FAS, personal communication.

[10] Nepstad, D. & C. Stickler. In press. Managing the tropical agriculture revolution. J. Sustainable Forestry

[11] USDA-FAS. 2003. Future Agricultural Expansion Potential Underrated Brazil. United States Department of Agriculture, Foreign Agriculture Service, Washington, D.C. (Available at http://www.fas.usda.gov/current2003.html accessed May 2005).

6. <u>This trend has already begun in the Amazon</u>, where deforestation oscillates depending upon the prices of soy and beef and the strength of the Brazilian currency (the Real) against the dollar[12]. In the first few years of the millenium, the weakness of the Real coincided with growing demand for soy in Europe (following "mad cow" outbreaks) and China, and soaring prices for beef. As a result, deforestation rates climbed to 27,400 km^2 in 2004, 50% above the long-term average. With the decline of soy and beef prices in 2005 and 2006, and the strengthening of the Real against the dollar, deforestation rates slowed to 18,800 and 13,100 km^2, respectively[13]. Currently, soy prices are climbing again as the demand for corn to make ethanol grows in the US, as sugar cane production for ethanol expands in Brazil, and as the demand for soy oil as a diesel substitute increases.

"Economic teleconnections" across the planet now exert an important influence on Amazon deforestation rates through the globalization of major drivers of forest clearing: cattle pasture formation and soy production. In this diagram, red arrows inhibit deforestation (such as the Russian boycott of Brazilian beef following the October 2005 outbreak of foot and mouth disease) while green arrows stimulate deforestation. After the European Union prohibited the use of animal carcasses in animal feed (following the "mad cow" outbreak), soy imports provided a new source of protein. China's soy imports supply animal ration for burgeoning poultry and pork industries. A disease, the Asian rust, has reduced yields in Brazil. Brazil's own expanding markets for ethanol and biodiesel are providing, directly and indirectly, new incentives for Amazon deforestation[12].

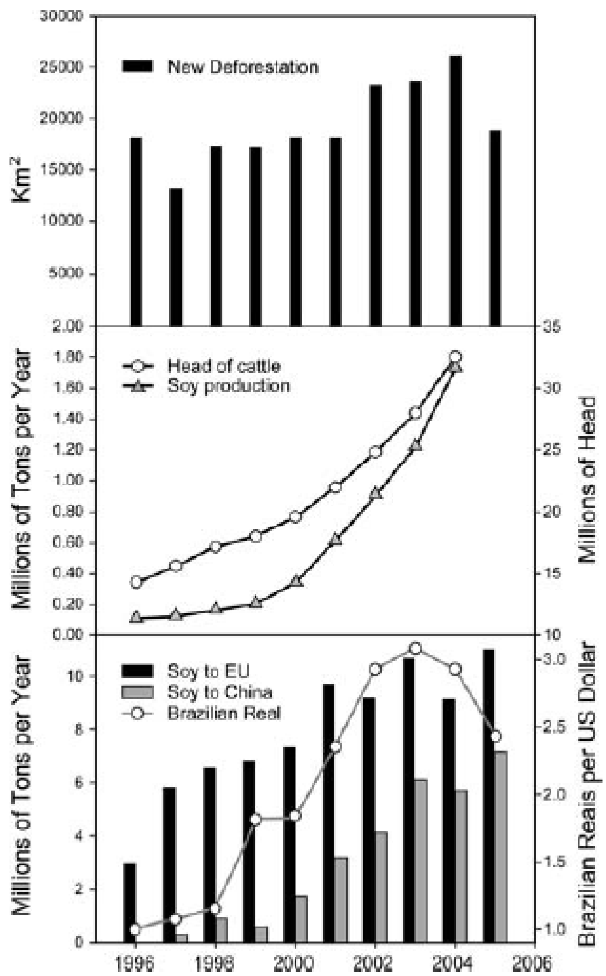


[12] Nepstad, D., C. Stickler, and O. Almeida. 2006. Globalization of the Amazon soy and beef industries: opportunities for conservation. *Conservation Biology 20(6): (due out in December)*

[13] INPE/PRODES. 2006. http://www.obt.inpe.br/prodes/ (last accessed: November 14, 2006)

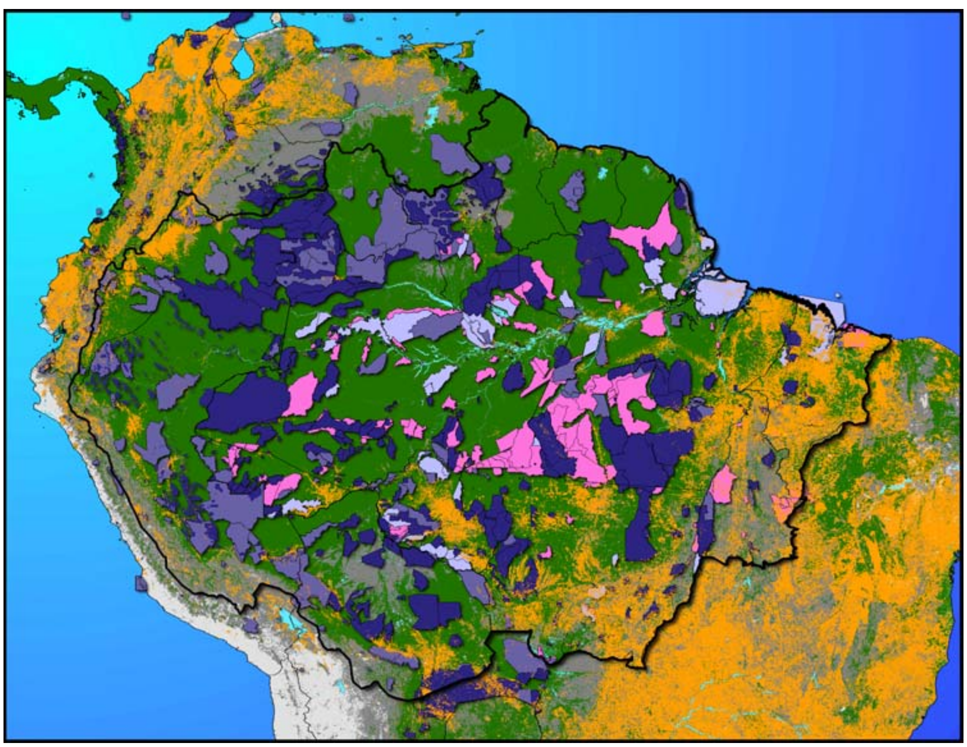
6. (cont'd)

Recent trends in Amazon deforestation, cattle herd expansion, soy production, soy imports by China and the European Union, and the value of the Brazilian Real[12]. (Brazilian Amazon only; cattle herd and soy production for forest biome only.)



7. But Amazon deforestation in 2005 and 2006 also declined because of the very effective intervention by the Brazilian government. In 2004 and 2005 the Brazilian government created 240,000 square kilometers of new protected areas in the Amazon, mostly in the contested region of active deforestation. The creation of these areas was greatly facilitated by political support from organizations of smallholder farmers[14], and by a previous commitment made by the government to expand its network of protected areas through the "ARPA" program[15]. The government sent army troups into regions of illegal deforestation and logging and has jailed illegal loggers, illegal ranchers, and corrupt government environmental personnel.

New protected areas created in the Amazon by the Brazilian government since early 2004 (pink) are a remarkable display of political will. Already existing protected areas and indigenous lands are indicated in shades of blue. Indigenous lands are dark blue.

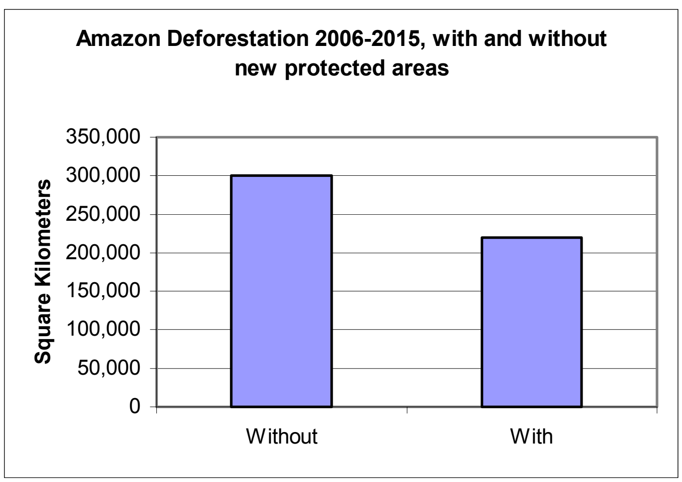


[14] Campos, M. and D. Nepstad. 2006. Smallholder farmers, the Amazon's new conservationists. Conservation Biology 20(5): 1553-1556.

[15] Montiel, F (2004) Programa Áreas Protegidas da Amazônia—ARPA. Resumo Executivo [online] khttp://www.mma.gov.br/port/sca/ppg7/doc/arpareex.pdfl.

8. The new protected areas created since 2004 will have an important effect in reducing future carbon emissions from deforestation. Using our land use simulation model[16], we estimate that <u>these protected areas—if enforced—will reduce deforestation by approximately 60,000 km^2 over the next decade, preventing emissions of more than 0.6 billion tons of carbon</u> to the atmosphere. The cost of reducing carbon emissions from the Amazon is approximately one thousand times lower than the economic damages to the world economy of doing nothing to prevent these emissions[17].

Protected areas in regions of active agricultural expansion reduce deforestation and associated carbon emissions by restricting the amount of land available for clearing. Our simulation model "SimAmazonia I" (see footnote 16) integrates the effects of highways, protected areas, urban centers, and land-use policy on deforestation trajectories.

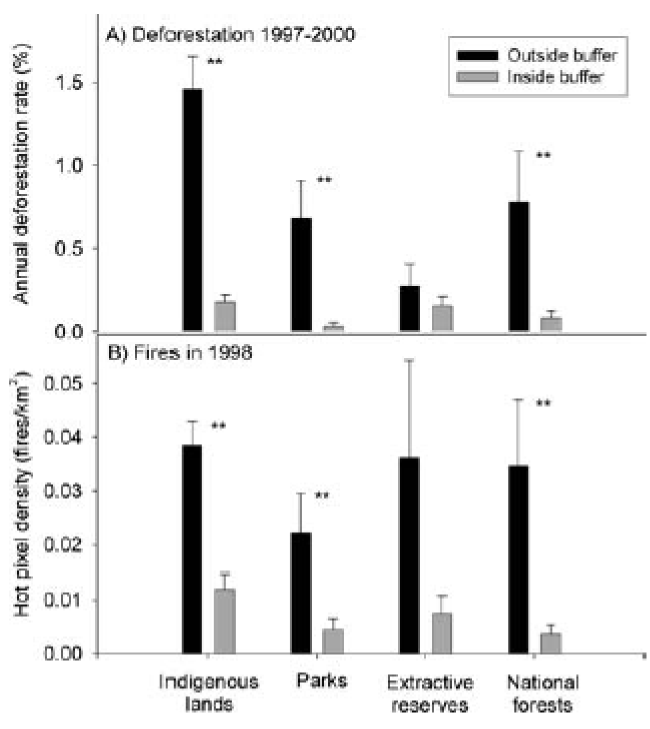


[16] Soares-Filho, B.S., D.C. Nepstad, L.M. Curran, G.C. Cerqueira1, R.A. Garcia, C.A. Ramos, E. Voll, A. McDonald, P. Lefebvre, and P. Schlesinger. (2006) Modelling conservation in the Amazon basin. Nature 440(7083):520-523.

[17] Even if it were to cost $100 million to create, enforce, and manage the protected areas created in the Amazon since 2004, (which is an overestimate), this amount is 1,000 times lower than the economic damages to the world economy associated with the release of one billion tons of carbon, since damages of $100 per ton are well within the range of current estimates: Stern Review: The Economics of Climate Change, Oct. 2006, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

9. Protected areas are effective at inhibiting both deforestation and fire. Indigenous lands are the most important type of protected area today in slowing Amazon deforestation because they include 21% of the forests of the Brazilian Amazon and because they are often located in the active agricultural frontier. Parks and nature reserves are often created in remote places where risk of invasion and opposition from local landholders is low. It is in this context that Brazil's recent accomplishments in creating new protected areas are remarkable.

In a satellite-based study, we compared the deforestation rates and fire occurrence along the outside versus the inside perimeters of Amazon protected areas as a measure of their inhibitory effects. Contrary to the notion that the Amazon is full of "paper parks" that are little more than lines on a map, indigenous lands, parks, extractive reserves, and national forests exert a strong inhibitory effect on deforestation and fire[18].



[18] Nepstad, D., S. Schwartzman, B. Bamberger, M. Santilli, et al. 2006. Inhibition of deforestation and fire by Amazon parks and indigenous lands. Conservation Biology 20(1):65-73

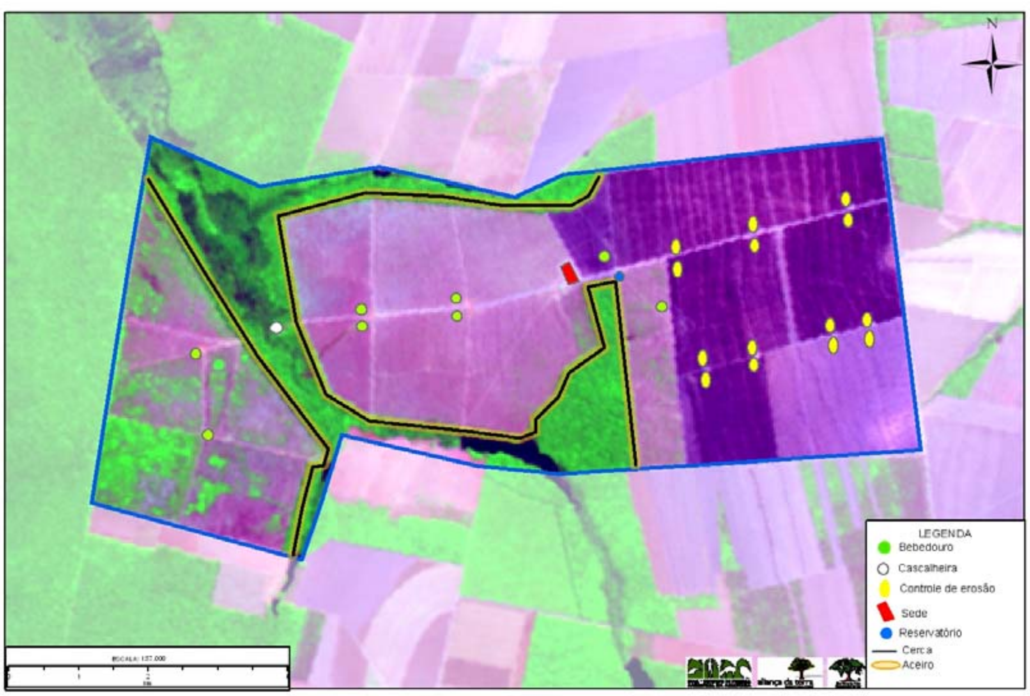
10. In addition to the creation of new protected areas, <u>powerful market forces could go a long way in lowering carbon emissions from tropical forests</u>. For imbedded in the growing worldwide demand for agricultural commodities is an increasingly rigorous set of environmental and social standards. Finance institutions, commodity traders, consumer groups, environmental NGOs, and human rights organizations are pushing to raise the bar on the socio-environmental "quality" of the agricultural commodity production chain.

Finance institutions that are striving to adopt the "Equator Principles" of social and environmental responsibility are beginning to attach socio-environmental conditions to their loans, reducing the risk associated with their investments as they force thousands of farmers to obey the law and adopt good land stewardship practices. Similarly, agricultural commodity traders are seeking socially and environmentally benign suppliers and are important participants in the development of international criteria for "responsible" soy[19], palm oil, and other commodities. Established agricultural sectors in industrialized countries see higher standards as a way of protecting their products from competition. In one of the most dramatic illustrations of these trends, the companies that buy most of the soy produced in the Amazon recently declared a two-year moratorium on the purchase of soy grown on recently cleared Amazon rainforest soil. This momentous decision was a response to a campaign launched by the environmental organization Greenpeace, which targeted European McDonald's restaurants for their use of Amazon soy in the feed that fattens their chickens.

[19] The "Round Table for Responsible Soy" (RTRS, see www.responsiblesoy.org) was transformed into a legal entity on November 8, 2006, and will now develop criteria and indicators for responsible soy production.

<u>11. Farmers and ranchers in remote reaches of the Amazon are feeling the pressure to obey the law and adopt sound land stewardship practices</u>. News is spreading like wildfire that to participate in the lucrative international commodity markets producers must increase the social and environmental "quality" of their products. Farmers and ranchers are realizing that they must eliminate forest fire, maintain private land forest reserves, avoid the use of dangerous agrochemicals, and protect their riparian zones if they are to succeed.

For example, this 4,200-hectare farm in Mato Grosso, Brazil, has all of its legally-required riparian zone (stream-margin) forest reserves intact, it has eliminated forest fire by investing in fire breaks, it prevents cattle from entering its stream by providing drinking tanks supplied by pumped water, it applies certified agrochemicals with tractors (not with crop-dusters), and its personnel are registered workers with full benefits and excellent living conditions. The property has too little forest cover (by law) and the owner is paying into a fund that protects other nearby forests as compensation. He has invested nearly $180,000 in these land stewardship practices. This property is abiding by a management plan developed as part of the "Registry of Socio-environmental Responsibility", a project of the Land Alliance (Aliança da Terra), Amazon Institute of Environmental Research (IPAM), and Woods Hole Research Center. The owner has already used his Management Plan to obtain rural credit, and a Brazilian supermarket chain has expressed its interest in purchasing beef from ranches that are part of the Registry.



12. During the eleventh Conference of the Parties of the UN climate convention (United Nations Framework Convention on Climate Change—UNFCCC), in Montreal, the possibility of a second source of hope in containing the agroindustrial explosion into the tropics came one step closer to reality: payments for nation-wide reductions in carbon emissions from tropical deforestation. Discarded during the Kyoto round of negotiations of the climate treaty, which defined the greenhouse gas emission goals and commitments for the period 2008-2012, the prospect of paying tropical forest nations to reduce their deforestation—a proposal called "Compensated Reduction"[20]—has now been incorporated into initiatives like the proposal submitted by the Coalition of Rainforest Nations[21], led by Papua New Guinea and Costa Rica, to the secretariat of the UNFCCC. More recently the proposal has been elaborated by Brazil into a mechanism of compensation for the reduction of deforestation emissions. The Brazil proposal is a very important step in strengthening the political momentum of this new component of UNFCCC negotiations. Brazilian President Luiz Ignácio "Lula" da Silva announced his support for this proposal on November 10. Many view this new development as one of the most exciting turns in the climate treaty process.

[20] Santilli MP, Moutinho P, Schwartzman S, Nepstad D, Curran L, Nobre C (2005) Tropical deforestation and the Kyoto Protocol: an editorial essay. Climatic Change 71:267-276.

[21] Bolivia, Central African Republic, Chile, Congo, Costa Rica, DR Congo, Dominican Republic, Fiji, Gabon, Guatemala, Nicaragua, Solomon Islands, Panama, Papua New Guinea, and Vanuatu. http://www.rainforestcoalition.org/eng/

13. The potential for reducing greenhouse gas emissions from tropical forests is illustrated by a simulation study of the Amazon rainforest under "business-as-usual" and "governance" scenarios. If current trends in Amazon deforestation are extended into the future, with the most likely road-paving projects completed over the next two decades, then approximately one million square kilometers of new deforestation will take place by the year 2050, releasing about 33 billion tons of carbon to the atmosphere. <u>If the Brazilian government fully implements ARPA, if all Amazon countries defend parks and indigenous lands from incursions, and if all Amazon countries keep 50% of private lands in forest cover[22], then one half of the projected deforestation can be avoided, reducing emissions to 17 billion tons</u>. The negative regional economic impact of this reduction in carbon emissions from the Amazon could be rather small since much of the deforestation that is to be avoided should be on marginal lands that are unsuitable for agriculture[23]. Not included in this exercise is the reduction of carbon emissions from accidental forest fire, an anthropogenic source of Amazon carbon emissions that brings economic advantages to no one, but that causes damages to the timber industry and to communities that depend upon forests. The long term economic benefits of maintaining a larger forest patrimony in the Amazon are potentially very large.

[22] According to the Brazilian "Forest Code" (Codigo Florestal), 80% of private lands in the Amazon forest region must be devoted to forest reserves. Enforcement of this ambitious law has been difficult.

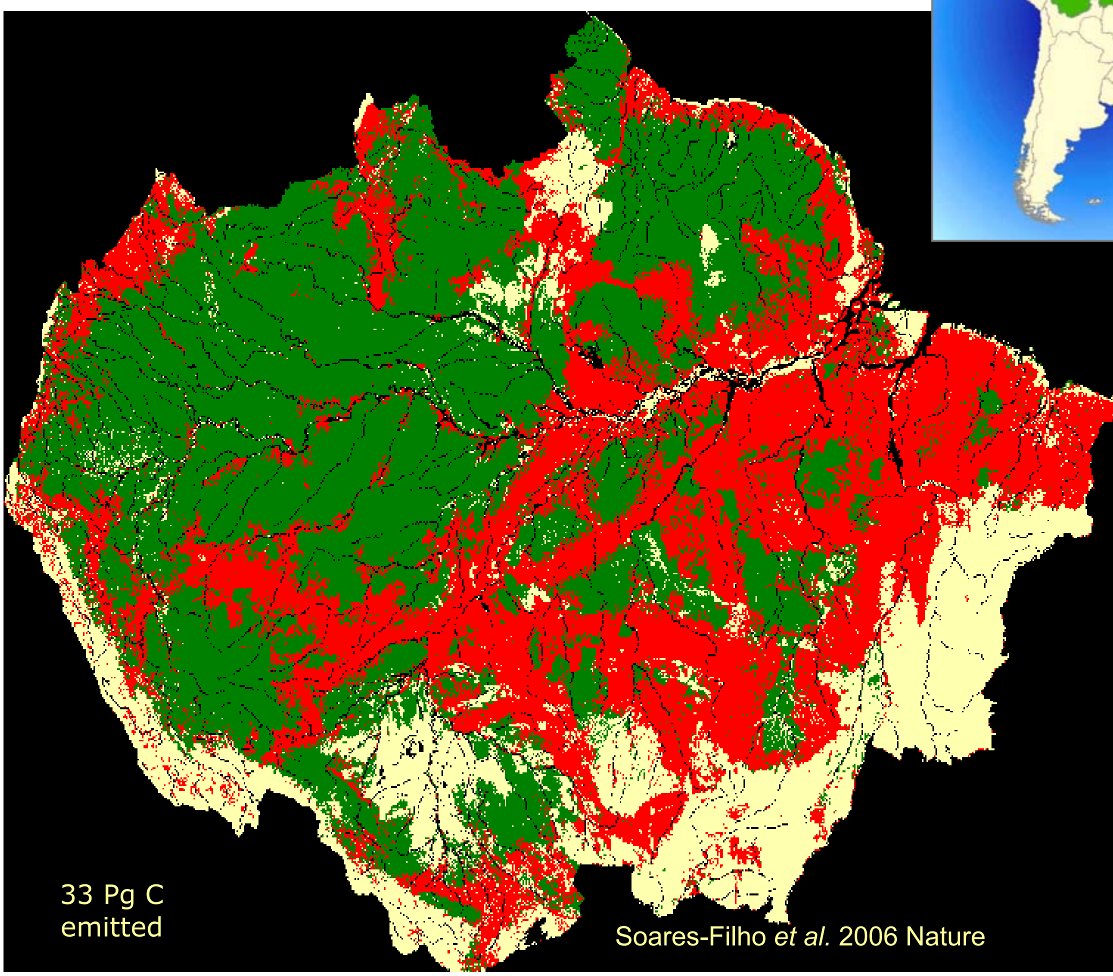
[23] Approximately one fourth of Amazon forestlands cleared for agriculture are abandoned, Houghton RA, Skole DL, Nobre CA, Hackler JL, Lawrence KT, Chomentowski WH (2000) Annual fluxes of carbon from deforestation and regrowth in the Brazilian Amazon. Nature 403:301-304

13. (cont'd)

The business-as-usual scenario:

2050 BAU Scenario:

Deforested	2,698,735 km^2
Forest	3,320,409 km^2
Non-forest	1,497,685 km^2



13. (cont'd)

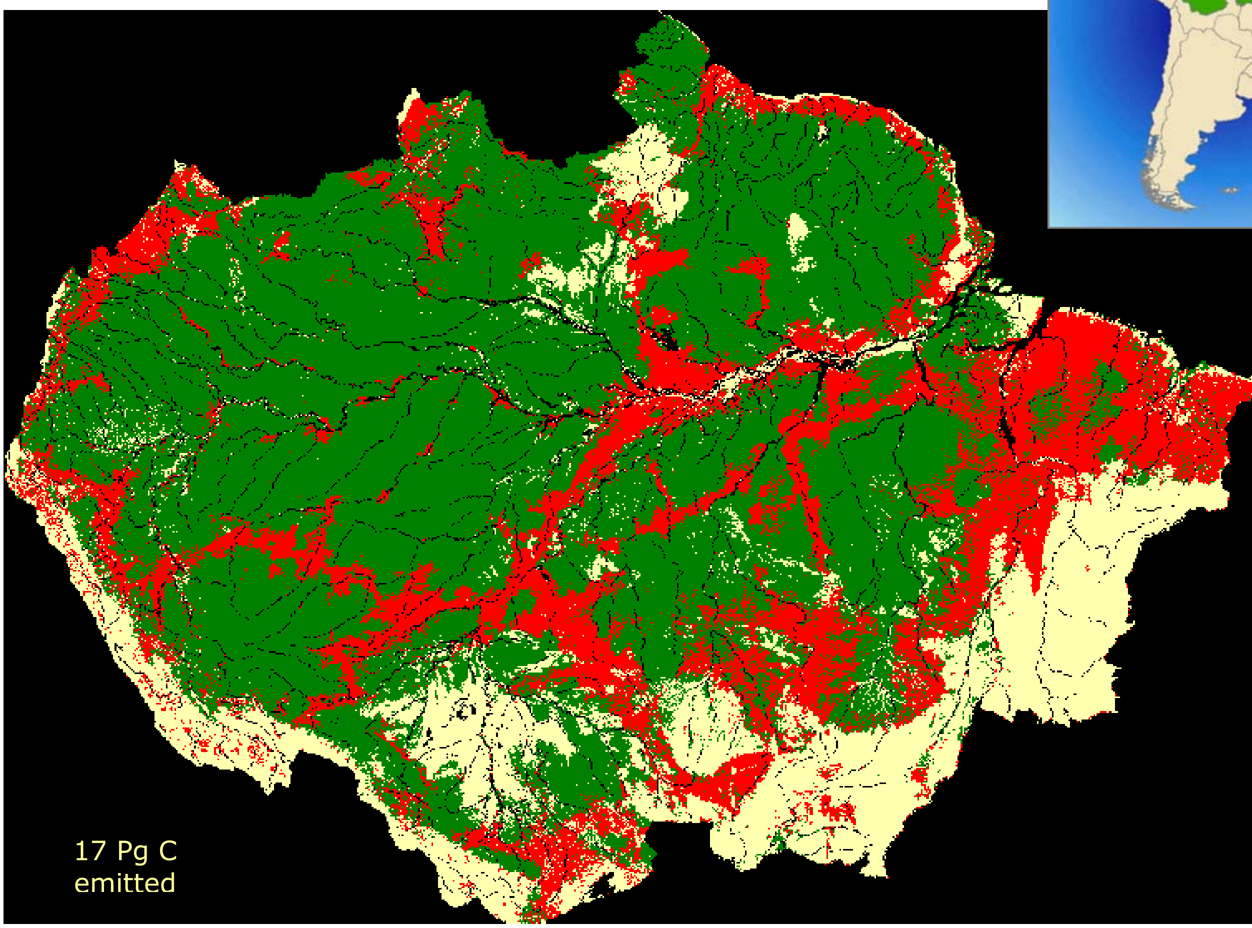
The "governance" scenario:

2050 Governance Scenario:

Deforested 1,655,734 km^2

Forest 4,363,410 km^2

Non-forest 1,497,685 km^2



14. <u>The need for integrated, equitable approaches to the conservation of tropical forests</u>. The reduction of carbon emissions from the Amazon forest—and from tropical forests anywhere in the world—must not be attempted in a vacuum. Rather, the prospect of payments for the reduction of carbon emissions must be viewed as an opportunity to promote sustainable development of tropical regions, reconciling the conservation and management of tropical forests with improved living standards for the people who live in these regions. The success of "compensated reduction" must be measured in terms of progress made in improving employment opportunities, incomes, health, water quality, and biodiversity conservation. The process of "compensated reduction" must draw upon the best science available for a given region, empower marginalized members of society committed to sustainable development, and meet the requirements for sustainable economic growth.