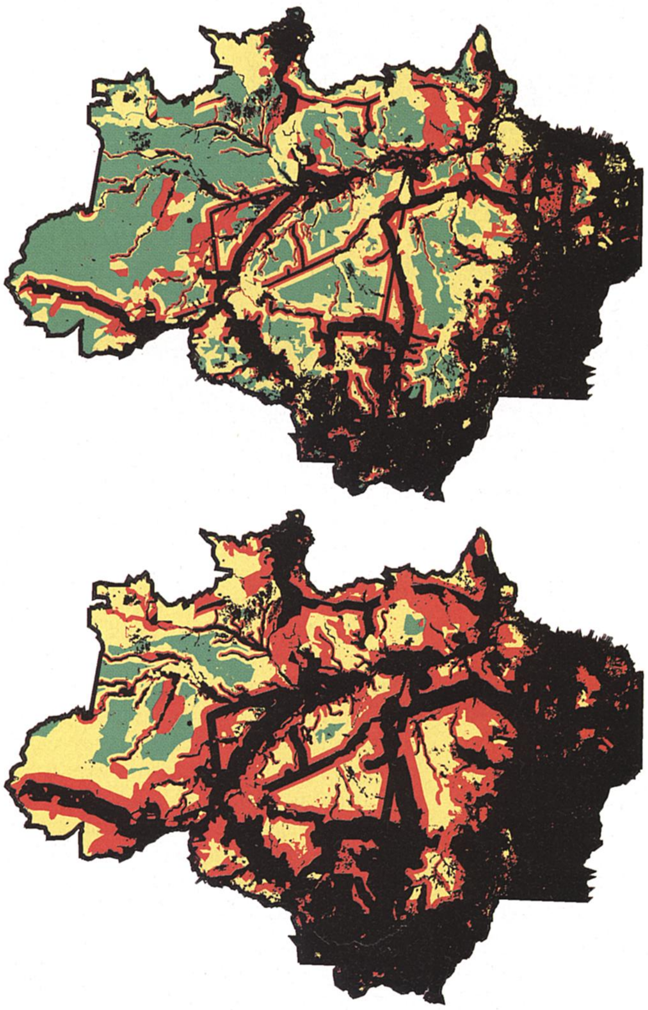
POLICY FORUM: ENVIRONMENT

The Future of the Brazilian Amazon

William F. Laurance,* Mark A. Cochrane, Scott Bergen, Philip M. Fearnside, Patricia Delamônica, Christopher Barber, Sammya D'Angelo, Tito Fernandes

The Brazilian Amazon contains about 40% of the world's remaining tropical rainforest and plays vital roles in maintaining biodiversity, regional hydrology and climate, and terrestrial carbon storage (*1*). It also has the world's highest absolute rate of forest destruction, currently averaging nearly 2 million hectares per year (*2*).

This rapid pace of deforestation has several causes. First, nonindigenous populations in the Brazilian Amazon have increased tenfold since the 1960s, from about 2 million to 20 million people, as a result of immigration from other areas of Brazil and high rates of intrinsic growth (*3*). Second, industrial logging and mining are growing dramatically in importance, and road networks are expanding that sharply increase access to forests for ranchers and colonists. Third, the spatial patterns of forest loss are changing; past deforestation has been concentrated along the densely populated eastern and southern margins of the basin, but new highways, roads, logging projects, and colonization are now penetrating deep into the heart of the basin. Finally, human-ignited wildfires are becoming an increasingly important cause of forest loss, especially in logged or fragmented areas (*4*).



Models of development in the Amazon. Optimistic (**top**) and nonoptimistic (**bottom**) scenarios, showing predicted forest degradation by the year 2020. (Black is deforested or heavily degraded, including savannas and other nonforested areas. Red is moderately degraded, yellow is lightly degraded, and green is pristine).

Growing concern over the rapid destruction of Amazonian forests has prompted a number of international and domestic initiatives to help promote conservation planning and sustainable development. The largest of these is the Pilot Program to Conserve the Brazilian Rainforest, which is attempting to channel $340 million from G-7 nations (Germany, Britain, France, Italy, the United States, Canada, Japan, and the European Community) into land-use planning, extractive (*5*) and Amerindian reserves, ecological corridor systems, and capacity-building for local governments (*6*). There also are bilateral programs between the Brazilian and other governments, domestic governmental initiatives, and activities of private organizations. Collectively, these programs involve hundreds of millions of dollars and the energies of many dedicated individuals.

These efforts, however, pale in comparison to the scale of ongoing and planned development activities in the Amazon. Under the auspices of its "Avança Brasil" (Advance Brazil) program (*7*), the Brazilian government is fast-tracking dozens of major infrastructure projects that will span large expanses of the basin—intended to accelerate economic development in the industrial agriculture, timber, and mining sectors of the economy. Investments totaling about $40 billion over the years 2000–07 will be used for new highways, railroads, gas lines, hydroelectric projects, power lines, and river-channelization projects. The Amazonian road network is being greatly expanded and upgraded, with many unpaved sections being converted to paved, all-weather highways. Key environmental agencies, such as the Ministry of the Environment, are being largely excluded from the planning of these developments (*6*).

The effects of these massive projects and other development trends on Amazonian forests have not been assessed systematically (*7*). Therefore, we developed models to integrate current spatial data on deforestation, logging, mining, highways and roads, navigable rivers, vulnerability to wildfires, protected areas, and existing and planned infrastructure projects. We also assessed the past impacts of highways and roads on Amazonian forests, and then used these analyses to predict the pattern and pace of forest degradation over the next 20 years.

We generated two models with realistic but differing assumptions—termed the "optimistic" and "nonoptimistic" scenarios—for the future of the Brazilian Amazon. The models predict the spatial distri-

W. F. Laurance is a research scientist at the Smithsonian Tropical Research Institute, Apartado 2072, Balboa, Panamá, and Biological Dynamics of Forest Fragments Project (BDFFP), National Institute for Amazonian Research (INPA), C.P. 478, Manaus, AM 69011–970, Brazil. M. A. Cochrane is a research scientist at the Basic Science and Remote Sensing Initiative (BSRSI), Michigan State University, East Lansing, MI 48823, USA. S. Bergen is a doctoral candidate at the Department of Forest Science, Oregon State University, Corvallis, OR 97331, USA. P. M. Fearnside is a research scientist at the INPA Ecology Department. P. Delamônica is assistant director of the BDFFP, C. Barber is a research associate at BSRSI, and S. D'Angelo and T. Fernandes are BDFFP research assistants.

*To whom correspondence should be addressed. E-mail: wfl@inpa.gov.br

bution of deforested or heavily degraded land, as well as moderately degraded, lightly degraded, and pristine forests (*8*). The principal differences between the models are that, under the optimistic scenario, degraded zones near highways, roads, and infrastructure projects are more localized and that protected and semi-protected areas near developments are less likely to be degraded (*9*).

Although the predictions of the two models differ substantially, both suggest that the Brazilian Amazon will be drastically altered by current development schemes and land-use trends over the next 20 years (see figure, previous page). Forest loss will be greatest along the southern and eastern areas of the basin, but there will also be extensive fragmentation and degradation of remaining forest blocks in the central and northern parts of the basin. Under the nonoptimistic scenario, few pristine areas will survive outside the western quarter of the region.

Policy Implications

Our models suggest that, under status quo conditions, current efforts to promote conservation planning in the Brazilian Amazon will be overwhelmed by prevailing destructive trends. Although a combination of threatening factors is responsible, special attention should be focused on Avança Brasil, because it is a massive new initiative that will open vast areas of the Amazonian frontier to development activities. Moreover, this program is far more amenable to policy modification than are intrinsic problems such as rapid population growth, and its implications have been very poorly discussed and debated in Brazil.

To assess the likely impacts of Avança Brasil and other planned infrastructures on Amazonian forests, we reran our models but without the dozens of planned highways, waterways, and other projects. For the optimistic and nonoptimistic scenarios, respectively, the predicted rate of deforestation drops by an amount ranging from 269,000 to 506,000 hectares per year, and the conversion of pristine or lightly degraded forest to moderately or heavily degraded lands slows by 1.53 to 2.37 million hectares per year. Forest fragmentation is also greatly reduced: under the nonoptimistic scenario, for example, the area retained in large (at least 100,000 km^2) blocks of pristine to lightly degraded forest exceeds the earlier model by more than 36% without these major new projects.

Avança Brasil typifies the current top-down planning process in the Amazon, in which megaprojects are proposed and approved long before the environmental costs and risks can be evaluated. Many projects (such as the BR-319 highway, the Urucu-Pôrto Velho pipeline, and the Araguaía-Tocantins waterway) will create corridors between densely populated areas and the remote Amazonian frontier. Such projects commonly initiate a process of spontaneous colonization, logging, mining, and land speculation that is almost impossible for governments to control (*3–5*). The results are often disastrous for forests.

Alternatives to Destructive Development

There are, however, viable alternatives. The Amazon provides a diversity of valuable environmental services that could help sustain a moderate population indefinitely (*10*). The destruction of each hectare of forest, for example, causes a net release of nearly 200 metric tons of CO_2-equivalent carbon (*11*). In the future, carbon-offset funds paid to developing countries are likely to become an important mechanism for promoting forest conservation (*12*). This is in addition to the benefits of intact forests for ameliorating floods, conserving soils, maintaining stable regional climates, preserving biodiversity, and supporting indigenous communities and ecotourism industries.

At present, however, Brazil's Ministry of Foreign Affairs opposes allowing carbon-offset funds to be linked to avoiding deforestation—a stance that alarms many Brazilian scientists and the Ministry for the Environment. In our view, this is an appalling mistake. As our study shows, the magnitude of projected forest destruction is tremendous, which means that substantial carbon credits could be gained if effective measures were taken to alter the course of development. For example, if the current wave of planned highways and infrastructure projects did not proceed, we estimate that the financial value of reduced carbon emissions alone would range from $0.52 to $1.96 billion per year (*8*). There is a clear potential for such revenues to improve living standards for Amazonian communities. If translated into currency through the Kyoto Protocol, such funds could radically alter the economic logic that is currently driving rapid forest destruction (*13*).

Rather than rampant exploitation, an alternative and far superior model for Amazonian development is one in which agricultural land is used intensively rather than extensively—whereby high-value agroforestry and perennial crops are favored over fire-maintained cattle pastures and slash-and-burn farming plots (*14*). Such a model is very unlikely to develop, however, when land is cheap, destructive wildfires are common, and vast new frontiers are being continually opened for colonization. Again, this militates against the short-term thinking and aggressive development strategy embodied in Avança Brasil.

Conserving Amazonian forests will not be easy. If the world expects Brazil to follow a development path that differs from its current one—and from a path that most developed nations have followed in the past—then substantial costs will be involved. The investment, however, would surely be worth it. At stake is the fate of the greatest tropical rainforest on Earth.

References and Notes

1. Recent studies suggest that intact Amazonian forests not only contain a massive stock of carbon, but may also be a globally significant carbon sink at present [J. Grace *et al.*, *Science* **270**, 778 (1995); O. L. Phillips *et al.*, *Science* **282**, 439 (1998)].
2. Deforestation rates from 1995 to 1999 averaged 1.89 ± 0.60 million hectares per year, not including small (<6.25 ha) clearings or extensive areas affected by selective logging or surface fires [*Deforestation Estimates for the Brazilian Amazon* (Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil, 2000)].
3. G. Goodman, A. Hall, Eds., *The Future of Amazonia: Destruction or Sustainable Development?* (Macmillan, London, 1990).
4. W. F. Laurance, *Trends Ecol. Evol.* **13**, 411 (1998).
5. Extractive reserves are intended to maintain natural environmental services while allowing sustainable harvests of rubber latex, Brazil nuts, or other natural prodı [P. M. Fearnside, *BioScience* **39**, 387 (1989)].
6. W. F. Laurance, P. M. Fearnside, *Trends Ecol. Evol.* **14**, 457 (1999).
7. The environmental costs of Avança Brasil were first highlighted in a report that projected the extent of deforestation caused by planned highway construction [D. C. Nepstad *et al.*, *Avança Brasil: Cenários Futuros para a Amazônia* (Instituto de Pesquisa Ambiental da Amazônia, Belém, Brazil, 2000)]. Our study is more conservative in its projection of highway impacts, being based on an assessment of past deforestation along all existing highways, rather than only four that are located in areas that are now heavily deforested. Our study also includes the impacts of unpaved roads and of existing and planned infrastructure projects (e.g., hydroelectric dams, power lines, gas lines, railroads), which also generate road networks and thereby strongly influence deforestation. Finally, our models distinguish among multiple levels of forest degradation, incorporate spatial data on protected and semiprotected areas, and include other planned projects (e.g., Xingu Dams beyond Belo Monte, Cuiabá-Santarém railway) that fall outside the Avança Brasil program.
8. Pristine forests are those free from nonindigenous uses.
9. For a detailed explanation of our models, including supporting data, analysis, and interpretation, supplementary material is available at *Science* Online at www.sciencemag.org/cgi/content/full/291/5503/438/DC1.
10. P. M. Fearnside, *Ecol. Econ.* **21**, 53 (1997).
11. ______, *Clim. Change* **46**, 115 (2000).
C. Kremen *et al.*, *Science* **288**, 1828 (2000).
13. P. M. Fearnside, *Biomass Bioenergy* **16**, 171 (1999).
14. D. C. Nepstad, A. G. Moreira, A. A. Alencar, *Flames in the Rain Forest: Origins, Impacts, and Alternatives to Amazonian Fires* (World Bank, Brasília, Brazil, 1999).
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