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The Future of the Brazilian Amazon

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

Science 2001; 291: 438-439 [\[Summary\]](#) [\[Full text\]](#)

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### ▼ The Future of the Brazilian Amazon

Roberto Goidanich (26 January 2001)

### ▼ Re: The Future of the Brazilian Amazon

W. F. Laurance et al. (1 February 2001)

### ▼ Carbon-Offset Funding and the Brazilian Amazon

Peter C. Frumhoff and Bill Stanley (31 May 2001)

### ▼ Author Response to P. Frumhoff and B. Stanley

Philip M. Fearnside and William F. Laurance (31 May 2001)

### ▼ Predicting the Effects of Amazon Development on Deforestation

Stephan Schwartzman and Robert Bonnie (31 May 2001)

### ▼ Author Response to S. Schwartzman and R. Bonnie

William F. Laurance, Mark A. Cochrane, Philip M. Fearnside, Scott Bergen, and Patricia Delamonica (31 May 2001)

### ▼ Science and the Future of Amazon Policy

D. Nepstad, P. Moutinho, AC Barros, G Carvalho, A Alencar, J Capobianco, L Solorzano (18 July 2001)

## The Future of the Brazilian Amazon

26 January 2001



Roberto Goidanich,  
Diplomat - Environment Attaché  
Brazilian Embassy

Send dEbate response to journal:  
[Re: The Future of the Brazilian Amazon](#)

E-mail Roberto Goidanich:  
[goidanich@brasilemb.org](mailto:goidanich@brasilemb.org)

With respect to some of the data and information quoted in the Laurance et al.'s Policy Forum, it is important to note the following points.

1) According to information provided by INPE (National Institute for Space Research), which ensures the monitoring of the Amazon by satellite, the deforestation rate of recent years has been as follows:

1995 to 1996 = 1.82 million hectares (ha)

1996 to 1997 = 1.32 million ha

1997 to 1998 = 1.74 million ha

1998 to 1999 = 1.69 million ha

These figures are available at the INPE site ([www.grid.inpe.br](http://www.grid.inpe.br))

2) The deforestation of 1.7 million ha and not 2 million ha as mentioned in the Policy Forum corresponds to about 0.4% of the forest coverage. If the same rate of deforestation continues for the next 20 years, which is highly unlikely taking into account the series of measures in place to protect the forest, the loss would amount to 8% and not 42% as stated by Laurance et al. in their supplementary material. The projections contained in the Policy Forum do not seem to have a sound basis because they take into account the experience of the last 25 years when none of the different policies now adopted was in place.

3) It is also important to keep in mind that since the discovery of Brazil, only 14% of the original rain forest has been deforested and the yearly rate has been decreasing (it should be noted that part of that 14% has been naturally regenerating). In 1994-95 for instance, the deforestation rate had reached 2.9 million ha. Such a decrease is the result of important programs of international cooperation, such as the PPG7 (Pilot Program to Conserve the Brazilian Rain Forest) and in particular to very strict measures

adopted by the Brazilian government.

4) With reference to Avança Brasil, the development program mentioned in the study, it is worth noting that the overall investment foreseen for the Amazon from 2000 to 2007 is about \$12 billion and not \$40 billion. Furthermore, the \$12 billion includes a series of sectors such as social development, information, and environment. The preservation of the environment and particularly of the rain forest is a top priority for Avança Brasil. Infrastructure accounts for no more than US\$ 8 billion. The paving of roads involves only a fraction of this amount. That is to say, nothing comparable with \$40 billion referred to in the article.

5) In the area of infrastructure, there is no new road planned but only the paving of existing roads, such as the 319 which was mentioned. The information on Avança Brasil is available at the site [www.abrasil.gov.br](http://www.abrasil.gov.br).

6) It is important to remember that there are about 17 million people living in the Amazon region. These people need supplies of energy, of water, sanitation, and telecommunications.

7) With reference to the carbon off-setting funds foreseen in the Kyoto Protocol - another topic featured in the study - Brazil is a pioneer country in the development of demonstration projects in this area, despite the fact that the Clean Development Mechanism has not yet been fully regulated in the context of the Framework Climate Change Convention. Brazil accepts the inclusion of reforestation and aforestation in the Clean Development Mechanism, but not of native forests, because such an inclusion might frustrate the purpose of the Kyoto Protocol, which is the reduction of greenhouse gas emissions. A similar approach is adopted by the European Union.

The necessary revision of the data and facts above does not mean that the issue of road construction in the Amazon region is not a serious matter to be carefully considered. In this respect, the Ministry of Planning in Brazil has already started a thorough review of the impact of some Avança Brasil projects on the environment.

Brazilian Embassy Environment Section

# Re: The Future of the Brazilian Amazon

1 February 2001



W. F. Laurance et al.

Send dEbate response to journal:

[Re: Re: The Future of the Brazilian Amazon](#)

E-mail W. F. Laurance et al.:

[wfl@inpa.gov.br](mailto:wfl@inpa.gov.br)

We are pleased to provide the following in response to the Brazilian Embassy statement regarding our recent Policy Forum in the 29 January issue of *Science* (p. 438). The Embassy response contains some key errors of fact and interpretation, which we will endeavor to correct here.

**Debate Over Deforestation Rates: The Brazilian Embassy says that the mean rate of deforestation in the Brazilian Amazon was actually 1.7 million hectares per year, which is lower than was indicated in our Policy Forum. In our article we used the mean rate of deforestation from the 1995- 1999 period, which was 1.89 (standard deviation = 0.60) million hectares per year. The Brazilian Embassy's estimate did not include data for the 1994-1995 interval (which is mainly for the year 1995). During this year, more than 2.9 million hectares of forest was destroyed--an area the size of Belgium. The omission of the 1994-95 interval is the reason that the deforestation rate quoted by the Brazilian Embassy is lower than ours.**

Therefore, we stand by our original statement that "deforestation in the Brazilian Amazon currently averages nearly 2 million hectares a year." It must be noted, moreover, that the deforestation statistics (which are produced by each year by INPE, Brazil's national space agency) are conservative because forest clearings smaller than 6.25 hectares are not included. In addition, other land uses that degrade forests (e.g. selective logging, ground fires, small-scale mining, overhunting) but do not cause a major loss of forest cover are also not incorporated into the INPE deforestation estimates.

**How Much Deforestation?: The Embassy statement that total forest loss by the year 2020 would amount to only 8% of the Brazilian Amazon is an obvious error. The statement says that this 8% value was much lower than that projected by our nonoptimistic model, which predicts that 42% of the region's forests will be destroyed or heavily degraded by 2020.**

At the outset, it is important to emphasize that INPE statistics indicate that 14.0% of the Brazilian Amazon has already been deforested (as of the end of 1999).

Hence, current deforestation alone is already far greater than the 8% figure the Embassy cites.

The Embassy's estimated rate of deforestation is also too low. The actual annual rate can be derived by dividing the annual rate of deforestation (1.89 million hectares/year) by the total remaining forest cover (about 344 million hectares), which yields an annual rate of 0.55%. This is significantly higher than the 0.4% figure cited by the Embassy.

Multiplying the 0.55% value by 20 years gives a figure of 11.0%, which when added to the 14.0% of forest already destroyed yields a figure of 25.0%. Thus, under status quo conditions, we would expect about 25% of the Brazilian Amazon's forests to disappear by the year 2020. Indeed, Brazil's Ministry for Science and Technology has already admitted publicly that they expect that about 25% of the Amazon's forests to have disappeared by the year 2020 (Folha de São Paulo, 22 January 2001).

Moreover, annual rates of forest loss are likely to rise significantly as a result of *Avança Brasil* and other investments in new highway upgrades, railroads, river-channelization projects, powerlines, gas lines, hydroelectric reservoirs, and other infrastructure projects. This was the key point of our Policy Forum--to highlight the potential effects of these new projects, many of which will penetrate into the remote interior of the Amazon and thereby accelerate rates of forest loss, degradation, fires, and fragmentation.

According to our models, annual rates of forest loss will increase by 269,000 to 506,000 hectares per year, whereas the rate of forest degradation (specifically, the conversion of pristine or lightly degraded forest to moderately or heavily degraded land) will increase by 1.53 to 2.37 million hectares per year. Large-scale forest fragmentation is also projected to increase by 36%.

Thus, the total area of Amazonian forest that is likely to be destroyed by the year 2020 could very easily exceed 25%. Under our nonoptimistic scenario, annual rates of forest loss would be about 0.70%, leading to a net loss of about 28% of the Brazilian Amazon by the year 2020. This figure, however, does not include vast areas of forest that would be seriously degraded by logging, ground fires, forest

fragmentation, edge effects, overhunting, mining, and other activities. Our estimate that up to 42% of the Brazilian Amazon could be destroyed or heavily degraded by the year 2020 includes such heavily degraded lands, which are likely to have only limited conservation value.

In addition, our models suggest that even greater expanses of forest are likely to be lightly to moderately degraded. Under our nonoptimistic scenario, less than 5% of the Amazon is projected to remain in natural condition (free from nonindigenous impacts) by the year 2020. Extensive areas of forest may appear superficially intact yet suffer important ecological changes from overhunting, illegal gold mining, predatory logging, and other activities. Hunters can have serious impacts on wildlife. Large expanses of the Amazon are already experiencing a major increase in hunting pressure, because of increasing access to forests via the region's expanding road network and the common use of shotguns. Population densities of many exploited species (e.g. larger monkeys, tapirs, deer, peccaries, agoutis, jaguars, pumas) decline sharply as a result of overhunting.

**The True Costs of Avança Brasil:** One of the most serious errors in the Brazilian Embassy statement concerns the planned costs of Avanca Brasil. In our article, we cited earlier government data (available on the Internet) that suggested that Avanca Brasil would involve a net investment of \$40 billion in the Brazilian Amazon (another research team, in a recent "Nature" paper, cited a figure of \$45 billion). The Embassy disputed this figure, arguing that the planned total was about \$12 billion, of which only \$8 billion would be used for infrastructure projects that could potentially degrade forests.

Because this is a key issue in the ongoing debate, we elected to develop a more definitive estimate for the projected costs of Avança Brasil in the Brazilian Legal Amazon, using the government's own detailed technical documents. Our source was the three-volume, 703-page report released last year that provides technical details for each project, including its location, description, and projected cost (Programa Brasil em Ação. 2000. Eixos Nacionais de Integração e Desenvolvimento: Identificação de Oportunidades de Investimentos Públicos e/ou Privados. Estudos dos

Eixos Nacionais de Integração e Desenvolvimento: Relatório Síntese Tomos I-3).

In preparing our estimate, we took care to include only projects that would be located within the Brazilian Legal Amazon. Some planned projects will span the Amazon and adjoining regions (e.g. certain highways, railroads, and gas lines), and in these cases we carefully estimated the proportion of the project that will occur within the Legal Amazon, and included only that portion of the cost in our estimate.

Our analysis suggests that the total planned investment in Avança Brasil projects in the Brazilian Amazon will total about \$43.6 billion. Of this total, about \$23.5 billion will be used for projects that are unlikely to have a direct impact on forests (e.g. telecommunications, waterworks, hospitals, schools, housing, ecotourism). The remaining investment of \$20.1 billion is for projects that are much more likely to affect forests. These costs are broken down as follows:

Description and Projected cost

Highway paving--\$2,793.7 million

Short roads--\$46.1 million

Agricultural roads--\$290.4 million

Railroads--\$1,748.6 million

Powerlines--\$650.9 million

Gaslines--\$450.0 million

Gas turbines--\$712.3 million

River-channelization--\$607.9 million

Dredging and razing--\$54.6 million

Acquisition and equipment installation--\$18.0 million

Hydroelectric reservoirs--\$11,942.0 million

River ports--\$26.5 million

Cargo facilities--\$388.8 million

Airports--\$401.9 million

TOTAL--\$20,131.7 million (\$20.13 billion)

Although these values are necessarily estimates

(given the need to calculate the proportions of some projects than spanned the Amazon and adjoining regions), they clearly indicate that the planned investment in Avança Brasil is far larger than the Brazilian Embassy statement has indicated, and much more in line with the statements in our article. In general, they suggest that a total of more than \$40 billion in investment is planned, of which over \$20 billion will be allocated for projects that could have a direct impact on Amazonian forests.

The original government documents on which we based our analysis are quite readily available (for example, copies could probably be obtained from the federal Ministry of Planning in Brasília). Our copies, which include a complete list of identified Amazonian projects, are available for inspection at our headquarters in Manaus, Brazil.

Importantly, it must be emphasized that our estimate does not include funds for many planned Amazonian infrastructure projects that fall outside the Avança Brasil program. Examples of such planned projects include the Xingu Dams beyond Belo Monte, the Cuiabá-Santarém railway, the Cuabá-Porto Velho railway, the Aripuanã-Apuí-Novo Aripuanã highway, and the Perimetral Norte highway.

If the costs of these additional projects are added to those embodied in Avança Brasil, then the total planned investment in infrastructure projects that are likely to threaten Amazonian forests greatly exceeds \$20 billion.

**Highway Paving:** The Brazilian Embassy statement argues that investments for highways will be used only for paving existing roads, rather than creating new highways. It must be emphasized, however, that the creation of about 7,500 kilometers of new highways will greatly affect the ease with which loggers, colonists, ranchers, and land-speculators can gain year-round access to forests, and will lower considerably the costs of transporting timber and other forest products to urban markets.

Moreover, highways in the Amazon frequently lead to the spontaneous generation of entire networks of additional roads. For example, the Belém -Brasília Highway (created in the 1960s) is today surrounded by a 300- to 400-kilometer-wide swath of state and

local roads and logging tracks that has led to a drastic rise in deforestation. Similar networks are evident throughout much of the southern and eastern Amazon. In tropical regions, new highways almost inevitably lead to sharp increases in rates of forest loss, degradation, fragmentation, and hunting--a trend that has been witnessed hundreds of times in many tropical countries.

In other cases, highway construction projects have been promoted as being environmentally benign, but have proven to be serious threats to forests. The 1000-kilometer-long Manaus-Boa Vista Highway, for example, was initially promoted as a "surgical cut" through the forest that would increase access to markets in Venezuela and the Caribbean.

Shortly after the highway was completed, however, Brazilian president Fernando Henrique Cardoso announced that 6 million hectares along the road would be opened for colonization, and asserted that the project would "double the nation's agricultural production" (Amazonas em Tempo, 25 June 1997). This highway has already led to sharp rises in rates of forest loss and degradation in a 100-kilometer swath north of Manaus, in the heart of the Amazon. (It should nonetheless be noted that a recent policy of INCRA, the federal agency responsible for planning and implementing colonization projects, to concentrate new settlements in areas that have already been cleared might help to slow deforestation in this area.)

**Controversy Over Carbon Offsets:** In our view, the Brazilian federal government is making a serious error in its failure to consider carbon offsets linked to avoided deforestation as a possible mechanism to promote forest conservation and sustainable development. According to our estimates, Brazil could potentially gain as much as \$0.52 to 1.96 billion per year over the next 20 years, if the increased deforestation attributable to the wave of new development projects did not proceed.

Clearly, there are still many political complications that must be resolved before carbon offsets can become a viable, large-scale mechanism to promote forest conservation. We agree with the stance of the European Union (EU) and many environmental organizations that the United States should be

pressured to undertake serious cuts in its burgeoning carbon emissions. Nevertheless, we do not agree with the stance that carbon offsets should not be linked to avoiding deforestation. In our view, this offers the most important, plausible mechanism available today to commit major financial resources for forest conservation. Moreover, the reduction in greenhouse gas emissions that could be achieved by reducing Brazil's high rate of deforestation would likely be far greater than that which could be gained by the establishment of new plantations and afforestation projects in Brazil.

One of the principal arguments against accepting carbon offsets linked to deforestation in Brazil is the frequently voiced concern regarding "internationalization" of the Amazon--the fear that industrial nations might attempt to assume control of the region if Brazil were to accept such funding. Certain politicians have played on the deep-seated fears of the Brazilian populace in this regard.

We firmly believe, however, that Brazil's unquestioned sovereignty over the Legal Amazon could be affirmed within a legal framework that involved the acceptance of carbon offset funding. Such a framework would help to alleviate concerns about the potential for undue foreign influence in the region, while providing an important and viable new mechanism for promoting forest conservation in the Amazon.

William F. Laurance(1,2), Sammya D'Angelo(2), and Ana Andrade(2)

(1)Smithsonian Tropical Research Institute, Apartado 2072, Balboa, Republic of Panamá

(2)Biological Dynamics of Forest Fragments Project, National Institute for Amazonian Research, C.P. 478, Manaus, AM 69011-970, Brazil. Email: wfl@inpa.gov.br

## Carbon-Offset Funding and the Brazilian Amazon

31 May 2001



Peter C. Frumhoff and Bill Stanley  
PCF: Union of Concerned Scientists; BS: The  
Nature Conservancy

Send dEbate response to journal:  
[Re: Carbon-Offset Funding and the Brazilian Amazon](#)

E-mail Peter C. Frumhoff and Bill Stanley:  
[pfrumhoff@ucsusa.org](mailto:pfrumhoff@ucsusa.org); [bstanley@tnc.org](mailto:bstanley@tnc.org)

We agree with W. F. Laurance and colleagues that carbon-offset funding for avoided deforestation through the Kyoto Protocol has the potential to substantially alter the economic logic that currently drives much forest clearing in Brazil and other developing countries. But they overestimate its potential to provide an alternative to the accelerated deforestation projected to result from major infrastructure development planned through the *Avana Brasil* initiative. Laurance et al. assess the financial value of annual avoided carbon emissions (269,047 to 505,846 hectares of conserved forest, 194 metric tons of carbon/hectare and a market price for carbon offsets at US \$10-\$20/ton) as US \$0.52 to \$1.96 billion. Little of this value, however, would likely be captured through a well-designed carbon-offset market.

Recent analyses suggest that perverse incentives to undertake activities that pose risks of deforestation in order to increase carbon- offset payments can be avoided by only allowing reductions below historical deforestation rates or similar objective baselines to qualify for carbon credit (1). Under this scenario, measures to slow projected increases in future deforestation associated with *Avana Brasil* would not be creditable, even though doing so would provide substantial climate and other environmental benefits. More generally, a combination of sound rules governing carbon crediting and cost-effective alternatives available to prospective investors may moderate the financial flows to slow deforestation in Brazil and other forest-rich developing countries (2).

Unrealistically high estimates raise unrealizable expectations among potential beneficiaries of carbon funding and fuel concerns among some environmentalists and governments who fear such financing will enable industrialized countries to meet Kyoto targets without significant reductions in fossil fuel emissions (3). Indeed, carbon-offset funding to protect forests threatened by *Avana Brasil*'s proposed development would alone account for 7% to 13% of the total emissions that industrialized countries will need to reduce by 2010 under a ratified Protocol (4). More plausibly, concerted efforts to mitigate climate change by protecting threatened forests throughout the tropics would generate about US \$1.5 billion of additional funding annually for

forest conservation and account for about 5% of total committed emissions reductions by 2010 (5). Hence, measures to reduce emissions by slowing deforestation could gain substantial new funding, provide significant biodiversity cobenefits, and complement reductions in fossil fuel emissions in the international effort to slow climate change.

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5. J. O. Niles, "Additional benefits of reducing carbon emissions from tropical deforestation" (Morrison Institute for Population and Resource Studies Working Paper #0084, Stanford Univ., 2000).

## Author Response to P. Frumhoff and B. Stanley

31 May 2001



Philip M. Fearnside and William F. Laurance  
National Institute for Amazonian Research (INPA)

Send dEbate response to journal:

[Re: Author Response to P. Frumhoff and B. Stanley](#)

E-mail Philip M. Fearnside and William F. Laurance:  
[pmfearn@inpa.gov.br](mailto:pmfearn@inpa.gov.br); [wfl@inpa.gov.br](mailto:wfl@inpa.gov.br)

Frumhoff and Stanley raise several relevant points. Clearly, the multitude of issues surrounding carbon offsets under the Kyoto Protocol (1) could not be explained fully in our Policy Forum (2), which focused on the future environmental impacts of planned Amazonian infrastructure. How and if avoided deforestation will be included in the Clean Development Mechanism (CDM), defined in Article 12 of the Kyoto Protocol, is still under negotiation, with major decisions expected in July 2001. The way in which baseline deforestation rates would be defined remains an open question, with important implications both for the amount of credit obtainable and for the potential for perverse incentives (3). Requirements regarding certainty (4), permanence (the period over which carbon would be kept out of the atmosphere) (5), and various forms of leakage (secondary effects of carbon-offset projects, such as displaced population or deforestation activity, that

could negate their intended mitigation results) (6) are key considerations.

In the Brazilian context, the suggestion by Frumhoff and Stanley that only historical deforestation rates should be allowed as a baseline implies that credit should be given for protecting forest remnants in areas of Brazil that had already experienced heavy deforestation by 1990, whereas avoiding the opening of new frontiers should not gain credit. As our paper illustrates, however, it is vital to find ways to credit avoided deforestation in new frontiers as well. What makes *Avana Brasil* so damaging—and such a potentially important source of additional carbon emissions—is precisely that it would open vast tracts of virgin forest to deforestation, logging, and fire. The likely cost of failing to give credit for avoiding these impacts would be the transformation of our computer-generated scenarios into reality. Clearly the stakes are high.

Notably, the CDM is not the only means by which Brazil might obtain credit for avoiding deforestation. Were Brazil to join Annex B of the Protocol, the country's massive carbon emissions from deforestation in 1990 (7) guarantee that such emissions would be included in Brazil's assigned amount (under Article 3.7 of the Protocol). Thus, any reduction in future emissions below 1990 levels could be used for emissions trading (8, 9). Unlike Article 12, however, the eligibility of forests for these credits does not require further negotiation. By increasing deforestation, *Avana Brasil* would create a substantial opportunity cost by rendering such reductions inviable.

We disagree with Frumhoff and Stanley's suggestion that pointing out the very high potential financial and carbon value of avoided deforestation might play into the hands of private organizations and governments currently intent on barring credit for avoided deforestation under the CDM [e.g. (10)]. Although we sympathize with the view of these organizations that the United States should be strongly pressured to reduce its burgeoning emissions from fossil fuels, we believe that carbon credits offer a potentially critical tool to help protect tropical forests—the rapid destruction of which is a massive source of emissions. Any realistic strategy to reduce global carbon emissions must incorporate viable and aggressive

measures to slow tropical deforestation in addition to reductions in fossil-fuel use.

We strongly believe that the carbon benefits of reducing deforestation should be included among projects eligible for crediting under the CDM. This is a widespread view among those concerned with environmental problems in Brazil (11). The Union of Concerned Scientists (UCS) has played a valuable role in pressing for recognition of the carbon value of forests and for strong controls under the CDM to assure that carbon benefits are real and that perverse incentives are avoided. We are both signatories of the UCS "Scientists' Statement" supporting these controls (12).

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## Predicting the Effects of Amazon Development on Deforestation

31 May 2001



Stephan Schwartzman and Robert Bonnie  
Environmental Defense, Washington, DC

Send dEbate response to journal:  
[Re: Predicting the Effects of Amazon Development on Deforestation](#)

E-mail Stephan Schwartzman and Robert Bonnie:  
[stephen\\_schwartzman@environmentaldefense.org](mailto:stephen_schwartzman@environmentaldefense.org)

Laurance and co-authors extrapolate arbitrarily from the effects of roads on Amazon deforestation to the effects of other infrastructure projects. The Instituto de Pesquisas Ambientais na Amazônia (IPAM) (1, 2) earlier published predictions of the effects of road improvement on deforestation, based on historical satellite data. IPAM's more conservative, but less debatable, results seem a better basis for policy discussion, because they do not require complex extrapolations and heroic assumptions.

Laurance et al. argue that the infrastructure projects in the Brazilian government's planned \$40 billion *Avança Brasil* (Forward, Brazil) development program would result in 269,000 to 506,000 hectares of additional deforestation per year. Although data exist to reliably quantify the relation between roads and deforestation (3-5, this is not the case for the power lines, railroads, river channeling, pipelines, and the other kinds of projects included in *Avança Brasil*. The conversion factor from road impacts to others is then arbitrary, and in some cases unwarranted (e.g., river channeling where margins are already deforested).

The authors' categories of "pristine" and "light, moderate, and heavy" impacts are also arbitrary. Whether a given area has 100%, >95%, or >85% of its forest cover intact depends on the scale of measurement, and ecological correlates of these levels of forest cover are unclear.

IPAM's earlier analysis estimates that the four major

road improvement projects in Avana Brasil would cause between 120,000 square kilometers and 270,000 square kilometers to be deforested over the next 20 to 30 years, with 187,000 square kilometers of forest at risk of fires. Even at the lower end of this range, the additional deforestation will mean, under business-as-usual conditions, that about a third of the Amazon will have been deforested by 2030.

Our experience as environmentalists suggests that policy makers (i.e., politicians) use sound science too infrequently. Hence, the clearer and less debatable the science, the better. Less, in this case, is more.

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5. D. L. Skole, C. J. Tucker, *Science* 260, 1905 (1993).

## Author Response to S. Schwartzman and R. Bonnie

31 May 2001



William F. Laurance, Mark A. Cochrane, Philip M. Fearnside, Scott Bergen, and Patricia Delamonica  
National Institute for Amazonian Research (INPA)

Send dEbate response to journal:

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E-mail William F. Laurance, Mark A. Cochrane, Philip M. Fearnside, Scott Bergen, and Patricia Delamonica:  
[wfl@inpa.gov.br](mailto:wfl@inpa.gov.br)

We are pleased to respond to Schwartzman and Bonnie, who assert that the study by the Instituto de Pesquisas Ambientais na Amaznia (IPAM) (1, 2) is more conservative than ours (3) and provides a better basis for policy conclusions. Although we were careful to give due credit to the pioneering work of IPAM, we believe that we have built a better mousetrap and dispute both of Schwartzman and Bonnie’s assertions. The IPAM estimates are not “more conservative” but only less complete.

Like us, the IPAM group evaluated historical deforestation along Amazonian highways and then extrapolated these results into the future. However, the IPAM effort was based on a subset of only four highways that had caused especially heavy deforestation. We used a more reliable method, which involved assessing deforestation along all Amazonian

highways, including several that had caused only limited deforestation. Our calculations were therefore more conservative and robust than those of IPAM. Because of this important bias, the IPAM study actually projects a greater increase in future deforestation rates (400,000 to 900,000 hectares per year) than does our study (269,000 to 506,000 hectares per year).

In addition, the IPAM study is far from comprehensive, because it fails to account for the effects of infrastructure projects and unpaved roads on Amazonian forests. Some roads, such as the Northern Perimeter Road, will carve large swaths across the Amazon, strongly influencing deforestation, logging, mining, and other activities. Infrastructure projects such as powerlines, gas lines, and hydroelectric reservoirs also contribute directly to forest-degrading activities because they require road networks for construction and maintenance. Examples of this can be seen in the Ecuadorian and Brazilian Amazon, where roads associated with gas lines, powerlines, and reservoirs have led to dramatic rises in slash-and-burn farming, logging, market hunting, and land speculation (4, 5). Our assumption that major infrastructure projects will affect deforestation in a manner similar to unpaved roads—because they cannot be constructed without first making roads—therefore is logical and defensible.

The IPAM study has other key limitations. It does not consider vast forested lands that would be inundated by planned hydroelectric reservoirs in the Amazon. It also fails to consider the influence of protected and semi-protected areas (such as national parks, national forests, and indigenous reserves) on spatial patterns of forest loss and degradation. Finally, it distinguishes only between forested versus deforested lands. Many activities, such as selective logging, forest fragmentation, surface fires, wildcat mining, and overhunting, can degrade forest ecosystems without causing deforestation per se. Thus, the failure of the IPAM study to predict the extent of forest degradation significantly reduces its utility.

Although most of Schwartzman and Bonnie's assertions can be easily rebutted, they do raise a valid point. A debatable aspect of our models is the assumption that river-channelization projects would likely lead to increased logging, deforestation, and

other degrading activities along rivers, comparable with those caused by unpaved roads. No such projects exist in the Amazon on which to base projections. Although our remote-sensing analyses suggest that forests near rivers with heavy boat traffic are especially prone to deforestation (5), further studies are needed to predict the impacts of river channelization on Amazonian forests. Contrary to Schwartzman and Bonnie's suggestion, however, our analysis does not exaggerate impacts by double-counting deforestation from river channeling (or other) projects in already deforested areas because our geographic information system automatically tracks the status of each point in the landscape, preventing any one from being deforested twice.

In summary, many of the large infrastructure projects included in our study—such as the Porto Velho-Urucu gas line, which will penetrate into the “pristine” heart of the Amazon—are likely to have dramatic impacts on the pattern and pace of forest conversion. Although predictive models such as ours can always be improved, ignoring such projects in the name of waiting for better data would be to neglect one of the most important features of *Avança Brasil*. Our Policy Forum helped to initiate a vigorous debate about the *Avança Brasil* program, and we regard this as a very healthy and timely development.

#### References and Notes

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D. Nepstad, P. Moutinho, AC Barros, G Carvalho,  
A Alencar, J Capobianco, L Solorzano,  
Scientist/Ecologist  
Woods Hole Research Center, Instituto de  
Pesquisa Ambiental da Amazonia, Instituto  
Socio-Ambiental

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E-mail D. Nepstad, P. Moutinho, AC Barros, G  
Carvalho, A Alencar, J Capobianco, L Solorzano:  
[dnepstad@whrc.org](mailto:dnepstad@whrc.org)

Two recent studies of the potential effects of road paving and other infrastructure investments on the forests of the Brazilian Amazon (1-3) present sharply contrasting uses of the same limited data. We respond here to Laurance et al.'s criticisms (4) of our study (1, 2).

The studies diverge most notably in the degree to which they extrapolate from the historical relation between roads and deforestation. We first predicted the effect of proposed road paving on Amazon deforestation on the basis of our analyses of deforestation along paved and unpaved highways (1), concluding that one-third or more of Amazon forests might be cleared and additional unknown areas of forest logged or burned over the next 20 to 30 years (1, 2). Laurance et al. (3) subsequently used the relation between roads and deforestation to make quantitative predictions of the influence of proposed railways, electrical lines, gas pipelines, waterways, industrial mines, and wildcat mines on future deforestation, concluding that up to 95% of the Amazon forest will be cleared or degraded by the year 2020. Although Laurance et al. (4) criticize our study as incomplete, we explicitly avoided quantitative predictions based on untested assumptions. Laurance et al. acknowledged this shortcoming in their prediction of increased deforestation along channelized rivers (4). The acknowledgment should be extended to their other predictions. Industrial mines, for example, often do not require road construction. Both industrial mines and gas pipelines are often accompanied by large investments in environmental protection measures (5).

By aggregating the road/deforestation relation for all of Amazonia, Laurance et al. (3) have ignored the empirical basis for determining a range of future deforestation scenarios. They aggregate the predicted forest effects of all infrastructure investments, making it impossible to ascertain from their study the relative importance of each type of investment. We measured past deforestation along the region's major paved roads individually (1, 2, 6) to provide a range of disaggregated deforestation predictions for the proposed paving of similar roads in Amazonia. We identified those road paving projects that could contribute most to alleviate the poverty that afflicts this region, while emphasizing the need to invest in

existing, older frontiers. We identified those protected areas that are most threatened by proposed road paving, the areas of fire-vulnerable forest, and the potential for increased logging. Our empirically derived range of deforestation predictions, which has now been extended to all Amazon road (6), is broader than that of Laurance et al. (3) because their estimates are based on the average historical deforestation rate along Amazon roads, to which they apply arbitrary “optimistic” and “nonoptimistic” adjustments.

Laurance et al. (3) use output from our forest flammability model (7) to make quantitative predictions of future forest fire using inappropriate, untested assumptions of actual fire occurrence. Their prediction of forest impoverishment through logging does not take into consideration the most extensive published survey of Amazon logging activity (7); their method for deriving this prediction is not described. Most of the infrastructure investments they include in their estimates will be delayed for many years and many may not be made in the next 20 years (8).

The predictions of Laurance et al. (3) are among the broad range of plausible scenarios for Amazonia, and warrant consideration. But as the limitations described here and others indicate, there are large uncertainties involved with predicting the future of Amazonia 20 years hence and many caveats that should constrain interpretation of semi-quantitative mapping exercises such as the one by Laurance et al.

#### References and Notes

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5. For example, the Mineracao Rio do Norte, Carajas

and other industrial mines have created protected areas adjacent to the mine area. The Urucu gas pipeline project has been vigilantly policed thus far.

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8. The Northern Perimeter road, for example, has been proposed by the Brazilian government for more than a decade. Many of the infrastructure investments are redundant (for example, parallel railway, channelization and road paving proposals in the Araguaia-Tocantins, Cuiabá-Santarém, and Madeira River corridors), and are unlikely to be made in their entirety.

