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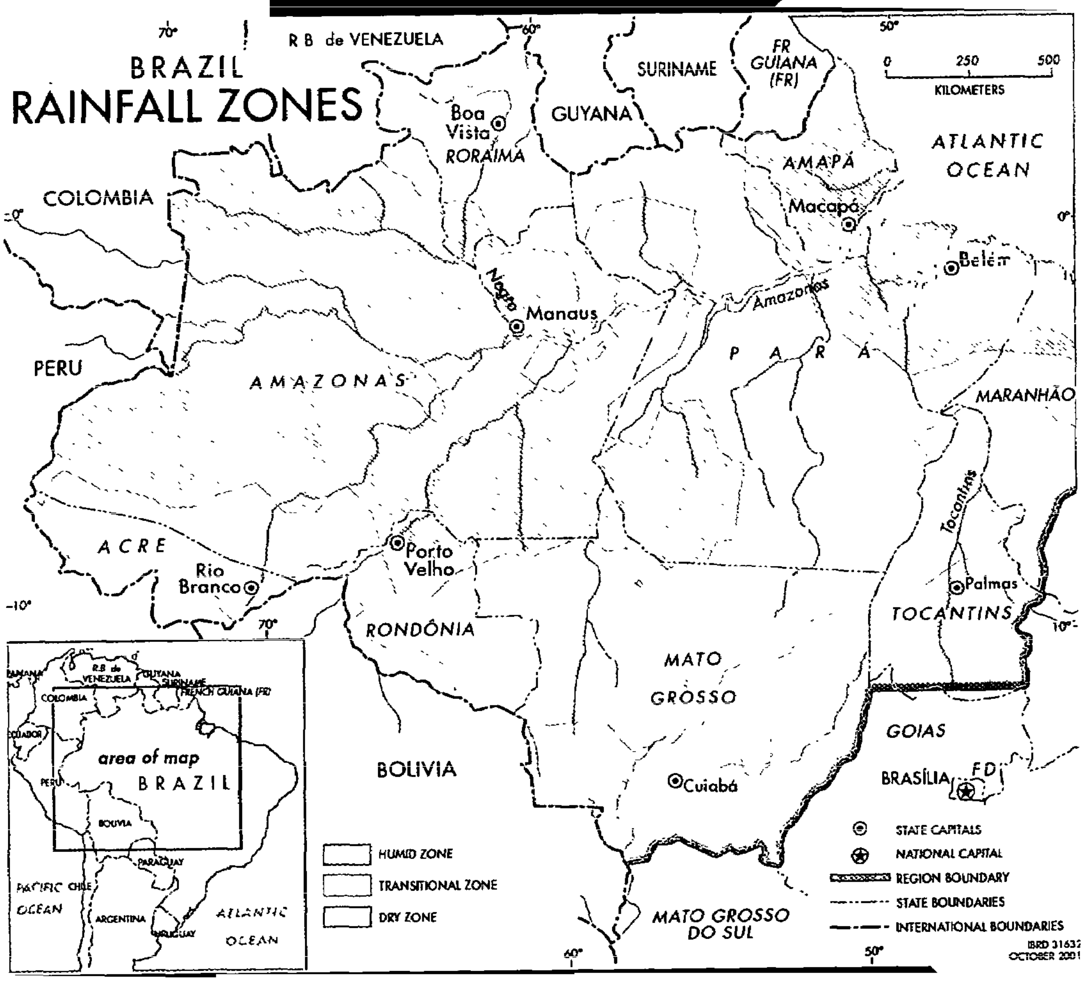
# Sustainable Amazon

## *Limitations and Opportunities for Rural Development*

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# Sustainable Amazon

## *Limitations and Opportunities for Rural Development*

*Robert R. Schneider*
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# Abstract

This report contributes to the debate surrounding land use in the Brazilian Amazon. It sets the context by reviewing the evidence concerning the deleterious effect of increasing levels of rainfall on agricultural settlement and productivity. Next, it compares the economic future of an Amazonian community under the traditional "predatory logging followed by ranching" model, and under sustainable logging. Last, the authors investigate the potential to create a system of national forests.

The authors make four conclusions. First, they demonstrate that increasing levels of rainfall seriously undermine agricultural productivity and sustainability. At the highest extreme, in the 45 percent of the Amazon with annual rainfall of over 2,200 mm, only forestry, and possibly some palm crops, are likely to be economically viable. Second, they assert that in this area of the Amazon and much of the transition area (rainfall between 1,800 mm and 2,200 mm), sustainable forestry would provide more stable communities and a higher standard of living than agriculture. Third, the authors conclude that regulatory competition and a short local political time horizon prevent sustainable forestry from being adapted, despite its better long-run performance. Finally, some 10 percent of the Amazon could be put into national forests in a way that would both meet current demand for Brazilian Amazonian timber and reinforce the Amazon park system, which is expected to fully conserve 10 percent of the Brazilian Amazon.

# Preface

The rich debate over the future of the Amazon continues in Brazilian society. In these discussions, researchers, decisionmakers, the private sector, social leaders, and environmental organizations have recognized the forestry vocation of this important portion of our territory. Many people believe that it is possible to ensure development in the region while guaranteeing conservation of its immense natural heritage. This sustainable path gains even greater economic and technical credibility with this report prepared by the World Bank and the Amazon Institute of People and the Environment (Imazon).

This World Bank/Imazon report contains three important messages for the future of the Amazon. First, there are severe natural restrictions (especially climatic) to the expansion of ranching and agriculture in vast areas of the Amazon. Using a solid economic argument and a vast literature, the authors reveal that as annual rainfall increases, agricultural productivity declines, with a concomitant reduction in economic return. According to the authors, agriculture and ranching have the greatest chance of economic success in the "Dry Amazon" (17 percent of lands), a zone characterized by moderate rainfall (less than 1,800 mm per year), situated in the south of the legal Amazon. The authors demonstrate that, for the remaining 83 percent of the Amazon, the best land use option is sustainable forest management.

Second, if market forces are not controlled, land use will continue to be based on predatory logging and extensive ranching. In this scenario, the authors sound the alert that the economy of Amazonian counties will tend to follow a "boom-and-bust" cycle. Illusory rapid growth (boom) in the first years will be followed by a severe decline in revenue, employment, and tax collection (bust). To avoid this unsustainable cycle, the report recommends a series of economic tools and strategies. These include adoption of a tax on wood derived from predatory logging, payment for environmental services provided by forests, expansion of the national and state forest systems, and incentives for forest management on private lands.

Finally, the report emphasizes the importance for the federal government to expand and consolidate the national forest system. The authors identify such an initiative as the most promising measure to stabilize the wood sector and promote forest management in the new economic frontiers of the region. The good news is that there is ample support from the productive sector and organized civil society for the creation of these conservation units. In addition, the report demonstrates that national forests can form part of a mosaic of protected areas, serving as buffer zones around parks and strict reserves (areas of full protection).

To summarize, this World Bank/Imazon report proposes a development policy for the Amazon with a strong emphasis on forest management. The authors claim that the economically viable land-use alternatives, that is, forest management and intensive agriculture, serve the interests of the local communities as well as the national and global objectives. For the diverse actors involved in planning and implementing land-use initiatives, this claim sounds extraordinary. It reveals concrete opportunities for a sustainable economy in the Amazon based on the forest itself. It remains for all of these actors to work with competence and determination to transform these opportunities into reality.

With the launching of the National Forest Program, the Ministry of the Environment hopes to stimulate initiatives for responsible use of forest resources that can replace the traditional model of deforestation, which has characterized the Brazilian forestry sector.

*José Carlos Carvalho*
Executive Secretary
Ministry of the Environment
Brazil

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Any errors in this report are solely the responsibility of the authors.

# Acronyms and Abbreviations

| | |
|---|---|
| ANEEL | National Electric Energy Agency |
| AVHRR | Advanced Very High Resolution Radiometers (NOAA/NASA) |
| CIFOR | Center for International Forestry Research |
| CDM | clean development mechanism |
| CSERGE | Center for Social and Economic Research on the Global Environment |
| EOS | Earth-Observing System (NASA) |
| FAO | United Nations Food and Agriculture Organization |
| FSC | Forest Stewardship Council |
| GDP | gross domestic product |
| GIS | Geographic Information System |
| GPV | Gross Present Value |
| GTA | Grupo de Trabalho Amazônico |
| ha | hectare |
| IBGE | Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics) |
| ICMS | Imposto sobre Circulação de Mercadorias e Serviços (sales tax) |
| Imazon | Instituto do Homem e Meio Ambiente da Amazônia (Amazon Institute of People and the Environment) |
| IPAM | Instituto de Pesquisa Ambiental da Amazônia |
| ISPN | Instituto Sociedade População e Natureza |
| IRR | Internal Rate of Return |
| ISA | Instituto Socioambiental |
| MARA | Ministério da Agricultura e Reforma Agrária |
| MMA | Ministério do Meio Ambiente |
| MT | Mato Grosso |
| NASA | U. S. National Aeronautics and Space Administration |
| NGO | nongovernmental organization |
| NOAA | U. S. National Oceanic and Atmospheric Administration |
| NPV | Net Present Value |
| PA | Pará |
| PPG7 | Pilot Program to Conserve the Brazilian Rain Forests (financed by the G7, the European Commission, and The Netherlands) |
| R | *real* (Brazilian currency) |
| SST | sea surface temperature |
| TO | Tocantins |
| TTF | Tropical Forest Foundation |
| UNDP | United Nations Development Programme |
| USDA | United States Department of Agriculture |

# Executive Summary

This report analyzes the current land-use patterns of predatory logging and cattle ranching, and the natural conditions of the Amazonian ecosystem, with an emphasis on rainfall. The purpose of the report is to help Brazilian society to make land use choices that bring the greatest possible social and biological benefits to current and future generations. The principal results of the report follow.

First, agricultural success in the Amazon is strongly influenced by annual rainfall and the duration of the dry season. As rainfall increases, agricultural productivity decreases, with a consequent decline in economic return. This decline in productivity and return occurs for several reasons. A wet tropical climate without distinct seasons provides ideal conditions for the proliferation of pests and plant diseases. In addition, the absence of a marked dry season increases the cost of road construction and maintenance, and makes mechanized harvesting virtually impossible.

In their analysis, the authors divided the legal Amazon (500 million ha, or 5 million sq km) in three rainfall zones: dry (< 1,800 mm/year), transition (1,800 – 2,200 mm/year), and humid (> 2,200 mm/year). Statistical analysis revealed that, keeping other factors constant, higher levels of rainfall in the Amazon reduce land conversion rates for agriculture as the well as pasture productivity. Moreover, the the wettest areas experience an increased rate of land abandonment and soil degradation.

Rising as annual rainfall increases, land abandonment reaches approximately 20 percent of the total agricultural area in the humid zone. This abandonment rate remains elevated even in areas within the humid zone that are close to large cities (markets) and with good transportation infrastructure.

Second, if market forces continue to operate freely in the future, land use will be based largely on the predatory logging associated with extensive ranching. Predatory logging is characterized by severe forest damage, excessive pressure on high-value species, and increased susceptibility of harvested areas to fire (Uhl and others 1997). In this scenario, Amazonian communities will tend to follow a boom and bust economic cycle. The rapid growth in the first years will be followeby a severe decline in profits and employment. This pattern is already evident in the oldest logging frontiers, for example, in the transitional areas such as Paragominas (eastern Pará).

The effect of timber resource depletion on the local economy has been lower in the dry Amazon (< 1,800 mm/year) and the driest portions of the transition zone, such as the old frontiers of Sinop (north-central Mato Grosso) and the Vilhena – Ji Paraná corridor (Rondônia). The reasons is that, in these dryer areas, it has been possible to develop an alternative economy based on agriculture, particularly grains.

Third, in the majority of land in the Amazon, especially in the humid zone, forest management could provide a more stable economy—income, employment, and taxes — than that produced by agriculture.

Fourth, it is necessary to expand and consolidate the national and state forest system as part of a broader strategy to promote sustainable land-use and biodiversity protection. The creation of national forests could (1) help protect large areas by creating a mosaic of managed National Forests and national parks, the former serving as buffer zones for the latter; (2) prevent rural colonization in areas without agricultural potential; and (3) separate agricultural and logging frontiers, thereby reducing the economic benefits that unsustainable agriculture receives from being associated with predatory logging.

A study by Veríssimo and others (2000) revealed that there are 1.15 million km$^2$ of forest in the Amazon with the potential to establish National Forests. Of this total, approximately 38 percent coincides with areas of high importance for conservation of biodiversity (1999 Macapá Consultancy). In cases of overlap, the authors recommend the designation of these areas for absolute protection. Even so, 0.7 million km$^2$ would remain for the creation of National Forests, an area more than capable of sustainably supplying the current and expected near-term demands on the Amazonian wood sector.

To ensure the success of National Forests, it is crucial that an environmentally responsible and administratively efficient concession system be established. In addition, to eliminate incentives for unsustainable logging, it is crucial that a tax be imposed on wood derived from predatory harvests outside National Forests.

Finally, local economic forces make sustainable development in the Amazon frontier difficult, because local political interests are served by rapid economic growth, even if it leads to transient communities based on unsustainable economies. Interest in the benefits of sustainable development is generally national and global.

Hence, it is essential that the federal government help state and local governments to guarantee sustainable development in the Amazon. The federal government could help stabilize the local economy through both economic and regulatory instruments. These instruments include taxing wood derived from predatory logging, creating National Forests, improving the monitoring and control system, and providing selective assistance to the implementation of forest management.

However, a more proactive government role is not without risk, which will have to be carefully managed from the outset. These risks include that

1. Ill-conceived policies or poor implementation may do more harm than good (implementation risk).
2. A strengthened and visible commitment of government to sustainable development in the Amazon might raise expectations and increase government's exposure to criticism for a less-than-complete resolution of the problem (reputational risk).

The authors believe that both implementation and reputational risk can be controlled through careful attention to project phasing, participation of stakeholders, and information dissemination. Based on the analysis presented in this report, the authors also believe that the benefits of a more proactive government role are well worth any possible risk.

# Introduction

This report comes at an opportune moment in the Amazonian debate. After almost two decades without substantial investment by the federal government in Amazonian transport infrastructure, the Brazilian government is planning actions that will profoundly alter the regional landscape.

First, a signficant expansion of the transportation system is planned under the program, *National Axes of Integration and Development*. This initiative, the most significant since the pavement of BR 364 (Cuiabá – Porto Velho interstate) at the beginning of the 1980s, will dramatically increase access to the Amazon's natural resources.

Second, the Ministry of the Environment is implementing a new forest policy based on the expansion and consolidation of national and state forests in the legal Amazon (referred to in the present report as the Amazon). The government's goal is to allocate 500,000 $km^2$ (10 percent of the Brazilian Amazon) for the creation of National Forests.

Finally, the federal government has made an international commitment to protect biodiversity in the Amazon through expanding national reserves (areas of complete protection) to cover a minimum of a representative 10 percent of the territory.

These government initiatives offer both opportunities and risks. The risks stem from the investments in infrastructure and from the difficulty of organizing the economic forces that improved access will unleash. The opportunities derive from a heightened government commitment to confront its environmental responsibilities, clearly articulated public support for more rational land-use patterns in the Amazon, and a the wealth of accumulated experience through the Pilot Program to Conserve the Brazilian Rainforests (PPG7).

In any case, the government cannot remain passive. Either it will lead the redirection of economic forces that are degrading the Amazon, or the national heritage will be appropriated for private interests.

The general objective of this report is to assist decisionmakers, civil society, and the private sector in guaranteeing that Amazonian natural resources will be maintained in the use that maximizes their social and environmental value. In the first chapter, the authors review the effects of rainfall on the agricultural productivity of Amazon. In the second, the authors analyze the economic performance of the principal land-use activities. For this analysis, the authors consider a typical Amazonian county in the humid zone whose economy is based on extensive ranching and predatory timber harvesting. In the third chapter, the authors examine the strategic role that government can play in ensuring economically sustainable development in the Amazon. Finally, the authors analyze the government's plan to expand and consolidate national and state forests (public areas of sustainable use) within this context of sustainable development.

# 1

# Effect of Rainfall on the Performance of Agriculture and Ranching in the Amazon

In this chapter, the authors summarize the information available in the literature on agricultural performance in the tropics, in particular the Amazon. For the purpose of subsequent analysis, they then conceptually divide the Amazon into three rainfall zones. Finally, the authors employ data from the 1995-96 agricultural census (Brazilian Institute of Geography and Statistics, or IBGE) to evaluate the effect of rainfall on the productivity and economic return of agriculture.

## Literature

There is an ample literature noting the generally low agricultural potential of the humid Amazon (Goodland and Irwin 1975, Moran 1981, Smith 1982, Hecht and others 1998, Cochrane and Sanchez 1992, Mattos and Uhl (1994). Schubart (1999), for example, concluded that approximately 90 percent of Amazonian soils are acidic, chemically poor, and excessively humid. The last characteristic favors the development of insects and plant disease. Goodland and Irwin (1975) affirmed that the hot, humid climate of the Amazon frequently is associated with high biotic pressure and acidic, infertile soils. Smith (1982) revealed that excessive rainfall can make slash burning (to prepare fields) unviable in many humid areas. Even when burns are successful, the gains obtained in soil fertility are largely lost due to excessive rainfall. Cochrane and Sanchez 1992) concluded that excessive rainfall and saturated soils, especially in the central Amazon, impose a natural barrier to agricultural development. Gallup and Sachs (2000) observed that climate is one of the key factors for the relative failure of agriculture in the tropics. These authors stated that, despite research efforts, the humid tropics continue to display low productivity for their primary crops, including corn, rice, tubers, vegetables, and cattle and pig ranching. The exceptions are perennial crops such as banana, coconut and oil palm.

A study of the state of the art of agriculture in the humid tropics, commissioned by the North American Council of Research on Sustainable Agriculture and the Environment in the Humid Tropics (a commission of the National Research Council) summarized the biological limits of agriculture in the tropics:

> The hot and humid climate provides ideal conditions for pests and diseases. The growing season is essentially continuous and facilitates the development of persistent pests. Losses of crops to pests in the humid tropics are great. Preharvest losses are estimated to be 36 percent of yield, and

> postharvest losses are estimated to be 14 percent. The impacts of fungi, and viral, and bacterial pathogens in developing countries have been studied less than those for insects, but the most comprehensive studies suggest that losses caused by pathogens are about equal to those caused by insects. Weed growth is often so prolific and hard to control that it is thought to be the most important cause of yield depression. (National Research Council 1993).

## Recent Evidence

Recent scientific discussions have also emphasized the effect of climate on agricultural production in the Brazilian Amazon. First, the analysis conducted by Win Sombroek (in press) stresses the necessity of a marked dry period for agricultural success (particularly for grains). Second, a study recently concluded by Kenneth Chomitz and Timothy Thomas (2001) statistically verifies the negative effect of high rainfall on agricultural productivity in Amazon. Finally, a recent symposium sponsored by Embrapa on the production potential of soy beans in the Amazon yielded similar conclusions to those of Sombroek and Chomitz and Thomas. These studies are summarized below.

### *Sombroek (2001)*

Sombroek emphasizes the necessity of a pronounced dry season for the establishment of agriculture. Using a minimum of two consecutive months with rainfall lower than 100 mm as the criterion for defining a dry season, he concluded:

*Roads*. The construction and maintenance of roads are problematic where there is no pronounced dry season.

*Storage*. The construction and maintenance of warehouses and silos are more expensive in humid regions. In these areas, where no marked dry season exists, losses are greater in drying grains due to pests and diseases.

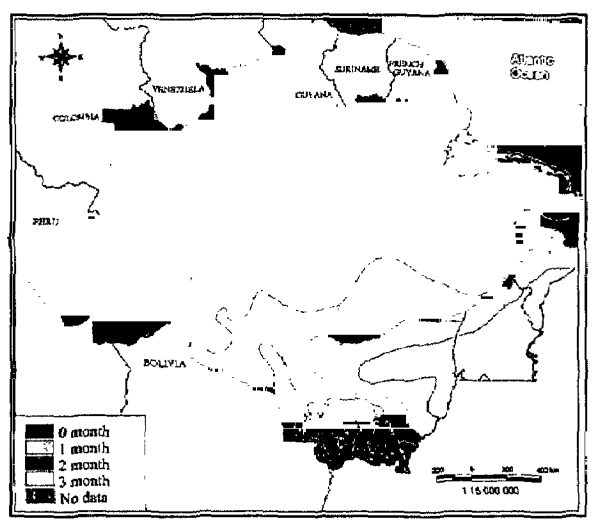
*Human and animal health*. Health is severely affected in areas without a pronounced dry season. The dry season is a positive factor, because it restricts the multiplication of endemic diseases and their vectors.

*Agriculture*: In areas without a defined dry season, burning recently cleared areas is generally incomplete. Crops such as rice, beans, and corn require a dry period for maturing and drying, as well as to prevent rotting. Soy, in particular, requires a dry season due to its vulnerability to pest and disease attack while in the vegetative stage, especially if the humidity of the air near the soil surface remains high during a large part of the day.

The use of heavy machinery on a commercial scale is viable only where the soil surface is relatively dry during the planting and harvest periods. Hence, in the Amazon, mechanized planting and harvesting would be limited to those zones that have at least one month with rainfall below 10 mm (figure 1).

In summary, the effect of rainfall is most significant for grains and, especially, soybeans,

**Figure 1. Consecutive months with rainfall less than 10 mm**




*Source:* Chomitz and Thomas calculations based on CAMREX data.

and slightly less so for ranching. In the case of perennial crops, the effect of rainfall is significant for crops such as black pepper, but has not been a limiting factor for crops such as oil palm, banana, and coconut.

### Chomitz and Thomas (2001)

Chomitz and Thomas conducted a statistical analysis of the 1995-96 agricultural census to relate agricultural land use (table 1) and pasture stocking rate (number of animals per hectare of pasture) (table 2) to soil characteristics, precipitation, market access, and historical deforestation. The advantage of this multivariate analysis is that it makes it possible to separate the effect of rainfall from that of other factors, for example, roads, distance to market, and soil characteristics. These authors confirmed that, controlling for all of these factors, precipitation has a significant negative effect on the intensity and type of land use.

The indpendent effect of rainfall can be observed by considering an example of a typical property in the Amazon with the following characteristics:

- Location: western Pará
- Soils: oxisols
- Distance to primary road: 25 km
- Distance from the nearest area deforested in 1996: between 100 and 200 km
- Distance from the closest city: 200 km.

Table 1 shows the prediction of the effect of rainfall on land use, holding all other variables constant.

Table 2 shows the effect of rainfall on the stocking rate on a 500-hectare ranch with the same characteristics as above.[1]

Consistent with the observations of Sombroek, Chomitz and Thomas note that soy represents a large proportion of agricultural production in areas with the following characteristics:

- Annual rainfall reaches 1,600 to 2,000 mm.
- There are 3 to 4 consecutive dry months.
- Limiting soil factors are a low level of phosphorus, nitrogen, and retention of organic matter.
- The basic vegetation is cerrado (savanna and scrub forest).

Curiously, dairy ranching also appears to be facilitated by a dry climate. Dairy farming occurs almost exclusively in areas with annual rainfall below 2,200 mm.

### Embrapa: Conference on Soy (1999)

In December 1999, Embrapa-Cpatu sponsored a symposium in Belém to discuss the potential and technical limitations of soybean cultivation in the humid Amazon. In his presentation, Nelson Ferreira Sampaio, executive director of Embrapa-Rondônia, made the following observations, which are highly consistent with those of Sombroek and Chomitz and Thomas:

1. Climatic, edaphic, and agronomic factors are fundamental to soy cultivation. A large part of the Amazon is covered by forests under an intense rainfall regime, with a reduced dry season. These conditions

**Table 1. Effect of rainfall on land in agricultural use**

| *Rainfall (mm)* | *Land in agricultural use (%)* |
|---|---|
| 1,600 | 22 |
| 2,000 | 8 |
| 2,300 | ~0 |

*Source:* Chomitz and Thomas 2001.

**Table 2. Effect of rainfall on stocking rate**

| *Rainfall (mm)* | *Stocking (animal/ha of pasture)* |
|---|---|
| 1,600 | .38 |
| 2,000 | .31 |
| 2,300 | .27 |

*Source:* Chomitz and Thomas 2001.

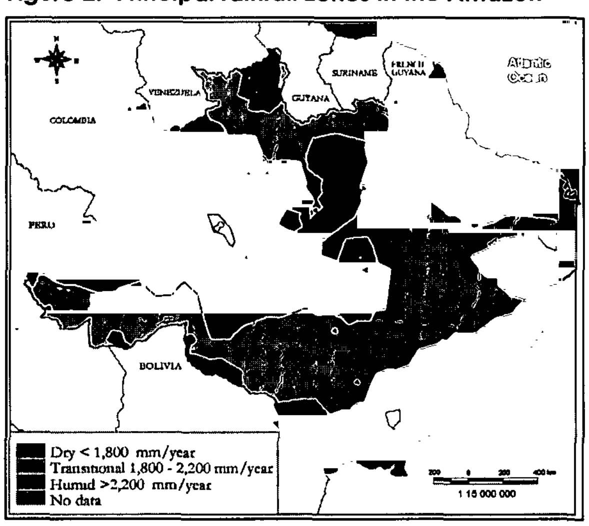
eliminate the opportunity for large-scale grain production in most Amazonian territory, simply due to either the presence of forest or the inability to intensively mechanize operations.

2. The potential for cultivating grains is found in the natural savannas and grasslands of the Amazon, which occur primarily in peripheral areas (south of the legal Amazon and Roraima), where there is a pronounced dry season.
3. The forests that cover the majority of the Amazon represent the natural vocation of the region. There is a great need to define areas with economic potential for occupation by current and future populations.

## Rainfall Zones of the Amazon

The analysis of Chomitz and Thomas (2001) based on the 1995-96 Agricultural Census data (IBGE) enabled the authors to identify three rainfall zones in the Amazon with distinct differences in agricultural performance (figure 2). The authors used data from the Radam Brasil project (1973-1978) to describe biophysical conditions and agricultural potential in these zones. The Radam classification of agricultural potential was based on information on climate, soils, relief, geology, and vegetation. The Radam Brasil project covered an area of approximately 3.7 million km$^2$, equivalent to 74 percent of Amazon. The cerrado and pantanal regions of Mato Grosso were not included.

**Figure 2. Principal rainfall zones in the Amazon**




*Source:* Chomitz and Thomas calculations based on CAMREX data.

### *Dry Amazon* (rainfall below 1,800 mm/year)

The dry Amazon, receiving less than 1,800 mm rainfall per year, comprises approximately 17 percent of the territory. This area is concentrated in the south of the Amazon basin and in isolated areas of natural grassland located primarily in the north of Roraima. In this region, climatic conditions are relatively favorable for agriculture. Although soils are predominantly poor, sparse stretches of fertile soils exist in Rondônia, Pará, and Mato Grosso. Soils are generally well drained, and the relief relatively favorable for mechanized agriculture. The vegetation is largely savanna with some sparse areas of open and semi-deciduous forests. These forests contain low volumes of commercially valuable timber species.

### *Transitional Amazon* (rainfall between 1,800 and 2,200 mm/year)

The transitional zone represents approximately 38 percent of the Amazon and is located largely in the transition belt between the central region (humid zone) and the arc of the Amazon deforestation in the south (dry zone). This transitional region is generally covered by dense *terra firma* forest, with areas of open forest in Mato Grosso and southern Pará. In general, soils are chemically poor (although patches of fertile soil do exist) and relatively well drained. The topography is largely rolling with significant elevation in Roraima and the north of Pará. In addition, isolated higher elevation areas are found in the center (Carajás) and south (Cachimbo) of Pará and the center of Mato Grosso (Parecis).

Excess rainfall and a short dry season create severe agronomic and economic difficulties for grain production in this zone. Perennial crops have had somewhat better agricultural success, although diseases such as leaf plague (*Microcyclus ulei*), which attacks rubber trees; witches broom (*Crinipellis perniciosa*); infestations of Cacao fusarium (*Fusarium solani* f. sp. Piperis) affecting black pepper; and the deadly yellowing (cause unknown) that damages oil palm have greatly restricted their economic viability. However, small landowners who employ diversified agricultural systems have achieved a reasonable increase in standard of living (Schneider 1994, Moran 1989, Ozório de Almeida 1992, Jones and others 1992, and Toniolo and Uhl 1994).

In the case of ranching, Mattos and Uhl (1994) documented the relative success of intensive cattle ranching in Paragominas, eastern Pará. Calculations made by the authors (appendix 1) demonstrate that reasonable economic returns to cattle ranching occur only under relatively advanced technological conditions.

***Humid Amazon*** (annual rainfall greater than 2,200 mm)

In this zone, annual rainfall exceeds 2,200 mm, with some areas receiving levels as high as 4,000-4,500 mm. In general, soils are infertile and poorly drained. In areas of relatively high relief, intense rains increase the risk of erosion. This zone, comprising 45 percent of the Amazon, is located primarily in the central region, occupying a large part of Amazonas and Amapá states; the northeast of Rondônia; and the southeast, northwest, and northeast (the island of Marajó and the Bragantine region) of Pará. The majority of this area is covered by dense forest. The adverse natural environmental conditions (excess rainfall and poorly drained soils) render virtually all forms of agriculture economically uncompetitive. Profitable activities occur only in areas well endowed with infrastructure and markets. For example, perennial crops (primarily black pepper, malva, oil palm, passion fruit, oranges, papaya) are cultivated in the outskirts of Belém, where good infrastructure and market conditions predominate (Serrão and Homma 1993). However even these initiatives face a difficult battle with disease and pests.

Combining the three rainfall zones with the data from Radam Brasil (study area 3.7 million km$^2$), the authors found that 84 percent of the area possessed high or medium potential for timber extraction. In contrast, Radam Brasil concluded that only 7 percent (approximately 0.25 million km$^2$) shows agricultural promise, whereas 93 percent of the land presents either low or no agricultural potential.

## Agricultural Performance in Relation to Rainfall

The humid Amazon is perhaps the area of the globe with the highest probability of sheltering a natural predator for any crop introduced by human beings. This implies that modifications introduced to control one pest have a high probability of rendering the crop vulnerable to a different predator. The history of agricultural failures in the Amazon is instructive (box 1).

There is a certain risk in generalizing from successes or failures of agricultural experiments without either a long period or a wide range of experience to observe the effect of varying production factors. Nevertheless, the results of Chomitz and Thomas (2001), reviewed above, which control statistically for many of these factors, enable the authors to generalize with some confidence about the negative effects of high levels of rainfall on agricultural productivity. A review of the most recent census data provides an additional test of the validity of these generalizations.

The most recent information pertaining to land use in the Amazon comes from the

**Box 1. Agricultural failures in the Amazon**

**Bragantina** (Pará). Attempts to transform the Amazon into a vast area of agricultural production began at the beginning of the twentieth century. During this period, the federal government supported the agricultural occupation of the Bragantine Region, northeastern Pará. In over 100 years of agricultural experimentation, almost all crops failed. Excessive rainfall (>2,200 mm) and a short dry season made vegetable and grain cultivation unviable Perennial crops, such as black pepper, also failed due to disease (fusariose). Today, the regional landscape is dominated by degraded and abandoned areas, extensive cattle ranching, slash-and-burn agriculture, and isolated crops (passion fruit, papaya, acerola, black pepper, oil palm)

**Perimetral norte** (Amapá). The recent occupation of an extensive area of northeast Amapá for agricultural reform resulted in failure Poor soils and excessive rainfall made grain cultivation unprofitable. Despite infrastructural support (paved roads, electricity, brick houses), the majority of lots are abandoned.

**Transamazonica** (Pará). Excessive rainfall results in prohibitively high costs for road building and maintenance. In over three decades of occupation, farmers have faced enormous natural (rainfall and humidity) and infrastructural (roads) challenges to agricultural development. All attempts to cultivate grains ended in failure. Only perennial crops (particularly fruit trees) show economic potential.

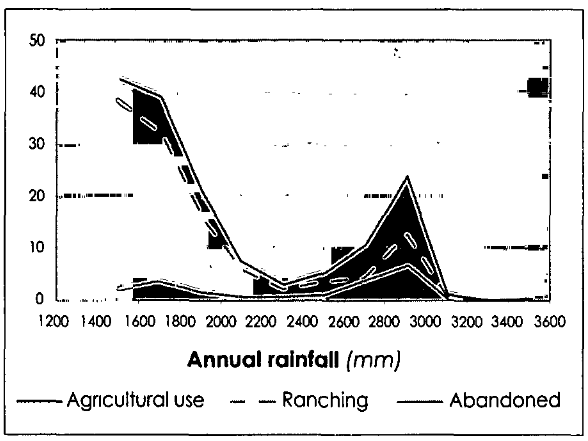
**Ranching.** In Acre, approximately 550,000 hectares (ha) of pasture are in an advanced state of degradation. A large majority of pasture is formed by *Brachiaria bizantha*, a grass that is intolerant of acidic and poorly drained soils. This type of soil is distributed over vast areas of the Amazon (approximately 20 percent of the territory), including Acre and southern Amazonas.

**Soybeans.** At the end of the 1990s, the government of Amazonas stimulated planting of soy in Humaitá, in the south of the state. Despite financial incentives the initiative failed. The drenched soils and high rainfall rendered cultivation unprofitable. Similar problems occurred in Santarém (Pará) with an experimental planting by the Quinico group. Due to excessive rains, it was impossible to harvest a third of the 600 ha that had been planted.

**Long-cycle perennial crops.** Experiments with homogeneous rubber and Brazil-nut plantations failed In the case of rubber, the fungus, *Microcyclus uley*, facilitated by the high humidity, is a limiting factor that remains insurmountable. The productivity of Brazil nut in open field conditions (Itacoatiara, Amazonas) was significantly lower than in the experiments conducted by Embrapa. This failure discouraged Brazil nut planting in other parts of the Amazon (Dean 1989).

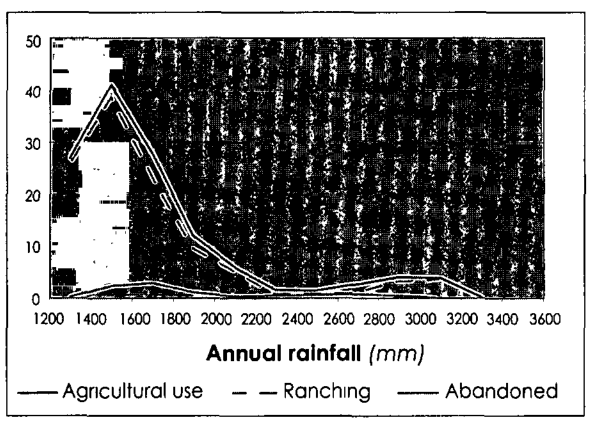
1995-96 Agricultural Census (IBGE). This information can be superimposed on rainfall data to analyze the relationship between rainfall patterns and land use in the Amazon.

**Figure 3. Areas in agricultural use (percent) in relation to rainfall: Within 25 km of a main road**




*Source:* Authors' calculations based on IBGE and CAMREX data provided in Chomitz and Thomas 2001.

**Figure 4. Areas in agricultural use (percent) in relation to rainfall: More than 25 km from a main road**




*Source:* Authors' calculations based on IBGE and CAMREX data provided in Chomitz and Thomas 2001.

Figures 3 and 4 are based on land-use data at the level of census unit (the finest scale of the census analysis) and on rainfall data interpolated between rainfall measurements of ANEEL (National Electric Energy Agency) and those of the U. S. National Aeronautics and Space Administration (NASA) Earth-Observing System (EOS) Amazon project of the University of Washington. As would be predicted by Radam Brasil, these data demonstrate a severe reduction in agricultural land area as rainfall levels increase.

To isolate the effect of distance from the property to the primary road, the authors considered two scenarios, represented by figures 3 and 4. Figure 3 includes only census areas that were less than 25 km from a primary road. Figure 4 displays results for census areas more than 25 km from roads. Interestingly, both figures show the same abrupt drop in the percentage of census area in agricultural use in areas with rainfall greater than 1,800 mm per year. Below 1,800 mm, both figures show that 30 percent to 40 percent of the land is designated agricultural. This number falls abruptly to 5 percent as annual rainfall rises to 2,200 mm. In areas farther than 25 km from roads, the agricultural land covers no more than 5 percent. In the case of land closer to roads, agricultural use increases to approximately 23 percent at 2,800-3,000 mm rainfall, then drops rapidly to almost 0 percent.

The low agricultural productivity in the Amazon frequently is blamed on poor infrastructure and absence of markets, rather than on climatic factors. The spike of the curve of agricultural use at 2,900 mm of rainfall shows the limitation of good transport and market systems in overcoming the negative effect of excessive rainfall. This spike represents largely the humid zone microregions of Belém-Bragança (Pará) and Macapá (Amapá), situated 25 km from a main road with easy access to large urban markets. Nevertheless, the zone displays low land use and a high proportion of abandoned land.[2] To better understand the dynamics of land use and rainfall, the authors classify the census data into the three rainfall categories discussed above. These zones correspond to 17 percent (dry), 38 percent (transitional), and 45 percent (humid) of the Amazon.

Table 3 presents the proportions of the census areas formally designated as being in farms (agricultural establishments) and the percentage actually converted to agricultural use, including abandoned lands.[3] The effect of rainfall is evident: 55.6 percent of land in the dry zone is in agricultural establishments, and 38.2 percent is in agricultural use, while, in the humid zone, these proportions reach only 7.5 percent and 3.2 percent, respectively.[4]

Table 4 displays the types of agricultural land use in each rainfall zone. Approximately 83 percent of land in agricultural use in the dry zone is under pasture, and approximately

**Table 3. Land use in the Amazon by rainfall zone**

| *Rainfall zone* | *Area ($km^2$)* | *% of total area* | *% of zone in agricultural establishments* | *% of zone in agricultural use* |
|---|---|---|---|---|
| Dry[a] | 836 573 | 17 | 55.6[b] | 38.2 |
| Transitional | 1 816 240 | 38 | 28.7 | 13.0 |
| Humid | 2 194 887 | 45 | 7.5 | 3.2 |
| Total | 4 847 700 | 100 | 24.0 | 13.0 |

a. The rainfall categories correspond to less than 1,800 mm (dry); 1,800-2,200 mm (transitional); and more than 2,200 mm (humid).
b. Agricultural establishment is a category used in the Brazilian census. It refers to privately held land in both agricultural and forest use.
*Source:* Authors' calculations based on Chomitz and Thomas 2001.

**Table 4. Use of agricultural areas in the Amazon** *(percent)*

| *Rainfall zone* | *% in agricultural use* | *Pasture (%)* | *Annual crops (%)* | *Perennial crops (%)* | *Abandoned lands (%)* | *Others (%)* |
|---|---|---|---|---|---|---|
| Dry[a] | 100 | 83.3 | 5.1 | 0.5 | 8.4 | 2.6[b] |
| Transitional | 100 | 77.7 | 9.1 | 1.9 | 7.7 | 3.6 |
| Humid | 100 | 56.8 | 7.2 | 4.4 | 20.9 | 10.7 |
| Humid with old colonization[c] | 100 | 54.4 | 5.8 | 4.6 | 28.5 | 6.7 |

a. The rainfall categories corresponds to less than 1,800 mm (dry); 1,800-2,200 mm (transitional); and more than 2,200 mm (humid).
b. Includes plantation forests and settlements.
c Corresponds to Belém-Bragantina (Para) and Macapá-Mazagao (Amapa). This area is humid but possesses relatively good infrastructure and market conditions.
*Note:* Area in agricultural use as a percentage of total land in rainfall area is as follows: dry: 38%; transitional: 13%: humid: 3%.
*Source:* Authors' calculations based on Chomitz and Thomas 2001.

8 percent is abandoned. Pasture falls to roughly 60 percent in the humid zone, with a concomitant increase in abandoned land to approximately 20 percent. Relatively good infrastructure and access to markets do not appear to improve the economic sustainability of agriculture in this zone (box 1, Bragantine Region).

The data presented above highlight the dangers in generalizing the modest success observed to date in Amazonian agriculture to future perspectives. The relatively high conversion rates observed for the dry zone in the 1995-96 Agricultural Census (IBGE) are consistent with the modest success found in Schneider's review of colonization studies in the dry and transitional areas (1994), based largely on work of Ozório de Almeida (1992), Emilio Moran (1989), FAO/UNDP/MARA (1992), and Jones and others (1992). However, data discussed above demonstrate that even this moderate success experienced in dry and transitional areas cannot be expected for the 45 percent of the Amazon with rainfall above 2,200 mm. For these areas, the most probable scenario is low agricultural productivity, weak economic performance, and eventual land abandonment.

# 2

# "Boom-and-Bust" or Economic Sustainability: The Community's Dilemma

Based on the land-use data and literature values assembled for this report (appendix 1), it is possible to predict the economic future of a typical Amazonian county in the humid zone (45 percent of the region). If market forces operate freely in the region, land use will be based largely on predatory logging associated with extensive ranching. In this case, the local economies will tend to follow a "boom-and-bust" cycle. Rapid growth in the first years (boom) will be followed by a severe decline in profit and employment (collapse).

## Land Uses

The major uses of land in the Amazon are timber harvesting and ranching.

### *Timber Harvesting*

The legal Amazon produces approximately 90 percent of the native wood in Brazil. The wood industry is the primary economic activity in the Amazon, representing roughly 15 percent of gross domestic product (GDP) of the states of Pará, Mato Grosso, and Rondônia. In 1998, the gross receipts of the sector were estimated at US$2.5 billion.[5] Moreover, the wood industry generates approximately 500,000 direct and indirect jobs (Veríssimo and others unpublished). The Internal Rate of Return (IRR) of forest management was estimated at 71 percent,[6] while for the predatory logging system, IRR reaches 122 percent (appendix 1).

### *Ranching*

Cattle ranching is the dominant land-use activity in deforested areas, representing 77 percent of converted areas in economic use (Chomitz and Thomas 2001). The current Amazonian herd is estimated at 32 million head. The average stocking rate is only 0.7 animals per ha. Ranching generates roughly 118,000 permanent jobs. In general, ranching presents a very low IRR (4.2 percent), in isolated cases (ranching in reformed pastures) achieving rates up to 13 percent (appendix 1).

## The Community's Dilemma

The authors will consider a county containing 1 million ha of dense forest.[7] Migrant loggers begin to arrive in the area in search of new timber stocks. The community discusses whether to try to control the influx of loggers and institute a sustainable management system, or to permit predatory logging of the forest with subsequent market-driven conversion to pasture.

If market forces act freely in the region, the community can anticipate rapid growth followed by a severe decline, as illustrated in figure 5. Economic activity grows relatively rapidly in the first eight years as trees are extracted and pastures formed. However, after eight years, when the supply of high-value trees has been depleted and a second round of logging (focused on low-value species) begins, the economy starts to decline. By approximately the twentieth year, marketable wood is completely exhausted, and the local economy enters a crisis.

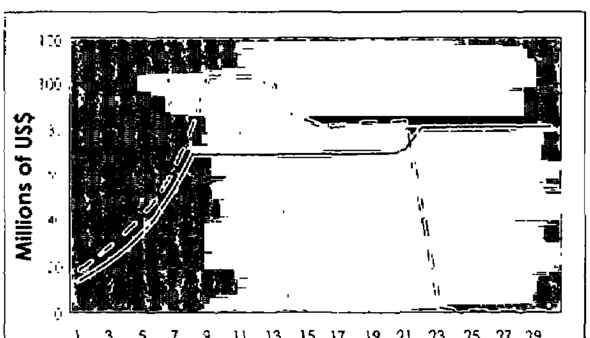
Economic activity, measured by the gross revenue from timber harvesting (extraction and processing) and ranching in this boom-and-bust cycle, reaches a maximum of US$100 million in the eighth year and falls to below US$5 million in the twenty-third year. During this period, loggers will abandon the county, leaving behind only low-productivity ranching. If the community were to compel the logging companies to adopt sustainable forest management, the gross revenue would reach US$70 million in the eighth year, instead of the US$100 million obtained by the predatory model. However, revenue would be sustainable indefinitely at this level, instead of dropping drastically with the exhaustion of timber supplies in the twenty-third year, as occurs in the predatory model.

Implications for employment are equally dramatic. Both models employ roughly the same number of workers during the first eight years. After this period, the predatory model peaks at 4,500 jobs in timber harvesting and ranching combined, while the sustainable model, based only on forest management, would remain stable, at 3,500 jobs (figure 6). However with depletion of marketable wood in the twenty-third year in the predatory model, the employment base migrates to another county, leaving behind fewer than 500 workers involved in ranching. If the community's timber resource were managed sustainably, the 3,500 jobs would be maintained indefinitely.

In areas of extremely good infrastructure and markets, the long-run employment advantage of managed forestry compared to business as usual is less pronounced, because the market-led conversion of land to ranching is considerably greater. Nevertheless, even in these favorable areas, authors' calculations show that direct employment drops by more than half (from year 21 to year 24), and the economic base collapses.

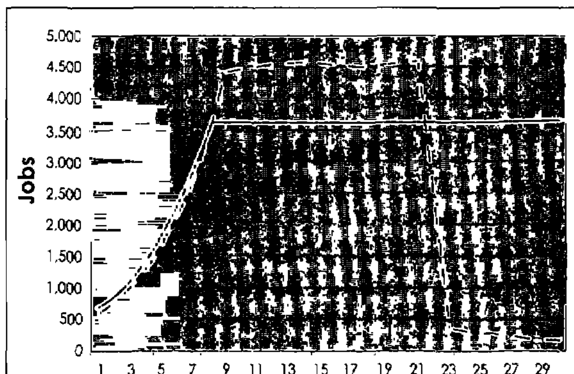
The above analysis indicates clearly that from the long-run perspective of stable growth,

**Figure 5. Gross revenue: Managed forest vs. predatory logging and ranching with poor infrastructure in the humid Amazon**




*Source:* Authors' calculations, appendix 1.

**Figure 6. Jobs: Managed forest vs. predatory logging and ranching with poor infrastructure in the humid Amazon**




*Source:* Authors' calculations, appendix 1.

building community, and investing in people, the managed forest offers a better alternative than uncontrolled market exploitation.

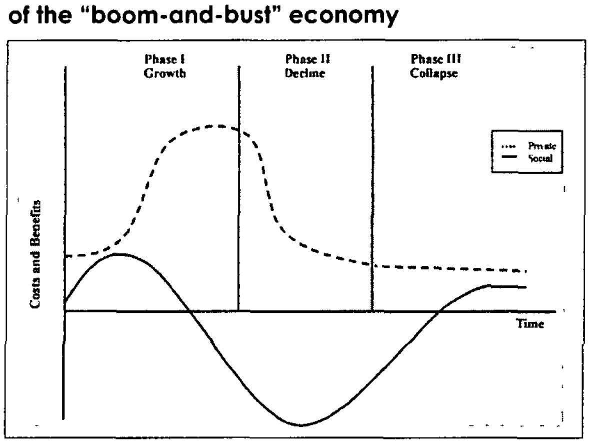
Figures 5 and 6 compare the effect of managed forest and market-led exploitation on economic activity in the community. Figure 7 illustrates the relationship between the private and *social* benefits of an unsustainable "boom-bust" pattern of development. Figure 7 displays a boom period, as the new activity attracts migrants and provides the economic base for growth of the private and public sectors. The collapse begins when the natural resource base that sustains this activity (in this case, timber) is depleted and the economy attains a new equilibrium based on extensive ranching. Although in this stage, economic benefits still exist, costs are elevated due to unemployment and migration of companies and people, and reductions in public services resulting from loss of the economic base of the community. In addition, the environmental costs, in the form of biodiversity loss and carbon emissions, are increased.

### Logging Dynamic

Most timber harvesting in the Amazon has occurred as a complement to agriculture. As a result, the logging frontier has accompanied the expansion of the agricultural frontier. Although there are several successful forest management initiatives, such ventures still represent a small fraction of logging activity (less than 5 percent of the volume extracted). The dominant pattern continues to be predatory logging, characterized by severe damage to the forest, excessive pressure on populations of high-value species, and increased susceptibility of harvested areas to fire (Uhl and others 1997).

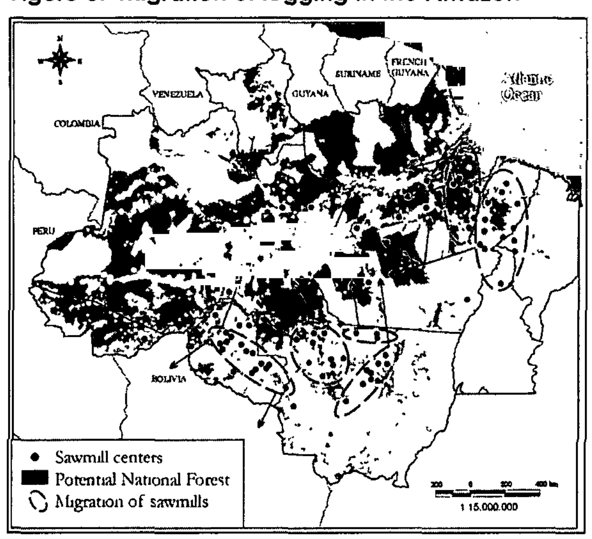
Predatory logging has already exhausted forest resources in old logging centers. The circled areas in figure 8 display the old logging frontiers: Paragominas (Pará), Sinop (Mato Grosso), Vilhena – Ji Paraná – Ariquemes (Rondônia); frontiers of intermediate age, such as the north of Mato Grosso and Tailândia – Marabá (Pará); and the new frontiers: Novo Progresso (Pará), Novo Aripuana-Apui (Amazonas) and Senador José Porfírio – Portel (Pará). The authors estimate that the scarcity of wood in the old frontiers will require logging companies to either migrate or close within five years. In the intermediate frontiers, natural timber stocks are sufficient for 10 to 20 additional years, whereas in the new areas,

**Figure 7. Social costs and private benefits of the "boom-and-bust" economy**




*Source:* Authors.

**Figure 8. Migration of logging in the Amazon**




*Source.* Veríssimo and others 2000.

timber supplies will be depleted in 30 to 40 years.

Loggers in Rondônia are relocating in the direction of Bolivia and the state of Amazonas, while companies from the old frontiers in Pará and Mato Grosso are migrating to the most recent frontiers (west of Pará and southeast of Amazonas), frequently illegally logging indigenous and protected areas (figure 8).

### *Migration of Logging Companies and Its Effect on Local Economies*

The current logging model has a strong impact on the economies of communities in the Amazon. Following the expansion period, the consequent exhaustion of resources results in an inevitable economic recession in the local economy. The gravity of this recession depends on the local agricultural potential, that is, on the extent to which the emerging agricultural economy can replace the loss of the timber economy. For example, Paragominas, the oldest logging frontier in Amazon, established at the end of the 1970s, is confronting a grave shortage of primary material due to the exhaustion of its forests. In the past 5 years, approximately 50 sawmills closed or migrated, and the volume of wood processed fell approximately 30 percent. A similar phenomenon can be witnessed in the county of Sinop (Mato Grosso), one of the largest logging centers in the 1980s, and in Redenção (south of Pará). However, due to the fact that Sinop and Redenção are located in areas of open forest (characterized by low density of marketable timber) situated in the dry zone, the decline in timber harvesting has been more rapid than in Paragominas.

In Sinop, the number of sawmills fell from approximately 400 at the end of the 1980s to fewer than 100 at the end of the 1990s. However, in this county, the decline in the timber sector has been largely compensated by the rapid growth of agriculture, principally ranching and soybean cultivation. The greater agricultural potential of the dry Amazon makes this transition possible.

On the other hand, Paragominas, situated on the border between the transitional and humid zones, has displayed a slower rate of forest decline due to its denser forests, which provide greater commercial volume per ha. Nevertheless, despite a relatively long history of land-use experimentation, a consistently lucrative form of agriculture that is capable of maintaining the vitality of the local economy has not emerged.[8]

### Summary

As the frontier moves from the dry zone into to the transitional zone, and especially to the interior of humid areas, agricultural performance will decline. If market forces are not restrained, communities constructed in the latter areas during the logging "boom" will become increasingly depressed during the subsequent "bust" to an ever weaker agricultural base. Unfortunately, local decisionmakers often have little incentive to adopt a sustainable development model. Therefore, below the authors analyze the potential for a national policy that prevents this decay of communities and contributes to sustainable development with a better distribution of benefits.

# 3

# Role of Government

The Brazilian government has a crucial role in determining the quality of development in the Amazon and in protecting the interests of the larger Brazilian society. Government policy should reconcile (1) the short- and long-term interests of society; and (2) the interests of the various segments of society, which involve local, state, national and global levels.

## Stabilize Local and Regional Economies

In frontier areas, land-use instability is caused primarily by economic forces. Therefore, the creation of a political coalition capable of promoting more orderly development is a difficult task. Local and regional interests support rapid development (in general, unsustainable), while national and global interests support the benefits of a slower, sustainable economic growth (Schneider 1994).

The case of "the community's dilemma" (chapter 2) is instructive. In the absence of government intervention, a community must choose between the boom-and-bust model (predatory) and sustainable development. A community has at least three reasons to choose the boom-and-bust model.

1. The short period of municipal mandates does not allow political leaders to adopt long-term perspectives with the objective of stabilizing and improving quality of life.
2. Many political leaders are personally involved in the predatory natural resource "mining" economy and do not consider the long-term interests of the community they are representing.
3. Most important, even if a community were to opt for the sustainable model, it would have great difficulty in attracting loggers under conditions of good forest management practices. The Internal Rate of Return for conventional harvesting and processing of timber (predatory model) is 122 percent, while the sustainable system (forest management) achieves a maximum of 71 percent (appendix 1). When faced with the choice between a community that enforces forest management and one that permits conventional logging, loggers naturally tend to opt to work in areas that permit the more lucrative system.

## Avoid Shortsightedness of Local Governments

The problem of the tendency for local governments to be shortsighted and "captured" by local economic interests has been recognized worldwide. In the literature, the phenomenon whereby local governments mortgage their futures for short-term benefits is called "regulatory competition." This competition involves a range of unhealthy practices, from negligent environmental and social regulations to subsidies and tax breaks offered by local governments to attract industries and corporations. These practices, guided by short-term political and economic benefits, frequently threaten the long-run financial health of the community. In the long term, such practices are unsustainable for all levels of society.

## Stimulate Sustainable Use of Forests

Various alternatives exist to stimulate sustainable forest resource use and thereby stabilize the local economy. These alternatives are summarized below.

### *1. Increase Profitability of Forest Management*

Revenue from forest management would be augmented if, for example, a market existed for the environmental services provided by forests. One of these services is the retention of carbon. Carbon retention contributes to the equilibrium of the global climate. Payment for this service has been the subject of international debate, but no decision has yet been made (box 2). The authors calculate that a remuneration of between US$2 and US$3 per ton of additional carbon sequestered in forest management, compared with that sequestered under predatory logging, would be sufficient to induce loggers to adopt forest management practices (appendix 3).[9]

### *2. Reduce Comparative Advantage of Predatory Logging*

Refining the command and control system combined with adopting a tax on the value of timber derived from predatory operations could reduce the advantage of predatory logging. The authors estimate that if a tax on wood from predatory harvests remained between US$1 and US$4 per $m^3$ (depending of the discount rate), logging companies would have no incentive to migrate from the county to avoid management restrictions (appendix 3).

### *3. Engender Respect for Forest Law*

It is critical that respect for forest legislation, in particular, the national Forest Code (*Códiga Florestal*), be ensured. Among other requirements, this legislation mandates that 80 percent of private property in the Amazon be maintained as a legal reserve; and, if it is logged, forest management must be used. The regulations of the Environmental Crimes Law (*Lei de crimes ambientais*) offer an opportunity to make fully effective the existing forest legislation. It is important that a division of responsibilities between local and federal governments be worked out to ensure an efficient and rigorous monitoring and control system.

### *4. Organize Regional Occupation*

The federal government should take the lead in altering the dynamic of disorganized territorial occupation in the Amazon. This pattern of colonization catalyzes deforestation, predatory logging, and fragmentation. One promising means of regulating this occupation is to expand and consolidate a network of public forests (national and state forests) in the Amazon (chapter 4).

### *5. Adopt Compensatory Measures*

The federal government could adopt compensatory measures to (1) increase political support for initiatives that reduce unsustainable short-term growth of the local economy and (2) avoid regulatory competition among counties. These initiatives might include improving local public services such as sanitation, education, and healthcare. Companies often prefer to install their operations in counties endowed with good healthcare systems, quality schools, cultural and recreation options, low crime rates, and healthy environments (low pollution, green spaces, clean water), instead of in districts whose only attractions are financial incentives and negligent regulations.

## Distribute Benefits from Use of National Patrimony

The government should guarantee that the benefits from both logging and the conversion to agriculture of Brazilian forests are properly distributed within Brazilian society. The

**Box 2. Clean development mechanism**

Significant alterations in world climate are being observed. The accumulation of "greenhouse gases," especially carbon dioxide emitted through fossil fuel burning since the industrial revolution, provokes a warming of the earth's atmosphere and, secondarily, a rise in sea level. In 1990, governments initiated discussions concerning what measures should be taken to combat global warming.

Brazil has had an important role in these discussions. For example, during the 1992 Rio Earth Summit (Rio-92), a Convention on Climate Change was approved, and its first signatory was Brazil's then-President Fernando Collor. In addition, in 1997, the official Brazilian delegation played an important role in making the Kyoto Protocol viable. Brazil has continued to be one of the key Parties in the negotiations to implement the Protocol, in particular, the clean development mechanism (CDM). The CDM enables industrialized countries to achieve part of their Kyoto Protocol emissions reduction targets by financing projects that reduce or sequester carbon in developing countries.

The Sixth Conference of the Parties of the Convention on Climate Change in July 2001 agreed on a compromise that makes afforestation and reforestation eligible for the CDM. In November 2001, the Seventh Conference of the Parties agreed on a package of rules and modalities for implementing the CDM Other types of projects that result in carbon sequestration through alterations in land use and forest management may be considered by the Parties for subsequent commitment periods.

It has been estimated that the global volume of of trade in $CO^2$ (without the United States) could reach US$5 billion to $10 billion annually from 2008 to 2012, a part of which may go to developing countries to invest in CDM projects. Thus, the CDM would make viable a series of afforestation and reforestation projects. Brazil could expect to attract 5 percent to10 percent of the market.

current situation reveals a series of social disparities. On one hand, the 1 percent of largest landowners (who own more than 2,000 ha) hold 47 percent of the agricultural land. At the other extreme, the 54 percent of smallest landowners (who own fewer than 20 ha) represent only 1.1 percent of the agricultural land.

In the logging sector also, benefits are distributed inequitably. Logging companies pay less than 20 percent of the income tax (ICMS) that is due, and most are exempt from payment of income tax due to regional incentive programs. In addition, loggers do not pay for their use of federal lands. For example, in Brazil, no fee is charged for standing timber extracted from public lands. Charging such fees is a common procedure in national forests in most other countries.

For economic, social, and environmental reasons, the Brazilian government's colonization policy—applicable in areas with agricultural potential—favors small landholders. However, it does not discourage the acquisition of large properties. The policy for lands with agricultural potential should be changed to discourage speculation because:

1. The acquisition of such large areas encourages predatory activities conducted merely to guarantee the right of ownership.
2. Large properties that are unproductive, or abandoned, encourage land speculation and subsequent ownership conflicts.
3. The distribution of quality land to small holders improves the quality of life for low-income populations and contributes to the equitable distribution of national resources.

## Preserve Options for Future Economic Use of the Amazon

In the future, technological changes may generate new economic benefits for the humid tropics, such as genetic engineering based on existing biodiversity, non-timber forest products, ecotourism, sustainable forest management, and ecological agriculture, that exceed today's values. By preventing forest degradation, the government would be preserving this ecosystem for possible future economic use. This argument justifies the designation of conservation and sustainable use areas, for example, national forests and extractive reserves, as a mechanism to maintain the option of employing the highest-value land uses in the future.

### Protect Biodiversity

The Brazilian Amazon supports the richest biodiversity and source of genetic information in the world. The Brazilian government is committed to do its part to help preserve this heritage for future generations. National Forests could perform a key role within a mosaic of Conservation Areas, acting as a buffer zone between protected areas and private lands.

### Help Stabilize the Wood Sector

The depletion of timber resources in the oldest processing centers has led to the migration of sawmills to frontier areas. This migration will intensify in the next five years. Disorganized migration results in irregular occupation of untitled lands, conflicts with indigenous groups, predatory logging, deforestation, and extensive ranching. In this scenario, the wood industry is the catalyst of a boom-and-bust occupation process.

However, the majority of logging companies would prefer to function within a system of greater stability and certainty that would include defined regulations, secure land ownership, and sustainable timber stocks. Recent research with 96 timber companies (Barreto and Arima 2000) revealed that a large majority (80 percent) of business owners want to exchange the current disorganized process for managed harvesting based on a forest concession system (and the creation of National Forests) (chapter 4).[10] Opinions differed on the role of government in this process, with 41 percent of logging companies preferring a system in which the government merely granted concessions and companies were responsible for management, and 56 percent preferring that the government be responsible for management. Similar percentages were obtained among nongovernmental organizations (NGOs), academic institutions, and professionals outside the forestry sector.

The migration of companies in the Amazon has already begun (figure 8). Neither the loggers nor the receiving communities are comfortable with the current process. Therefore, the window of opportunity to initiate the transition to an industry based on forest management is now.

### Organize Regional Occupation

To ensure conservation and sustainable resource use, government intervention to control market forces is necessary. As "The Community's Dilemma" (chapter 2) illustrates, in the absence of payments for environmental services, the federal government should prevent regulatory competition. In other words, the government should prevent states and counties from competing to attract predatory logging and ranching industries with the goal of obtaining the economic "boom," despite the inevitability of the long-term collapse. Preventing regulatory competition entails both good forestry legislation and effective enforcement. The federal government should discourage states and counties from using tenuous rules for monitoring and control to attract unsustainable and transitory investments.

# 4

# Role of National Forests

Involving the federal government in prevention of regulatory competition is in the interests of all parties. First, by insisting that long-term interests be considered, the government fortifies the authority of communities. Second, responsible logging companies would be protected by law from unjust competition from other companies that harvest wood illegally. Finally, greater formality in the industry would guarantee a greater contribution to state and local revenue.

The stabilization of the wood sector will require the adoption of forest management in both public and private areas. The mining of resources from forests on private land in old logging centers (Sinop, Paragominas, Ji-Paraná) has impelled the migration of sawmills to unoccupied lands in the west of Pará and southeast of Amazonas. In these regions, the government can act now to avoid continued predatory resource use and the alienation of public lands. The most promising mechanism to do so is the creation of National Forests.

National, state, or municipal forests are sustainable-use conservation units whose purpose is to produce goods (timber, non-timber forest products) and maintain environmental services. The federal government can directly manage these forests or temporarily concede forest-use rights to private companies (Veríssimo and others 2000). In either case, forest management in these forests should be certified in accord with recognized international standards, such as those of the international Forest Stewardship Council (FSC).

In forests on private lands, the government should encourage the adoption of forest management, including through the development of a system to effectively monitor the execution of forest management projects. If the monitoring system is not federal, the government should periodically evaluate the integrity of the state or local system. To stimulate forest management, it is essential that a tax be imposed on wood deriving from deforestation permits. This tax must be at least equal to the difference in cost between sustainably and unsustainably produced timber. Such a tax would eliminate the unfair competitive advantage of wood derived from predatory operations.

## National Forests

National and state forests today represent a modest portion (83,000 km$^2$, or 1.6 percent) of the Amazon region. This area would be sufficient to sustainably supply only 10 percent of the current demand for unsawn timber in the region. To satisfy the present and near-future demand in a sustainable fashion, the government would need to designate approximately 700,000 km$^2$, or 14 percent of the Amazon, for the creation of National Forests.[11]

Veríssimo and others (2000) developed criteria to identify areas with potential for designation as National Forests. The principal results from their study follow.

### Absence of Competitive Use

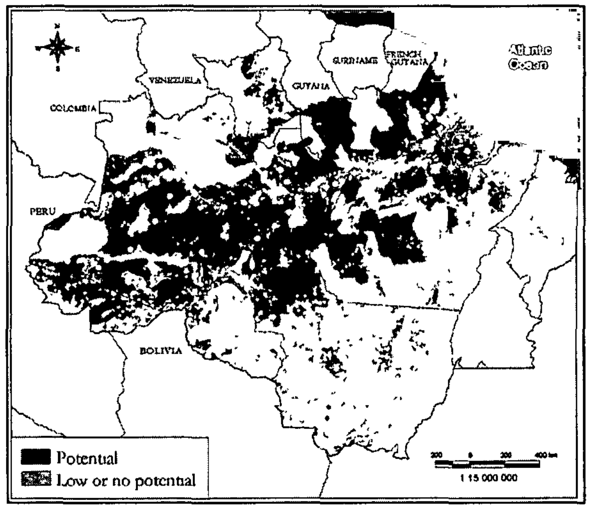
To reduce possible land-use conflicts, the new National Forests should be established in areas that have minimal competitive uses, avoiding zones of agricultural occupation and protected areas.

Protected areas represent approximately 1.4 million km², or 28 percent of the Amazon, of which 1 million km², or more than 20 percent, are indigenous lands (Veríssimo and others 2000). Settled areas were mapped based on "hot pixels" (from the thermal channel of the NOAA AVHRR sensor), [12] government agrarian reform settlements, and county seats. The superimposition of these maps reveals that approximately 9 percent of unprotected forested areas possess detectable human occupation (figure 9).

### Economic Potential

Figure 10 displays the results of an analysis of forestry potential (vegetation map) and economic accessibility. The result is an area of 1.15 million km² (23 percent of the Amazon) that could be designated for forest management, possessing the following combination of characteristics: (1) no official protection, (2) forest cover and marketable timber, (3) low human occupation, and (4) location within the radius of economic accessibility.

**Figure 10. Areas with potential for National Forests**

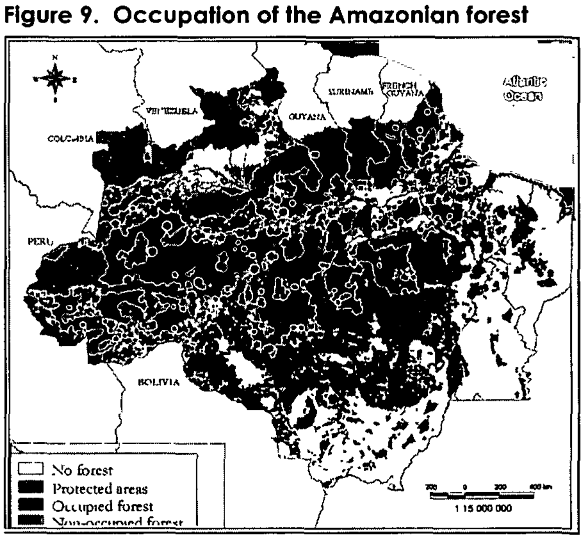



*Source:* Veríssimo and others 2000.

### Biodiversity

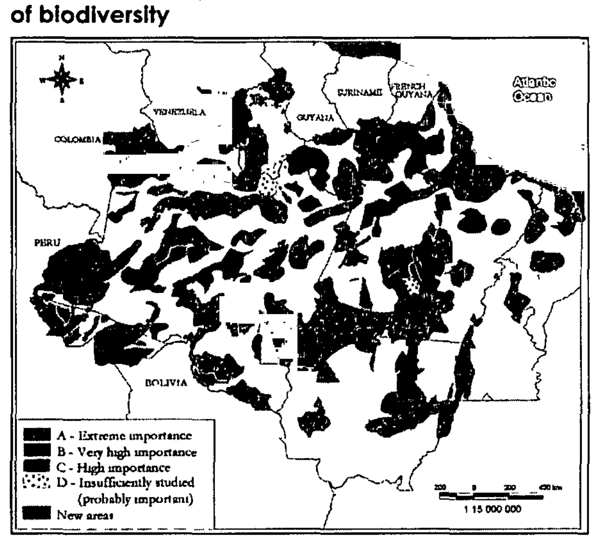
To protect areas of high biological significance, it is desirable for the federal government to create a mosaic of conservation areas

**Figure 9. Occupation of the Amazonian forest**




*Source:* Veríssimo and others 2000.

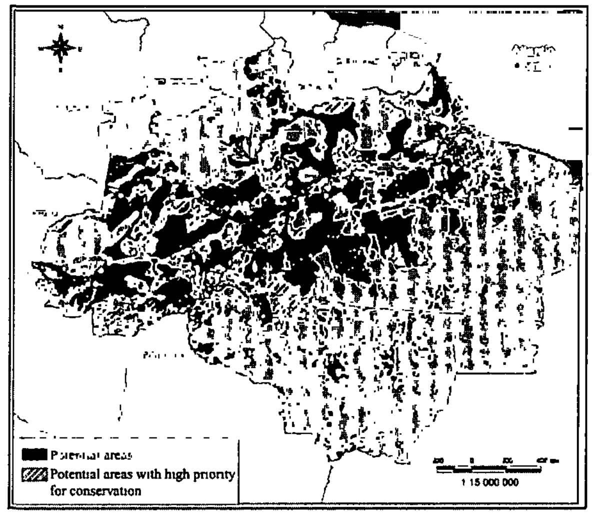
**Figure 11. Priority areas for conservation of biodiversity**




*Source:* ISA and others 1999.

that combines National Forests (sustainable use) with parks and biological reserves (full protection). In this system, National Forests would form a buffer around parks and reserves. In this manner, National Forests can protect reserves from invasion and provide corridors for species to move among core areas. With the goal of realizing the potential to create such a land-use mosaic, the authors combined the map of areas with potential for national forest designation (figure 10) with the map of priority areas for conservation (figure 11). The superimposition of these maps reveals that 38 percent of the 1.15 million km$^2$ (437,000 km$^2$) with commercial potential for forestry is also of high biodiversity conservation priority (figure 12). Therefore, the authors recommend that the 38 percent be put under conservation.

**Figure 12. Overlay of areas with potential for National Forests and for biodiversity conservation in the Amazon**




*Source:* Veríssimo and others 2000.

# 5

# Crucial Issues for the Amazon's Future

The analysis in chapter 4 demonstrates the complementary potential of sustainable forest use and biodiversity conservation. It shows that, without significant competition for the use of these lands, it would be possible to create approximately 700,000 km$^2$ of national forests (roughly 14 percent of the Amazon). This area would be large enough to support sustainably the current and expected near-term future demand for Amazonian timber.

This report proposes a development policy in the Amazon based on forest management. The development of this policy will require additional studies (economic, legal, social, administrative, and biological) and implementation of experimental pilot projects. In this chapter, the authors raise the following important issues that must be addressed for the future of the Amazon.

## Learn the Lessons of Zoning

The theme, "land-use zoning in the Amazon," is once again surfacing in the regional political debate. The recent discussion in the Brazilian Congress over the revision of the presidential Provisionary Measure (Medida Provisória) governing the minimum percentage of private lands to be maintained in forest reserves has raised the stakes on zoning. It has become clear that future discussion of the amount of land to be left in conservation use will not center on the percentage of legal reserve on private properties. Rather, the discussion will take place within the context of local and regional zoning initiatives and will demand a profound analysis of the physical, economic, and social questions that are the topics of this study.[13] The federal government should be prepared to participate proactively in this emerging debate. Fortunately, the government's Multi-Year Plan reserved R$300 million for the Ministry of the Environment to promote zoning over the next three years.

However, if this money is to be well spent, the lessons of the experience to date must be fully learned. This experience includes zoning experiments at the state level conducted with support of the World Bank in Rondônia, Mato Grosso, and Tocantins, as well as zoning for priority regions within each Amazonian state (in Acre, the whole state) being developed under the Pilot Program to Conserve the Brazilian Rain Forests (PPG7).[14]

## Eliminate Land Abundance

Migration, abandonment, and natural resource "mining" are extreme forms of extensive land use stimulated by abundance of land and its consequent low cost. The decision to abandon land, instead of managing it with sustainable agricultural and silvicultural techniques, is guided by the relative costs of purchasing land, on the one hand, and managing more intensely, on the other. Policies that reduce land availability, such as zoning and national forest creation, will lead to intensification of its use.

### Separate Logging and Agricultural Frontiers

Historically, logging and agricultural frontiers evolved in a mutually beneficial fashion. In general, ranchers sell trees to finance forest conversion. For loggers, it is easier and less expensive to buy wood from forest conversion areas than to obtain it through forest management plans. Loggers in turn open access roads for agriculture and offer transportation. In addition, loggers frequently are involved in opening roads in response to local political interests.

The establishment of National Forests, especially in humid areas, effectively would separate the agricultural frontier from areas of logging activity, breaking this dynamic. First, establishing National Forests would reduce the potential for illegal logging by drastically reducing the scale of wood harvesting in agricultural frontier areas. Second, the natural subsidy for future deforestation could be reduced through a tax on wood derived from predatory harvests.

### Understand the Motives for Ranching

Currently, approximately 80 percent of agricultural lands in the Amazon are being used for ranching, or have been unused for more than four consecutive years. Around 40 percent of the pasture in use has a stocking rate of less than 0.5 animals per ha, with an average of 0.7 (Chomitz and Thomas 2001). The present authors' calculations indicate that a ranch employing typical technology receives an Internal Rate of Return of less than 4 percent on investment (appendix 1). Under the most optimistic hypotheses in relation to ranching technology, the authors calculate an IRR of 14 percent.

Even beyond generating few private or social benefits, the conversion of forest to pasture concentrates Amazonian lands in the hands of a small number of people. Some hypotheses explain the investment in an activity with such low return: (1) land speculation based on potential price increases, generally due to anticipation of construction of a new road; (2) behavior influenced by taxes related to profits from other activities; and (3) application of resources derived from illegal economic activities such as drug traffic and corruption. This phenomenon calls for a better understanding.

### Managing Risk

A more proactive role for government is not without risk, which will have to be carefully managed from the outset. Included are the risk that ill-conceived policies or poor implementation may do more harm than good (*implementation risk*), as well as the risk that a strengthened and visible commitment of government to sustainable development in the Amazon might raise expectations and increase government's exposure to external and internal criticism for a less-than-complete resolution of the problem (*reputational risk*). We believe that the latter risk is much greater than the former, but both forms must be well managed. Both implementation and reputational risk can be controlled through careful attention to project phasing, participation of stakeholders, and information dissemination.

Implementation risk can be controlled through project phasing in several ways. For example, essential policy change can be put in place prior to implementation of physical activities. In addition, activities can be implemented on a limited scale, carefully monitored, with additional scaling up of activities conditioned on satisfactory results in the first phase. Participation and information dissemination throughout project preparation and implementation are critical to ensure that all stakeholders have a common understanding of emerging problems and to provide the best possible chance that mutually agreeable solutions can be found.

Reputational risk has two dimensions. Both can be controlled through solid programs of stakeholder participation, monitoring, and information dissemination. The first is the possibility that the project could be blamed for activities that are beyond its scope. For example, illegal, predatory logging undoubtedly will continue in most of the Amazon for decades after the initiation of any project. To help to delineate reasonable expectations for the project, it will need a solid base of stakeholders: industry; indigenous peoples; state, federal, and local governments; as well as NGOs and academics. Part of the role of these stakeholders will be to monitor and evaluate the project, and to disseminate to the general public accurate interpretations of its success. In addition, as mentioned above, stakeholders would help monitor progress and establish the conditions to expand the project's activities.

Finally, the authors believe that risk must be evaluated against potential gain. The authors believe that this report has made the case that in terms of improving quality of life for local Amazonian communities, as well as protecting the forest environment, a proactive role for government to establish National Forests and strengthen the policy framework for sustainable logging is well worth the possible risks.

# Conclusion

Agricultural performance in the Amazon is strongly determined by rainfall patterns; experience with agriculture in the Amazon has been based primarily on the development of relatively dry areas. The evidence suggests that, in the humid tropics, agricultural performance would be substantially worse than the marginal performance observed to date.

In the humid tropics, sustainable forest management can offer more jobs, more stable communities, and a better return on investment in infrastructure than can agriculture (including ranching).

If market forces act freely in the region, predatory logging associated with ranching will predominate. In this case, the economy of Amazonian communities will tend to follow a boom-and-bust cycle. In other words, the first years will be characterized by rapid growth (boom), which will be followed shortly by a severe decline in revenue and employment (bust).

The predatory logging model has exhausted forest resources in the older logging centers. In response, companies are migrating in a disorganized manner to new frontiers, such as Novo Progresso (Pará) and Apui-Nova Aripuana (Amazonas). In these regions, the government has the opportunity to avoid the repetition of the predatory cycle and the alienation of unsettled lands. The most promising alternative, from both the social and environmental points of view, is the creation of a network of National Forests. These public forests would form part of a mosaic of conservation areas, including areas of complete protection (parks and reserves). A recent study revealed that there are at least 700,000 km$^2$ of forests in the Brazilian Amazon (14 percent of the region) with potential for the creation of National Forests (Veríssimo and others 2000). This area would be sufficient to meet sustainably the current and near-term future demand on the wood sector.

The sustainable use of natural resources would result in greater benefits (revenue and employment) in the long term. However, in the short term, the financial and political benefits of predatory logging tend to be greater. Therefore, it is essential that the government assume the responsibility of guaranteeing sustainable development.

The government should stabilize the local economy through economic tools and command and control. These instruments include increasing the profitability of forest management, applying a tax on wood derived from predatory logging, designating National Forests, and improving the monitoring and control system.

# Appendix 1
# Methods Used in the Economic Analysis of Logging and Ranching Activity

The authors divide the methods used to prepare an economic analysis of logging and ranching in three parts. Initially, the procedures to model predatory timber harvesting and forest management are explained. Then the values and technical coefficients used to calculate the gross revenue for ranching are described. Finally, the authors present the calculation of jobs generated and the financial analyses of ranching and timber harvesting.

### Modeling Timber Harvests

In the simulation, the authors used an area of approximately 10,000 km$^2$ (1 million ha) (figure A1-1). This area is cut by a highway and by two secondary roads. The wood-processing center is located in the center of the area. At the beginning of the simulation, the authors assume that the entire area is covered by intact native forest ($t$=0).

#### *Predatory Logging*

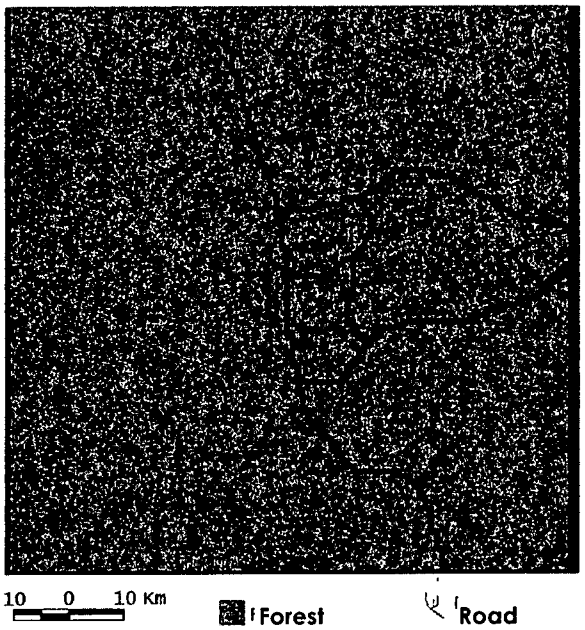
The simulation of predatory logging was based on the concept of "waves of extraction" in accord with the work of Stone (1998b) and Schneider and others (unpublished). Loggers from a given sawmill center maximize profits by harvesting trees with the highest net profit (subtracting the cost of transportation). The net profit ($\pi$) of extraction of a group of species $k$ located in the cell $i$ can be described as

$$[1] \quad \pi_{i,k} = X_{i,k}\left[\phi\left(P_k - C_p\right) - C_e - St_k - Ct_i\right]$$

where

- $X_{i,k}$ is the timber volume of species group $k$ extracted in the cell $i$
- $\phi$ is the conversion factor for logs to sawn timber (0.35)
- $P_k$ is the price of sawn wood (US\$/m$^3$ sawn)
- $Cp$ is the variable cost of production (US\$/m$^3$ sawn)

**Figure A1-1. Area used in logging simulations**




*Source:* Authors

$Ce$ is the variable cost of extraction (US\$/m$^3$ unprocessed)

$St_k$ is the standing value of timber (US\$/m$^3$ unprocessed)

$Ct_i$ is the cost of transport from cell $i$ to the sawmill center (US\$/m$^3$ unprocessed/km).

Therefore, the objective of the industry is to maximize the total profits, considering limitations of production capacity:

[2] $$Max \sum_i \sum_k \pi_{i,k,t}$$

such that

[3] $$\sum_i \sum_k X_{i,k,t} \leq \overline{Y}_t$$

where

$$\overline{Y}_t = \overline{Y}_0 (1+r)^t$$

and

$$\overline{Y}_{MAX} = 1{,}207{,}000\ m^3$$

where $\overline{Y}_t$ is the processing capacity of the processing center at time $t$. The processing capacity varies through time. In this exercise, the authors consider the initial processing capacity ($\overline{Y}_0$) to be 190 thousand m$^3$ of logs/year, growing at a rate $r$ of 0.26 per year ((value observed in Paragominas by Veríssimo and others (1992) and used by Stone (1998b) as the maximum growth rate)). This capacity increases up to a limit of 1.2 million m$^3$ of logs per year (half the value found in the sawmill center of Paragominas).[15] The authors group tree species into three value classes: high, intermediate, and low.

The calculations of optimization were made by simultaneously using ArcView (GIS) and an Excel spreadsheet, as described in Stone (1998b). The authors used the ArcView algorithm *cost grow* to model transport costs. Transport (costs) frictions were defined based on work by Veríssimo and others (1992, 1995, 1998, unpublished) and Stone (1998b). Parameters used to calculate transport costs and profitability are presented in table A1-1.

In the case of predatory logging, without management, the authors assume that loggers transport only 84 percent of the volume of cut timber to patios and sawmills. In accord with Barreto and others (1998), the remaining volume is simply forgotten in the forest or lost due to inappropriate felling techniques.

The gross revenue in year $t$, in accord with equations [1] and [2] is

$$RB_{i,k} = \sum_i \sum_k \phi X_{i,k} P_k$$

where

$X_{i,k}$ optimizes equation [2].

### Forest Management

Current legislation regulating forest management does not permit "extraction waves." Once a given area has been logged, it cannot

**Table A1-1. Parameters used to model timber extraction**

| Parameter | Value |
|---|---|
| Price of high value sawn wood (US\$/m$^3$) | 280.00 |
| Price of medium value sawn wood (US\$/m$^3$) | 239.00 |
| Price of low value sawn wood (US\$/m$^3$) | 158.00 |
| Price of standing timber – high value (US\$/m$^3$) | 9.38 |
| Price of standing timber – medium value (US\$/m$^3$) | 5.21 |
| Price of standing timber – low value (US\$/m$^3$) | 3.75 |
| Average variable cost of extraction (US\$/m$^3$) | 7.59 |
| Average variable cost of processing (US\$/m$^3$) | 24.58 |
| Transport costs – paved road (US\$/km) | 0.10 |
| Transport costs – closed forest (US\$/km) | 2.00 |
| Transport costs – logged forest (US\$/km) | 1.30 |
| Volume of high value wood (m$^3$/ha) | 3.50 |
| Volume of medium value wood (m$^3$/ha) | 17.50 |
| Volume of low value wood (m$^3$/ha) | 14.00 |

*Source:* Veríssimo and others 1992, 1995, 1998, unpublished.

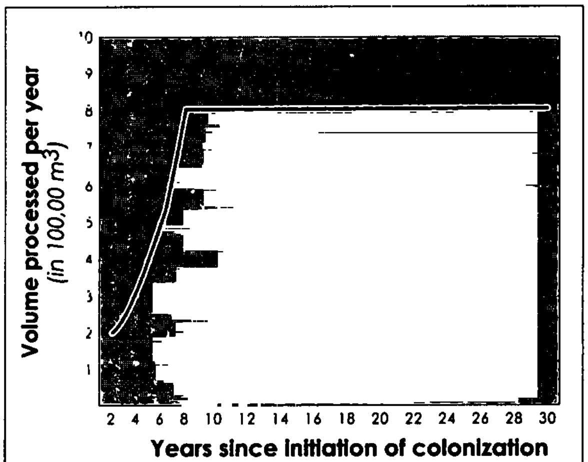
suffer a new harvest before the rotation cycle, estimated at 30 years, is complete. The problem to be maximized can be described in the same way as in equation [2]. However, there are two crucial differences. First, the significance of subscript $k$ changes. The problem now is to choose the cells that offer the greatest possible profit. For each cell there are three options:

- $k$=1 Harvest species from the three value groups (high, medium, low) simultaneously
- $k$=2 Harvest species from high- and medium-value groups
- $k$=3 Harvest only the high-value species.

The second difference is in the growth of the sawmill center's processing capacity. The growth of the center was limited, because the total economically viable volume was extracted ( $\overline{Ytotal}$ ) over the 30-year rotation cycle, in accord with equation [5]. Figure A1-2 illustrates the processing capacity during those 30 years.

[4] $$\left[\sum_{i}\sum_{k}\sum_{t} X_{i,k,t} \mid \pi_{i,k,t} > 0\right] = \overline{Ytotal}$$

**Figure A1-2. Aging processing capacity of logging center under forest management**




*Source:* Authors' calculations above.

*Growth in processing capacity.* The authors calculate the growth rate ($r$) in such a way that

[5] $$\sum_{t=0}^{T} \bar{Y}_0(1+r)^t + (30-T)\bar{Y}_T = \overline{Ytotal}$$

$$r \leq 0.26$$

where

> $Y_T$ is the capacity reached in year $T$ which will permit processing ( $\overline{Ytotal}$ ) over the 30-year cycle. Year $T$ and growth $r$ are calculated by iteration, holding $r$ as close to 0.26 as possible.

## Ranching

*Area in pasture.* The area in pasture considered for the calculation of gross revenue was proportional to the tabulations made by Chomitz and Thomas (2001). In dry regions, 31.8 percent of the total area was pasture; in the transitional zone, pasture represented 10.1 percent; and in the humid zone, this proportion was 1.8 percent. In humid areas with good infrastructure and market access (Bragantine region, Pará), this value increased to 13 percent (table A1-2).

The authors considered that pasture planting would occur shortly after logging medium-value species (between years 4 and

**Table A1-2. Pasture planted per rainfall zone and average stocking rate of pastures**

| Rainfall zone | Percent of total pasture area | Average stocking of pastures (head/ha) |
|---|---|---|
| Dry | 31.82 | 0.67 |
| Transitional | 10.10 | 0.67 |
| Humid | 1.82 | 0.40 |
| Humid (good infrastructure) | 13.00 | 0.67 |

*Source:* Chomitz and Thomas 2001.

22). At each period, an area proportional to the percentage of pasture in each region was converted following logging. In this fashion, at the end of the twentieth year, the pastureland in the dry region corresponded to 31.8 percent of the total land area. The same procedure was adopted to calculate pasture area in the transitional and humid zones (figure A1-3).

$$AP_{r,t} = M_t \frac{\gamma_r}{\rho}$$

$$t = 4 \ldots 22$$

where

$AP_{r,t}$ = area converted to pasture in year $t$ in region $r$
$M_t$ = area logged for timber of medium value in year $t$
$\gamma_r$ = proportion of pasture in region $r$
$\rho$ = proportion of the total area possessing medium-value timber in the entire period (0.788).

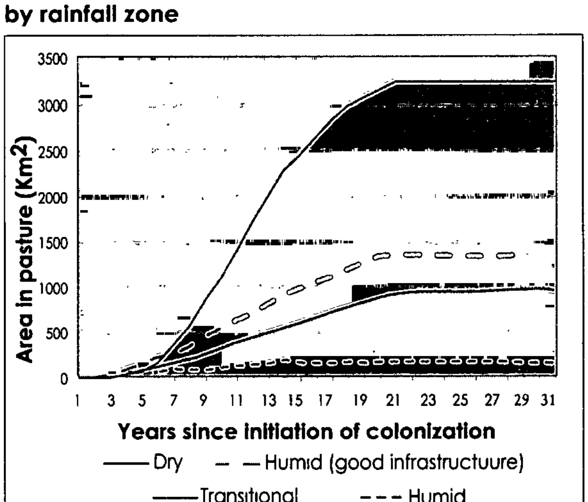
The number of cattle was determined as follows: for each year, the authors calculated the herd of the pasture area according to the sum of the stocking rate in each cell. Stocking pastures in each cell varied according to the age of the pasture. The average stocking rate during the period was 0.67 animals per ha (table A1-3). For example, pasture with 2 years of use supported a density of 2 animals per ha, while pastures with 12 years of use supported only 0.2 animals per ha. In the humid zone, a constant pasture-stocking rate of 0.4 animals per ha was used, consistent with Chomitz and Thomas (2001). After 12 years of use, the present authors assumed that pastures would be replanted and the cycle would recommence.

$$Herd_t = \sum_{i=1}^{N} L_{i,a} C_i$$

where

$Herd$ = number of animals in year $t$
$N$ = total number of cells in pasture in year $t$
$L$ = stocking of pasture of age $a$ in cell $i$ (animals/km$^2$)
$C$ = area in cell $i$ (km$^2$)
$t$ = 4…30.

**Figure A1-3. Aging of area in pasture by rainfall zone**




*Source:* Authors' calculations (see text above).

**Table A1-3. Stocking pastures**

| Pasture age (years) | Stocking (animal/ha) |
|---|---|
| 1 | 0.25 |
| 2 | 2.00 |
| 3 | 1.25 |
| 4 | 1.00 |
| 5 | 1.00 |
| 6 | 0.75 |
| 7 | 0.50 |
| 8 | 0.30 |
| 9 | 0.20 |
| 10 | 0.20 |
| 11 | 0.20 |
| 12 | 0.20 |

*Source:* Hecht and others 1988.

**Table A1-4. Assumed zootechnical indices**

| *Assumed zootechnical indices* | *Rate (%)* |
|---|---|
| Birth rate | 70 |
| Death rate of heifers | 8 |
| Death rate of yearlings | 3 |
| Death rate of adults | 2 |

*Source:* Arima and Uhl 1997.

**Table A1-6. Sale value of animals**

| *Animal* | *US$/unit* |
|---|---|
| Bull | 420.00 |
| Cow | 252.60 |
| Fattened bull | 346.50 |

*Source:* Arima and Uhl 1997.

After the authors had obtained the total number of animals in each year (*herd*), the authors simulated the herd composition according to zootechnical indices described in table A1-4. The simulation of the herd also provided the number of animals sold.

The authors assumed that the whole herd is meant for beef production—calf production, steer raising, fattening—the most common case in the Amazon (table A1-5).

The gross revenue from ranching was calculated by multiplying the number of animals sold by the prices (table A1-6).

### Jobs Generated

Predatory logging employs workers in the harvest, transport, and processing phases. To generate one job, 283 $m^3$ of unprocessed wood are required. On the other hand, in addition to the above phases, forest management employs people in silvicutural treatments and harvest planning, In a managed system, 258 $m^3$ of wood are necessary to support one job. The number of jobs was calculated using technical coefficients taken from the literature (Veríssimo and others 1992, Barreto and others 1998).

Ranching generates one job per group of 39 animals, including permanent and temporary employment. Employment coefficients were calculated based on the works of Mattos and Uhl (1994) and Arima and Uhl (1997).

### Net Present Value

The Net Present Value (NPV) and Internal Rate of Return (IRR) of logging activity, including timber extraction and wood processing, were obtained through the methodology described for items A and B (table A1-7). The value of equipment, investments, and useful life were obtained from Veríssimo and others (1992) and Barreto and others (1998).

**Table A1-5. Example of herd composition**

| | *Herd composition: Cow-calf operation* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Adult 3-4 years* | | *2-3 years* | | *1-2 years* | | *0-1 year* | | |
| | *Bulls* | *Cows* | *Males* | *Females* | *Males* | *Females* | *Males* | *Females* | *Males* | *Females* | *Total* |
| Existing | 2,402 | 60,054 | 17,814 | 17,814 | 18,177 | 18,177 | 19,337 | 19,337 | — | — | 173,112 |
| Purchased | 721 | — | — | — | — | — | — | — | — | — | 42,038 |
| Births | — | — | — | — | — | — | — | — | 21,019 | 21,019 | 34,434 |
| Deaths | — | 1,201 | 356 | 356 | 364 | 364 | 1,160 | 1,160 | 1,682 | 1,682 | 173,112 |
| Sales | 721 | 9,008 | 17,457 | 7,248 | — | — | — | — | — | — | |
| Balance | 2,402 | 49,845 | — | 10,209 | 17,814 | 17,814 | 18,177 | 18,177 | 19,337 | 19,337 | |

*Source:* Authors' calculations.

**Table A1-7. Calculated Internal Rate of Return (IRR) and Net Present Value (NPV) of ranching and of extracting and processing wood**

| Activity | IRR (percent) | NPV 6% (US$) | NPV 10% (US$) |
|---|---|---|---|
| Extracting and processing wood | 122 | 138,615,463 | 97,980,954 |
| Ranching (dry zones; 31.82% of pasture area) | 4 | −9,672,789 | −14,733,392 |

*Source:* Authors' calculations.

Appendix 2

# Financial Returns from Timber Harvesting and Ranching in the Amazon

The objective of this brief literature review is to compare the financial returns of logging and ranching presented in this study with data in other published studies on the subject. The comparison is rendered difficult by the different perspectives taken in other studies. For example, no article on financial returns from logging addresses the harvest and processing phases while considering the increase in transport costs that result from wood scarcity in the proximity of sawmills.

## Logging Activity

Recently, Pearce and others (1999) conducted a literature review on financial returns from predatory logging and forest management in tropical forests (summarized in table A2-1). Note that, unless specified, the analyses in these studies did not include log processing.

In general, this review points out that forest management is not economically competitive with predatory logging. In virtually all cases, management generates positive Net Present Values (NPV) (with discount rates varying from 5 percent to 20 percent). The only exception is the study on Peru by Southgate and Elgegren (1995), in which the NPV was negative.

Practically all the NPVs of conventional systems cited in this review are superior to those encountered in the present study (table

**Table A2-1. Review of literature**

| *Study* | *Country* | *NPV (US$/ha)* | *Assumed discount rate (%)* |
|---|---|---|---|
| Bann 1997 | Cambodia | PL = 1,697 / FM = 408 | 6 |
| Haltia and Keipi 1997 | Costa Rica | Forest management better than ranching | — |
| Howard and others 1996 | Bolivia | PL= 334-449 / FM= 204-263 | 10 |
| Kishor and Constantino 1993 | Costa Rica | PL =1292 / FM = 854 | 8 |
| Kumari 1996 | Malaysia | PL = 860-1380 / FM = 322-944 | — |
| Mendoza and Ayemou 1992 | Côte d'Ivoire | Forest management + processing = 160 | 10 |
| Richards 1991 | Mexico | 14%–15% annual return on capital, including processing | — |
| Southgate and Elgegren 1995 | Peru | NPV negative | — |

*Note:* PL = predatory logging; FM = forest management.
*Source:* Pearce and others 1999, 16–18.

A2-2). This difference occurs due to the scale of the analysis. These studies (cited in table A2-1) analyzed the financial return at the scale of the property. The present authors' study was done at the municipal scale, at which transport costs have a large influence on financial returns.

Only two articles incorporated both the extraction and processing phases. Mendoza and Ayemou (1992), in Côte d'Ivoire, observed a NPV/ha of US$160, using a discount rate of 10 percent. At this same discount rate, the present authors' study found a value of approximately US$100/ha (table A2-2). Richards and others (1991), in Mexico, noted an annual return rate on capital of 14 percent to 15 percent. Unfortunately, it is not possible to compare these results with the present authors' study, because the latter used a horizon of 30 years.

Studies of timber harvesting in the Amazon consist primarily of those conducted by Imazon. Studies by Uhl and others (1991), Veríssimo and others (1992, 1995), Barros and Uhl (1995), and Johns and others (1996) analyzed the financial returns of predatory harvesting and processing in different regions of the Amazon. The scale of the analyses was that of a typical sawmill. In general, the annual profit margins (profit/gross revenue) were greater than 25 percent. Barros and Uhl observed Internal Rates of Return (IRR) of 124 percent for small sawmills that used fluvial transport in the estuary of the lower Amazon. Larger sawmills on *terra firma* harvesting wood up to 100 km from the mill obtained IRR of 14 percent to 62 percent,.

Ozório de Almeida and Uhl (1995) used the data of Veríssimo and others (1992) to calculate an IRR for logging activity on the municipal scale. In the predatory system, extraction and processing generated IRR of 108 percent, whereas in the managed system, IRR was 103 percent. Considering only the harvesting phase, the returns were 33 percent and 29 percent with and without management, respectively. The differences in the returns obtained in Ozório de Almeida and Uhl and in the present study (122 percent without management, 73 percent with) occurred principally due to the fact that Ozório de Almeida and Uhl did not explicitly incorporate differences in transport costs or the "extraction waves" described in appendix 1. The difference in area harvested under managed forestry and traditional predatory logging is shown in table A2-3.

Barreto and others (1998) analyzed the costs and benefits of forest management on an experimental scale (100 ha). The authors observed a NPV per ha of US$430 with a discount rate of 20 percent. In addition, they concluded that management is more profitable than predatory logging due to greater efficiency of machine use and better use of logs.

Another study, for the USDA Forest Service, conducted recently by Holmes and others in the Paragominas region, observed results similar to those of Barreto and others (1998).

**Table A2-2. Net Present Values (NPV) per ha**

| Discount rate (%/year) | Management (NPV/ha) | Predatory logging (NPV/ha) |
|---|---|---|
| 6 | 163.27 | 150.41 |
| 10 | 99.50 | 106.32 |
| 15 | 58.54 | 72.03 |
| 20 | 35.82 | 50.75 |
| 30 | 16.46 | 27.53 |

*Source:* Authors.

**Table A2-3. Area harvested**

| Wood value class | Area harvested (ha) | |
|---|---|---|
| | Managed forestry | Predatory logging |
| High, medium, low | 456,400 | 492,200 |
| High, medium | 382,800 | 303,600 |
| Medium | 59,100 | 125,800 |
| **Total** | 898,300 | **921,600** |

*Source:* Authors' calculations.

Holmes and others compared an industrial-scale managed harvest (500 ha) to the predatory system and found that management was more lucrative: US$11.6/$m^3$ versus US$9.84/$m^3$, or US$294/ha versus US$250/ha.

Stone (1998a) employed GIS and an optimization model of industry profit (harvesting and processing) to project logging in the state of Pará for the period 1996-2000. In the scenario in which timber prices increase 3 percent per year and processing capacity grows at an annual rate of 16 percent, an area of 22 million ha would be logged during this 4-year period, generating gross revenue of US$1,677 per ha in today's values (discount rate of 5 percent). In the present authors' study, the present value of gross revenue was US$940 per ha for the predatory system compared to US$965 per ha for managed forests, using the same discount rate (5 percent).

## Ranching

The literature on ranching on *terra firma* in the Brazilian Amazon can be divided into three phases. In the first phase—1960 to 1970—the studies had an agricultural and zootechnical focus and demonstrated that the Amazon region was appropriate for cattle production, because the grasses grew vigorously and the animals achieved good weight gains (Falesi 1976).

The articles in the second phase of the literature, the 1980s, showed that ranching did not have a satisfactory financial performance. Hecht and others (1988) observed that, using traditional technology, the IRR was negative. The return rates were positive (5 percent to 31 percent) only when there was a combination of two or more of the following factors:

1 Ranches received financial incentives and subsidized credit.
2 Land prices increased (speculation).
3 Overstocking took place in the initial period.
4 There was a high ratio between cattle prices and input prices.

Browder (1988) and Fearnside (1980) reached similar conclusions.

In the 1990s, in general, the ranching studies supported the conclusions from work in the previous decades, but they also demonstrated the economic viability of specific ranching models, such as small-scale milk production. For example, Mattos and Uhl (1994) analyzed ranches in Paragominas and observed that ranching practiced in an extensive form generated IRR lower than 5 percent. In contrast, dairy ranching on a small scale produced returns of 12 percent, and beef ranching in reformed pastures obtained returns of 12 percent to 21 percent.[16]

Muchagata and others (1999) completed a detailed survey of 20 small properties in the Marabá region (PA) during one year. The authors noted annual incomes (net of variable costs and depreciation) that varied from negative R$39/ha for very small ranches (12 ha of pasture) to positive values of R$42/ha for larger ranches (85 ha of pasture). These properties sold milk and animals and, in some cases, rented pastures.

Faminow and others (1998) demonstrated that the predominance of pasture and cattle on small properties was due to the lower risk of this activity in relation to agroforestry systems. In addition, they showed that the risks of variation in prices and production limited the adoption of more intensive technologies. The average profits per ranch were R$6,000, much higher than the Brazilian per capita GDP.

The data used in the present study were obtained from Arima and Uhl (1996). Ranching on *terra firma* (south of Pará state) in the traditional extensive system generated IRR of 3 percent to 5 percent. Small ranches specializing in dairy production obtained higher IRR, around 9 percent. These numbers are consistent with a study conducted by the Rural Syndicate of Araguaina, Tocantins (Nehmi Filho 1999) in which the IRR was 5 percent in

Redenção (south of Pará), 7 percent in Araguaina (TO), and 5 percent in Guaporé (MT).

In summary, the studies conducted to date demonstrate that the extensive ranching practiced by the majority of ranchers generates a very low return. Small dairy ranches located close to highways obtain satisfactory returns (~10 percent). Despite these findings, the increases in the Amazonian cattle herd and in extensive ranching continue without apparent economic justification. Various explanatory hypotheses, such as capital gains with land valuation, await empirical verification.

# Appendix 3
# Calculating Carbon Compensation and Taxation Values under Predatory Logging

This appendix explains how the authors obtained the carbon compensation values and the taxes necessary to equalize revenues between predatory logging and forest management

## Analysis of Gross Revenue

Table A3-1 shows the Gross Present Values (GPV) without compensation for carbon or taxation.

The calculation of carbon compensation values is simple. The authors assumed the payments for additional carbon retained in the system under management were made in year $t$=0, following equation [1]. Only the values of the benefits were discounted in time (gross revenue). The values obtained are listed in tables A3-2a and A3-2b.

$$\sum_{t=0}^{23} \frac{Bt_t}{(1+r)^t} = \sum_{t=1}^{30} \frac{Bm_t}{(1+r)^t} + CP \qquad [1]$$

where

$Bt$ = gross revenue of the predatory system (extraction + processing + ranching)
$Bm$ = gross revenue of management (extraction + processing)
$CP$ = carbon payment
$r$ = discount rate.

**Table A3-1. Gross Present Value (GPV) in the current situation: Humid zone and transitional areas**

| | GPV at 10% (US$) | GPV at 4.92% (US$) | GPV at 3.8% (US$) |
|---|---|---|---|
| Predatory logging + ranching (humid zone)[a] | 525,713,391 | 876,524,943 | — |
| Predatory logging + ranching (transitional zone) | 539,133,403 | — | 1,021,434,609 |
| Managed system | 463,900,558 | 876,524,943 | 1,021,434,609 |

*Note:* Under a discount rate of 4.92% (in humid areas), society would be indifferent between the GPV of predatory logging/ranching and managed forestry. Under a discount rate of 3.86% (in transitional areas), society would be indifferent between the GPV of predatory logging/ranching and managed forestry.
a. 1.83% pasture, without carbon payments or taxes.
*Source:* Authors' calculations.

**Table A3-2a. Value of payments for carbon necessary to equalize the GPV of the predatory system and management (humid zone) under different discount rates**

| Discount rate (percent) | GPV (US$) | Value of carbon credits | Price of carbon (US$/ton) |
|---|---|---|---|
| 10 | 525,713,391 | 114,384,172 | 8.67[a] |
| 15 | 343,775,327 | 111,823,577 | 8.48 |
| 20 | 239,838,181 | 96,709,188 | 7.33 |

*Note:* Assumes carbon payments in year $t_0$.
a. For calculation of carbon saved, see D below.
*Source:* Authors' calculations.

**Table A3-2b. Value of payments for carbon necessary to equalize the GPV of the predatory system and management (transitional zone) under different discount rates**

| Discount rate (percent) | GPV (US$) | Value of carbon credits | Price of carbon (US$/ton) |
|---|---|---|---|
| 10 | 539,133,403 | 129,146,186 | 4.05[a] |
| 15 | 350,650,557 | 119,730,092 | 3.76 |
| 20 | 243,686,326 | 101,326,961 | 3.18 |

*Note:* Assumes carbon payments in year $t_0$.
a. For calculation of carbon saved, see D below.
*Source:* Authors' calculations.

## Private Sector Analysis: Compensation for Carbon

The analysis for the private sector was similar to the calculation above. The difference is in the use of liquid values {equation [2]}. The current values without compensation are given in table A3-3, and the values with carbon compensation appear in table A3-4.

$$[2] \quad \sum_{t=0}^{23} \frac{Bt_t - Ct_t}{(1+r)^t} = \sum_{t=1}^{30} \frac{Bm_t - Cm_t}{(1+r)^t} + CP$$

where

$Bt, Ct$ = costs and benefits of extraction and processing, predatory system
$Bm, Cm$ = costs and benefits of management
$CP$ = carbon payment
$r$ = discount rate.

## Private Sector Analysis: Taxes

The authors calculated the tax on conventional logging necessary for equalization of financial returns of predatory and managed logging {equation [3]}.

**Table A3-3. Economic performance of predatory logging and forest management**

| Parameter | Predatory logging | Forest management |
|---|---|---|
| IRR | 122% | 71% |
| NPV at 10% | 97,980,955 | 89,468,031 |

*Source:* Authors' calculations.

**Table A3-4. Value of carbon payments necessary to equalize NPV under different discount rates**

| | NPV (US$) | Value of carbon credits (US$) | Price of carbon (US$/ton) |
|---|---|---|---|
| Equalize IRR (122%) | — | 1,749,196 | 0.19[a] |
| NPV at 10% | 97,980,955 | 18,311,019 | 2.01 |
| NPV at 15% | 66,384,009 | 23,750,838 | 2.61 |
| NPV at 20% | 46,773,192 | 23,049,966 | 2.54 |

*Note:* Assumes carbon payments in year $t_0$.
a. See calculation of reduction in carbon emissions in D below: 9,100,000 tons.
*Source:* Authors' calculations.

$$[3] \qquad \sum_{t=0}^{23} \frac{(Bt_t \times \pi) - Ct_t}{(1+r)^t} = \sum_{t=0}^{30} \frac{Bm_t - Cm_t}{(1+r)^t}$$

where

$\pi < 1$ is the tax charged.

The value of the tax per cubic meter of wood harvested ($\overline{X}$) was obtained by dividing the total value of the tax by the total volume extracted (table A3-5).

$$[4] \qquad \sum_{t=0}^{23} Bt_t \times (1-\pi) = X$$

$$\overline{X} = \frac{X}{Vol}$$

where

$\overline{X}$ = value of tax (US$/m$^3$)
$Vol$ = total volume harvested (m$^3$ of logs).

## Carbon Emissions

The difference in the amount of carbon released by predatory logging and forest management was obtained following equation [5]. The quantities of carbon emitted at each harvest intensity are given in table A3-6.

$$[5] \qquad \Delta C_{im} = \sum_{i=1}^{3} C_i N_i - \sum_{m=1}^{3} C_m N_m$$

where

$C_i$ = amount of carbon released under predatory logging under harvest intensity $i$ (tons/ha)
$C_m$ = amount of carbon released by forest management at harvest intensity $m$ (tons/ha)
$N$ = area extracted at intensity $i, m$ (ha).

Predatory logging releases approximately 9 million additional tons of carbon when compared to forest management in an area of

**Table A3-5. Value of taxes on wood derived from predatory logging to equalize NPV under different discount rates**

| | NPV (US$) | Value of tax (US$/m$^3$) |
|---|---|---|
| Equalize IRR *(71%)* | — | 6.20 |
| NPV at 10% | 89,468,031 | 1.03 |
| NPV at 15% | 52,590,772 | 2.41 |
| NPV at 20% | 33,077,864 | 3.30 |

*Source:* Authors' calculations.

**Table A3-6. Carbon emission per ha**

| Harvest level | Released carbon (ton/ha) Predatory logging | Managed forest |
|---|---|---|
| High[a] | 4.0 | 2.19 |
| High and medium[a] | 13.0 | 7.13 |
| High, medium and low | 31.0 | 17.00 |
| Pasture | 240.1 | — |

*Source:* Gerwing and others.
a. Assuming that management reduces carbon emissions proportionally to high harvest intensity (17/31 = 0.548).

equal size (table A3-7). Pastures release an additional 4 million tons of carbon, although occurring in only 1.83 percent of the total area. In transitional areas (10.1 percent pasture), this difference between ranching and forest management reaches 22.7 million tons. In sum, the predatory system releases 13 million more tons of carbon than is released under forest management.

**Table A3-7. Carbon emissions in each activity**

| Activity | Carbon emitted (tons) | Additionality |
|---|---|---|
| Forest management | 10,617,432 | — |
| Predatory logging | 19,708,200 | 9,090,768 |
| Pasture – humid area (1.83% of total) | 4,407,698 | 4,095,616 |
| Pasture – transitional areas (10.1% of total) | 24,495,026 | 22,760,684 |

*Note:* Base = forest management
*Source:* Authors' calculations.

# Notes

1 As would be expected, the size of the property also has an important effect on the stocking rate.

2 A longer history of colonization (approximately one century), which resulted in more prolonged soil use, could be part of the cause of this low level of land use and high abandonment rate. On the other hand, this long history also implies that ample time has passed to identify adapted crops and technologies; yet none appears to have emerged.

3 Agricultural uses include pasture, annual crops, perennial crops, extractivism, and abandoned land.

4 To interpret these data, it is important to observe that the majority of public protected areas are in the humid zone, thus reducing the percentage of census areas in agricultural use. This high percentage in protected areas undoubtedly is also partially influenced by the low agricultural potential of these areas.

5 The net revenue is estimated at US$500 million, assuming a profit margin of 20 percent. (Profit margins oscillate from a minimum of 15 percent to a maximum of 25 percent. Veríssimo and others, unpublished.)

6 This forest management system has been developed and described by Imazon, Embrapa, and the Tropical Forest Foundation (TFF). Basically, the system consists of a selective harvest based on an inventory of commercial trees; planned roads, patios, and skid trails; vine cutting; directional felling; and planned skidding. In addition, the management plan should contain techniques to stimulate regeneration and growth of commercial trees and an annual harvesting schedule.

7 The economic model underlying this section is described in appendix 1.

8 Initially, Paragominas was established as a ranching frontier, stimulated by financial incentives. Mattos and Uhl (1994) interviewed 27 ranchers at the beginning of the 1990s and observed an Internal Rate of Return for ranching of 13 percent. Calculations made in this study reveal a rate of return of 3.1 percent for traditional techniques and 10 percent to 14 percent for more technologically advanced operations (appendix 1). Field evidence indicates that significant decapitalization has occurred in the region. However, it remains to be seen whether the decapitalization will lead to the abandonment of the rural area, or its consolidation under advanced technology.

9 This value, US$2-3 per ton, equalizes the Net Present Value (NPV) of sustainable

and predatory harvesting techniques, under discount rates varying from 10 percent to 20 percent.

10 The results of these interviews are: 80 percent were in favor of National Forests, 3 percent were opposed to their creation, and 17 percent had no opinion.

11 This section is based on the Ministério do Meio Ambiente (MMA) document, "Identification of Areas with Potential for the Creation of National Forests in the Legal Amazon" (Veríssimo and others 2000). The data and methodology are detailed in that publication.

12 The NOAA/ NASA AVHRR Oceans Pathfinder sea surface temperature (SST) data are derived from the 5-channel Advanced Very High Resolution Radiometers (AVHRR) aboard the NOAA-7, -9, -11, and -14 polar orbiting satellites. See <http://podaac.jpl.nasa.gov/sst/>.

13 Zoning land for agricultural use is seen by some farmers as a possible way to escape the restrictions of the legal reserve, which require at least 80 percent of each property to be under managed forests.

14 See <http://www.worldbank.org/html/extdr/offrep/lac/ppg7/index_e.htm>.

15 The simulation area corresponds to half of Paragominas county, the most important lógging center in the Amazon.

16 Pasture reform consists of removing invading vegetation, grading the area, planting better-adapted grasses, and, in some cases, applying fertilizer.

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