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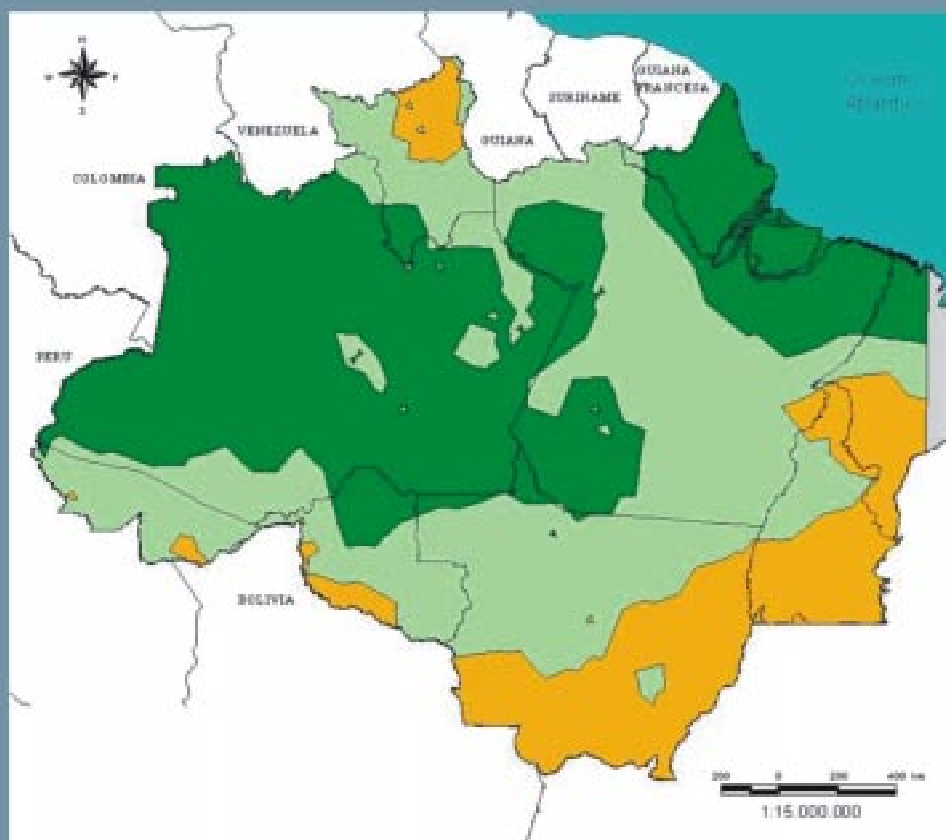
Sustainable Amazon: limitations and opportunities for rural development



Robert R. Schneider
Eugênio Arima
Adalberto Veríssimo
Paulo Barreto
Carlos Souza Júnior

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Robert R. Schneider
Eugênio Arima
Adalberto Veríssimo
Paulo Barreto
Carlos Souza Junior

Translation:
Mark Schulze

Editing:
Tatiana Corrêa

Electronic Editing and Cover:
Jânio Oliveira

Support:
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Paulo Barreto and Carlos Souza Jr. 2000

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Imazon
Caixa Postal 5101
66.613-970 - Belém, Pará - Brasil

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Any errors that exist in this report are the sole responsibility of the authors.

PREFACE

José Carlos Carvalho
Executive Secretary of the Ministry of the Environment

There is currently a rich debate in Brazilian society over the future of the Amazon. In these discussions, researchers, decision-makers, economic agents, social leaders, and environmental organizations have recognized the forestry vocation of this important portion of our territory. We all believe that it is possible to ensure development in the region while at the same time 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) entitled "Sustainable Amazon: limitations and opportunities for rural development".

The World Bank/Imazon report contains three important messages for the future of Amazon. First, there are severe natural restrictions (especially climatic) to the expansion of ranching and agriculture in vast areas of 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 so-called Dry Amazon (17% of lands), a zone characterized by moderate rainfall (less than 1,800 mm per year), situated in the south of the legal Amazon. In the rest of the Amazon (83%), the authors demonstrate that 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 case, the authors alert that the economy of Amazonian counties will tend to follow a "boom-and-bust" cycle. In the first years there will be illusory rapid growth (boom), followed by a severe decline in revenue, employment and collection of taxes (bust). In order to avoid this unsustainable cycle, the report suggests a series of economic tools and strategies, including adoption of a tax on wood derived from predatory logging, payment for environmental services provided by forests, expansion of the national forest and state systems, and incentives for forest management on private lands.

Finally, the report emphasizes the importance of expansion and consolidation of the national forest system of the federal government. The authors identify this initiative as the most promising measure for stabilizing the wood sector and promoting forest management in the new economic frontiers of the region. For the authors, 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).

In synthesis, the 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 (forest management and intensive agriculture) serve the interests of the local communities as well as national and global objectives. For the diverse actors involved in planning and implementation of land-use initiatives this announcement sounds extraordinary. It reveals concrete opportunities for a sustainable economy in Amazon based on the forest itself. It remains for us 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 classic model of deforestation that has characterized the Brazilian forestry sector.

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SUMMARY

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

First, agricultural success in 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 occurs because a wet tropical climate, without distinct seasons, offers the ideal conditions for 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 our analysis, we divided the legal Amazon (5 million hectares) 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, maintaining other factors constant, higher levels of rainfall in the Amazon reduce land conversion rates for agriculture as well as pasture productivity. Moreover, in the wettest areas there is an increased rate of land abandonment and soil degradation.

Land abandonment rises as annual rainfall increases, reaching approximately 20% 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 predatory logging associated with extensive ranching. In this case, Amazonian communities will tend to follow a boom and bust economic cycle. In the first years there will be rapid growth, followed by a severe decline in profits and employment. This pattern is already evident in the oldest logging frontiers, 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). This is because 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 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 creation 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; 3) separate agricultural and logging frontiers, thereby reducing the economic benefits that unsustainable agriculture currently receives from being associated with predatory logging.

A study by Veríssimo et al (2000) reveled that there are 1.15 million km^2 of forest in Amazon with potential for establishment of national forests. Of this total, approximately 38% coincides with areas of high importance for conservation of biodiversity (Macapá Consultancy 1999). In cases of overlap, we recommend designation of these areas for absolute protection. Even so, 0.7 million km^2 would remain for creation of national forests; an area more than capable of sustainably supplying the current and expected demands of the Amazonian wood sector.

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

Finally, local economic forces make sustainable development in the Amazon frontier difficult, as 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 more 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 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.

A more proactive role for government is not without risk, however, which will have to be carefully managed from the outset. This includes the risk that ill-conceived policies or poor implementation may do more harm than good (implementation risk), as well as the risk that a strengthed 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). We believe both implementation and reputational risk can be controlled through careful attention to project phasing, participation of stakeholders, and information dissemination. We also believe, based on the analysis presented in this paper, that the benefits of a more proactive 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 in Amazonian transport infrastructure, the Brazilian government is planning actions that will profoundly alter the regional landscape.

In the first place is a significant planned expansion of the transportation system 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 1980's, would 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 report as Amazon). Government's goal is to allocate 500,000 km^2 (10% of the Brazilian Amazon) for creation of national forests.

And, finally, the federal government has made an international commitment to protect biodiversity in Amazon through expanding national reserves (areas of complete protection) to cover a minimum of a representative 10% 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 unleashes. 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 wealth of accumulated experience through the Pilot Program to Conserve the Brazilian Rainforests (PPG7).

Government cannot remain passive, however. 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 decision-makers, economic agents and civil society in guaranteeing that Amazonian natural resources will be maintained in the highest value use, from an economic, social, and environmental perspective. In the first section we review the effects of rainfall on the agricultural productivity of Amazon. Second, we analyze the economic performance of the principal land-use activities. For this analysis, we consider a typical Amazonian county in the humid zone, whose economy is based on extensive ranching and predatory timber harvesting. In the third part, we examine the strategic role that government can play in ensuring economically sustainable development in the Amazon. Finally, we analyze Government's plan to expand and consolidate national and state forests (public areas of sustainable use) within this context of sustainable development.

THE EFFECT OF RAINFALL ON THE PERFOMANCE OF AGRICULTURE AND RANCHING IN THE AMAZON

In this section, we summarize the information available in the literature on agricultural performance in the tropics, and in particular the Amazon. We then conceptually divide the Amazon into three rainfall zones for the purpose of subsequent analysis. Finally, we employ data from the 1995-96 agricultural census (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 et al., 1998; Cochrane and Sanches, 1992; Uhl and Mattos, 1994). Schubart (2000), for example, concluded that approximately 90% of Amazonian soils are acidic, chemically poor and excessively humid. The last characteristic favors the development of insects and plant disease. Goodland and Smith (1975) affirmed that the hot, humid climate of Amazon is frequently 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 Sanches (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. The authors stated that, despite research efforts, the humid tropics continue to display low productivity for their primary crops (corn, rice, tubers, vegetables, and cattle and pig ranching). The exceptions are perennial crops such as banana, coconut and oil palm (Gallup and Sachs, 2000).

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, summarized the biological limits of agriculture in the tropics in the following manner:

> " 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 fungai, 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." (Sustainable Agriculture and the Environment in the Humid Tropics, 1993).

Recent Evidence

Recent scientific discussions have also emphasized the role of climate in the determination of 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 Ken Chomitz and Timothy Thomas (World Bank, 2000) offers a statistical verification of 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 Amazon, yielded similar conclusions to those of Sombroek and Chomitz and Thomas. Below, we summarize these studies.

Sombroek (unpublished) 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 the following:

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, there are greater losses in the drying of 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, as it restricts the multiplication of endemic diseases and their vectors.

Agriculture: In areas without a defined dry season, burning of recently cleared areas is generally incomplete. Crops such as rice, beans and corn require a dry period for the maturation and drying of the grains, 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 at a commercial scale is only viable 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 (especially soybeans) 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.

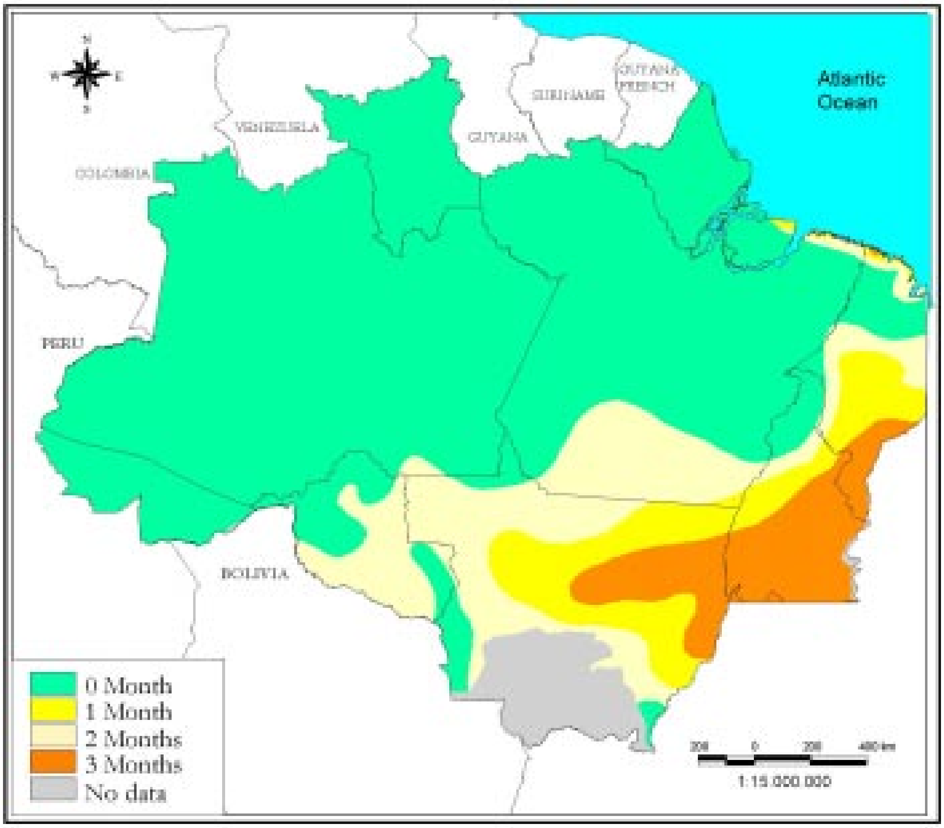

Figure 1. Number of consecutive months with rainfall inferior to 10 mm.

Chomitz and Thomas (2000)

Chomitz and Thomas conducted a statistical analysis of the 1995-96 agricultural census, relating agricultural land use and pasture stocking rate (number of animals per hectare of pasture), 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 (e.g. roads, distance to market, and soil characteristics). These authors confirmed that, controlling all these factors, precipitation has a significant negative effect on the intensity and type of land use.

The independent effect of rainfall can be observed by considering an example of a typical property in the Amazon with the following characteristics: 1) location: western Pará; 2) soils: oxisols; 3) distance to primary road: 25 km; 4) distance from the nearest area deforested in 1996: between 100 and 200 km; 5) distance from the closest city: 200 km.

In this case, the prediction of the effect of rainfall on land use, holding all other variables constant, is the following:

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

The effect of rainfall on the intensity of land use on a 500-hectare ranch[1] with the same characteristic as above would be the following:

Rainfall (mm)	Stocking (animals per hectare of pasture)
1,600	0.38
2,000	0.31
2,300	0.27

Consistent with the observations of Sombroek, Chomitz and Thomas note that soy represents a large proportion of agricultural production in areas where annual rainfall reaches 1,600 to 2,000 mm; there are 3-4 consecutive dry months; the limiting soil factor is a low level of phosphorus, nitrogen and retention of organic matter; and the basic vegetation is cerrado (savanna and scrub forest). Curiously, dairy ranching also appears to be favored by a dry climate, occurring almost exclusively in areas with annual rainfall below 2,200 mm.

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

First, climate and edaphic and agronomic factors are fundamental to soy cultivation. A large part of Amazon is covered by forests under an intense rainfall regime, with a reduced dry season. These conditions eliminate the opportunity for large-scale grain production in most Amazonian territory, either simply due to the presence of forest or to the inability to intensively mechanize operations.

Second, the potential for cultivating grains is found in the natural savannas and grasslands of the Amazon, which mainly occur in peripheral areas (south of the legal Amazon and Roraima) where there is a pronounced dry season.

Finally, the forests that cover the majority of the Amazon represent the natural vocation of the region; there is a great need to define areas for occupation by current and future populations.

Rainfall Zones of the Amazon

The analysis of Chomitz and Thomas (World Bank, 2000), based on the 1995-96 Agricultural Census data (IBGE) enabled us to identify three rainfall zones in the Amazon with distinct differences in agricultural

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

performance (Figure 2). We 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 base on information on climate, soils, relief, geology and vegetation. The Radam Brasil project covered an area of approximately 3.7 million km^2, or equivalent to 74% of Amazon. The cerrado and pantanal regions of Mato Grosso were not included.

Dry Amazon *(rainfall below 1,800 mm/year)*. The dry Amazon, receiving less than 1,800 mm rainfall per year comprises approximately 17% 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, there are sparse stretches of fertile soils 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.

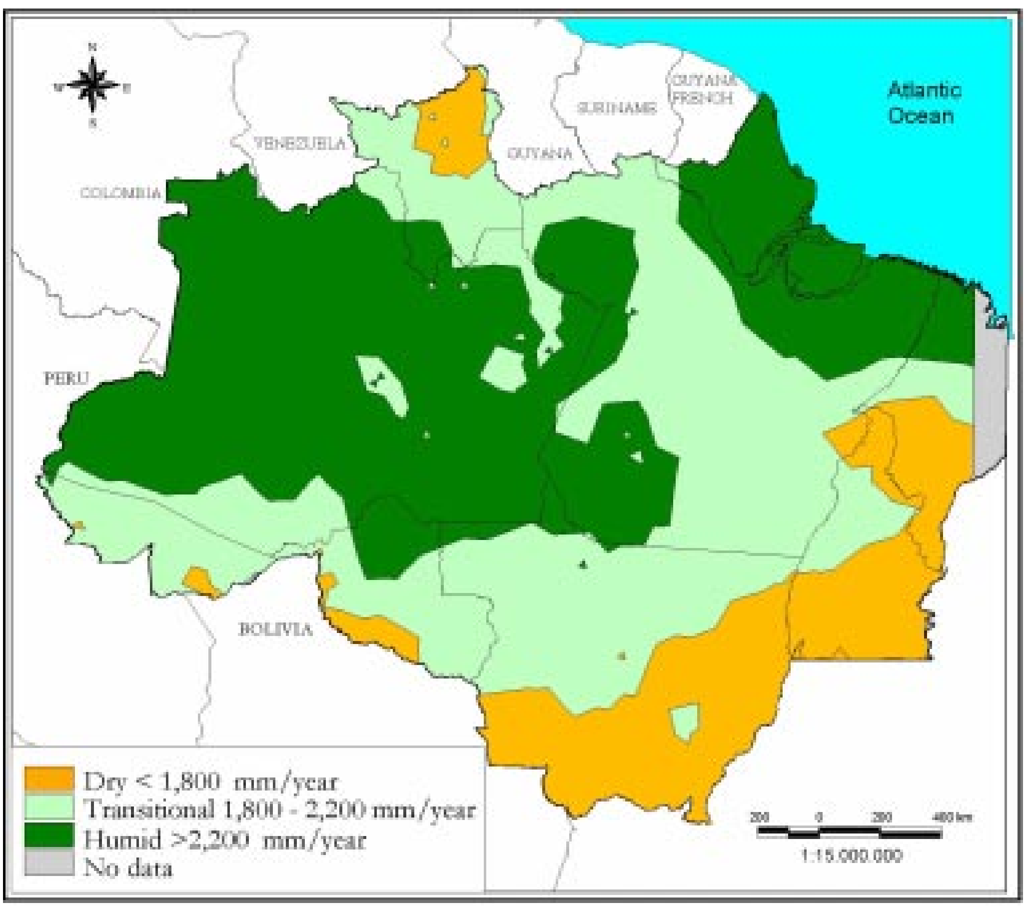

Figure 2. Principal rainfall zones in Amazon.

Transitional Amazon *(rainfall between 1,800 and 2,200 mm/year)*. The transitional zone represents approximately 38% of the Amazon and is largely located in the transition belt situated between the central region (humid zone) and the arc of Amazon deforestation in the south (dry zone). This region is generally covered by dense *terra firme* 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, there are isolated higher elevation areas 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*) that 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 that employ diversified agricultural systems have achieved a reasonable increase in standard of living (Schneider, 1994; Moran, 1989; Ozorio de Almeida, 1992; Jones et al., 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 (see 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% of 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) we found that 84% of the area possessed high or medium potential for timber extraction. In contrast, Radam Brasil concluded that only 7% (approximately 0.25 million km^2) shows agricultural promise, whereas 93% of the land presents either low or no agricultural potential.

Agricultural Performance on 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 man. 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 Amazon is instructive (see box).

AGRICULTURAL FAILURES IN AMAZON

Bragantina (Pará). Attempts to transform the Amazon into a vast area of agricultural production began at the beginning of the 20th century. In 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, and brick houses) the majority of lots are now abandoned.

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

Ranching. In Acre, approximately 550,000 hectares 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 Amazon (approximately 20% of the territory), including Acre and southern Amazonas.

Soybeans. At the end of the 1990's, 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. It was impossible to harvest a third of the 600 hectares that were planted, due to excessive rains.

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 is still insurmountable. The productivity of Brazil nut in open field conditions (Itacoatiara, Amazonas) was significantly lower than in the experiments conducted by Embrapa. This failure served to discourage Brazil nut planting in other parts of the Amazon (Dean, 1989).

There is a certain risk in generalizing from successes or failures of agricultural experiments, however, without either a long period or wide range of experience to observe the effect of varying production factors. The results of Chomitz and Thomas (2000) which controls statistically for many of these factors however, allow us to generalize with some degree of confidence about the negative effects of high levels of rainfall on agricultural productivity. A review of the most recent census data also provides further test of the validity of these generalizations.

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

In order to differentiate the effect of distance from the property to the primary road, we considered two situations, 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 graphs show the same abrupt drop in the percentage of census area in agricultural use in areas with rainfall greater than 1,800 mm

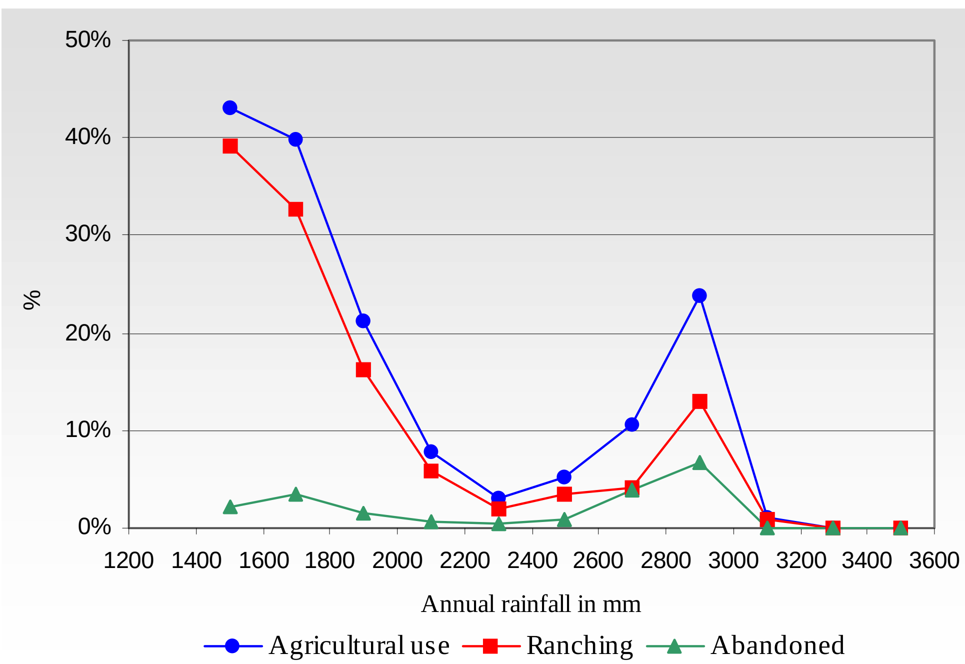

Figure 3.
Areas in agricultural use (%) in relation to rainfall: within 25 km of a main road.

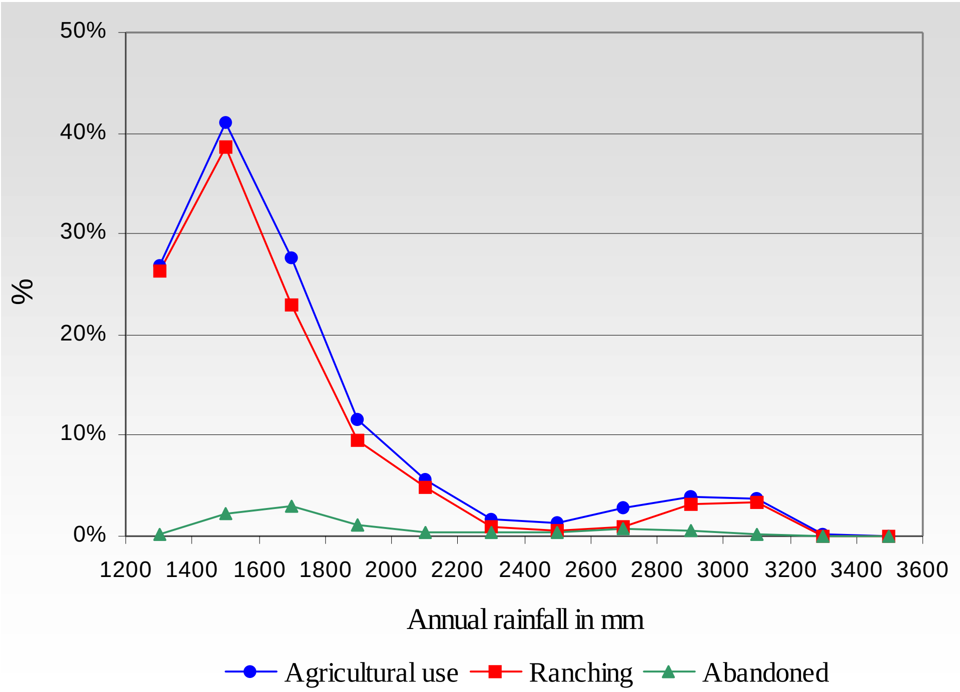

Figure 4.
Areas in agricultural use (%) in relation to rainfall: more than 25 km from a main road.

per year. Below 1,800 mm, both graphs show that 30-40% of the land is designated agricultural. This number falls abruptly to 5% as annual rainfall rises to 2,200 mm. In area farther than 25 km from roads, the agricultural land covers no more than 5%. In the case of land closer to roads, agricultural use increases to approximately 23% at 2,800-3,000 mm rainfall, and then drops rapidly to almost 0%.

The low agricultural productivity in Amazon is frequently blamed on poor infrastructure and absence of markets rather than on climatic factors. The apex of the curve of agricultural use allows us to judge up to what point a good transport and market system can overcome the negative effect of excessive rainfall. This apex in the curve represents the Humid Zone micro-regions of Belém-Bragança (Pará) and Macapá (Amapá), situated 25 km from a main road and with easy access to large markets. Nevertheless the zone displays low land use and a high proportion of abandoned land compared to the humid zone as a whole.[2]

In order to better understand the dynamics of land use and rainfall we classify the census data into the three rainfall categories discussed above. These zones correspond to 17% (dry), 38% (transitional), and 45% (humid) of Amazon.

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 appear to have emerged.

In Table 1, we present the proportions of the census areas with established agriculture and the percentage destined for agricultural use.[3] The effect of rainfall is evident: 55.6% percent of land in the dry zone is in agricultural establishments and 38.2% is in agricultural use, while in the humid zone these proportions only reach 7.5% and 3.2%, respectively.[4]

In Table 2, we display the types of agricultural land use in each rainfall zone. Approximately 83% of land in agricultural use in the dry zone is under

Table 1. Land use in Amazon by rainfall zone.

Rainfall Zone[1]	Area (km^2)	% of total area	% of zone in agricultural establishment[2]	% of zone in agricultural use
Dry	836,572	17	55.6	38.2
Transitional	1,816,240	38	28.7	13
Humid	2,194,887	45	7.5	3.2
Total	4,847,700	100	24	13

1 The rainfall categories correspond to less than 1,800 mm (dry); between 1,800-2,200 mm (transitional); and more than 2,200 mm (humid).
2 Includes forest land in private agricultural holdings.

Table 2. Use of agricultural areas (%) in Amazon.

Rainfall Zone[1]	% in agricultural use	Pasture %	Annual crops %	Perennial crops %	Abandoned lands %	Others[2] %
Dry	100	83.3	5.1	0.5	8.4	2.6
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[3]	100	54.4	5.8	4.6	28.5	6.7

1 The rainfall categories correspond to less than 1,800 mm (dry); between 1,800-2,200 mm (transitional); and more than 2,200 mm (humid).
2 Includes plantation forest and settlements.
3 Corresponds to Belém-Bragantina (Pará) and Macapá-Mazagão (Amapá). This area is humid, but possesses relatively good infrastructure and market conditions.
Memorandum: area in agricultural use as a percentage of total land in rainfall area is as follows: Dry, 38%; Transitional, 13%; Humid, 3%.

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, which reduces the percentage of census areas in agricultural use. This high percentage in protected areas is partially influenced by the low agricultural potential of these areas.

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

The data presented above highlight the dangers in generalizing the modest success observed in Amazon agriculture to date, over future perspectives. The relatively high conversion rates observed for the dry zone in the 1995-96 Agricultural Census (IBGE) are consistent with the evidence presented in Schneider's (1994) review of colonization studies, based largely on work of Ozorio de Almeida (1992), Emilio Moran (1989), FAO/UNDP (1992) and Jones et al. (1992). In this review, based on case studies in the dry and transitional areas, Schneider (1994) confirmed a modest sucess. In economic terms, the perfomance was considered moderate, comparate to indicators of profit in other parte of Brazil. However, data discussed above demonstrate that even this moderate success cannot be expected for the 45% of 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.

'BOOM-AND-BUST' OR ECONOMIC SUSTAINABILITY: THE COMMUNITY´S DILEMMA

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

Land Uses

Timber harvesting**.** The legal Amazon produces approximately 90% of the native wood in Brazil. The wood industry is the primary economic activity in Amazon, representing roughly 15% of gross domestic product (GDP) of the states of Pará, Mato Grosso and Rondônia. In 1998, the gross income of the sector was estimated at US$ 2.5 billion.[5] Moreover, the wood industry generates approximately 500,000 direct and indirect jobs (Veríssimo et al., unpublished).

The Internal Rate of Return (IRR) of forest management[6] was estimated at 71%, while for the predatory logging system this rate reaches 122% (Appendix 1).

Ranching**.** Cattle-ranching is the dominant land-use activity in deforested areas, representing 77% of converted areas in economic use (Chomitz and Thomas, 2000). The current Amazonian herd is estimated at 32 million head of cattle. The average stocking rate is only 0.7 animals per hectare. Ranching generates roughly 118,000 permanent jobs. In general, ranching presents a very low IRR (4.2%), in isolated cases (ranching in reformed pastures) achieving rates up to 13% (Appendix 1).

The Community´s Dilemma[7]

We will consider a county containing 1 million hectares of dense forest. Migrant loggers begin to arrive in the area in search of new timber stocks. The community discusses whether to try and 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.

5 The net revenue is estimated at US$ 500 million, assuming a profit margin of 20% (profit margins oscillates from a minimum of 15% to a maximum of 25%; Veríssimo et al., unpublished).

6 This forest management system has been developed and described by Imazon, Embrapa, and the Tropical Forest Foundation (TFF). It consists basically of a selective harvest based on an inventory of commercial trees; planning of roads, patios and skid trails; vine cutting; directional felling and planning of 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.

If market forces act freely in the region, the community can anticipate rapid growth followed by a severe decline, as illustrated in Figures 5 and 6. Economic activity grows relatively rapidly in the first eight years as trees are extracted and pastures formed. However, the economy begins to decline 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. By approximately the 20th year complete exhaustion of marketable wood has occurred, and the local economy enters a crisis. The economic activity, measured by the gross revenue from timber harvesting (extraction and processing) and ranching in this boom-and-bust cycle can reach a maximum of US$ 100 million in the eighth year and fall to below US$ 5 million in the 23rd. In this period, loggers will have abandoned the county, leaving behind only low-productivity ranching. If the community were to compel the logging companies to adopt

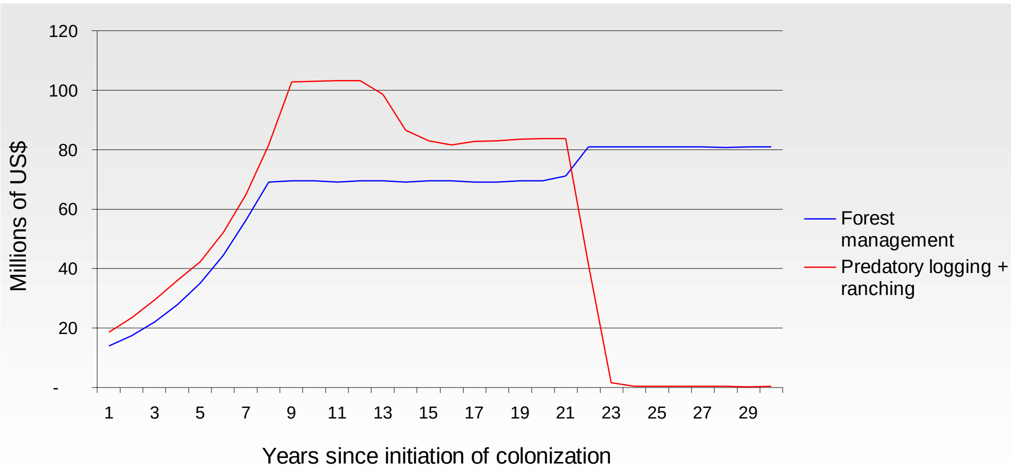

Figure 5. Gross revenue: forest management versus predatory logging and ranching in the humid Amazon.

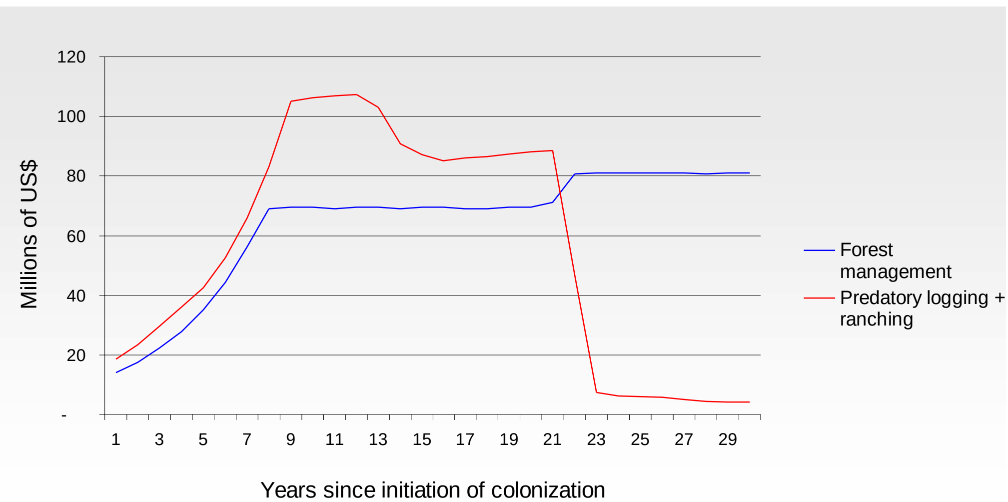

Figure 6. Gross revenue: forest management versus predatory logging and ranching in the humid Amazon with good infrastructure.

sustainable forest management, the gross revenue would reach US$ 70 million, instead of the US$ 100 million obtained by the predatory model. However, revenue would be indefinitely sustainable at this level, instead of dropping drastically with the exhaustion of timber supplies in the 23rd year as occurs in the predatory model.

The 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, with 3,500 jobs (Figure 7). However with depletion of marketable wood in the 23rd 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, direct employment more than halves from year 21 to year 24 leading to serious social dislocation, and the economic base collapses.

The above analysis indicates clearly that from the long-run perspective of stable growth, building of community, and investing in people, the managed forest offers a better alternative than uncontrolled market exploitation.

Figures 5, 6 & 7 compared the effect of managed forest and market-led

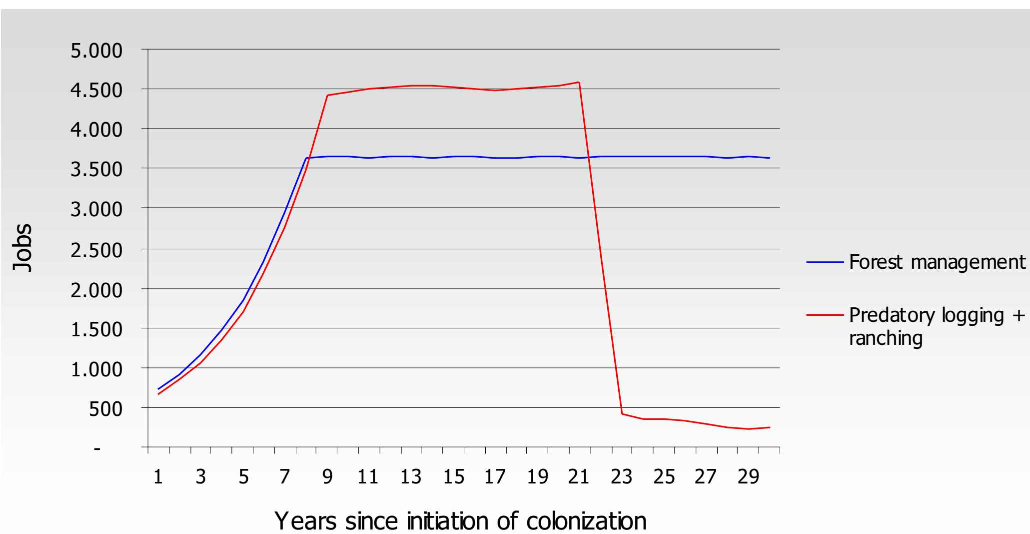

Figure 7. Jobs: forest management versus predatory logging and ranching in the humid Amazon

exploitation on economic activity in the community. Figure 8 below, on the other hand illustrates the relationship between the private and *social* benefits of an unsustainable "Boom-Bust" pattern of development as described above. This figure 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

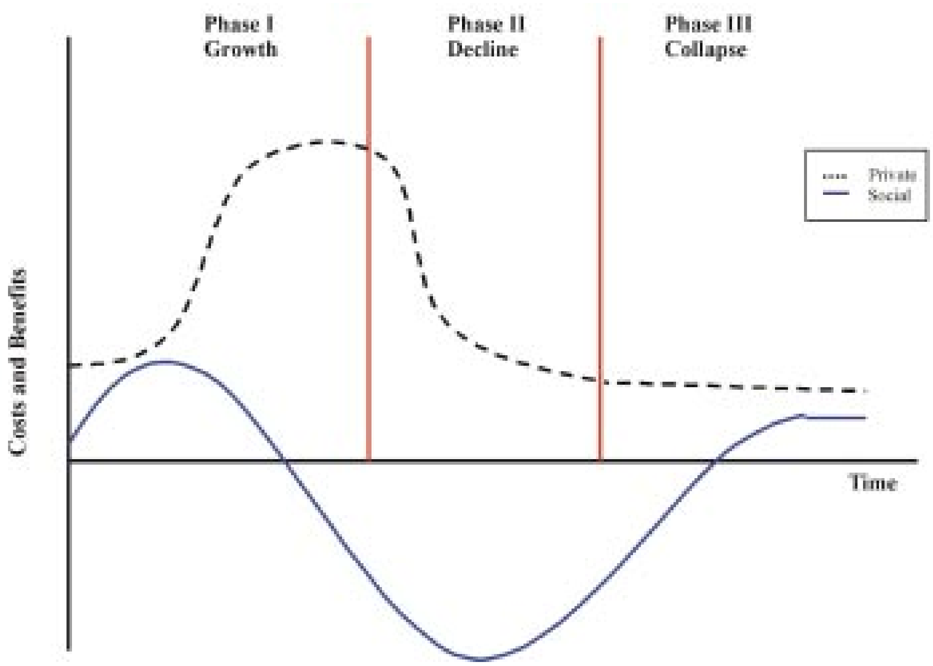

Figure 8.
Social costs and private benefits of the "boom-and-bust" economy.

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 there are still economic benefits in this stage, there are elevated costs associated with 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.

The 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, these still represent a small fraction of logging activity (less than 5% of the volume extracted). The dominant pattern is predatory logging, characterized by severe damage to the forest, excessive pressure on populations of high value species, and increase in the susceptibility of harvested areas to fire (Uhl et al., 1997).

Predatory logging has already exhausted forest resources in old logging centers.

Figure 9 displays: 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 finally the new frontiers Novo Progresso (Pará), Novo Aripuana-Apui (Amazonas) and Senador José Porfírio – Portel (Pará). We estimate that the scarcity of wood in old frontiers will require logging companies to either migrate or close within the next five years. In the intermediate frontiers, natural timber stocks are sufficient for 10-20 additional years, whereas in the new areas timber supplies will be depleted in 30-40 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 9).

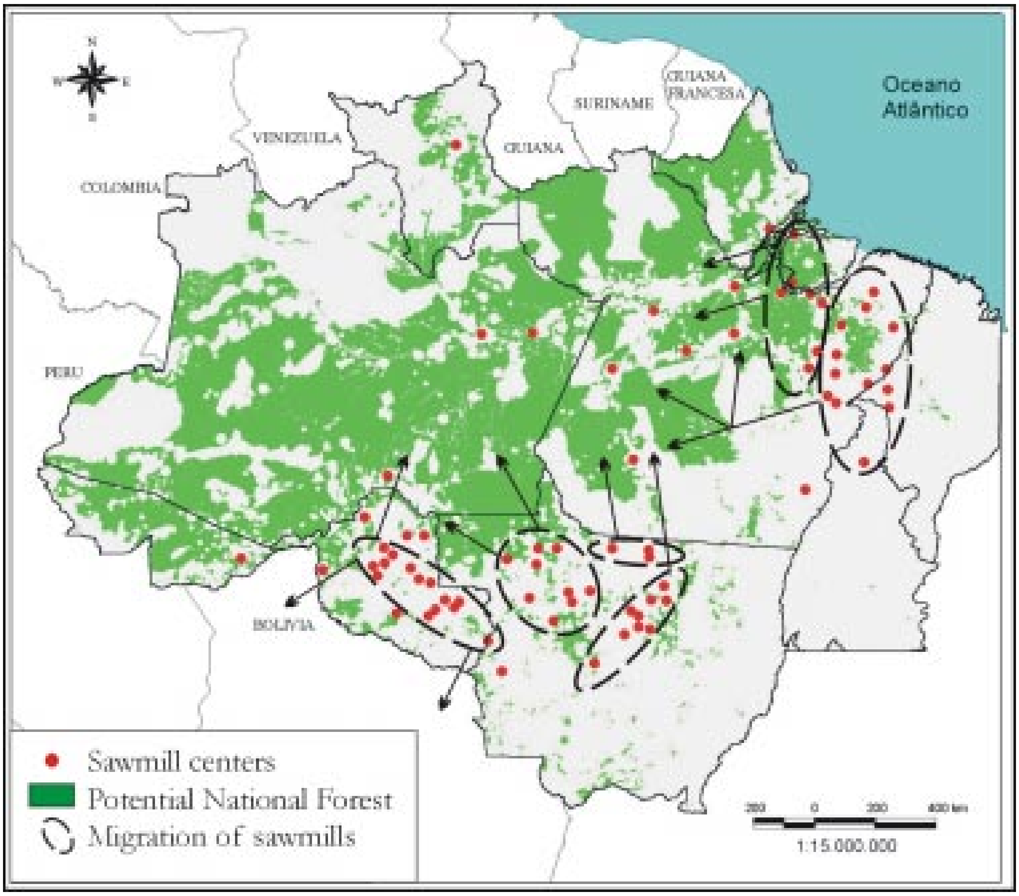

Figure 9. Migration of logging in Amazon.

The migration of logging companies and its effect on the local economy. The current logging model has a strong impact on the economies of communities in 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 1970's, is currently confronting a grave shortage of primary material due to exhaustion of forests. Approximately 50 sawmills closed or migrated in the last five years, and the volume of wood processed fell approximately 30% over this period. A similar phenomenon can be witnessed in the county of Sinop (Mato Grosso), one of the largest logging centers in the 1980's, 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 1980's to fewer than 100 at the end of the 90's. 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 make 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 (greater commercial volume per hectare). Nevertheless, despite a relative 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 progressively decline. If market forces are not restrained, communities constructed during the logging "boom" will become increasingly depressed during the subsequent "bust" to an ever weaker agricultural base. As we discuss below, local decision-makers, unfortunately, often have little incentive to adopt a sustainable development model. We analyze, therefore, the potential for a national policy that prevents this decay of communities and contributes towards sustainable development with a better distribution of benefits.

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

THE ROLE OF GOVERNMENT

The government has a crucial role in determining the quality of development in the Amazon, and in the protection of the interests of the larger Brazilian society. Government policy should reconcile: 1) 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.

Stabilizing the Local and Regional Economy

In frontier areas, land use instability is primarily caused 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 interests in the benefits of a slower, sustainable economic growth are national and global (Schneider, 1994).

The case of the "dilemma of the community", discussed in the previous section, is instructive. In the absence of government intervention, the community will have to decide for itself between the boom-and-bust model (predatory) and sustainable development. There are at least three reasons for the community to choose the boom-and-bust model. First, the short period of municipal mandates does not allow political leaders to adopt a long-term perspective with the objective of stabilizing and improving quality of life. Second, many political leaders are personally involved in the predatory natural resource "mining" economy, and don't consider the long-term interests of the community they are representing. Finally, the third and most important reason: even if the community were to opt for the sustainable model, it would have great difficulty to induce loggers to enter under conditions of good forest management practices. As Appendix 1 demonstrates, the internal rate of return for conventional harvesting and processing of timber (predatory model) is 122%, while the sustainable system (forest management) achieves a maximum of 71%. When faced with the choice between a community that enforces adoption of forest management and one that permits conventional logging, loggers will naturally tend to opt to work in areas that permit the more lucrative system.

How to Avoid Short-sightedness of Local Governments

The problem of the tendency for local governments to be short sighted and "captured" by local economic interests has been recognized worldwide. In general, the phenomenon whereby local governments mortgage their future for short-term benefits is referred to in the literature as "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.

Instruments for Stimulating the Sustainable Use of Forests

Various alternatives exist for stimulating sustainable forest resource use and thereby stabilizing the local economy. What follows is a summary of these alternatives.

Increase the profitability of forest management. Revenue from management would be augmented if, for example, there existed a market for the environmental services provided by forests. One of these services is the retention of carbon, which contributes to the equilibrium of global climate. The payment for this service has been the subject of international debate, but no decision has yet been made (see box). We 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.[9]

Reduce the comparative advantage of predatory logging. The refinement of the command and control system, along with adoption of a tax on the value of timber derived from predatory operations could reduce this advantage. We 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 in order to avoid management restrictions.

Respect the law. It is critical that respect for forest legislation be ensured (in particular the Forest Code). This legislation *inter alia* mandates that 80% of private property is maintained as a legal reserve, and, if logged, requires forest management. The regulation of the environmental crimes law offers a concrete opportunity to make fully effective the existing forest legislation. It is important that a division of responsibilities between local and federal governments be maintained in order to ensure an efficient and rigorous monitoring and control system.

Organize regional occupation. The government can take the lead in altering the dynamic of disorganized territorial occupation in Amazon. This pattern of colonization catalyzes deforestation, predatory logging and fragmentation. One promising manner of regulating this occupation is to expand and consolidate a network of public forests (National and State Forests) in Amazon (see the next section for details).

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% to 20%.

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 between counties. These initiatives might include improvement of public services such as sanitation, education and healthcare. In many cases, companies 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, etc.), instead of in those districts whose only attraction would be financial incentives and negligent regulations.

Distribute the Benefits From Use of the National Patrimony

The government should guarantee that the benefits from both logging and agricultural conversion of Brazilian forests are properly distributed within Brazilian society. The current situation reveals a series of social disparities. On one hand, the one percent of largest landowners with more than 2,000 hectares hold 47% of the agricultural land. At the other extreme, the 54% of smallest landowners, with fewer than 20 hectares, represent only 1.1% of agricultural land.

In the logging sector, benefits are also distributed inequitably. Logging companies pay less than 20% of the

Clean Development Mechanism

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

Brazil has had an important role in these discussions. During Rio-92 a Climate Convention was approved, and its first signatory was then president Fernando Collor. In addition, in 1997, the official Brazilian delegation played an important part in making viable the Kyoto Protocol and served as a protagonist for the introduction of one of the provisions in the protocol, the CDM (clean development mechanism). This mechanism allows industrialized countries to achieve part of its emission reduction targets by financing projects that promote the sequestration of carbon in developing countries.

However, an important question that has not yet been answered is whether projects that result in carbon sequestration through alterations in land-use, primarily forest management and conservation, will be considered. These questions were to have been defined during the 6th Conference of Participants (COP6) to take place in Haia, Holland in November of 2000, but were deferred for COP7 in 2001.

It is estimated that the global volume of Certified Emission Reduction credit transactions may reach US$ 20-30 billion annually, of which a part will be destined for developing countries for investments in projects of CDM. If permitted under the convention, budget for reduction of greenhouse gases would make viable a series of forest management projects. If these projects were admitted, Brazil could expect to attract 5-10% of the market.

income tax (ICMS) that is due, and most are exempt from payment of income tax. In addition, loggers do not pay for the use of federal lands. For example, no fee is charged for standing timber extracted from public lands, a common procedure in national forests in other countries.

For economic, social and environmental reasons, the government colonization policy (applicable in areas with agricultural potential) should favor small landholders and discourage the acquisition of large properties for speculative motives. First, the acquisition of such large areas encourages predatory activities conducted merely to guarantee the right of ownership. Second, large properties that are unproductive, or abandoned, encourage land speculation and subsequent ownership conflicts. Finally, 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 the Option of Future Economic Use of Amazon

In the future, technological changes may generate new economic benefits for the humid tropics (biodiversity, non-timber forest products, ecotourism, sustainable forest management, ecological agriculture, etc.) that are greater than today's values. By preventing forest degradation, we 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 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 to 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 (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%) of business owners want to exchange the current disorganized process for managed harvesting based on a forest concession system (National Forests).[10] Opinions differed on the role of government in this process, with 41% preferring a system in which the government merely granted concessions and companies were responsible for management, and 56% preferring that the government be responsible for management. Similar opinions were obtained among NGO's, academic institutions and professionals outside the forestry sector.

As Figure 9 (previous chapter) demonstrates, the migration of companies in Amazon has already begun. Neither the loggers, nor the receiving communities are comfortable with the current process. The window of opportunity is now, therefore to initiate a transition to an industry based on forest management.

Organize Regional Occupation

In order to assure conservation and sustainable resource use, government intervention to control market forces is necessary. As the section "The Com-munity´s Dilemma" illustrates, in the absence of payments for environmental services, the federal government should prevent regulatory competition. In other words, 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 in order to attract unsustainable and transitory investments.

10 The results of these interviews are the following: 80% were in favor of national forests, 3% were against their creation, and 17% had no opinion.

THE ROLE OF NATIONAL FORESTS

The involvement of the federal government in prevention of regulatory competition is in the interests of all parties. In insisting that long-term interests be considered, the government fortifies the authority of communities. Responsible logging companies would be protected by law from unjust competition from other companies that harvest wood illegally. And a 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 government can directly manage these forests or temporarily concede forest use rights to private companies (Veríssimo et al., 2000). In any case, forest management in these forests should be certified in accord with recognized international standards, such as the FSC (Forest Stewardship Council).

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 Union 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. In this manner, the unfair competitive advantage of wood derived from predatory operations is eliminated.

National Forests

National and State forests today represent a modest portion (83,000 km^2 or 1.6%) of the regional territory. This area would be sufficient to sustainably supply only approximately 10% of the current demand for unsawn timber in the region. In order to satisfy this present and near future demand in a sustainable fashion, the government would need to designate approximately 700,000 km^2, or 14% of Amazon, for creation of national forests.[11]

Veríssimo et al. (2000) developed a criteria for the identification of areas with potential for designation as national forests. Below, we present the principal results from this study.

Absence of competitive use. In order 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 km^2, or 28% of Amazon, of which 1 million are indigenous lands (Veríssimo et al., 2000). Settled areas were mapped based on "hot pixels" (from the thermal channel of the NOAH AVHRR sensor), government agrarian reform settlements and county seats. The superposition of these maps reveals that approximately 9% of unprotected forested areas possess detectable human occupation (Figure 10).

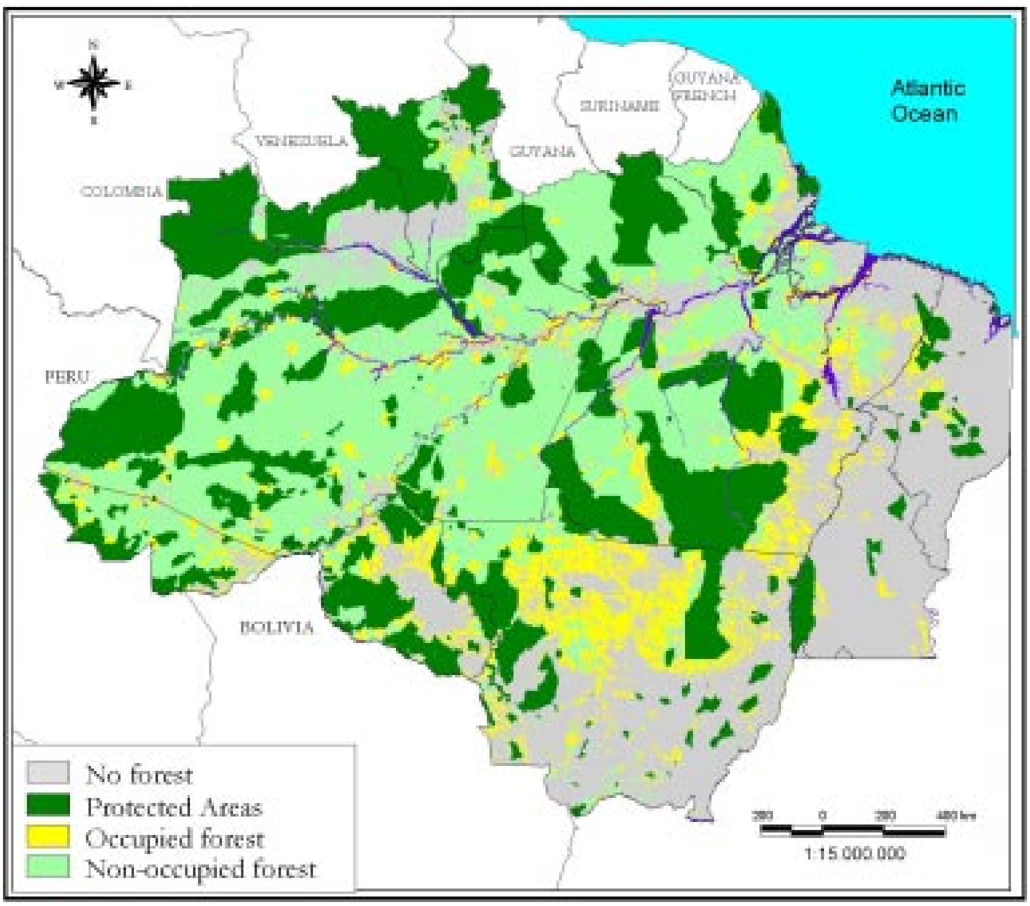

Figure 10. Occupation of the Amazonian forest.

11 This section is based on the MMA document: Identification of areas with potential for creation of national forests in the legal Amazon (Veríssimo et al., 2000). The data and methodology are described in greater detail in this document.

Economic Potential. Figure 11 displays the results of an analysis of forestry potential (vegetation map) and economic accessibility. The result is an area of 1.15 million km^2 (23% of 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) located within the radius of economic accessibility.

Biodiversity. To protect areas of high biological significance it is desirable to create a mosaic of conservation areas 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 movement of species between core areas. With the goal of realizing the potential for creation of such a land use mosaic, we combined the map of areas with potential for national forest designation (Figure 11) with the map of priority areas for conservation (Figure 12; ISA et al., 1999). The superposition of these maps reveals that 38% of the 1.15 million km^2 with commercial potential for forestry (437,000 km^2) is also of high biodiversity conservation priority (Figure 13); which we would therefore recommend be put in conservation use.

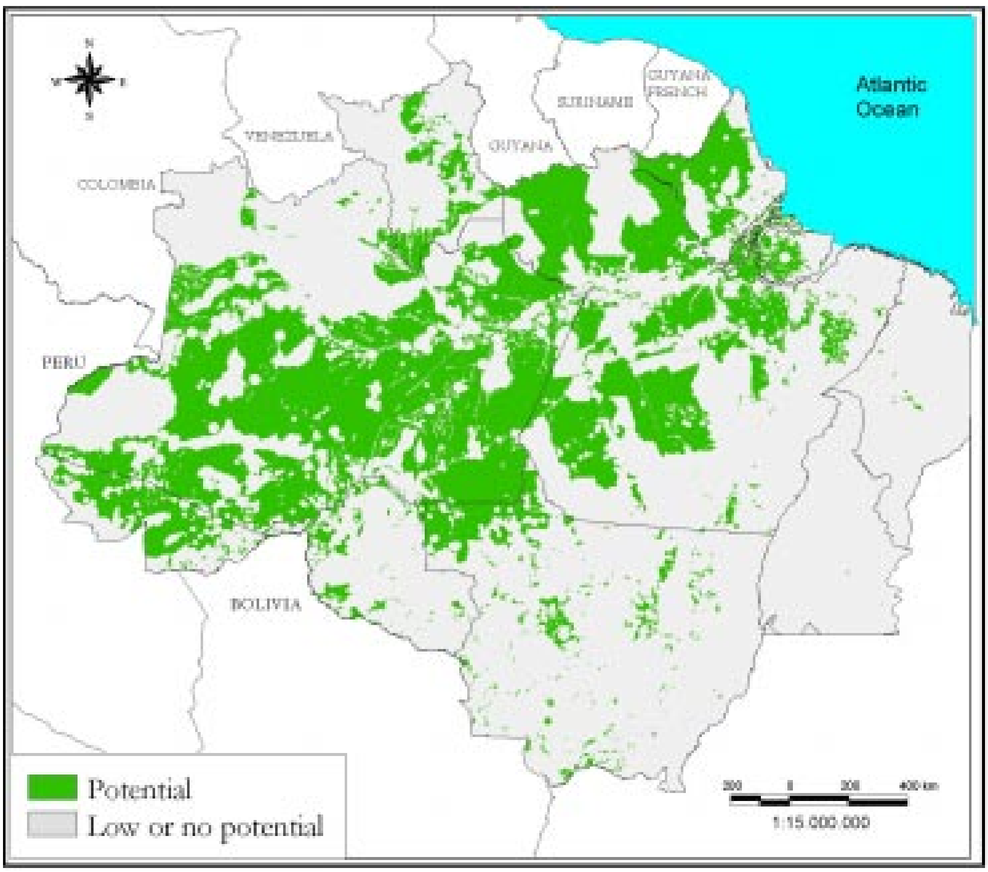

Figure 11.
Areas with potential for National Forests (Veríssimo et al., 2000).

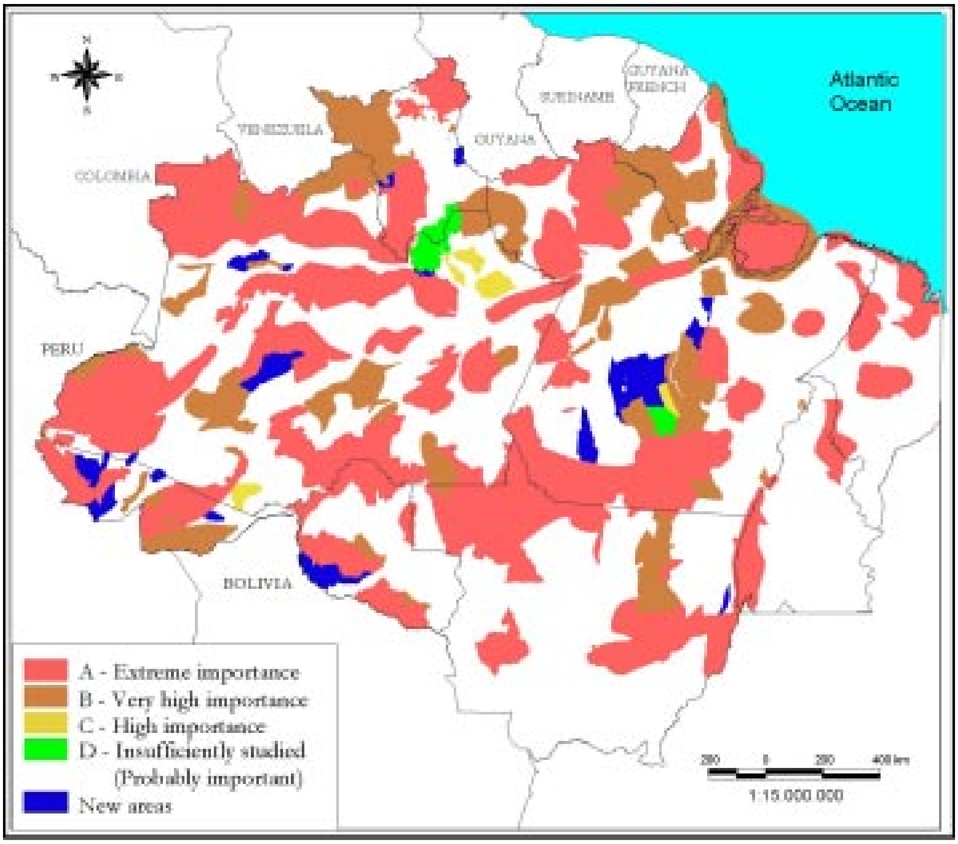

Figure 12.
Priority areas for conservation of biodiversity (ISA et al., 1999).

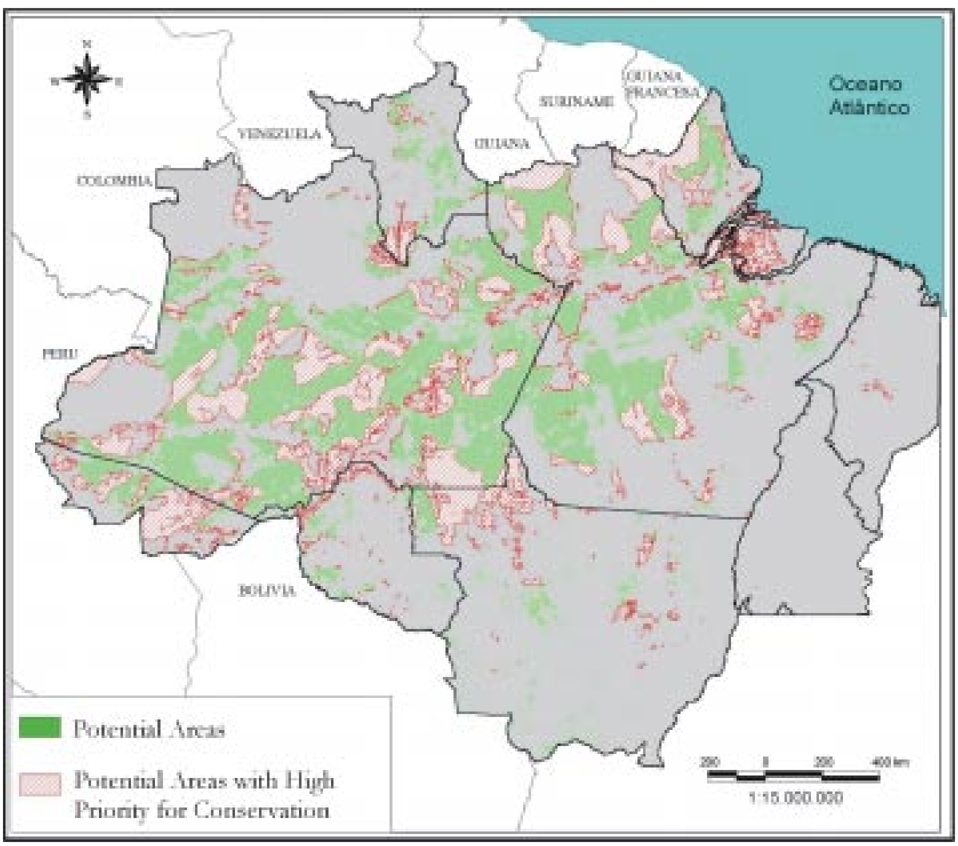

Figure 13.
Overlay of areas with potential for National Forests and for biodiversity conservation in Amazon.

CRUCIAL QUESTIONS FOR THE AMAZON´S FUTURE

This analysis demonstrates the complementary potential of sustainable forest use and biodiversity conservation. It shows that, without significant competition for use of these lands, it would be possible to create approximately 700,000 km^2 of national forests (roughly 14% of Amazon); an area that is large enough to support the current and expected demand for Amazonian timber in a sustainable manner.

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 section, we raise some important questions that must be addressed for the future of Amazon.

***Learn the lessons of zoning*.** The theme land-use zoning in Amazon" is once again surfacing in the regional political debate. The recent discussion in congress, over the revision of the Provisionary Measure 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 over the amount of land to be left in conservation use will not be center on the percentage of legal reserve on private properties. It will, rather, 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[12]. The federal government should be prepared to participate in this emerging debate in a pro-active manner. Fortunately, the government's Multi-year Plan reserved R$ 300 million for the Ministry of the Environment to promote zoning in the next three years. If this money is to be well spent, however, 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 Forest.

12 Zoning land for agricultural use is seen by some farmers as possible way to scape of the restrictions of the legal reserve which require at least 80% under forest in each property.

Eliminate land abundance. Migration, abandonment and natural resource "mining" are extreme forms of extensive land use stimulated by land abundance 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 (for example 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 areas of forest conversion than to obtain it through forest management plans. Loggers in turn open access roads for agriculture and offer transportation. In addition they frequently are involved in the opening of roads in response to local political interests. The establishment of national forests (especially in humid areas) would effectively separate the agricultural frontier from areas of logging activity breanking this dynamic. First, it would reduce the potential for illegal logging activity by drastically reducing the scale of wood harvesting in agricultural frontier areas. Secondly, the natural subsidy for future deforestation could be reduced through a tax on wood derived from predatory harvests.

Understand the motives for ranching. Approximately 80% of agricultural lands in the Amazon are currently being used for ranching, or have been unused for more than four consecutive years. Around 40% of the pasture in use today has a stocking rate of less than 0.5 animals per hectare, with an average of 0.3 (Chomitz and Thomas, in press). Our calculations indicate that a ranch employing typical technology receives an internal rate of return (IRR) of less than 4% on the investment. Under the most optimistic hypotheses in relation to ranching technology, we calculate an IRR of 14%.

The conversion of forest to pasture, aside from generating few private or social benefits, concentrates Amazonian lands in the hands of a small number of people. There are some hypotheses that can 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.

Implementation and reputation risk.A more proactive role for government is not without risk, which will have to be carefully managed from the outset. This includes the risk that ill-conceived policies or poor implementation may do more harm than good (implementation risk), as well as the risk that a strengthed 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 activities conditioned on satisfactory results in the first phase. Participation and information dissemination, throughout project preparation and implementation and 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.

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

Finally, we believe, risk must be evaluated against potential gain. We believe that this report has made the case that in terms of improved quality of life to 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 risk.

CONCLUSION

Agricultural performance in the Amazon is strongly determined by rainfall patterns; experience with agriculture in Amazon has been based primarily on development of relatively dry areas. The evidence suggests that agricultural performance in the humid tropics 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) but will be followed shortly by a severe declined in revenue and employment (bust).

The predatory logging model has resulted in the exhaustion of 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 can avoid the repetition of the predatory cycle and the alienation of unsettled lands. The most promising alternative, for both social and environmental point 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 (Veríssimo et al., 2000) revealed that there are at least 700,000 km^2 of forests in the Brazilian Amazon (14%) with potential for creation of national forests. This area would be sufficient to attend the current and near future demand of the wood sector in a sustainable manner.

The sustainable use of natural resources would result in greater benefits (revenue and employment) in the long term. However, in the short term, 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, application of a tax on wood derived from predatory logging, designation of national forests and improvement of the monitoring and control system.

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Appendices

Appendix I

Methods Utilized in the Economic Analysis of Logging and Ranching Activity

We divide the methods in three parts. Initially, we explain the procedures for modeling predatory timber harvesting and forest management. We then describe the values and technical coefficients employed in the calculations of gross revenue for ranching. Finally, we present the calculation of jobs generated and the financial analyses of ranching and timber harvesting.

Modeling of Timber Harvests

In the simulation we utilized an area of approximately 10,000 km^2 (1 million hectares; Figure 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. We assume that the entire area is covered by intact native forest at the beginning of the simulation (t=0).

Figure 1.
Area utilized in the logging simulations.

A. Predatory Logging

The simulation of predatory logging was based on the concept of 'waves of extraction' in accord with the work of Stone (1998) and Schneider et al. (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 (ð) of extraction of a group of species *k* located in the cell *i* can be described as:

$$\pi_{i,k} = X_{i,k}\left[\phi\left(P_k - Cp\right) - Ce - St_k - Ct_i\right] \qquad [1]$$

where:

$X_{i,k}$ is the timber volume of species group k extracted in the cell *i*

f 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)

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)

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

$$Max \sum_i \sum_k \pi_{i,k,t} \quad \text{such that} \quad \sum_i \sum_k X_{i,k,t} \le \overline{Y}_t \qquad [2]$$

$$\text{where, } \overline{Y}_t = \overline{Y}_0(1+r)^t \quad \text{and, } \overline{Y}_{MAX} = 1.207.000 \ m^3 \qquad [3]$$

Where $\overline{Y}_t$ is the processing capacity of the processing center at time t. The processing capacity varies through time. In this exercise, we 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 et al. (1992) and used by Stone (1998) a the maximum growth rate]. This capacity increases up to a limit of 1.2 million m^3 of logs per year (half the valor found in the sawmill center of Paragominas)[1]. We group tree species into three value classes: high, intermediate and low.

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

The calculations of optimization were made by simultaneously using ArcView (G.I.S.) and an Excel spreadsheet, as described in Stone (1998). We used the ArcView algorithm *cost grow* to model transport costs. Transport (costs) frictions were defined based on work by Veríssimo et al. (1992; 1995; 1998; unpublished) and Stone (1998). Parameters used in calculation of transport costs and profitability are presented in Table 1.

Table 1. Parameters used in modeling of 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 et al., 1992; 1995; unpublished.

In the case of predatory logging, without management, we assume that loggers transport only 84% of the volume of cut timber to patios and sawmills. In accord with Barreto et al. (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].

B. Forest Management

Current legislation regulating forest management does not permit "extraction waves". Once a given area has been logged, it cannot 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]. There are two crucial differences, however. 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 2 illustrates the processing capacity during those thirty years.

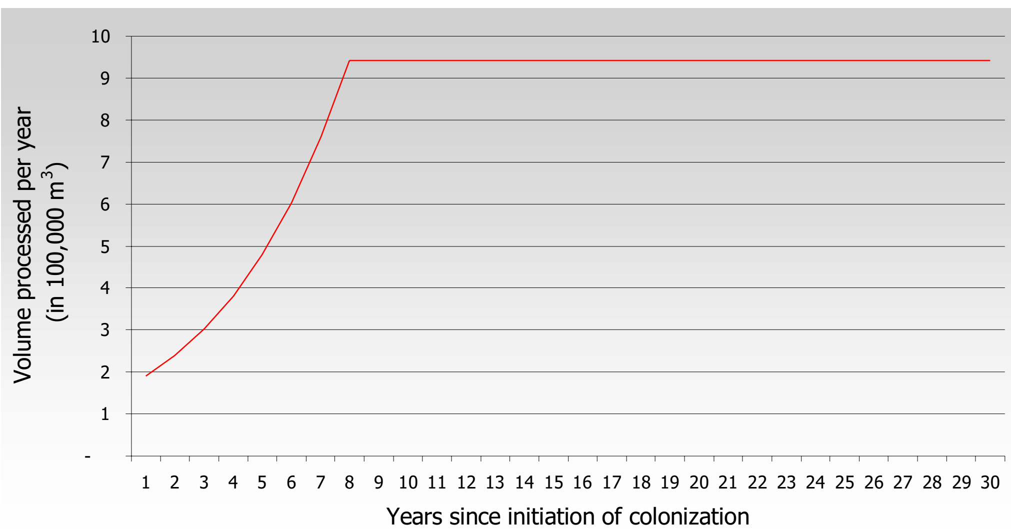
$$\left[\sum_i \sum_k \sum_t X_{i,k,t} \mid \pi_{i,k,t} > 0\right] = \overline{Ytotal} \qquad [4]$$

Growth in processing capacity. We calculate the growth rate (r) in such a way that:

$$\sum_{t=0}^{T} \overline{Y_0}(1+r)^t + (30-T)\overline{Y_T} = \overline{Ytotal} \qquad [5]$$
$$r \leq 0{,}26$$

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

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



C. Ranching

Area in pasture

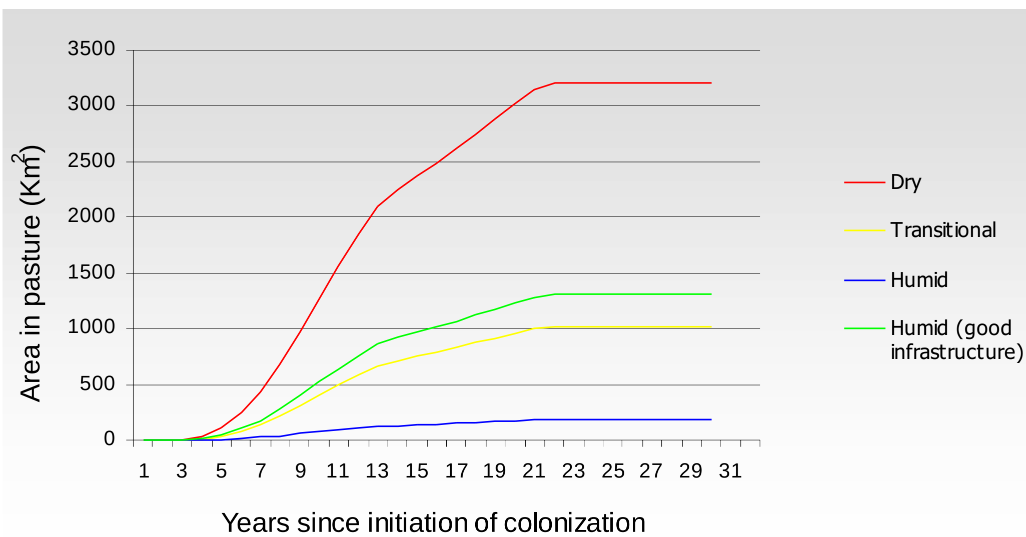
The area in pasture considered for the calculation of gross revenue was proportional to the tabulations made by Chomitz and Thomas (World Bank, 2000). In dry regions, 31.8% of the total area was pasture: in the transitional zone pasture represented 10.1%; and in the humid zone this proportion was 1.8%. In humid areas with good infrastructure and market access (Bragantine region, Pará) this value increased to 13% (Table 2).

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

Rainfall zone	% 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

We considered pasture planting would occur shortly after logging of medium value species (between years 4 and 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% of the total land area. The same procedure was adopted for calculation of pasture area in the transitional and humid zones (Figure 3).

Figure 3. Aging of area in pasture by rainfall zone.



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

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
g_r = proportion of pasture in region r
r = 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 we calculated the herd of the pasture area according to the sum of stocking rate in each cell. The stocking of pastures in each cell varied according to the age of the pasture. The average stocking rate during the period was 0.67 animals per hectare (Table 3). For example, pasture with two years of age supported a density of two animals per hectare and pastures with twelve years only 0.2 per ha. In the humid zone, we used a constant pasture stocking rate of 0.4 animals per hectare, consistent with Chomitz and Thomas (World Bank, 2000). After twelve years of use, we assumed that pastures would be replanted and the cycle would commence again.

Table 3. Stocking of pastures.

Pasture age	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 et al., 1988.

$$\text{Herdt}_t = \sum_{i=1}^{N} L_{i,a} C_i$$

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

After we had obtained the total number of animals in each year (herd), we simulated the herd composition according to zootechnical indices described in Table 4. The simulation of the herd also provided the number of animals sold. We assumed that the whole herd is for beef production (calf production – steer raising – fattening), the most common case in Amazon (Table 4).

Table 4. Zootechnic indices.

Zootechnic indices	Rate (%)
Birth rate	70
Death rate of heifers	8
Death rate of yearling	3
Death rate of adults	2

Source: Arima and Uhl, 1997.

Table 5. Example of herd composition.

Herd composition: calf production – steer production – fattening											
			3 a 4 years		2 a 3 years		1 a 2 years		0 a 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	-	-	-	-	-	-	-	-	-	721
Births	-	-	-	-	-	-	-	-	21,019	21,019	42,038
Deaths	-	1,201	356	356	364	364	1,160	1,160	1,682	1,682	8,324
Sales	721	9,008	17,457	7,248	-	-	-	-	-	-	34,434
Balances	2,402	49,845	-	10,209	17,814	17,814	18,177	18,177	19,337	19,337	173,112

The gross revenue from ranching was calculated by multiplying the number of animals sold by the prices in Table 6.

Table 6. Sale value of animals.

Animal	US$/unit.
Bull	420.00
Cow	252.60
Fattened bull	346.50

Source: Arima & Uhl, 1997.

D. 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. Forest management employs people in silvicutural treatments and harvest planning in addition to the above. In the management 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 et al., 1992; Barreto et al., 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).

E. 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 7). The value of equipment, investments, and useful life were obtained from Veríssimo et al. (1992) and Barreto et al. (1998).

Table 7. The Internal Rate of Return (IRR) and Net Present Value (NPV) of ranching and of extraction and processing of wood.

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

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Appendix II

Financial Returns from Timber Harvesting and Ranching in Amazon

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

A. Logging Activity

Recently, Pearce et al. (1999) conducted a literature review on financial returns from predatory logging and forest management in tropical forests. Table 1 summarizes this article. Note that except where noted the analysis of these studies did not include log processing.

Table 1. Review of literature (Source: Pearce et al., 1999; Table 2 pp. 16-18).

Study	Country	NPV (US$/ha)	Discount rate of NPV
Bann, 1997	Cambódia	PL = 1,697 FM = 408	6%
Haltia and Keipi, 1997	Costa Rica	Forest management better than ranching	—
Howard et al., 1996	Bolívia	PL= 334-449 FM= 204-263	10%
Kishor and Constantino, 1993	Costa Rica	PL =1292 FM = 854	8%
Kumari, 1996	Malásia	PL = 860-1380 FM = 322-944	—
Mendoza and Ayemou, 1992	Ivory Coast	Forest management + processing = 160	10%
Richards et al., 1991	México	14-15% annual return on capital, inclunding processing	—
Southgate and Elgegren, 1995	Peru	NPV negative	—

Obs: PL = Predatory logging; FM = Forest management. References cited in table: see Pearce et al (1999).

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

Practically all the Net Present Values (NPV) of conventional systems cited in the review are superior to those encountered in the study (Table 2). This difference occurs due to the scale of the analysis. The cited studies analyzed the financial return at the scale of the property. Our study was done at the municipal scale, where the transport costs have a large influence on financial returns.

Table 2. Net Present Values (NPV) per hectare.

	NPV/Hectare	
Discount rate (%/year)	**Management**	**Predatory logging**
6	163.27	150.41
10	99.60	106.32
15	58.54	72.03
20	36.82	50.75
30	16.46	27.53

Only two articles incorporated both the extraction and processing phases. Mendoza and Ayemou (1992), in the Ivory Coast, observed a NPV/hectare of US$ 160, using a discount rate of 10%. At this same discount rate our study found a value of approximately US$ 100/ha (Table 2). Richards et al. (1991), in Mexico, noted an annual return rate on capital of 14-15%. Unfortunately, it is not possible to compare these results with our study, as we used a horizon of thirty years.

Studies of timber harvesting in the Amazon consist primarily of those conducted by Imazon. Studies by Uhl et al. (1991); Veríssimo et al. (1992;1995); Barros and Uhl (1995); and Johns et al. (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%. Barros and Uhl (1995) observed Internal Return Rates (IRR) of 124% for small sawmills that utilized fluvial transport in the estuary of the lower Amazon. Larger sawmills on *terra firme* obtained IRR of 14-62%, harvesting wood up to 100 km from the mill.

Almeida and Uhl (1995) used the data of Veríssimo et al. (1992) to calculate an IRR for logging activity at the municipal scale. Extraction and processing in the predatory system generated IRR of 108%, whereas in the managed system this rate was 103%. Considering only the harvesting phase, the return were 33% and 29% with and without management, respectively. The differences in the returns obtained in Almeida and Uhl (1995) and in the present study (122% without management, 73% with) occurred principally due to the fact Almeida and Uhl (1995) did not explicitly incorporate differences in transport costs or the "extraction waves" described in Appendix 1.

Table 3. Area harvested.

	Area harvested	
Wood Value Class	**Management**	**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**

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

Another study, of the USDA Forest Service, conducted recently by Holmes et al. (submitted) in the Paragominas region, observed results similar to those of Barreto et al. (1998). Holmes et al. (submitted) compared an industrial-scale managed harvest (500 ha) to the predatory system and found management more lucrative (US$ 11.6/m^3 versus US$ 9.84/m^3, or US$ 294/ha versus US$ 250/ha).

Stone (1998) employed GIS and an optimization model of industry profit (harvest and processing) and projected logging in the state of Para for the period 1996 to 2000. In the scenario in which timber prices increase 3% per year and processing capacity grows at an annual rate of 16%, an area of 22 million hectares would be logged during this period, generating gross revenue of US$ 1,677 per hectare in today's values (discount rate of 5%). In our study, the present value of gross revenue was US$ 940 per hectare for the predatory system and US$ 965 per hectare for management, using the same discount rate (5%).

B. Ranching

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

The articles in the second phase of the literature, in the 1980's, showed that ranching did not have a satisfactory financial performance. Hecht et al. (1988) observed that the Internal Rate of Return (IRR) was negative with use of traditional technology. The return rates were positive (between 5 and 31%) only when there was a combination of two or more of the following factors: 1) when ranches received financial incentives and subsidized credit; 2) when land prices increased (speculation); 3) when there was overstocking in the initial period; 4) when there was a high ratio between cattle prices and input prices. Similar conclusions were reached by Browder (1988) and Fearnside (1980).

In the 90's, various ranching studies were published. In general, the studies gave support to the conclusions from work in the previous decades, but also demonstrated economic viability for certain ranching models, such as small-scale milk production.

Mattos and Uhl (1994) analyzed ranches in Paragominas and observed the ranching practiced in an extensive form, generated IRR lower than 5%. Dairy ranching at a small scale produced returns of 12%, and beef ranching in reformed pastures[1] obtained returns of 12-21%.

Muchagata et al. (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 per hectare for very small ranches (12 hectares of pasture) to positive values of R$ 42 per hectare for larger ranches (85 hectares of pasture). These properties sold milk and animals, and in some cases, rented pastures.

Faminow et al. (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, he 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 PIB.

The data used in this study were obtained from Arima and Uhl (1996). Ranching on *terra firme* (south of Pará state), in the traditional extensive system, generated IRR of 3-5%. Small ranches, specializing in dairy production, obtained higher IRR, around 9%. These numbers are consistent with a study conducted by the Rural Syndicate of Araguaina, Tocantins (Nehmi Filho, 1999). The IRR obtained in that study was 5% in Redenção (south of Pará), 7% in Araguaina (TO) and 5% 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%). However, the increase in the Amazonian cattle herd and in extensive ranching continues without an economic justification. Various explanatory hypotheses, such as capital gains with land valuation await empirical verification.

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

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Appendix III

Calculation of the Carbon Compensation Values and Rate Under Predatory Logging

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

A. Analysis of gross revenue

Table 1 shows the Gross Present Values (GPV) without compensation for carbon or taxation. The calculation of carbon compensation values is simple. We assumed the payments

Table 1. Gross Present Value (GPV) in the current situation: humid zone (1.83% pasture, without carbon payments or taxes) and transitional areas.

	GPV at 10% (US$)	GPV at 4.92% (US$)	GPV a 3.86% (US$)
Predatory logging + ranching (humid) zone	525,713,391	876,524,943	
Predatory logging + ranching (transitional zone)	539,133,403		1,021,434,609
Management	463,900,558	876,524,943	1,021,434,609

Obs: under a discount rate of 4.92% (in humid areas) society would be indifferent between the GPV of predatory logging/ranching and management. Under a discount rate of 3.86% (in transitional areas) society would be indifferent between the GPV of predatory logging/ranching and management.

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 2a and 2b.

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

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

Table 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	GPV (US$)	Value of carbon credits	Price of carbon (US$/ton)[1]
10	525,713,391	114,384,172	8.67
15	343,775,327	111,823,577	8.48
20	239,838,181	96,709,188	7.33

Obs: assuming carbon payments in year t_0.
1) For calculation of carbon saved, see D below.

Table 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	GPV (US$)	Value of carbon credits	Price carbon (US$/ton)[1]
10	539,133,403	129,146,186	4.05
15	350,650,557	119,730,092	3.76
20	243,686,326	101,326,961	3.18

Obs: assuming carbon payments in year t_0.
1) For calculation of carbon saved, see D below.

B. 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 3 and the values with carbon compensation, in Table 4.

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

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

Table 3. Economic performance of predatory logging and forest management.

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

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

	NPV (US$)	Value of carbon credits	Price of carbon (US$/ton)[1]
Equalize IRR (122%)	-------------	1,749,196	0.19
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

Obs: assuming carbon payments in year t_0.
1) See calculation of reduction in carbon emissions in D below: 9,100,000 tons.

C. Private Sector Analysis – Taxes

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

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

where
p < 1 is the tax charged

The value of the tax per cubic meter of wood harvested (X) was obtained by dividing the total value of the tax by the total volume extracted (Table 5).

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

where,

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

Table 5. Value of taxes on wood derived from predatory logging in order to equalize NPV under different discount rates.

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

D. 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 harvest intensity are given in Table 6.

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

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)

Table 6. Carbon emission per hectare.

Released carbon (ton/ha)		
Harvest level	Predatory logging	Forest management
High[a]	4	2.19
High and medium[a]	13	7.13
High, medium and low	31	17.00
Pasture	240.1	—-

Source: Gerwing et al. Land cover and carbon density maps for the Brazilian Legal Amazon. Imazon, manuscript prepared for the World Bank Global Overlay project.
[a]Assuming that management reduces carbon emissions proportionally to high harvest intensity (17/31 = 0.548).

Predatory logging releases approximately 9 million additional tons of carbon when compared to forest management in an area of equal size (Table 7). Pastures release an additional 4 million tons of carbon, although only occurring in 1.83 % of the total area. In transitional areas (10.1% 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 7. Carbon emissions in each activity.

Activity	Tons of carbon emitted	Additionality
(base=forest management)		
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