The Dynamics of Deforestation and Economic Growth in the Brazilian Amazon

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1 Introduction

> I used to worry that all the trees in the jungle would be cut down to make paper for their reports on how to save the rainforest!
>
> Nick Birch, Forester in Rondonia (Breton 1993, p. 26)

It could be argued that there is no one single region in the tropics that has received so much attention from naturalists, scientists, and explorers the world over than the Amazon. It represents about 40 percent of the world's remaining rainforests and holds by far the largest intact section of diverse tropical wildlife. To many people the Amazon has become *the* quintessential symbolic last stand of a major wild, natural environment against the encroachment of civilization. Undoubtedly the Amazon has captured the imaginations of millions; but the future of this region should not be left to imagination, but rather to studied analyses based on the facts as we can best ascertain them. There has been remarkable progress over the past decades in conducting hard, scientific studies of the ecology, biology, and economics of the Amazon rainforest. Nevertheless the region is still the subject of many popular myths.

Indeed, the ongoing public and governmental struggle over the Amazon's future mirrors broader current discourses on "the environment." While opinions among experts and laypersons alike vary widely along a continuum of perspectives, the two poles between which most of the discourse lies can broadly be thought of as (1) the school of defenders of global ecological services ("conservationists") and (2) the school of development interests in the countries hosting these forests ("developmentalists"). Both conservationists and developmentalists make a number of valid points and sport very good arguments. Developmentalists note that countries in the North cut down their own forests centuries ago and benefitted greatly from the land uses that replaced those forests. They find it hypocritical that these developed countries now try to deny developing countries the same opportunities, and they fail to see justice in the insistence that the poor bear the costs of preserving forests whose benefits primarily accrue to wealthy foreigners and future generations.

Conservationists, on the other hand, argue that we have a very incomplete understanding of the tropical forests' functions in the global eco-system, and that we may cause catastrophic damages to the global life support systems if we clear too much forest. They point out that at the current rate of deforestation of approximately 11.3 million hectares of forest worldwide each year (FAO/UN 1997), the forests may be irreparably depleted long before a full scientific understanding of the implications of that loss is achieved. Furthermore, they generally find that the long-run value of an intact forest is much higher than the value of alternative land uses. The following quote from Anderson (1990) typifies this position:

> The tragedy of deforestation in Amazonia as well as elsewhere in the tropics is that its costs, in . . . economic, social, cultural, and aesthetic terms, far outweigh its benefits. In many cases, destruction of the region's rainforests is motivated by short-term gains rather than the long-term productive capacity of the land. And, as a result, deforestation usually leaves behind landscapes that are economically as well as ecologically impoverished. (Anderson 1990, p. xi)

Developmentalists argue quite the opposite: that the tangible benefits of current deforestation and the land uses that replace the forest outweigh the potential future benefits of standing forests. They note that the total amount of forested area in the world has been reduced from a maximum of about 6 billion hectares to about 3.5 billion hectares without yet causing catastrophic damage to global life support systems, and they question the proposition that such a change, were it to occur, would prove insurmountable. They contend that a more likely scenario is that global climate change could be dealt with by adaptation and the development of new technologies, leaving their populations better off (on net) in the long run.

Successive Brazilian governments have been clear proponents of the developmentalist view and very skeptical of the environmentalists. Indeed, as Barbosa (2000) notes:

> [Many Brazilians found] the call for preservation ironic because it was coming from governments with a long history of environmental destruction and, in the case of the United States, a long history of violation of Indian rights. Brazilian officials claimed that the rich countries had used their natural resources to achieve very high levels of economic development. Now, it was the turn of third-world countries. (Barbosa 2000, p. 85)

The Brazilian president José Sarney (1985–1989) argued that it was unrealistic to expect Brazil to restrict its economic development to accommodate the environmental concerns of the North, especially in light of staggering foreign debts. Furthermore, he contended that industrialized

countries such as the United States had no right to lecture Brazil on environmental responsibility when they were, after all, the biggest global polluters of all (*Time*, September 18, 1989).

In theory, much of the practical, if not philosophical, discrepancy between environmentalists and developmentalists could be minimized if it were possible for the people who value forests' environmental services to pay owners to conserve the forest. In that manner the global benefits of the standing forest would be internalized, and the owners of the forests could more easily decide whether preservation or conversion would be the most beneficial use for a given plot of land. Although theoretically sound, in practice the task of creating well-functioning markets for forest services and monitoring their maintenance over time is daunting. It will require extraordinary international cooperation to set up the necessary institutions and mechanisms to create markets that could facilitate the sales and purchases of environmental services in an efficient manner.

Even if we do accept the idea that some sort of payment should be made by those who benefit from forests' environmental services to those who must bear the costs (mainly opportunity costs) of providing these services, several key questions remain. In particular, how much forest is "enough" for current and future generations? What would be an equitable payment to ensure that such an amount is preserved? These are very difficult questions, which require us to put a value on tropical forests as well as values on alternative land uses. However, the practice of valuing public goods is still in its infancy; for example Graves (2001) argues that by not taking into account the behavioral effects that the actual creation of heretofore hypothetical markets could have on peoples' choices, economists have tended to underestimate the value of most public goods.

Furthermore, quite aside from the technical difficulties, some conservationists argue that it is ethically wrong to try to attach a monetary value to tropical forests. From their point of view, the forests and all the species they house have an inherent right to exist independent of any services or benefits they provide to mankind, and thus we have a moral obligation to preserve them. Our response to these claims is that, whether or not they are true, in the world in which we exist today it is extremely unlikely that the remaining forests will be preserved to the levels deemed necessary or socially optimal unless their value and the true trade-offs to the actors involved are better understood. Such an understanding is a necessary prerequisite for any international effort to compensate poor countries for preserving their forests.

This book attempts to move in this direction, by improving our understanding of the services that tropical forests generate as well as the benefits that derive from alternative land uses in the Brazilian Amazon.

Both issues have already been the focus of intense debate and numerous studies, but we hope to contribute to the knowledge base by thoroughly analyzing new deforestation and development data covering the entire Brazilian Amazon at the municipal level at several points in time during the period 1970–1996. By making explicit some of the major trade-offs involved, we wish to enrich the current debate, raise new questions, and stimulate additional research. We believe this kind of analysis is all the more important given the current ongoing discussions about major infrastructure developments, as well as huge donor-led conservation initiatives in the Amazon.

We acknowledge that the results of such an exercise will always come with their own set of methodological caveats and disclaimers, ranging from limitations in the available data and estimation methods to large uncertainties in the underlying biophysical processes. For this reason we emphasize that the underlying research that has culminated in this book represents but a starting point. There is a severe need for much more scientific, agricultural, economic, and statistical research in this area even as hard policy decisions need to be taken today.

Deforestation and development

As the title of the book suggests, along with much of the more recent academic work on tropical ecology, we recognize the dynamic nature of deforestation and development. Indeed, over the course of history, many misunderstandings and misconceptions have arisen from viewing the Amazon rainforest as a static, virgin forest and considering deforestation a once-and-for-all conversion that will either civilize the place and bring great prosperity to its conquerors, or result in ecological disaster and desertification. These rather simplistic views have ignored the fact that everything about the Amazon forest, its use and development, is more dynamic and much less homogeneous than has perhaps been commonly perceived.

In fact recent research has shown that the Amazon forest is a dynamic entity that has been affected by both natural and man-made disturbances for thousands of years. The geological record suggests considerable ebb and flow of the forest cover in response to climatic conditions (e.g.Colinvaux 1989; Turcq *et al*. 1998). Historically there have also been relatively dense populations of indigenous people practicing slash-and-burn farming, hunting, and gathering in the region. Before European arrival there were probably between 1 and 6 million people living in Amazonia (Smith 1980). Over the years, these people have had a large

influence on the current structure of the Amazon forest through clearing and promotion of the more useful species (Smith *et al*. 1995).

While historical Amerindian settlement in the Amazon occurred without government support, more recent migration to the region was instigated by aggressively expansionary official development policies beginning in the 1960s. Since that time the non-indigenous population of the region has increased almost tenfold, from 2 to 18 million people. Along with other factors, this has resulted in an historically unprecedented rate of change of land-use.

In fact, nowhere in the world has so much forest disappeared so rapidly as in the Brazilian Amazon. According to FAO's statistics, Brazil deforested annually 25,540 km^2 between 1990 and 1995, the bulk of which occurred in the Amazon. This national figure is between double and triple the amount of forest lost by any other single country (Indonesia is second on the list, with 10,840 km^2). In spite of this large absolute loss, FAO estimates that the Brazilian deforestation rate is a modest 0.5 percent per year. The sheer size of the forest means that accumulated deforestation over the last forty years of aggressive development policies has thus far affected less than 15 percent of the Amazon forest. Much of the Amazon thus remains a relatively undisturbed environment, and the land-use decisions made by many local actors often reflect this perception of drawing on a seemingly endless pool of forest resources.

Before any meaningful statements can be made about the current state of the Amazon, some agreement on what constitutes "forested" and "deforested" land must be made. Traditionally, deforestation in the Amazon has often been defined as "the complete and permanent destruction of forest" (e.g. Myers 1993) for the purpose of allowing for alternative land uses (agriculture, pasture, infrastructure, etc.). This reflects a choice by many observers to focus on land-use change, recognizing the tendency of deforestation in the Amazon to be driven by demand for new crop land and pastures rather than predominantly by demand for timber, as in much of Asia, or firewood, as in parts of Africa (e.g. Geist and Lambin 2001).

At first glance it appears that areas of "complete and permanent destruction of forest" would be easy to detect and measure. In fact, this is far from the case. Natural vegetation patterns are generally not uniform and forests of different types and densities are mixed with savannah, lakes, rivers, and natural clearings, creating a mosaic of vegetation covers. Along most of the border of the Amazon basin, natural savannah gradually blends into transitional forest, which gradually blends into open or seasonal forest. This makes it difficult to define what is naturally forested

and what is not. Hence, there are few countries in the world where estimates on forest stocks differ so dramatically as do those for Brazil: FAO's national forest estimate for 1995 was 5.51 million km^2 (65 percent of Brazil's land area). The same figure is used by the World Bank, implying that about 90 percent of the national forest stock (around 5 million km^2) was in the Amazon (Lele *et al*. 2000). These "inclusive" estimates contain large transition zones to the *cerrado* savannah areas. However, the World Conservation Monitoring Centre, which applies a more "purist" forest definition, yields a Brazilian forest estimate of just 3.42 million km^2 – corresponding to less than two-thirds of the "inclusive" figures (Harcourt and Sayer 1996, table 25.2).

The choice between "purist" and "inclusive" forest definitions thus has a large impact on forest stock estimates. Furthermore, since most of the land clearing in the Amazon since 1960 has taken place in areas with relatively open vegetation, especially in the border areas to Southern Brazil where a so-called "arch of deforestation" has developed, the choice of definition has an even larger impact on estimates of forest *change*.

In this book we distinguish between "clearing" and "deforestation." Both refer to the complete removal of natural vegetation cover for alternative land uses. "Clearing" is the more inclusive term of the two, since it can take place on land with all kinds of vegetation ranging from dense forest to open savannah to wetlands. "Deforestation," on the other hand, takes place only in areas with natural forest vegetation ranging in tree density from transitional forest to dense forest. We have chosen to focus on clearing for three different reasons. First, clearing is much more accurately measured than deforestation in our data set. Second, as mentioned above, it has been noted that much of the change in forest cover in the Amazon has been driven by the need for new agricultural land and thus an understanding of the dynamics of land clearing is of primary importance. Finally, from an ecological perspective the non-forested areas of our study area are remarkably rich in biodiversity and store surprisingly large amounts of carbon (mostly below ground); in fact many naturalists argue that the naturally non-forested areas are just as important as the forested areas. Mares (1992), for example, points out that the drylands in South America are habitat to 53 percent more endemic mammalian species, and 440 percent more endemic genera, than the Amazonian lowlands. Thus, while we do use a more narrow deforestation measure in order to facilitate comparisons with other estimates of deforestation, for our analysis of the causes and consequences of replacing the natural vegetation in Legal Amazonia we have chosen the more inclusive concept of "clearing." The focus on conversion of natural areas to alternative land uses means that we ignore some important intermediate processes

that are not directly intended to create agricultural land, e.g. logging and wildfires, although these may often be intimately linked to a subsequent complete removal.

Both purist and inclusive definitions of deforestation face an additional complication in the issue of how to treat forest fallow and secondary re-growth. How tall and how dense does vegetation cover have to be to merit the label "forest?" Forest re-growth is not accounted for in the definition of "permanent" land-use change, but the fact is that large amounts of cleared forest have been abandoned and are now growing into secondary forest, part of which will become indistinguishable from primary forest over time. Studies by Browder (1989a) and Uhl (1987) suggest that 20–40 percent of deforested land in Amazonia was beginning to feature secondary growth by the late 1980s, a figure which has probably increased since then owing to the nationwide slowdown in agriculture.

Not only is the forest a dynamic and heterogeneous entity with the concept of "deforestation" difficult to precisely define, but perceptions about land-use potentials are also undergoing continuous change. In the middle of the eighteenth century the lush greenery caused Europeans to view the Amazon as a potential "world granary" (see Faminow 1998). Eventually, after several failed efforts at colonization, the conventional wisdom switched to the view that the rainforest covered very poor soils which could not sustain agriculture for more than a few years before being left barren. More recently a different view of the Amazon has emerged, owing primarily to a number of careful site-specific studies carried out in areas that were settled relatively early, and where farmers thus have had time to experiment with and adapt alternative agricultural strategies (e.g. Mattos and Uhl 1994; Almeida and Uhl 1995; Toniolo and Uhl 1995; Arima and Uhl 1997). At the center of this new thinking is the recognition that the region is really a mosaic of micro-environments, each with its own unique characteristics and potential. Some areas in fact have excellent soils, but even the highly leached oxisols and ultisols widely found in the Amazon may have potential for sustainable agriculture if adequately managed (Smith *et al*. 1995).

The international debate surrounding deforestation in Brazil has also evolved dramatically over time. In the 1970s and 1980s there was a considerable literature questioning the economic rationale of the deforestation process and subsequent land uses, especially cattle ranching (Bunker 1985; Hecht 1986; Mattos and Uhl 1994). Non-destructive uses of the standing forest, such as sustainable non-timber forest product extraction, were believed to have both a socially and economically superior potential (Anderson and Jardim 1989; Peters *et al*. 1989; Anderson *et al*. 1991). The fact that forest clearing continued despite these economically

preferable alternatives was largely blamed on policy failures. These included infrastructure projects and land-conversion incentives, such as tax exemptions and credit subsidies (Browder 1985; Mahar 1989) that were deemed socially "irrational" and economically perverse. In addition, these policies were seen as favoring the vested interests of land speculators and large cattle ranchers to the detriment of both the environment and the Brazilian society as a whole (Hecht and Cockburn 1989).

However, in the 1990s an increasing number of case studies and economic analyses began to question this mainstream view of Amazon deforestation as a "lose–lose" scenario, and pointed to a more differentiated outlook. It was observed that much deforestation, especially in the Western Amazon, had actually been carried out *without* government subsidies (Almeida and Campari 1995; Schneider 1995; Lele *et al*. 2000). In particular, cattle ranching appeared to be a profitable land-use option, even in the long run and without subsidies (Faminow 1998). It also became increasingly clear that the anti-inflationary policies of fiscal restraint and subsidy reduction had reduced the rate of deforestation only during the recessionary period of 1987–1991. As investment rates and economic growth recovered in the 1990s, the rate of deforestation gradually increased again (Young 1995). Finally, non-destructive alternatives such as non-timber forest product extraction, bio-prospecting, eco-tourism, and sustainable timber management were found to have much less economic potential than had been previously claimed (Southgate 1998). The recent literature thus paints a very different picture of Amazonia, one in which deforested land has economically profitable and sustainable alternative uses. The recent debate also points to a sharper conflict of interest between economic development and forest conservation (Kaimowitz 2001), and emphasizes the importance of gaining a better understanding of the trade-offs.

This book belongs to and complements this "new generation" of deforestation studies. We focus on the economics of land clearing, recognizing that at some levels and under some conditions the benefits of deforestation may outweigh the costs. However, the "old" theories have not been proven to be wrong across the board. As Moran (1989) points out in his stages hypothesis, frontier settlement is a gradual learning-by-doing adjustment process. Many earlier studies of Amazon deforestation prematurely judged the profitability of different land uses exclusively on the basis of the first settlement stages. In parts of the Amazon, we are now able to observe the agricultural intensification and consolidation taking place in later stages. The long-term profitability of deforestation can only be judged using an extended time horizon, and if the land turns into permanent and sustainable agriculture supporting local urban areas, indirect

benefits could be large, as they have been for most of the developed world.

Our main objective here is not to promote more or less deforestation *per se*, but to analyze how changes in land-use affect the lives of the people living in the Amazon and what the implications are for the rest of the world in terms of reduced environmental services. Recognizing that deforestation has both costs and benefits, and beginning to measure the magnitude of these, is the first step towards developing meaningful international and domestic policies that will deliver both the environmental services so desired in the North as well as the economic development so needed in the South.

Structure of the book

This book presents an empirical analysis of the development processes in the Brazilian Amazon using municipality-level data for the entire region at several points in time between 1970 and 1996. We present summary statistics and analyze trends for a number of important variables as well as developing econometric models with which we can analyze policies and compare outcomes under different scenarios. In contrast to site studies, which by definition focus on a specific bit of land, our data covers the whole of the Brazilian Amazon. Throughout the book the models and analyses pay due respect to the dramatic spatial differences in vegetation, soil, rainfall, market access, population density, and many other important factors. However, we are still operating at the municipal level, which means that we cannot take into account differences at the plot level, which site studies and very detailed GIS studies can and do.

The remainder of the book is structured as follows. Chapter 2 highlights central features of the study area, and discusses the changing governmental policies that have been applied in Brazil over time. Chapter 3 describes the data set we are using to analyze deforestation processes and compares our measure of deforested and cleared areas with estimates derived from satelite imagery. Chapter 4 discusses the different agents and drivers of deforestation, i.e. cattle ranching, agriculture, logging, mining, etc. Chapter 5 discusses extractivism as a possible alternative to deforestation.

In chapter 6 we present an econometric model that takes into account both the dynamics of development in the Amazon and the spatial features of frontier development. The model is estimated using municipality-level data from the agricultural surveys covering Legal Amazonia in 1975, 1980, 1991, and 1996. This chapter estimates the trade-off between land clearing and economic growth, i.e. the economic benefits that result from

land clearing. The estimated model is used to simulate the effects of two currently proposed, and controversial, development policies: the *Avança Brasil* government plan to expand and improve infrastructure and promote other development investments in the Amazon and a revised ceiling limit on the percentage of privately held land plots that can be cleared by law. We then compare our estimates to those of other recent studies.

In chapter 7 we use another dynamic model of land-use changes to estimate carbon emissions arising from land-use changes in the Brazilian Amazon. Our estimates are lower than the estimates provided by many previous studies because we take into account the heterogeneity of the natural vegetation and we allow for secondary forest re-growth.

Chapter 8 attempts to estimate the opportunity costs of land clearing. For this purpose we gather estimates from the literature of the value of the economic and environmental services that an intact forest provides and present them in a consistent framework.

Conclusions and policy recommendations are provided in chapter 9.