Natural Resource Management in the Brazilian Amazon

An integrated research approach

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The Amazon region of Brazil contains billions of cubic meters of high-quality wood whose overall value after sawing would be several trillion dollars. Given this timber wealth, it is common to consider forestry as the natural vocation for Amazonia (Pandolfo 1974). Already, well over half of the wood consumed in Brazil comes from Amazonia, and this domestic demand for Amazonian roundwood is expected to grow (Veríssimo et al. 1992). Foreign consumption of Amazonian wood, although low at present, is also likely to increase as Asian tropical hardwood stocks decline.

Brazil, which possesses almost one-third of the world's rain forest area, is well positioned to dominate the tropical timber trade in the twenty-first century. However, in Amazonia, as elsewhere in the humid tropics, timber extraction is done carelessly and has significant impacts on forests, leading to severe canopy loss, increased likelihood of fire, and vine and grass invasion (Johnson and Cabarle 1993, Pinard et al. 1995, Uhl and Kauffman 1990, Veríssimo et al. 1992). In only rare instances are forests in the Brazilian Amazon being managed sustainably for timber production.

It is possible, in both technical and economic terms, to sustainably manage Amazonian forests

Although millions of dollars are directed to Amazon forestry research each year by international development agencies, philanthropic foundations, and national governments, few of these investments are providing the kinds of information necessary to understand and remedy forest sector problems. A review of forestry-related studies from the Brazilian Amazon showed that only 3% addressed the question of forest management, a mere 1% examined logging practices, and virtually none addressed economic and forest policy issues (Weaver 1991 and other sources therein).

As biologists and environmental scientists, we generally restrict our attention to the technical aspects of resource-use problems. But environmental problems are many-faceted clusters of problems, and technical information represents only a part of the total information needed to develop and implement sound forest-use practices. Also required are case studies, economic analyses, policy research, and enforcement studies.

In this article, we present an overview of the types of research (and resultant information) that are helpful in developing wise management approaches for Amazonian forests. We begin by summarizing the results of case studies that focus on what loggers and millers do and the environmental, economic, and social significance of their actions. The case studies are used to detect patterns in wood sector activity and to identify the reasons for these patterns. We then discuss how the results of case studies can be used to develop models that predict logger behavior and the spread of logging activities. Finally, we discuss research on effective forest practices. This research not only includes research on "best" logging and forest management practices, but, just as important, encompasses research on "best" policy initiatives and "best" regulation (e.g., zoning and law enforcement) approaches.

The research we describe has been conducted by the Instituto do Homem e Meio Ambiente da Amazônia (IMAZON), a small, private research institution located in Pará State in Eastern Amazonia. IMAZON is founded on the belief that the ability of scientists to influ-

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ence prevailing patterns of resource use lies in the relevance of the questions that we ask; in the quality of our investigations; and in our willingness to make the results of our research available to the media, the government, and the public at large.

Research on wood sector patterns and trends

The wood industry has grown rapidly in the Brazilian Amazon for several reasons. The most obvious reason is roads: The Brazilian government provided access to Amazonia in the 1960s and 1970s via an ambitious colonization and road construction program. The roads (e.g., Belém-Brasília, Trans-Amazon, and Cuiabá-Santarém Highways) are focal areas for logging activities and represent a large subsidy to the timber industry. A second reason is the depletion of hardwood stocks in the south of Brazil, which, together with rapidly growing economies in the South and Northeast, has created a large domestic demand for Amazonian wood (Veríssimo et al. 1992). The third reason is that much of the land on which logging has occurred has been unclaimed; as a result, timber has been abundant and available at low cost (sometimes even for free) in Amazonia.

Not one, but many, wood sectors. The wood industry in the Brazilian Amazon is commonly described using summary statistics and averages, but this approach provides only limited information. In our field research, we have found that there are few central tendencies in the industry, but there are some patterns. Detecting these patterns has required a combination of extensive sampling and intensive case studies (Barros and Uhl 1995, Uhl et al. 1991, Veríssimo et al. 1992, 1995).

The factors that influence the actions of the wood industry include the species composition of local stands (especially the presence of high-value species), transport options (e.g., fluvial versus terrestrial), marketing options (e.g., domestic versus export buyers), local socioeconomic systems (e.g., traditional debt and barter systems versus modern market economy), and the availability of investment capital. The role of these factors is evident in Pará state (Figure 1), where most Amazonian logging activities are concentrated. We have identified five patterns of logging in this state.

Two patterns of logging are found in várzea, or floodplain forests (Table 1). One involves the harvest of virola (*Virola surinamensis* [Rol.] Warb.) and is highly selective, with only one to two individuals harvested per hectare. Local people cut the virola trees with axes, and the logs are floated out of the forest during periods when the forest floods. This logging has few environmental impacts. Landowners or mill agents provide food, supplies, and money to cutters in exchange for logs. The contractual arrangements are similar to those used in the rubber trade in the late 1800s.

This traditional logging system has flourished because virola has been common along the main stem of the Amazon River, fluvial transport is cheap, and a socioeconomic system based on debt-peonage existed that could be easily co-opted.

Recently, a second, more intensive type of logging has become common in the várzea. In this model, local people, usually working in pairs, cut trees and tether the buoyant logs to their canoes and then paddle to nearby cottage-style mills. A typical mill of this type consists of little more than a thatched shelter covering a large circular saw. The same motor that is used to run the family boat is often employed to power the saw. Barros and Uhl (1995) tallied approximately 1000 such small mills in the Amazon Estuary. Because of their small size, these mills specialize in logs between 20 and 45 cm in diameter and work with approximately 50 species. This more aggressive logging can lead to significant forest impoverishment; over a period of years, dozens of trees might be removed from each hectare of forest.

This high-impact, várzea logging model has become prominent for several reasons (Table 1). First, demand for construction-grade boards in the rapidly growing cities and towns of eastern Amazonia is increasing. In addition, the local labor force is able to get logs from forest to mill with almost no capital investment. Moreover, the ability to use preexisting small boat engines to run low-cost circular saws makes it relatively easy to set up a mill.

In general, várzea forests show promise for timber production and forest management because they are simpler floristically than terra firme

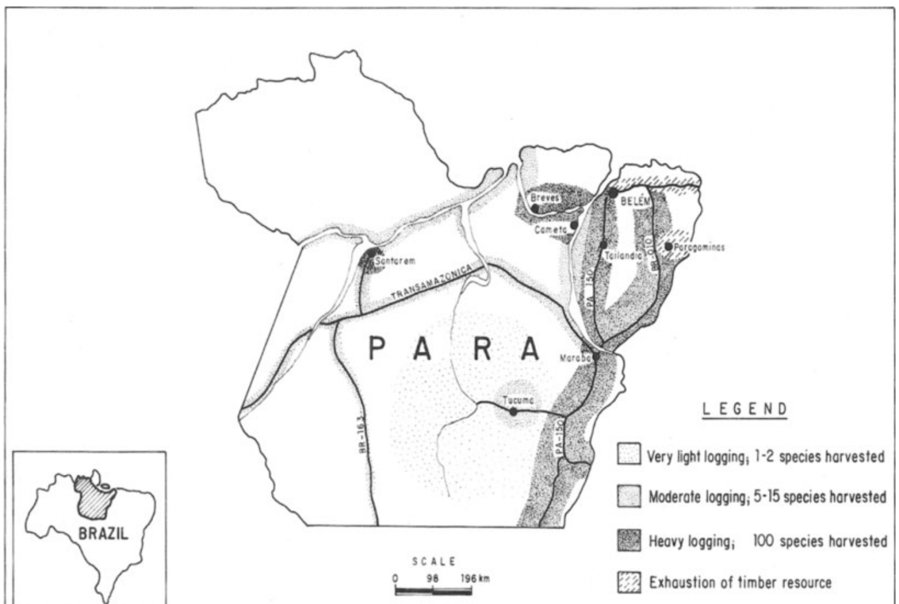

Figure 1. Patterns of logging in Pará state, Brazil. Várzea logging is concentrated in the estuary and along the main stem of the Amazon River. Terra firme logging is generally concentrated along government highways. Mahogany logging is an exception—the exceptionally high value of this species results in its extraction in regions that are far from government roads.

Table 1. The characteristics of the five predominant models of timber harvesting in eastern Amazonia in the 1990s.

Model	Selectivity of timber harvest	Number of species harvested	Number of individual trees harvested per ha	Economic/social system
Várzea—traditional	Highly selective (low-impact logging)	1–2	1–2	Paternalistic—local people hand harvest wood in exchange for staples; large, distant companies do the wood processing; final product of export quality.
Várzea—contemporary	General harvest (high-impact logging)	Approximately 50	More than 10	Cottage industry—local families hand harvest and process small diameter logs in small household mills; final product of low quality and suitable only for regional markets.
Terra firme—incipient frontier	Highly selective (low-impact logging)	1	Less than 1	Big business—diversified well-capitalized companies from outside the region build roads and extract mahogany; final product of export quality.
Terra firme—new frontiers	Somewhat selective (moderate-impact logging)	5–15	1–3	Small family business—families from outside the region with some experience in wood processing establish simple mills near government roads, relying on others to conduct logging and transport logs to mill; final product for domestic market.
Terra firme—old frontiers	General harvest (high-impact logging)	100–150	5–10	Large family business—families from outside the region conduct logging, transport, and milling in vertically integrated operations; final product of moderate to high quality, sometimes destined for export market.

forests yet are well stocked with timber. Also, trees generally grow more rapidly in the more fertile várzea soils than in most terra firme areas. Finally, várzea logging usually results in less damage than terra firme logging because trees can be floated out of the forest, obviating the need for heavy machinery.

Although logging has traditionally been centered in the várzea, in recent years the wood industry has expanded into interfluvial terra firme zones, where three patterns are evident: "low"-, "moderate"-, and "high"-impact logging (Table 1).The most highly publicized form of low-impact terra firme logging is that centering on mahogany (*Swietenia macrophylla* King), a species of exceptionally high value that occurs in southern Pará state (Figure 1). In this region, mahogany logging companies have opened up forest roads that extend as far as 500 km from their mills. Although heavy machinery is used in road building and skidding, forest damage is low because of the highly dispersed distribution pattern of adult mahogany trees. Mahogany trees are usually restricted to low-lying areas and, even in these zones, usually occur at a density of only one or two adults per hectare.

In a recent study, Veríssimo et al. (1995) found that only two dozen mills were responsible for processing 90% of the mahogany harvested in southern Pará. Annual profits of these large companies often exceeded $1 million. This third logging model illustrates that when timber companies have capital and the bait of high-value timber, they can extend road networks hundreds of kilometers into the forest. Furthermore, we have found that the rudimentary infrastructure of roads and bridges built by loggers is often the first step in the conversion of forests to farm fields and pastures.

Increased infrastructure is often associated with more aggressive logging practices. For example, moderate-impact terra firm logging is common in official colonization areas, where construction of government-financed roads is recent, such as along Pará Highway 150 (built in the 1980s; Figure 1). In such areas, conditions for the rapid growth of the logging sector are present, even though species of exceptional value, such as mahogany, are absent. In these areas, timber is available close to roads and settlers, who are eager to clear forests for farms, are willing to provide logs to small, family-run mills at low cost. Frequently, the colonists themselves do the logging and negotiate with local truckers to get logs to mills (Uhl et al. 1991). Only a few trees are removed per hectare—those with the best form and in highest demand. This fourth model (Table 1) illustrates that in the absence of a truly high-value species, terra firme logging begins only after the government provides roads. Once this occurs, a variety of actors (small landholders, truck drivers, and millers) pool the talent, capital, and labor necessary to give rise to a local wood products sector.

Although terra firme wood industries typically begin by logging only one (low-impact case) or a few (moderate-impact case) species, logging often changes to high impact as frontiers age and infrastructure and access to markets improves. For example, at the old logging center of Paragominas on the Belém-Brasília Highway (built in 1960s), logging companies use bulldozers to harvest some 100 tree species (5–10 individuals/ha). The more successful logging operators in this region have gradually accumulated capital and created vertically integrated industries. With time, these successful operators often make contact with international buyers and begin exporting a portion of their production. The environmental impacts of this fifth, aggressive logging style are significant: approximately 30 trees greater than 10 cm in diameter are destroyed for each tree harvested, and canopy cover is often reduced from 80%–90% in prelogged forest to less than 50% following logging (Uhl and Vieira 1989, Veríssimo et al. 1992).

Factors that affect the spread of the wood sector. From the logging patterns discussed above, it appears that participants in the Amazon wood products sector respond in predictable ways to differences in timber value and access, capital availability, and historical and cultural factors (Table 1). Based on the various resource-use patterns within the wood products sector, we can predict how the wood industry might evolve and how it might respond to increasing wood scarcity.

Logging in Pará currently results in the harvest of approximately 4000 km² of forest each year, producing approximately 8 million cubic meters of roundwood.[1] Meanwhile, the Brazilian economy is projected to grow at 7% annually for the foreseeable future (Veja 1994). If the Amazon wood products sector experiences this same level of growth, Pará loggers will soon be removing considerably more timber ("capital") from the state than will be replaced (through natural regrowth), and timber will become increasingly scarce in many parts of the state.

The response to wood scarcity in the várzea could be rapid. For example, if timber becomes more scarce around the major trading center, Belém, and prices for sawn timber go up, more small mills (cottage industries) will likely be established, not just in the estuary but also in more remote regions of the várzea. Moreover, as the costs of terra firme logging increase (because of the increased expense associated with transporting logs from distant sources), river-based logging may become increasingly economically attractive to large logging companies. Indeed, the banks of the Amazon River should be attractive to lumber companies because of the low price of roundwood, the availability of cheap labor, the low cost of fluvial transport, and the easy access to international markets. Hence, if market forces alone operate, it is possible that many large mills will be established in this region in the near future (Figure 2).

Meanwhile, wood scarcity has already become a reality in some terra firme areas. For example, timber was once only a few kilometers from logging towns like Paragominas and Maraba (Figure 1), but over time mill owners have had to go farther for their wood and to pay more for it. As wood supplies are exhausted close to government-built roads, the terra firme companies that have the capital to build their own roads, acquire their own forest land, and do their own logging are among the best equipped to survive. In the mid-1990s, the most highly capitalized terra firme firms began buying large tracts of virgin forest and then literally moving their operations onto these tracts (Figure 2). This provided the first clear sign of a shakeout in the timber industry in "old" terra firme frontier regions.

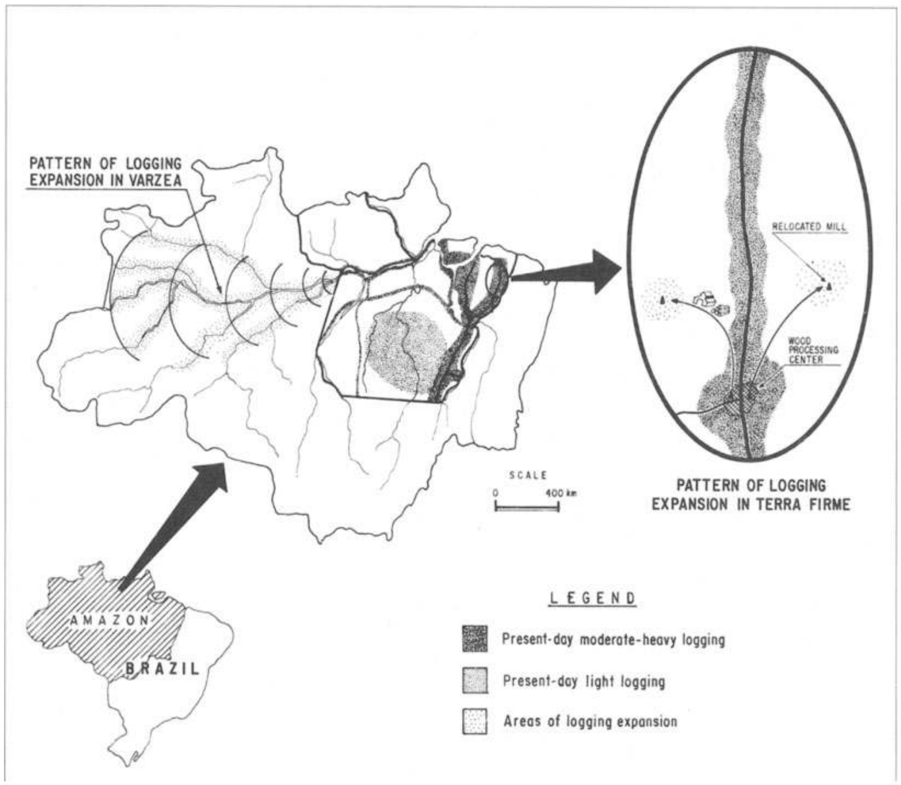

Figure 2. The expansion of logging activities in the Brazilian Amazon. (Left) Várzea logging operations are likely to spread from east to west up the main stem of the Amazon River. (Right) The more highly capitalized terra firme logging operations are likely to relocate deeper in the forest (i.e., closer to timber stocks).

[1]A. Veríssimo, 1995, unpublished data.

The less successful operators (i.e., those with limited capital) in these old frontiers are abandoning logging altogether or moving to virgin forests along newly constructed government roads to participate in "model 4" ("new frontiers") logging (Table 1).

IMAZON researchers are now in the process of going beyond these descriptive scenarios for wood industry expansion; we are creating a geographic information system–based model that allows for predictions of wood sector expansion in an array of economic and policy environments.[2] Hence, it should soon be possible to predict, in explicit spatial terms, how factors such as wood prices, new roads, new energy sources (e.g., hydropower), taxes, and tariffs could influence the expansion of the Amazon wood sector.

[2] S. Stone and A. Veríssimo, 1995, unpublished data.

Research on best management and regulation practices

Promoting sound forestry in the Brazilian Amazon requires more than an accurate characterization of the wood products sector and more than models to predict what might happen under different policy and economic conditions. Specifically, there is an urgent need for empirical information concerning best forestry practices and best regulation techniques.

How to best manage forests? We limit our discussion of "best" forestry practices to terra firme forests because of the predominance of this forest type. However, as indicated above, várzea forests also have forestry potential, and there is a need for forest management models for these forests as well.

Present-day terra firme logging practices are best characterized as "forest mining" operations (Figure 3). Loggers first enter forests to remove the high-value timber species (a few individuals/ha). If these logged stands are left to recuperate, canopy cover and stocking should eventually return to preharvest conditions (although there will almost surely be modest shifts in species composition). However, loggers usually reenter logged forest stands at short time intervals to remove lesser-value species or to remove smaller individuals of certain high-value species. These activities result in the opening of new roads and skid trails and, hence, in further forest deterioration. Furthermore, vines are frequently favored by logging disturbances. Vines can form thick mats that cast dense shade, and they can weigh down juvenile trees, causing bole deformities. Fire is an additional impediment to recovery in logged forests. These forests are rich in fuel (broken and damaged trees), and the opening of the forest canopy, which increases the amount of radiation reaching the forest floor, can dry this

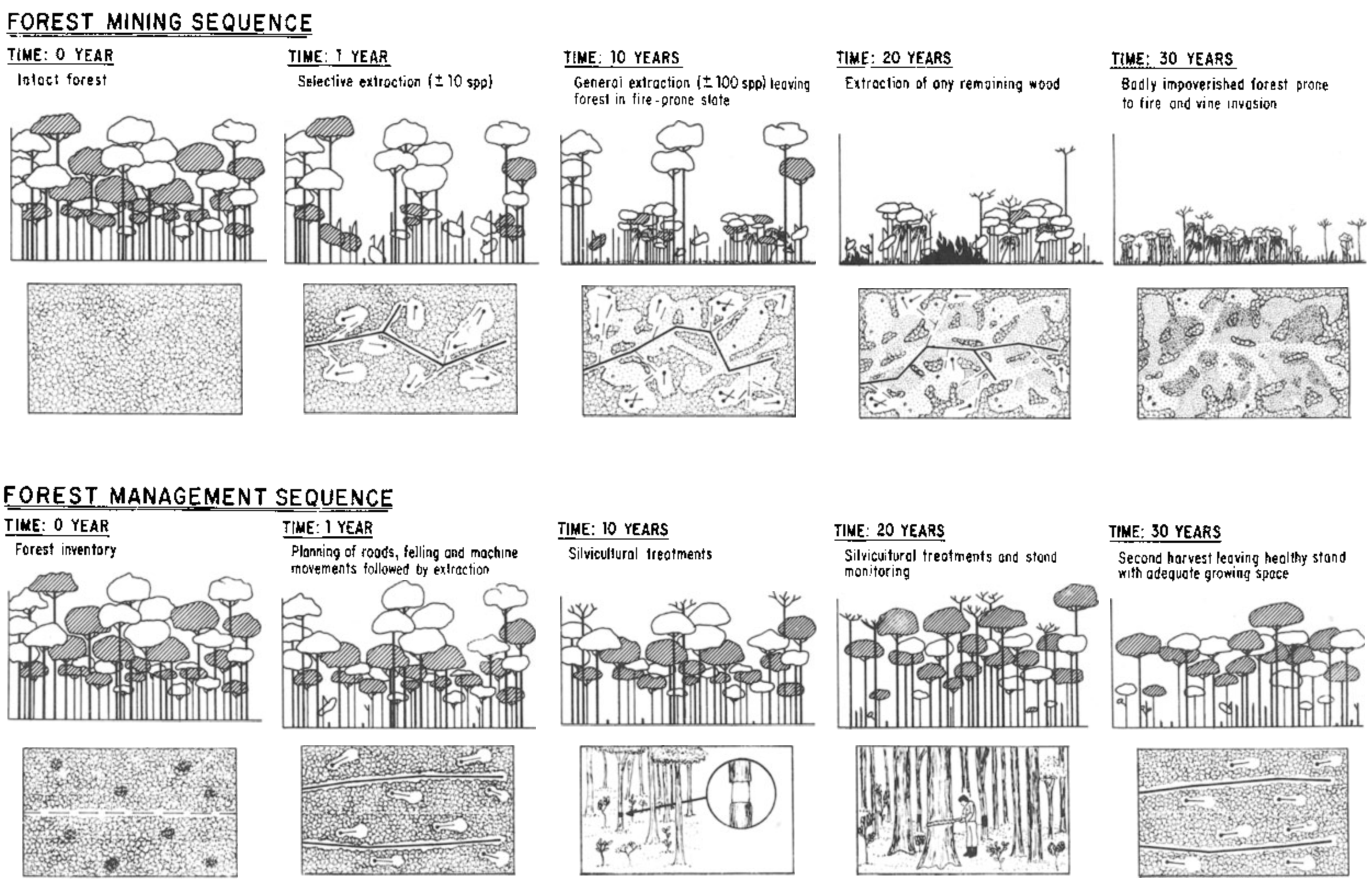

Figure 3. (Top) Typical terra firme logging ("mining") practices that lead to forest degradation in eastern Amazonia. (Bottom) The alternative is forest management and includes conducting forest inventory, planning of extraction activities, and silvicultural treatments. With this approach, sustainable cutting cycles might be reduced from 70–100 years to 30–40 years. For each step in these sequences, the upper panel shows a side view of the forest, and the lower panel shows a view from above or a close-up side view.

slash to a fire-ready state during dry periods (Uhl and Kauffman 1990). The end result of terra firme logging is often a highly degraded ecosystem that has lost much of its forest character. Indeed, in its present guise in much of eastern Amazonia, logging is really step-wise deforestation.

The lack of careful approaches to terra firme logging in eastern Amazonia is not surprising. The very abundance of timber resources means that timber is undervalued and, therefore, used carelessly. Forest management would require that land users adopt a long-term perspective and carefully manage their forest holdings to achieve a sustainable cash flow. However, in "boom-and-bust" frontier economies, a "free-for-all" mentality frequently operates, and it is difficult for settlers to resist the temptation to quickly liquidate forest resources.

Despite these pressures, information is accumulating showing that it is possible to manage these forests. In 1990, IMAZON set out to provide information on "best" harvest and post-logging silvicultural practices. The work was conducted in Paragominas (Figure 1) in side-by-side plots—one subjected to typical logging practices and the other to "best" forestry practices—on a forest tract owned by a local wood products company. This effort was intended to evaluate the economic and ecological costs and benefits of planned versus unplanned selective logging operations.

The research has demonstrated six important advantages of managed logging (Figure 4). First, conducting forest inventory and mapping procedures before logging resulted in less waste during logging. In typical operations, one or more trees per hectare (amounting to almost 7 m^3/ha) are felled but never found by skidder operators. However, in planned logging operations, all skid trails are flagged, and machine operators are guided to felled trees by trained woodsmen. Hence, the waste of cut, but not harvested, timber is eliminated. Second, the careful planning of machine movements resulted in an approximately 25% reduction in the ground area affected by machine movements compared to nonplanned logging (Johns et al. in press). Third, vine cutting, conducted two years before logging, resulted in an approximately 30% reduction in damage to trees (greater than 10 cm in diameter) during felling operations (Johns et al. in press). Without vine cutting, felling operations resulted in

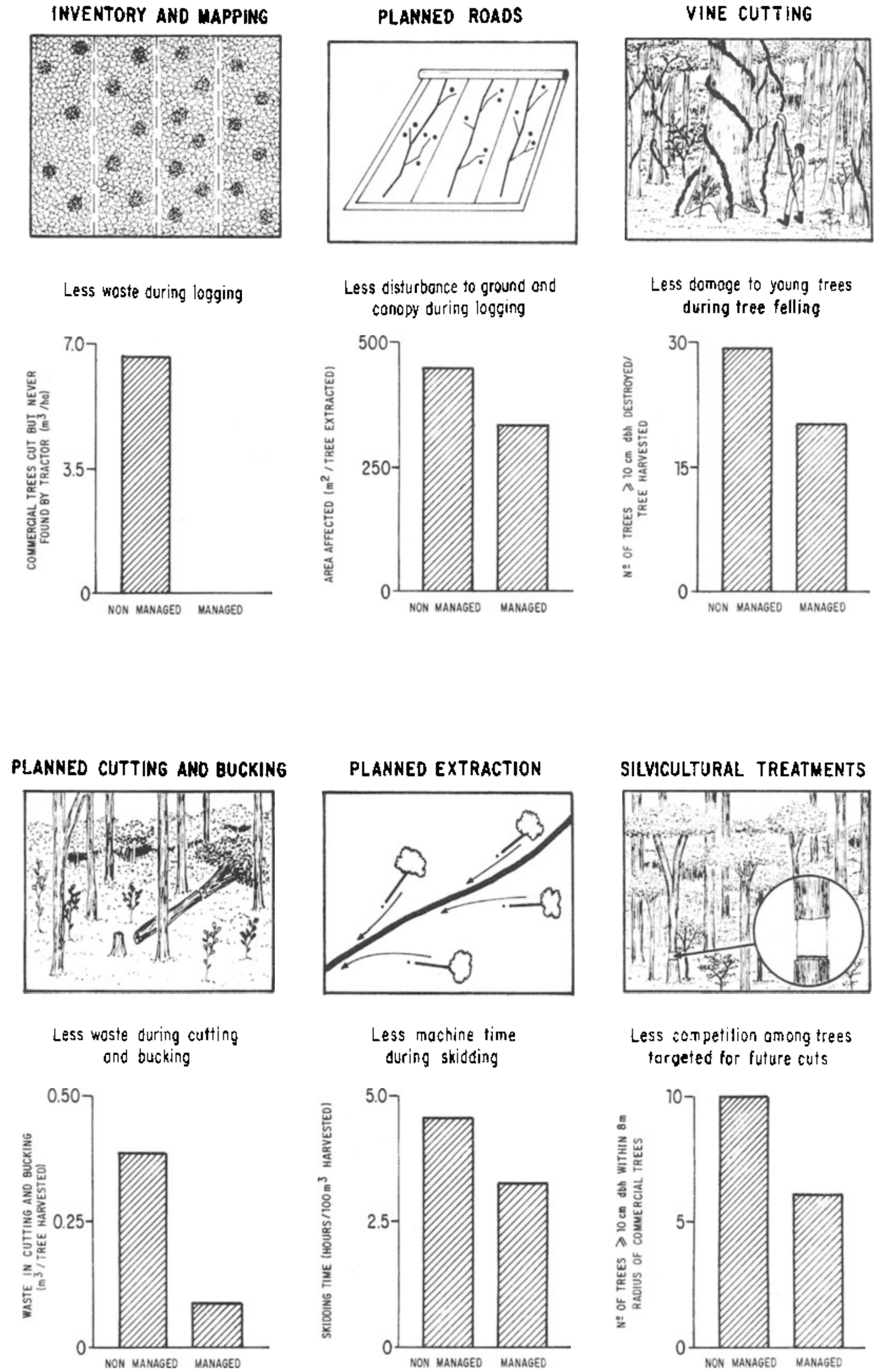

Figure 4. Six logging management steps that bring measureable benefits in eastern Amazonia terra firme forests. The benefits include: less waste during logging, less disturbance to the ground and canopy during road building and felling, less damage to young trees during felling, less waste during cutting and bucking, less machine use during skidding, and better growing conditions (less competition) for trees targeted for future cuts.

severe damage to subcanopy trees (linked to canopy trees by vines) that otherwise would have been available for future harvests. Fourth, we observed that trained loggers were able to achieve a threefold reduction in waste associated with felling and bucking in planned logging operations (Figure 4). They did this by making cuts closer to the ground and reducing bole splitting by using correct felling procedures.[3] Fifth, machine operating time was reduced by approximately 20% in the planned operation compared with traditional operations.[4] This reduction was possible because all skid trails were preflagged, allowing machine operators to move quickly to the felled trees. Finally, deliberate girdling to kill undesirable trees after logging provided significantly more growing space for the commercial individuals targeted for future cuts (Figure 4).

Of course, insofar as managed logging entails forest inventories, vine cutting, and careful planning, it has an added cost (approximately $50/ha). However, the monetary losses from ineffective use of machinery and unnecessary wood waste in unplanned operations may often be greater than the additional costs associated with planned logging operations.[5] Hence, managed logging might actually lead to increased profits. Furthermore, there is at least the possibility that nontimber forest products, such as oils, fruits, and resins, might be managed and marketed together with timber, thereby improving returns even more.

Perhaps our most significant findings about forest management relate to cutting cycles. Implementing the low-impact, selective logging approaches and silvicultural treatments described here could reduce cutting cycles in half, from 70–100 years without management to 30–40 years with management (Barreto et al. 1993). In other words, forest management might double production in many situations; in such cases, individual mills would require half as much forest as at present to supply their annual wood needs. To help ensure that the species composition of future cuts does not change significantly, healthy populations of seed trees of all commercial species must be maintained in logging areas.

Finally, IMAZON's research reveals that an increase in sawmill efficiency would further reduce the amount of forest land required to maintain current wood production levels. At present, only approximately one-third of each harvested log is transformed into sawn products, but processing efficiency could be increased to nearly 50% through simple improvements in machinery maintenance and by training the labor force.[6] Companies that couple such increased efficiency with forest management would require only approximately one-third of the forest land that they now require to produce the same amount of sawn timber.

The results of this forest management research are being disseminated through conventional academic outlets (Barreto et al. 1993, Johns et al. in press). However, the most eager recipients of this information are practitioners in the wood sector. The results of our work have been compiled in a forestry manual specifically targeted at these practitioners. People in the timber sector are alert for information that will raise their efficiency because they are increasingly concerned about future supplies of roundwood. A heightened appreciation for the value of timber resources, both in the mill and in the forest, is important for the gradual process of developing a sustainable forest products sector (see box, next page).

How to best regulate logging activities? Knowing how to manage forests is important, but this knowledge must be combined with an effective policy that specifies where logging is to be permitted and prohibited (i.e., zoning of logging) and a sensible forestry code that is fully enforced.

At IMAZON, we have just completed a project to help policy makers and society consider how to zone logging activities (Veríssimo et al. in press). We have incorporated information on vegetation characteristics, species endemism, and protected lands into a geographical information system for Pará state. Superimposing these spatial data has provided a basis for an informed discussion about where logging might be promoted or prohibited. For example, logging might be prohibited on land with moderate to high levels of endemism and biodiversity and on all Indian lands and parks. In this scenario, logging would be permitted on only 20% of the Pará's lands (250,000 km^2). Of course, other zoning scenarios are possible. A geographical information system application like this helps to provide society with the information it needs to engage in an informed debate on resource management and conservation.

The second challenge in the regulatory sphere is to adopt and enforce a sensible forestry code. At present, there are too many government regulations; everything is regulated—planting, cutting, transport, processing, and marketing. Meanwhile, the objectives of the regulations are often poorly thought out and serve conflicting purposes.[7] Also, the legal standing of many rules is questionable. Some have the status of bona fide laws, but others are edicts and proclamations of untested legitimacy produced by state and federal environmental agencies. Finally, all this regulatory morass is nearly moot because forest sector laws are seldom enforced.

In Pará, some government agencies are eager to receive help in developing reasonable regulations from researchers. IMAZON has recently initiated a project together with SECTAM (Pará State Secretary of the Environment) that includes a classification of existing forest laws with regard to relevance and enforceability, policy analysis (e.g., effects of different laws on the behavior of the wood sector), and economic investigations (e.g., evaluation of the costs and benefits of different approaches to enforcement).

We believe that it is necessary to dramatically simplify the regulatory apparatus. Rather than a mass of laws of dubious value that are largely

[3] E. Vidal, 1995, unpublished data.
[4] P. Amaral, 1995, unpublished data.
[5] P. Barreto, 1995, unpublished data.
[6] J. Gerwing, 1995, unpublished data.
[7] R. Kaplin, 1993, unpublished data. World Bank, Washington, DC.

ignored, it would be wiser to establish a limited number of easy-to-enforce laws that would ensure forest well being. Indeed, we believe that the effective enforcement of just one three-part forestry law would be sufficient to greatly reduce abuses to Amazonian forest resources. The regulation might be called "Edict 5/50/5." The first "5" refers to our proposed limit on the number of trees that could be removed per hectare in a logging episode; the "50," to our conservative proposal for the minimum number of years between logging episodes; and the final "5," to the width, in meters, of the fire break that we propose be maintained around all logged stands in the first decade following logging to avoid ground fires. The enforcement of such a law would protect forest stands from the three factors that are leading to forest demise—excessive harvest, repeated harvest at short intervals, and fire.

Conclusions

We have focused on the research required to produce the information that society needs to develop sound approaches to Amazon forest management. Although we believe that it is possible, in both technical and economic terms, to sustainably manage Amazonian forests, we wish to stress that this is unlikely to occur in the absence of an active civil society and political will.

To date, Brazil has exercised little authority over the process of land occupation and land-use regulation in Amazonia. But Brazil is a new democracy; the country was under military rule until 1984, and there are signs that Brazilian civil society is becoming better organized and more vocal.

The rapid growth of nongovernmental organizations in Brazil is a manifestation of the growing strength of civil society. There are dozens of environmentally focused nongovernmental organizations in Amazonia, many of which are assuming responsibilities that the government has not fulfilled. For example, some of these organizations are demarcating Indian lands and extractive reserves, others are identifying environmental crimes and prosecuting offenders, and still others are providing technical informa-

Sustainability—incremental steps toward an elusive goal

We believe that the development of a sustainable forestry sector in Amazonia will evolve gradually, over a period of years, and will be marked by five steps or levels of awareness:

Step 1: Appreciation of the magnitude of wood waste in sawmills. Until recently, wood was so abundant and cheap in the Brazilian Amazon that there was little inclination to be concerned about mill waste. As logs have become more scarce in old logging centers and as log value has increased, this has begun to change. Now, mill owners are alert when we point out ways of reducing waste. This heightened appreciation for the value of the resource is the first step in the progression that leads to sustainable forestry practices.

Step 2: Appreciation of the magnitude of wood waste in logging operations. IMAZON researchers have documented that approximately 7 m^3 of wood/ha are left in the forest (Figure 7) because machine operators fail to locate felled trees. This statistic is alarming to many wood companies, and it may spur them to conduct forest inventories to determine, beforehand, the locations of all timber to be felled. From there, it is only a small step to recognizing that waste is also associated with careless felling, bucking, and skidding practices. Many smaller trees of commercial species are unnecessarily damaged in these operations. Here again, loggers reaching this level of awareness demonstrate an appreciation for the value of the resource.

Step 3: Appreciation of cutting-cycle limits. A decade ago, many loggers in eastern Amazonia believed that tree growth was so rapid that forests could be relogged every ten years. Only recently have some of the older loggers observed firsthand that this is not the case. When told that sustainable cutting cycles will often be 70 or more years without management and that careful extraction practices and silvicultural measures could shorten cutting cycles to perhaps 30–40 years, some forward-looking timber operators are ready to adopt forest management practices, the third level of awareness.

Step 4: Appreciation of nontimber forest products. Loggers are business people—they want to make money. Hence, they might come to have more than a passing interest in nontimber forest products. An appreciation for the potential economic importance of such products is an important step toward the realization that forests are more than just wood and that the myriad species in forest stands should be treated with care.

Step 5: Appreciation of ecosystem services. The final step in this progression is the awareness that forests provide many valuable services that are not accorded market values. The careless and destructive use of forest resources has detrimental effects on climate (e.g., carbon loss contributing to global warming), biodiversity (species loss), and hydrology (increased incidence of flooding). Ideally, forest managers would eventually come to have an appreciation for the role of forest ecosystems in maintaining regional hydrology, protecting biodiversity, and storing carbon.

As full awareness of forest value increases from Step 1 to Step 5, there should be a corresponding increase in interest in maintaining regional biodiversity and developing truly sustainable forestry. In the case of Pará, we note that the most "enlightened" wood companies began at Step 1 and are now, perhaps, at Step 3.

tion and extension services to forest communities.

The case of IMAZON is instructive. At IMAZON, we have come to appreciate that there are three characteristics that are important for institutions wishing to address complex problems, such as those confronting Amazonia. First, addressing such problems requires time: in the case of IMAZON, some 25 years of researcher time over the past 7 years have been dedicated to the wood sector research described herein, and many years of work lie ahead. For many environmental problems, it seems to take three to five well-trained people devoting full attention for five to ten years before significant headway is made.

Second, environmental problems are many sided and require that research teams be willing to cross disciplinary lines. We began this wood sector research expecting to limit our attention to ecological issues. We soon realized, however, that the economic, policy, legal, and regulatory sides of the problem merited as much attention as the ecological side, and so we read, networked, and brought on new talent. A willingness to "go where the problem leads" is essential to successful environmental problem solving.

Finally, our approach has required a willingness to produce information in a variety of forms (e.g., manuals, films, short courses, and popular articles, in addition to scientific papers) for a diverse audience. In the academic world, there are few incentives to communicate findings to the general public (although this is changing in some quarters). We believe that these three characteristics—a long-term commitment to resolving the problem under study; a recognition that resource-use problems are many sided, requiring a cross-disciplinary research approach; and a commitment to communicating findings to the full range of stakeholders—are fundamental to the successful resolution of the many environmental problems that now confront humanity.

In conclusion, it is important to remember that governments, whether in Brazil or the United States, generally aim to protect the status quo (i.e., special interests); they are not, by nature, advocates for social justice or for the environment (e.g., for the US case, see McGrory Klyza and Trombulak 1994, Zinn 1991). Hence, it is likely that the Amazon environment will continue to become impoverished until citizens become better organized and more vocal. Scientists are in a unique position to speed this process of civic awakening. We can do this by the very nature of the questions that we ask, by the quality and breadth of our investigations, and by the efforts we make to channel our findings to the media and to society at large.

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