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LOGGING ALONG THE AMAZON RIVER AND ESTUARY: PATTERNS, PROBLEMS AND POTENTIAL

Ana Cristina Barros
Instituto do Homem e Meio Ambiente da Amazônia (IMAZON)
Caixa Postal 1015
Belém, Pará, 66.017--000, Brazil

and

Christopher Uhl*
Biology Department
The Pennsylvania State University
University Park, PA 16802, USA

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*Affiliation in Brazil: Instituto do Homem e Meio Ambiente da Amazônia (IMAZON), Belém, Pará.

ABSTRACT

Over the last several centuries most of the logging in the Brazilian Amazon has occurred along the Lower Amazon River and estuary and for good reason. Timber has been abundant there, the costs of wood extraction and transport have been low, and access to markets has been good. In this paper we first characterize the structure of the wood sector in this region considering the number, types, and spatial distribution of mills. We then analyze the different timber extraction, transport, milling, and marketing options available in this region in terms of investment requirements and profitability. We conclude by describing how the wood industry is likely to expand in this region and offer a blueprint for the development of a sustainable forestry sector.

We gathered our data by visiting all the counties along the Lower Amazon River and estuary over a one-year period (1990-1991). In our travels, we conducted almost 200 formal interviews (questionnaires) with wood extractors, log transporters, mill owners, and wood retailers, as well as hundreds of informal interviews with long-time residents of the region including merchants, boat captains, and politicians.

We registered 1,295 functioning wood industries. Of these, 1,191 were small mills (circular saw) with an average annual production of 650 m^3 of sawn wood; 98 were medium-size, bandsaw-type mills with an average annual production of 3,500 m^3; and the remaining six mills were large veneer/ply board operations with an average annual production of 33,850 m^3. Together, these 1,295 mills generated some 28,500 jobs and produced 1.3 million m^3 of sawn wood or 31% of the production of the state of Pará.

Many strategies are employed in the extraction, transport, processing, and selling of wood. Each strategy has its peculiar capital

requirements, operating costs, and profits. The approach that required the least capital entailed extraction of wood from floodplain forests, transport in log rafts, and processing in cottage-style mills but the end product of this sequence was low-value, rough-sawn boards sold to local buyers. Although profits are only $2,800/yr/mill, these returns are good compared to other options for small households, and more than a thousand such mills have been built in recent years.

Operators with more capital establish bandsaw-type mills. Annual profits from these mills ranged from $30,000 to $200,000 and were strongly affected by wood type (wood from terra firme forest is of higher value), transport mode (e.g., transport in barges is only one-third the cost/m^3 of truck transport), and marketing strategy (international buyers pay higher prices than domestic buyers). In all cases, the options giving a higher return (i.e., extracting logs from terra firme forests, barge transport, and international marketing) required more operating capital to initiate. The most capital intensive mills were the large veneer/plyboard mills. In compensation, annual profits for these operations approached one million dollars.

The potential for the expansion of the timber industry up the Amazon River is great, in large part, because of the abundance of timber and the advantages offered by fluvial transport. But a special opportunity now exists for the development of sustainable forest management. The factors necessary for the development of sound forestry practices are uncontested dominion over forest resources for local people, well designed economic incentives that encourage management, and new bottom-up administrative models.

INTRODUCTION

Commercial logging has been practiced for more than four centuries in Amazônia. In the sixteen hundreds exotic timbers were removed from the margins of the Amazon River and carried to European cities. At that time and until the 1800s, wood was a product of low importance when compared to such items as cacão, brazilnut, and rubber (Santos, 1980; Silva, 1987; Gentil, 1988). In the twentieth century logging activities began to intensify. The first saw and veneer mills were established in the Amazon estuary in the 1950s. These were built with foreign capital, powered by steam, and oriented to export markets. Two species, Virola surinamensis and Carapa guianensis, were processed in these mills. The state of Pará (Fig. 1), especially the estuary of the Amazon River, dominated the Amazon wood sector from 1950-1970, accounting for three-quarters of all the wood produced (FAO, 1976; Palmer, 1977; Silva, 1987; Reis, 1989; Browder, 1989).

It was only in the 1970s, with the building of roads, that logging activities penetrated the interfluvial areas of Brazilian Amazonia. In Pará the building of the Belém-Brasília Highway, the Belém-Marabá Road (PA 150), and the Santarém-Cuiabá Highway (PA 163) provided access to large areas of terra firme (upland) forest.

In a recent series of papers published in Forest Ecology and Management, we have documented three distinct patterns of logging in the terra firme forests of Pará State. One pattern is that seen in old frontiers, such as in Paragominas County located along the Belém-Brasília Highway (Fig. 1). Here, a good infrastructure exists and mills are often large and vertically integrated (Veríssimo *et al.*, 1992). The mills have field crews that do the logging and more than a hundred tree species are harvested. Another pattern is seen in new frontier areas, such as around Tailândia along PA Highway 150 (Fig. 1) (Uhl *et al.*, 1991). Here the mills are small. Mill owners buy logs from loggers who, in turn, often harvest wood from small forest tracts owned by farmers. Only about a dozen species are harvested and extraction is done manually. The third pattern of terra firme logging occurs in incipient frontier areas. In this case, no infrastructure is present. Hence, the wood companies, themselves, build the roads. This model is only possible where the forest timber is of extremely high value. It is seen in the South of Pará (Fig. 1) where well capitalized wood industries go as far as 500 km into the forest is search of mahogany (Veríssimo *et al.*, 1995).

In this paper, the final in this series of four, we examine logging activities along the Amazon River-- far removed from the influence of roads and recent government colonization programs. No single logging pattern characterizes this region. Small, medium, and large companies operate; they extract trees from both terra firme and várzea forests. However, all operations depend on rivers to transport cut timbers and/or processed wood. Fluvial transport, then, becomes a defining characteristic of Amazon River logging.

Our specific goal in this paper is to analyze timber extraction, transport, and processing activities in the Lower Amazon River and estuary. We will create a typology to distinguish the types of extraction, transport, and processing that we observed in the field. Then, through an analysis of investments and profits associated with different systems of extraction, transport and processing, we will reveal the logic behind the behaviors of different actors in the wood sector. We will also determine the social and economic significance of this industry at a regional level by estimating labor generation and gross monetary returns. Finally, based on a consideration of historical factors and present conditions, we will present evidence for the likely expansion of the wood industry up the main stem of the Amazon River and provide and discuss the measures necessary to help assure that logging be practiced in a sustainable fashion in the region.

METHODS

The data that we present in this paper were collected through interviews conducted in 1990 and 1991 in the Lower Amazon River and estuary of Pará State. This is a region that encompasses Marajó Island and extends 1,200 km from the port of Belém at the mouth of the Amazon up to the border with Amazonas State (Fig. 1). The study region is composed of 29 counties and the first author visited each of these counties for a minimum of 3-4 days. Longer periods of time (6-10 days) were necessary to gather information in three counties, Breves, Cametá, and Santarém, where wood processing activities were most pronounced. And in Breves, owing to the very high density of small, family-run mills, a two-week field survey by boat was conducted.

Approximately 250 general interviews were conducted in the visits to the 29 county seats. Interview subjects were leaders, extensionists, river traders--in short, people who had lived in the region for a long time and who traveled frequently to the interior. They provided information on the location, age, and types of sawmills in each county. All information was confirmed by at least one additional informant. The locations of the mills were plotted on county maps produced by the Brazilian Institute of Geography and Statistics (FIBGE). Mills were placed in three categories: 1) mills using circular saws (always small, cottage-style mills); 2) mills using bandsaws (almost always medium-size mills employing about 30 people); and 3) veneer/plyboard mills (always large mills employing hundreds of people).

In these general interviews, we also asked informants for the names of people actively involved in the different sectors of the wood industry. We then prepared special questionnaires for loggers (n=10 interviewees), wood transporters (n=34), and mill owners (n=89 small mills; n=60 medium-size bandsaw mills; n=5 large veneer mills). Questions addressed to the loggers considered the number of people in extraction teams, equipment used in extraction, productivity, ownership of forest land, and costs of logging operations. Questions addressed to transporters focused on operational costs of barges, tugboats and trucks. We acquired detailed information on the cost to construct boats by visiting five small factories that built the tugboats and barges used in wood transport. Similarly, we received more detailed information on boat maintenance costs by visiting three boat mechanic shops. Finally, questions addressed to mill owners considered year of installation, previous activities, work force, annual production, types of wood used, sources of wood, transport methods, costs, and buyers. All financial data were expressed in 1991 dollars.

RESULTS AND DISCUSSION

There are many styles of logging, transport, and milling evident in the Lower Amazon River and estuary. For example, timber is removed from both upland and flooded forests and extraction practices are different for each case; log transport might occur in open rafts, in enclosed barges, or by truck; processing might be done at the household level (cottage industry), in medium-size, bandsaw-type mills, or in very large mills (Fig. 2). We begin our presentation by analyzing logging practices in terra firme and várzea forests of the study region. Then, we go on to analyze log transport and log processing activities.

Timber Extraction in Várzea and Terra Firme Forests

Várzea logging

"Várzea" or floodplain forests are subjected to daily flooding (estuary) or seasonal flooding (beyond about 800 km up river). Since colonial times, timber extraction in the várzea has been done by hand. Even in the early 1990s trees were still, generally, felled by ax; wood cut by chainsaw was present in only 19% of the 63 mills, processing várzea woods, that we visited. After felling, trees were usually extracted manually from the forest (90% of cases, n=63 mills) . Generally, extraction teams relied on tides or wet season floods to buoy the felled logs and then they guided these logs from the forest to the river's edge. Otherwise, logs were literally pushed to the water's edge on top of poles laid cross-wise along a skid trail (Fig. 2). In a few cases, alternative techniques, such as water buffalo (8%) or hand-operated winches (2%), were employed to drag the boles from the forest.

Logging teams in the várzea were typically composed of three men. In one day a team cut and extracted, on average, 4.85 m^3 ("real" volume) of roundwood (Table 1). In a few cases, these logging teams were employed by mill owners but in most cases (91%) the loggers were independent. However, mills did finance loggers (83% of mills, n=63) by providing advance payments. These payments were frequently administered by independent boaters (middlemen) who gathered the logs at water's edge and delivered them to the mill.

The biggest cost of várzea logging was labor (57%) followed by the cost to purchase the trees (43%) (Table 1). The total cost to extract 1 m^3 of wood from the várzea was estimated at \$6.70 (Table 1).

Terra firme logging

In many parts of the Lower Amazon River Basin, dry land or "terra firme" forests occur in close proximity to the main stem and its tributaries. The wood from terra firme forest species is, generally, valued more than that from várzea species.

Terra firme logging teams were composed of 5 men (Table 1). In contrast to várzea logging, chainsaws were always used to fell trees in terra firme operations and trucks were necessary to move the logs from the forest interior to the river's edge or to the edge of public roads. Due to the more mechanized approach, the return on human labor was greater in terra firme logging (492 m^3 harvested/person/yr vs. 265 m^3 harvested/person/yr in várzea logging). However, the use of trucks greatly increased extraction costs as compared to the várzea where extraction was manual, relying on tides and seasonal floods (Table 1).

In both the terra firme and the várzea, logs, generally, were extracted from lands owned by third parties who were paid for the trees. Loggers paid, on average, \$5.85/m^3 for terra firme logs versus \$2.90/m^3 for várzea logs.

As in the várzea, terra firme logging teams frequently received financing from mills in the form of equipment or advance payments. The higher costs for standing timber and the elevated equipment costs in the terra firme operations resulted in total logging cost/m³ more than two times higher than those for the várzea ($14.30 vs. $6.70).

Transport of Logs from Forest to Mills

Following tree felling and extraction to river's edge or public roads, logs are transported to mills. In the case of várzea logging, transport is done via log rafts; timbers from terra firme forest are transported to mills in barges or by truck.

Várzea log transport

The log rafts used in várzea log transport are sometimes nothing more than a few logs strung together and guided to a nearby family-run mill by a person in a dugout canoe. At the other extreme, these rafts may be composed of a thousand or more logs that are guided by a tugboat for many hundreds of kilometers to a mill (Fig. 2). In the estuary, the rafts move forward when the tides are in their favor and are guided to quiet backwaters when the tides do not facilitate forward movement. These large log rafts supply the large veneer/ply board mills situated in the estuary.

Because of the large quantities of wood that can be transported and the necessity of only a tug boat, wood transport in log rafts is far cheaper than other options in the region (Table 2). We estimated that the cost to transport 1 m³ of roundwood to a mill located one hundred kilometers from the site of cutting was only about one dollar using large log rafts.

Terra firme log transport

The timbers of the terra firme forest are generally too dense to float and, therefore, cannot be rafted. Trucks are commonly used for log transport in upland areas of Amazônia, but truck transport is expensive. In the lower Amazon, logging trucks are typically small (4.3 m^3 capacity) and the transport cost was about \$30.00/m^3/100 km (Table 2) or 25 to 30 times that registered for transport using log rafts.

In the case of the Lower Amazon, proximity to waterways allows barges to be used for the transport of heavy terra firme logs as an alternative to truck transport. Barges in this region typically carried 270 m^3 of roundwood (Table 2, Note 2). A \$220,000 investment was required to purchase a barge and accompanying 20-t tugboat, but for distances greater than about 20 km from forest to mill, the transport cost/m^3 using a barge was less than that for trucks (Fig. 3). And to transport logs to a mill a 100 km away, the cost of the barge system was about one-fourth that of truck transport (\$30.00/m^3 vs. \$8.00/m^3) (Table 2).

Processing of Wood from Várzea and Terra Firme Forests

In 1990/1991 we recorded 1,295 wood processing mills in operation in the Lower Amazon River and estuary region (Fig. 4). We divided these mills into three groupings based on their equipment: 1) 1,191 mills with circular saws (all small operations); 2) 98 mills with bandsaws (generally medium-size operations); and 3) 6 veneer/plyboard industries (large outfits).

Wood processing in small mills

Most of the mills (92%) in the study region were small and almost all (95%) were situated in the estuary (Fig. 4). These small mills were frequently household operations; 53% relied on familial labor; and 88% of the owners (n=60) were native residents. The establishment of most of these small mills occurred in the 1980s (Fig. 5) in response to a demand for rough-finished wood for house construction from Belém, the capital city of the region, and from the Northeast of Brazil. Also, the international demand for Virola surinamensis was high at this time and the large veneer/plywood mills in the estuary were keen to buy V. surinamensis boards from small mills which they, then, refinished and sold abroad.

These small mills were able to produce boards at low cost. This is, in part, because most of the mills (82%) processed wood from nearby várzea forest. Hence, log extraction and transport costs were low (Table 1). Also, the cost to establish these mills was small. The motor from a household boat can be used to power the saw and the mill structure can be constructed with poles, lashings, and palm leaves from the surrounding forest. The total cost for a fully operational mill was less than $3,000 (Table 3, note 1). Frequently, wood buyers helped finance new mills, providing capital or equipment to interested families.

A typical small mill produced 650 m^3 of sawn wood per year from 1,850 m^3 of roundwood (Table 3). The price paid for logs at water's edge ranged from \$2.00-\$4.50/m^3. This was less than the extraction cost of approximately \$6.70/m^3 when timber was felled through wage labor arrangements with medium-size bandsaw mills (Table 1). This difference is the result of the lower quality wood going to these small mills, lower prices for standing timber, and reduced labor costs (non-wage labor).

The annual operating cost for these small mills was approximately \$14,800 (i.e., \$22.80/m³ of sawn wood produced). The average sale price of wood was \$27/m³. Profits for these small mills were estimated at \$2,755/year (Table 3). In cases where all labor, including that for log transport, was provided by the household, annual returns could climb to \$8,500. This amounts to roughly \$1,700 for each family member, given a family with five workers. This is an attractive return compared to other options for small producers in the Amazon estuary.

Wood processing in medium-size mills

We tallied a total of 98 medium-size bandsaw-type mills in the study region (Fig. 4). These mills produced, on average, 3,500 m³ of sawn wood per year (n=41 mills, s.d.=3,456) (Fig. 5). These mills, typically, have one bandsaw and a total work force of 30 people. They had a 35% (s.d.=9) processing efficiency. Hence, the average mill used 10,200 m³ of roundwood to produce 3,500 m³ of sawnwood. The owners of these mills were frequently natives of Pará (48%), or other Brazilian states (43%), and only occasionally foreigners (10%). The cost to establish these single-bandsaw mills was approximately \$170,000 (Veríssimo *et al.*, 1992); 20% of the mills that we surveyed had received financing for construction.

We observed that extraction costs, transport options, and marketing opportunities differed substantially among these bandsaw operations. This being so, we considered costs and profits for three models of bandsaw mill: 1) mill using logs extracted from várzea forests, relying on log raft transport, and directing production to both export and domestic markets; 2) mill using logs extracted from the terra firme forest, relying on barge transport, and directing production to both export and domestic markets; and 3) mill using logs extracted from terra firme forest, relying on truck transport and directing all of production to domestic market (Table 4).

Model 1: Forty-eight bandsaw mills processed logs from várzea forest that were rafted to their mills. Fifty-odd species were harvested by these mills; the most important were Virola surinamensis ("whitewood") and Carapa guianensis ("redwood"). Approximately 30% of the annual operating cost was for the purchase of logs ($9/m^3$, Table 4) and 3% was spent for transport via log rafts ($1.08/m^3$, considering wood 100 km away; Table 2). Most operating costs (65%) were for wood processing in the mill.

These mills produce boards for national and international markets at an average sale price of $106/m^3$ (Table 4). Hence, mills in this model realized an annual profit of about $60,000/yr or $17/m^3$ of sawn wood. The Internal Rate of Return (IRR) was 37% and the Net Present Value (NPV) was $523,000 (6% discount rate) (Table 4).

Model 2: Fourteen bandsaw mills relied on barges to transport logs from terra firme forest to their mills. These mills were distinguishable from the others by having more capital. Their operational costs were $473,000/yr, separated into purchase of logs (39%), log transport (17%), and log processing (43%) (Table 4). The standard-dimension boards produced by these mills were sold to both national and foreign buyers. The total value of production was approximately $686,000; the annual profits were approximately $215,000 or $60/m^3$ of processed wood. The IRR was 62% and the NPV (6%) was $2,000,000. This model is lucrative in spite of the relatively high costs for raw materials and transport because the value of the processed boards is higher than in the other models.

The projected profits for Model 2 might actually be higher than those reported in Table 4. In our calculations for the return on the sale of export-bound wood, we used the official wood prices provided by CACEX (Foreign Trade Board of Brazil) and referred to by the interviewees. But the actual payment received for sawnwood exceeded the official value by an average of 36% (s.d. = 22) based on data for 16 species from three industries. Payment above the official value is usually deposited in foreign banks to avoid taxes. If returns were, indeed, 36% higher for the fraction of production destined for the export market, then annual profits for Model 2 would be approximately $400,000 with an IRR of 111%.

Model 3: We encountered 36 companies that relied on trucks to transport wood from terra firme forests to their mills. Most of these outfits (86%) sold their production to domestic buyers, but they were interested in developing contacts with foreign buyers. Given the relatively high cost of truck transport and the relatively low price paid for sawn timber on the domestic market, this model was only viable when extraction was done close to the mill site. For example, if the logging site were 20 km from the mill, there would be no net profit. If the mill processed timber coming from an average distance of 10 km and all production was sold domestically, then net profits were estimated at $30,600, IRR at 14% and NPV at $157,000 (6% interest) (Table 4). If the mill were able to sell two-thirds of its production to foreign markets, as in Model 2, then the net return might increase to $223,000, IRR increase to 93%, and NPV rise to $2,123,000 (6% interest rate). In the case of this export model, even if extraction was conducted 50 km from the mill (requiring a fleet of 8 trucks), returns might still be $45,000, IRR, 30%, and NPV, $836,000, assuming that public roads were available. These examples show how the selling price of wood could influence extraction patterns.

Wood processing in veneer and plyboard factories

The first veneer mill was set up in the Amazon estuary in the late 1950s. By 1973 there were four such mills, all working almost exclusively with Virola surinamensis to produce veneer for export (Bruce, 1976). Today the six peeler mills in the study region (Fig. 4) are working with approximately 15 species to produce both high quality veneer and rough veneer sheets for plywood filler. None of the owners were from Pará state: they were foreigners (50%) and Brazilians from other states (50%) (Fig. 5).

These mills produced, on average, 33,850 m^3 of processed wood each year (n=5, s.d.=22,216) from approximately 91,000 m^3 of roundwood (n=5, s.d.=39,739). This production was ten times greater than that of typical bandsaw mills (Fig. 5). Because of a requirement for large, well formed logs, the wood supplying these large mills was floated from várzea forests as far away as 2,500 km. These large mills sometimes use hand-operated winches and water buffalo that allow for the extraction of wood from várzea forests during low-water periods. The start-up investment to establish a large veneer/ply board mill was approximately one million dollars or about six times more than the investment to install a bandsaw mill and more than three hundred times the investment to establish a small mill.

In Table 5 we present the financial records for one of these large veneer/plyboard mills. The annual operating and marketing costs for this mill, with a production of 23,755 m^3/yr, was 5.3 million dollars. The production of this mill was sold to domestic and international buyers and resulted in net returns of about $590,000. However, the company's data for wood sale price (average price=$249/$m^3$; Table 5, Note 3) were below the average value that we calculated based on our interviews ($268/$m^3$; n =5, s.d.=36.3). Using the interview data, we estimate the value of production at 6.4 million dollars and the net return at approximately one million dollars.

Conceptual Framework for Understanding Amazon River Wood Sector

The hallmark of the wood industry in the Lower Amazon River and estuary is the diversity of actors involved and the many strategies employed in timber extraction, log transport, and wood processing. Extraction teams operate in both várzea and terra forest; timbers are transported to mills in floating rafts, barges, or trucks; the mills, themselves, range from rustic cottage industries through medium-size bandsaw mills to very large veneer/plyboard factories.

Our analysis reveals that capital availability greatly influences the behavior of the wood sector in this region. The small household mills in the 1980s in the várzea were established by people with very limited amounts of capital. These mills were successful because of the low costs of extraction and transport in this aquatic setting but their returns ($2,000-$4,000/yr) are modest when compared to the amount of money necessary to graduate to a more sophisticated enterprise (e.g, $170,000 to establish a bandsaw mill). At best, small mill operators might invest their meager profits in a second small mill or a small motorized boat to facilitate the transport of log rafts from forest to mill.

The prospects for increasing earnings are much better for the owners of bandsaw mills that rely on the várzea. As we saw, these mills have a net profit of about $60,000/yr (Model 1, Table 4). If the mill owner were to invest in a barge/tugboat unit ($220,000), and extract wood from terra firme forests, profits might triple to $210,000 (Model 2, Table 4). Indeed, in the early 1990s, eight of the 48 bandsaw mills that had been using wood from várzea forests (Model 1) had invested in barges to transport wood from terra firme forests (Model 2). These mills continued to float logs out of the várzea in the rainy season when it was impossible to extract logs from terra firme forest because of the wet conditions. But in the dry season, when logs could no longer be removed with ease from várzea forests, these mills shifted extraction activities to terra firme forests. In addition to providing higher value terra firme wood, this season-specific logging had the advantage of providing a steady supply of logs throughout the year. This meant that companies no longer needed to accumulate large log inventories during the wet season to guarantee log supplies during the dry season. In economic terms, it meant that companies could avoid immobilizing their capital in large roundwood inventories.

There are other options available to medium-size companies anxious to increase earnings. One is to produce more highly elaborated (value-added) products. A second is to develop the capacity to produce veneer and plyboard, but this requires an investment some five times greater than that necessary to switch from várzea to terra firme woods and considerable technical challenges, as well. A third option is to relocate industries closer to the source of raw materials. In this case, mills move from wood-depleted regions in the estuary up the main stem to more remote river-edge locations where wood is abundant. Several mills took this step in the early 1990s and we expect that more will follow.

In sum, then, this analysis of investments and profits explains to a significant extent the decisions and actions of the different actors in the Amazon River wood sector.

Significance of Wood Industries in the Lower Amazon River and Estuary

Job generation

In the early 1990s, the wood industries in the Lower Amazon River and estuary provided 25,400 jobs, split more or less evenly between jobs in logging and jobs in wood processing (Table 6). If we add the jobs related to wood transport (approximately 3,100) , the total rises to 28,500 or about half of all jobs provided by the wood industry in the state of Pará (A. Veríssimo, pers. comm.).

Considering that 28.5% of the population in the study region (29 counties) was employed at the time of our study (FIBGE, 1991), then the wood industry provided 7.4% of these jobs. However, the wood industry did not have the same importance throughout the study area. For example, along the Lower Amazon River there were only 29 bandsaw mills and 59 small mills (Fig. 4). In contrast, the area in and around Marajó Island contained all six large mills, 59 of the bandsaw mills and 975 of the small mills, making logging and wood processing a very important source of employment in this region (i.e., accounting for 25% or more of all jobs in some counties).

Revenue generation

The total production of the wood industries in the study region was approximately 1.3 million m^3 of processed wood in the early 1990s--1.1 million m^3 in the form of sawn boards and 0.2 m^3 classified as wood sheeting/veneer (Table 7). The majority (59%) of this wood was produced by the small mills. Bandsaw mills produced 26% and the remainder (15%) was produced by large veneer mills.

Most of the wood that was processed in the study region came from várzea forests. The 972 small mills, 48 bandsaw mills, and 6 big mills that processed várzea timber produced one million m^3 of wood in 1991 or 77% of the total production.

Although the six veneer/plywood mills produced only 15% of the total wood volume, they accounted for 45% of the total value of wood sales because of the relatively high value of their end products. The small mills, by contrast, accounted for only 18% of the total value of production for the region (Table 7) in spite of producing more than half the sawn wood volume. This is because the end products of these small mills was of poor quality.

In the entire state of Pará, there were 1,874 wood industries in 1991 with a total production of roughly 4.3 million m^3 (A. Veríssimo pers. comm.). The industries in our study area (Fig. 4) produced 31% of this volume and one-fifth of the total value of this production (Table 7).

Sustainability of Present Wood Industry Activities

In the early 1990s there were over one thousand mills operating in the Lower Amazon River and estuary. The question arises: Is there enough wood in the region's forest to continue to supply these mills or, even, to support additional mills? Knowing the number of mills and the volume of roundwood that each mill processes each year (Table 7), it is possible to estimate the amount of forest in the study region that is logged in a year. This figure can then be compared to the total area of standing forest in the study region and provides a measure of the potential sustainability of logging activities. Based on information from SUDAM/IBDF (1988) on forest cover in the 29 counties in the study region and our data on the types of wood (várzea or terra firme species) processed by mills in each of the counties, we estimated that there are 3.7 million ha of várzea forest and 26.7 million hectares of terra firme forest in the study region (excluding areas designated as Indian Reserves and Conservation Units). Assuming a volume of harvestable timber of 56 m^3/ha in the várzea forest (N. Maciel, pers. comm.), each of the 972 small mills that process 1,850 m^3 of várzea roundwood/yr would use 33 ha of forest each year; the medium-size várzea-based mills that process 10,200 m^3/yr would need 182 ha/yr, and the veneer mills would require 1,625 ha/yr. Hence, assuming intensive logging practices, the industries that rely on várzea forest use 50,604 ha of forest each year or about 1.4% of the estimated extent of the várzea forest in the study region. This means that in theoretical terms, at least, the cutting cycle could be 73 years.

Meanwhile, the area of terra firme forest logged by the 219 small mills and 50 bandsaw mills that operate there would be 24,083 ha, assuming an intensive extraction model (i.e., 38 m^3 removed/ha; Veríssimo et al., 1993). This represents less than 0.1% of the terra firme forest in the study region.

Overall, the amount of wood in the study region appears to be more than adequate to supply the wood industry's needs. However, in some areas, such as in Breves County on Marajó Island, the density of mills is very high and harvest pressure may already be excessive. This county contains 271,503 ha of várzea forest (SUDAM/IBDF, 1988) and contains 175 small mills, 30 medium-size mills, and 1 large veneer mill. Assuming an extraction intensity of 56 m^3/ha, the mills now present in Breves could remove the timber from the entire county in 21 years [See Anderson *et al.*, (1994) for a detailed treatment of the impacts of intensive logging in this region].

This exercise is an oversimplification for several reasons. First, our estimate of várzea forest area is based on several assumptions and not on ground measures. Second, veneer mills and many sawmills process only a subset of the total potential sawwoods of the region. Hence, the volume of wood extracted/ha is sometimes considerably less than the value (56 m^3/ha) we use. Third, cutting cycles can be reduced substantially if forests are managed (Barreto *et al.*, 1993). Hence, while a period of 30 years between harvests might be much too short in the absence of management, such an interval might be reasonable if forests were managed. Finally, the exercise assumes that all timber can be readily harvested. However, much of the timber in the terra forest in the study region is far removed from transport routes (roads or rivers) and unavailable for harvest. Nevertheless, the exercise does provide a good measure of the overall abundance of timber in the study region relative to the present-day demands of the wood industry.

Expansion of Logging up the Main Stem of the Amazon River

At the time of our survey, the six heavily capitalized large veneer/plywood mills that processed wood for the export market were operating at full capacity, but many of the small and medium-size mills that processed primarily for local and national markets were operating at only about 50-75% capacity because of a national recession.

When economic conditions improve, the 1,191 small mills could double production to 1,300 m^3/yr (this is the production level for small mills operating at full capacity (n=21, s.d.=884) by increasing their work force and making equipment improvements; the medium-size bandsaw mills could, likewise, double production to 7,000 m^3/yr. In this were to occur, overall production in the study region would increase from 1.3 to 2.3 million m^3, an 85% increase. Economic recovery (i.e., increased domestic demand) or increased export demand could prompt this change. Both were beginning to occur in the mid 1990s.

Furthermore, increases in national and international demand for Amazonian woods could stimulate the building of new mills in the region and/or the relocation of mills from other regions to the banks of the Amazon. For example, as the timber stocks in the forests along the Belém-Brasília Highway have declined, some mills have relocated deeper in the forest where wood is again abundant and others are contemplating such moves. The Lower Amazon River and estuary are clearly attractive to lumberman because of the low price of roundwood, the availability of cheap labor, the low transport costs (owing to fluvial access), and the proximity to ports and international markets.

One limitation on the expansion of the wood industry into the tributaries of the Amazon River is navigability. The tributaries flowing out of the Brazilian and Guianian Shield areas have frequent rapids and are treacherous in places. Hence, the zone of expansion is likely to be more in a westerly direction (Fig. 6, shaded area). This shaded area is frequently referred to as "traditional Amazonia". This is where pre-conquest populations were concentrated and where lifeways follow traditional extrativist modes. Meanwhile, the Shield areas are not necessarily beyond the reach of loggers. Logs could be removed from these areas using fluvial transport coupled with small spur roads that skirt rapids.

Forest Management: A Possibility Now

Deforestation will continue unabated in the Brazilian Amazon unless the standing forest is perceived as more valuable than alternative land uses associated with deforestation. Fortunately, the potential of Amazonian forests to provide food, fiber, medicinals, and game, as well as timber, is increasingly appreciated--not to mention the beneficial influence that this large forested expanse has on regional and global climate. It will take some time, though, before markets develop for the non-timber forest products that the Amazon forest has to offer. However, there is an immediate and tangible opportunity to develop sustainable economies based on the harvest and management of the timber in these forests.

In the second paper of this series (Veríssimo *et al.* 1992), the potential for forest management for timber production was considered. In that paper we focused on terra firme forests associated with the network of roads that has recently penetrated interfluvial areas in eastern Amazonia. Here, we consider the potential for forest management in várzea forests that are common along the Lower Amazon River and estuary.

Várzea forests in this region offer particular promise for timber production and forest management for several reasons. First, they are simple floristically (in comparison to terra firme forests) and they are well stocked with timber. Second, várzea forest trees grow more rapidly (perhaps two times as fast, on average) than trees in terra firme forests. Finally, the damage to the canopy and ground and to young trees incurred during várzea logging operations is much less than during terra firme forest logging. This is because the vines that link tree crowns together and cause damage to neighboring trees during felling are less frequent in várzea forests than in terra forests and because no heavy equipment is needed for várzea timber extraction--logs are usually just floated out of the forest.

There are three prerequisites for a switch from the "timber mining" mentality that now characterizes logging in the Lower Amazon River Basin to an approach based on timber management and forest stewardship. The first prerequisite is for a more complete knowledge of how to manage the forest. Fortunately, many of the inhabitants of the Lower Amazon River and estuary for several generations. These people are comfortable in the forest and they possess an impressive woods lore, but they need technical training in inventorying, felling, extraction, and thinning techniques to be effective forest managers.

The second prerequisite for the adoption of sustainable forestry in the Lower Amazon region is to provide rural communities with guaranteed access to forest tracts through long-term concessionary arrangements and/or through the establishment of community forests. INCRA (Federal Institute of Colonization and Reform) as well as state land titling agencies have the authority to do this. The region's residents must have secure title to the forest before they will invest their time and creativity in forest management.

But forest management must be lucrative and this is where the third prerequisite for sustainable forestry--policy change--enters in. At present, timber is greatly undervalued in Amazonia. This is, in large part, because of the policy forbidding the export of logs. This policy was designed to stimulate the growth of sawmills and this has occurred. However, it has meant that the regional forest and the logs that this forest contains have in many cases been undervalued because the demand for these logs is relatively low compared to their abundance. If forest communities could sell logs on the international market, these communities would very likely receive five to ten times what they receive on local markets [J. Zweede, pers. comm., based on comparisons of Amazonian roundwood prices on both domestic (Brazilian) and international (other Amazonian countries) markets]. Higher returns could not be expected for all Amazonian timber species, but there is a significant subset of these timber species (about one-third) that are acceptable to foreign buyers.

Of course, if the Brazilian ban on log exports was simply lifted and no other measures were adopted, it is likely that this would encourage the rapid and careless logging of still greater areas of Amazonian forest. It would seem to make most sense, then, to only lift this ban for logs that originate in forest tracts that are being sustainably managed. Fortunately, there are several NGOs, such as Certification Systems International, with the mission of certifying companies that meet forest management standards. These organizations have developed rigorous certification procedures and actually affix "green" labels to sustainably produced timber. Permitting the export of green-labeled logs is a straightforward way of making forest management more lucrative for forest communities, while also assuring that forests are carefully managed.

In sum, this three-step approach has many of the elements of a win-win solution--deforestation is held in check because forests are more fully valued, forests are carefully managed because the people best qualified to manage the forest are made forest stewards, and rural livelihood is improved because high-quality logs coming from managed forests are sold freely on the international market.

Participation of the Brazilian government would be essential for such a plan to succeed. At a minimum, the government agency, INCRA, would have to legalize community claims to forest lands; and CACEX (Foreign Trade Board) would have to agree to relax the ban on log export for logs bearing "green labels" (i.e, logs coming from sustainably managed forest holdings). Finally, IBAMA (Federal Bureau of the Environment) would need to carefully monitor logging activities and enforce forest management regulations.

Of course, nothing will happen unless some entity acts as an organizing force and spearheads this work. A conservation-oriented NGO with experience in working with forest communities, forestry expertise, and good ties with government organizations might offer the best hope for bringing such a plan to fruition. The first step would be for the NGO to develop protocols for the establishment of community forests, as well as for the development of a forestry extension service, the monitoring of timber extraction activities, and the export of green labelled logs. Then, these elements could be linked and the whole model could be demonstrated. Indeed, the goal of forest stewardship throughout the planet may be best achieved by competent non-governmental organizations first demonstrating what is possible and then working to help government organizations implement solutions on a broader scale.

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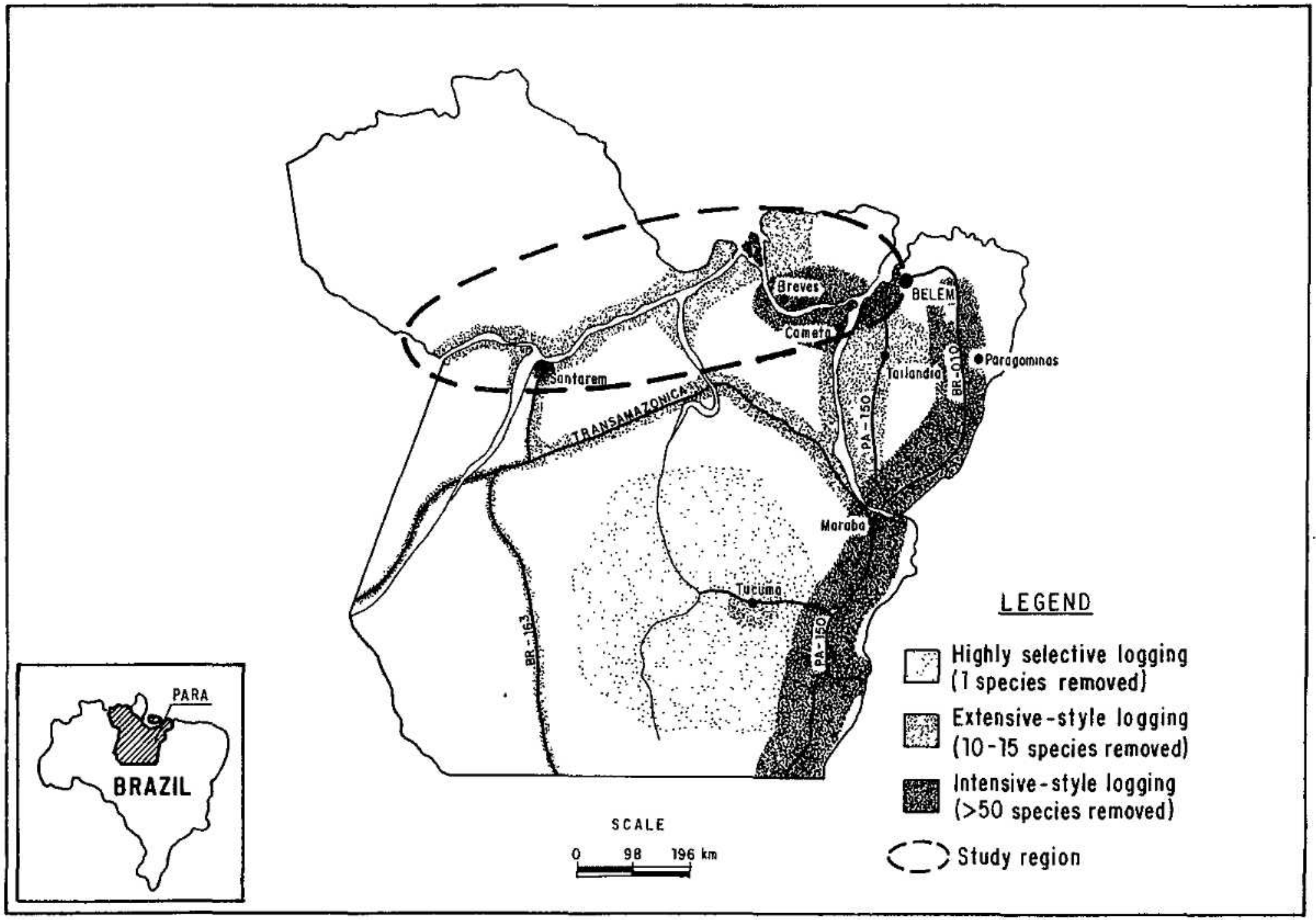
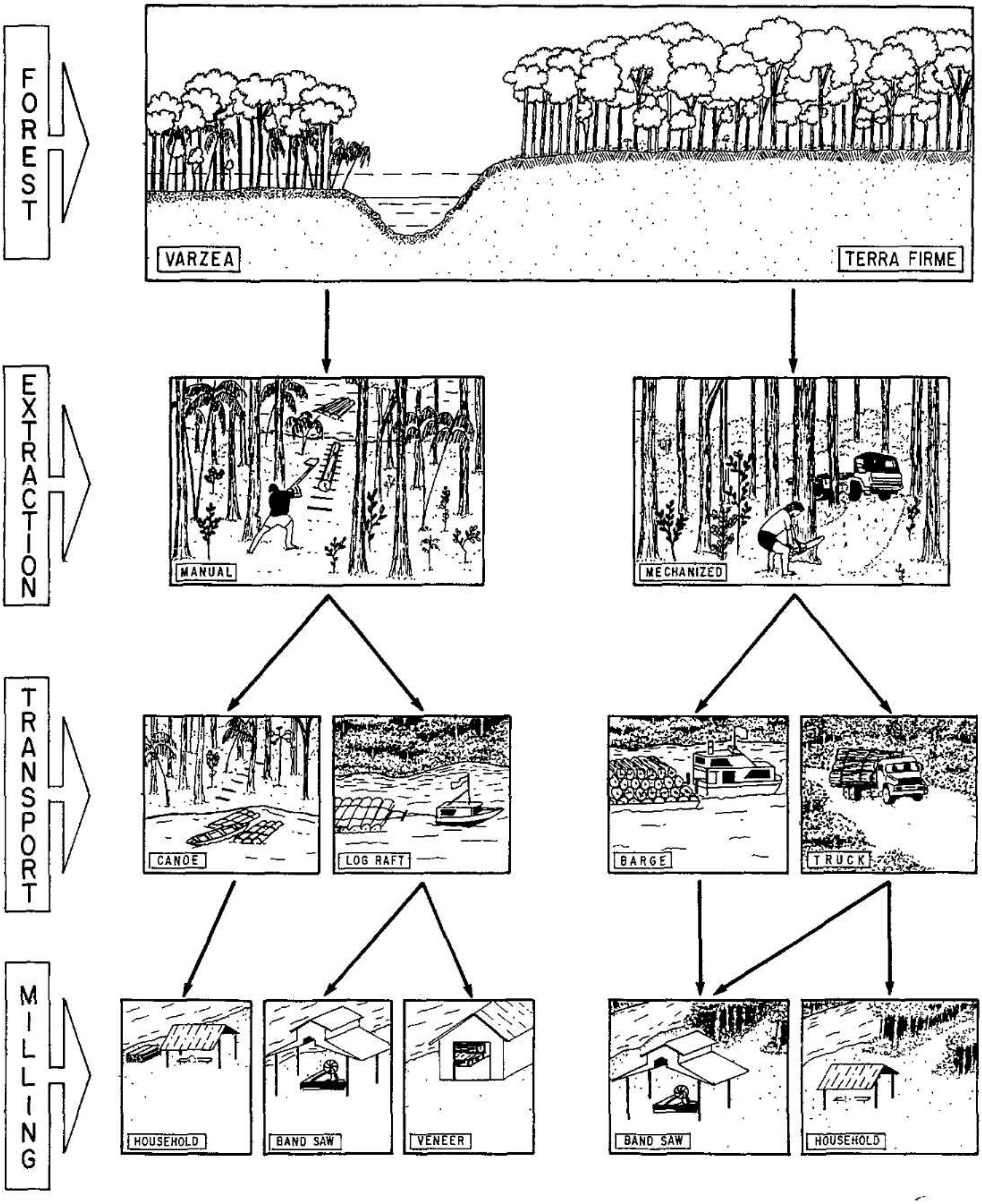


Fig 1
Kamos/Uhl


FOREST
VARZEA
TERRA FIRME
EXTRACTION
MANUAL
MECHANIZED
TRANSPORT
CANOE
LOG RAFT
BARGE
TRUCK
MILLING
HOUSEHOLD
BAND SAW
VENEER
BAND SAW
HOUSEHOLD

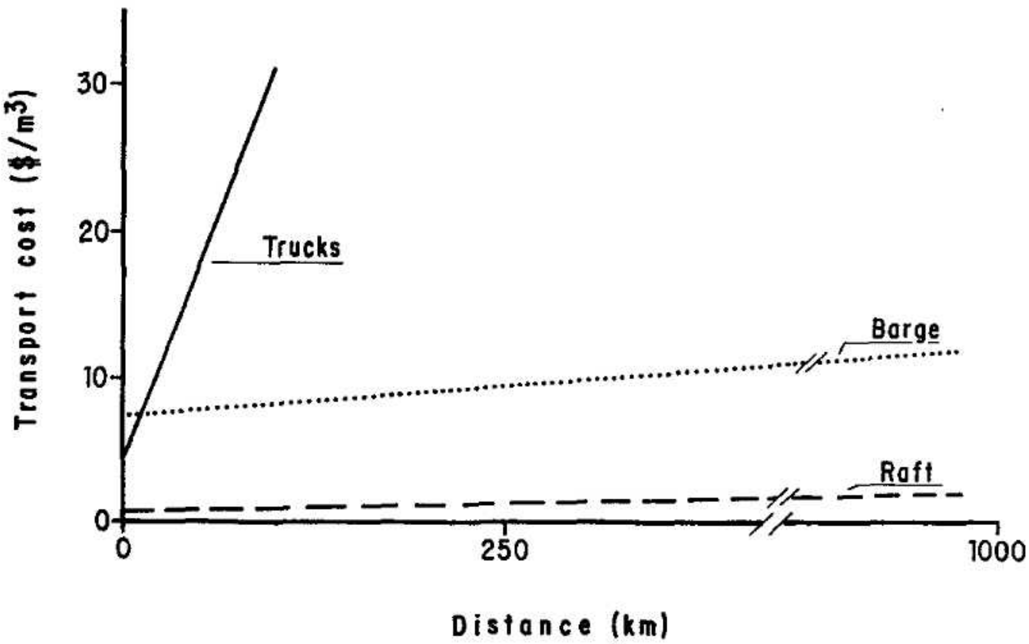
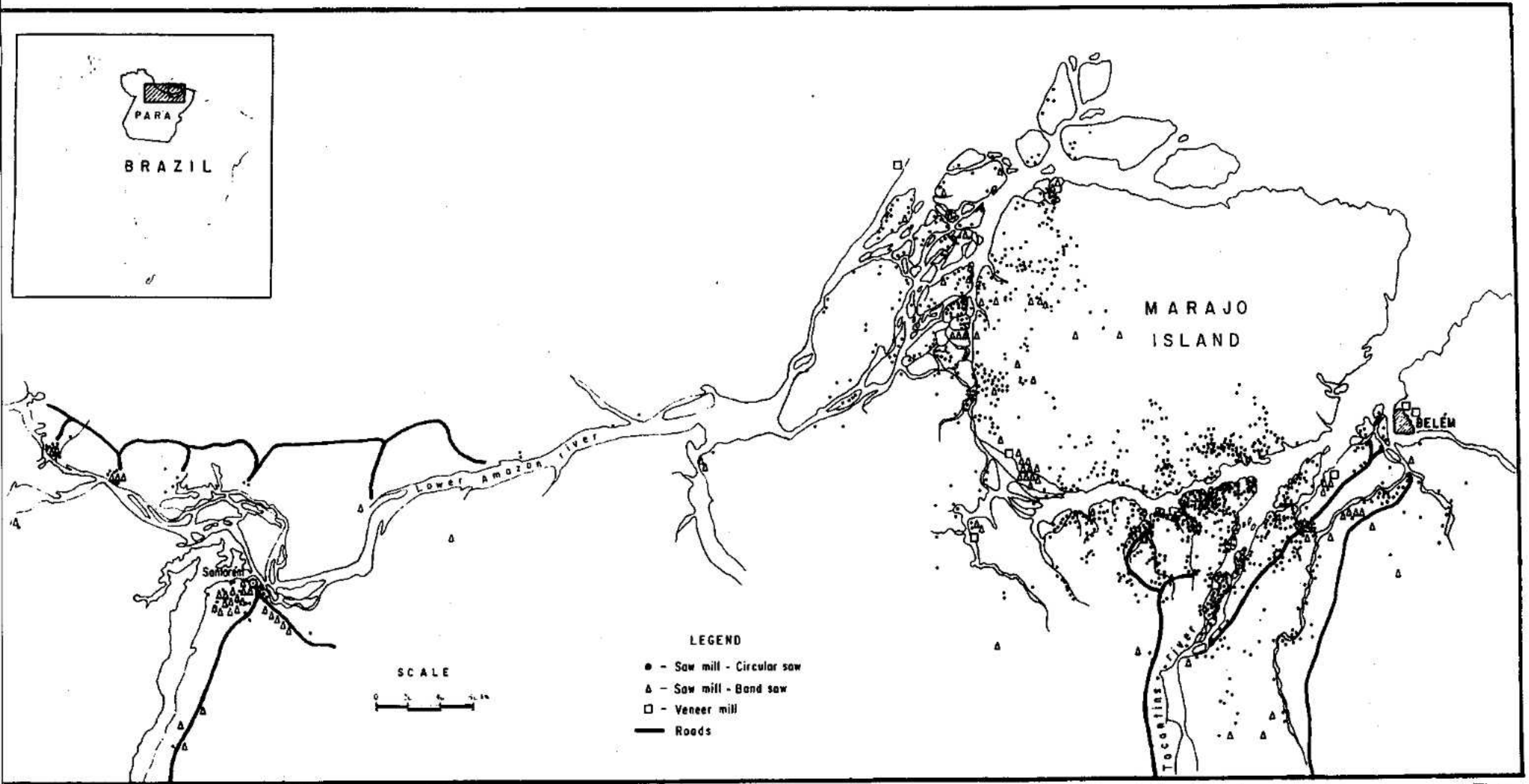
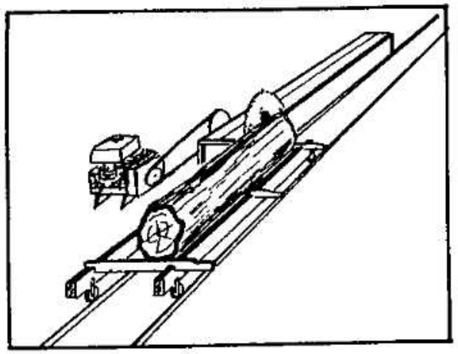


Fig.3 Barne/UK


PARA
BRAZIL
MARAJO
ISLAND
BELEM
Santarem
Lower Amazon river
Tocantins river
LEGEND
• - Saw mill - Circular saw
Δ - Saw mill - Band saw
□ - Veneer mill
Roads
SCALE

SMALL MILLS



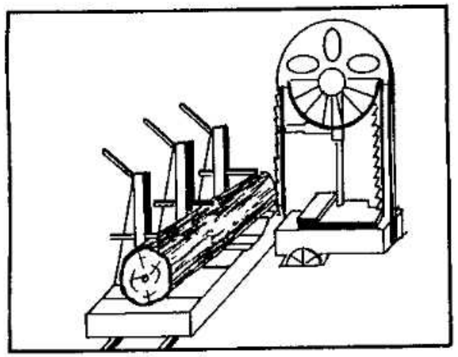
1,191 in operation

Equipment: circular saw

Instalation cost: $ 3,000

Productivity: 650 m^3 boards/year

MEDIUM SIZE MILLS



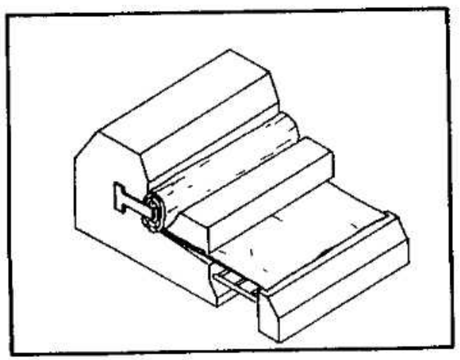
98 in operation

Equipment: band saw

Instalation cost: $ 172,000

Productivity: 3,500 m^3 boards/year

LARGE MILLS

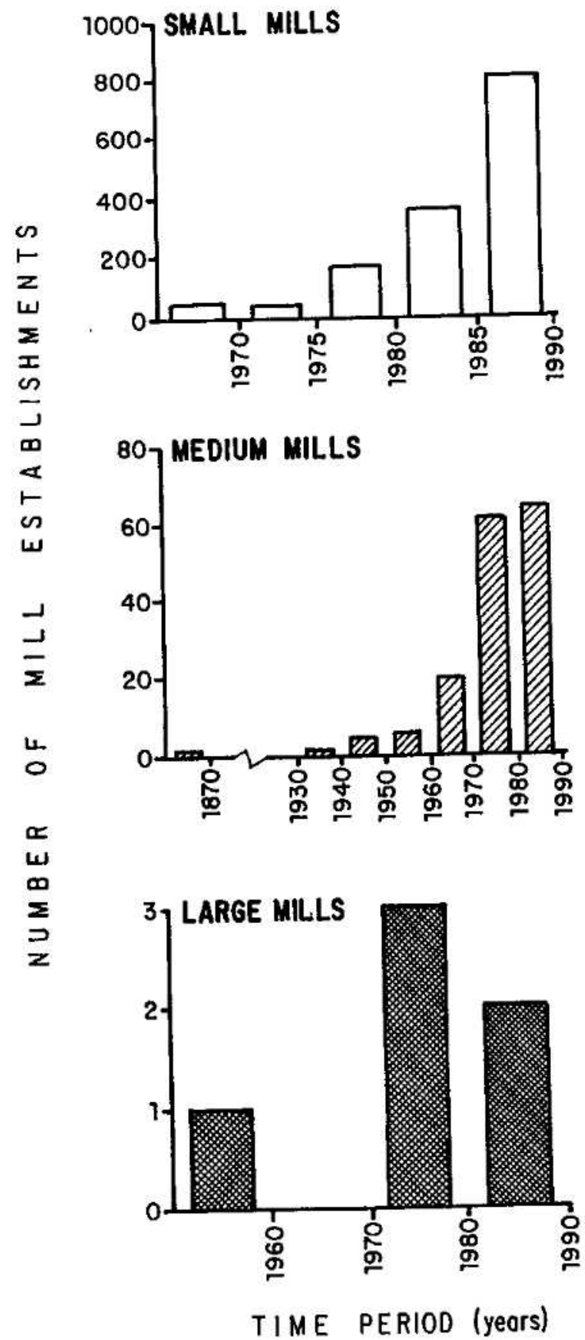


6 in operation

Equipment: log pealer

Instalation cost: >$ 1,000,000

Productivity: 34,000 m^3 of veneer and plyboard/year



F.g.5

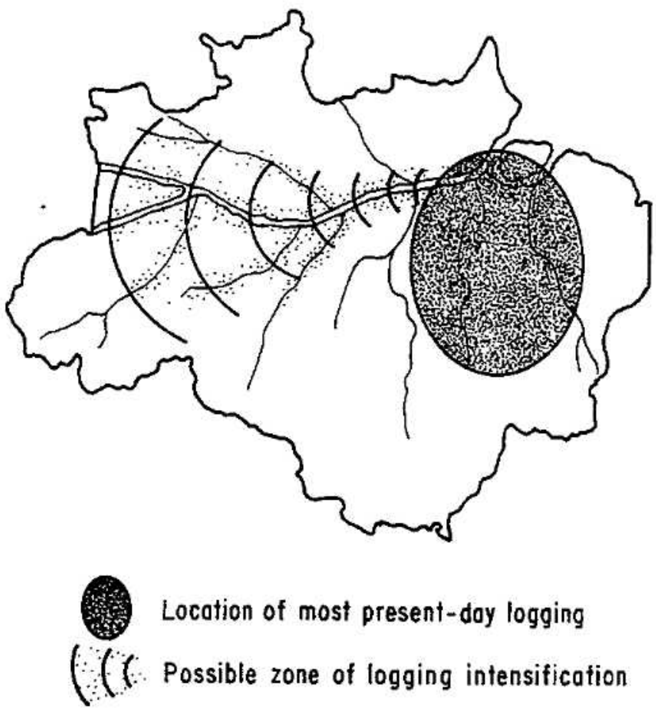


Fig 6.
Barros/UHC

Table 1. A comparison of productivity and costs for logging teams in várzea and terra firme forests that supply bandsaw mills in the Lower Amazon River and estuary.

	Várzea (Floodplain)	**Terra firme (Dryland)**
Productivity		
Volume harvested (m^3/yr) [1]	873	2,311
Production/person (m^3/yr)	265	492
Costs/yr:		
Labor [2]	\$3,338	\$4,755
Purchase of standing trees [3]	\$2,532	\$13,519
Equipment and fuel for felling [4]	\$1.90	\$1,119
Equipment and fuel for extraction [5]	\$0.0	\$13,689
Total Annual Cost of Logging	**\$5,872**	**\$33,082**
Cost/m^3 to extract wood [6]	**\$6.73**	**\$14.32**
Cost/m^3 for mill to buy wood	**\$9.00**	**\$18.00**

[1] Várzea logging teams had, on average, 3.3 men (n-19, s.d.-2.4) with an average production of 4.85 m^3/day. Logging teams in terra firme forest had, on average, 4.7 men (n-6, s.d- 1.4) (including a chainsaw operator, a truck driver and helpers to cut access paths for the trucks) and produced 12.84 m^3/day. Logging teams in both forest types worked for approximately 180 days each year. Hence, the total production was 873 m^3/yr for varzea logging and 2,311 m^3/ for terra firme logging.

[2] The average salary paid in the region was \$3.93 /day (n-28, s.d.-1.2). Food was also provided to laborers at an average daily cost of \$1.69. Hence, in 180 days of work the cost of labor in várzea logging was \$3,338 (3.3 men x 180 days) (\$3.93 + \$1.69). A similar calculation was done for the terra firme case.

[3] Throughout the region the cost of quality standing timber averaged \$2.90/m^3 and \$5.85/m^3 in várzea and terra firme forest, respectively. This was roughly one-third of the price paid for logs delivered to the gate of bandsaw mills (i.e., \$9 and

Table 2. The comparative cost of log transport using rafts, barges, and trucks for a typical bandsaw-type mill located 100 km from the wood source and requiring 10,200 m^3 of roundwood/yr in the Lower Amazon River and estuary.

	FORMS OF LOG TRANSPORT[1]		
	Raft	**Barge**	**Trucks**
Capacity (m^3)[2]	960	270	4.28
Annual cost of transport:			
Depreciation[3]	$1,335	$10,009	$79,200
Maintenance[4]	$4,417	$7,898	$75,000
Labor[5]	$3,035	$49,236	$30,348
Capital investment costs[6]	$890	$6,673	$14,850
Fuel[7]	$1,357	$7,174	$106,757
Total Annual Costs	**$11,034**	**$80,990**	**$306,155**
Cost/m^3/100 km	**$1.08**	**$7.94**	**$30.02**

[1] A typical bandsaw mill along the lower Amazon River that required 10,200 m^3 of roundwood/yr has three options for transporting logs from the forest to the mill. If the mill relied on raft transport, it required one tugboat. If the mill relied on barge transport, it needed one barge and one tugboat. Relying on truck transport, the mill required a fleet of trucks to meet its roundwood supply needs.

[2] **Log rafts:** Log rafts consisted of logs cabled together side-by-side. They contained, on average, 960 m^3 (n -4, s.d. - 89). They were guided down river by 10-20 t boats (ave. - 12 t, n-4, s.d.-3.6). **Barges:** Barge sizes ranged from 150--550 t (ave -381 t, n-13, s.d.-113) with an average volumetric capacity of 270 m^3. We used a standard 400-t barge with an accompanying 20 t tugboat in this example. **Trucks:** The capacity of a typical truck was 4.3 m^3. A company transporting 10,200 m^3 of wood a 100 km distance would require 15 such trucks. This assumes that the truck operators work 180 days/yr and that roughly 10% of the scheduled work time is lost to repairs.

table 2, cont.

[3] **Log rafts:** The 10-t tugboats that accompanied log rafts costs $29,670 new. We considered a use-period of 20 years after which the residual value was 10% of the purchase price. Hence, depreciation was $1,335. **Barges:** The cost of a new 400 t barge was $165,200 (Empresa Técnica Nacional S.A.). Considering a use-period of 20 years and a residual value of 10%, depreciation was $7,434. The tugboat (20 t) that moves the barge had a purchase price of $57,218 and annual depreciation of $2,575. Hence, total depreciation in the barge transport system was $10,009. **Truck:** The cost for a new 6-ton truck was $33,000. Considering a use-period of five years and a 20% residual value, depreciation was $5,280 per truck or $79,200 for a fleet of 15 trucks.

[4] **Log raft:** Maintenance for a 10-t tugboat included painting , caulking, replacement of rotted wood, and motor repair at an estimated annual cost of $670. Approximately 1,000 m of cable were used in one year to link the logs together at a cost of $3,200; 2,000 pins were used/yr to act as attachment points for the cables at a cost of $500; and 100 m of heavy nylon rope was purchased/yr to attach the tug boat to the rafts ($47). Hence, total maintenance expenses were $4,417. **Barges:** Maintenance for barges includes cleaning, painting, caulking, and welding and amounted to 4% of the initial investment or $6,608 (Empresa Técnica Nacional S.A.) Maintenance costs for the tugboat were $1,290/yr--similar to those for log-raft tugs, but accounting for the greater size (20-t) of these barge tugs. Hence, total maintenance expenditures for barge transport were estimated at $7,898. **Truck:** Maintenance costs for logging trucks were approximately $5,000/yr (Veríssimo et al., 1993) or $75,000 for the fleet of 15 trucks in this example.

[5] **Log raft:** The crew of a log raft was composed of three men. Daily wages were $3.93 plus food ($1.69/day). Given 180 work days/yr, the total expenditure in salaries/food was estimated at $3,035. **Barge:** The crew size of a 400-t barge was 6 men (stipulated by the Port Authority). Salaries were $683.80/month, on average (Boat Workers Union of Pará and Amapa). Hence, total labor costs for a 400-t barge were $49,236. **Truck:** A truck crew for long-distance transport consisted of two people that received $3.93 in wages and $1.69 in food each day over a 180-day period or $2,023 per year. Hence, wages and food for the crews of all 15 trucks would be $30,348/yr.

table 2, cont.

[6] The cost of capital investments was determined using a 6% interest rate and the data provided in Note 3.

[7] **Log rafts:** We considered that the 10-t tugboats that worked with log rafts moved, on average, 4 km/hr on their trips throughout the estuary and lower Amazon (Belém Port Authority). These tugs consumed 10.7 liters of diesel fuel/hr (n=5, s.d.=3.2) and 0.05 liters of oil/hr (n = 3, s.d.=0.01). The price of diesel fuel was $0.23/liter and that of oil was $1.87/liter. Hence, the cost of fuel to transport 10,200 m^3 a distance of 100 km (200 km roundtrip) was $1,307 plus $50 for oil. **Barge:** The 20-t tugs that move the barges travelled 9 km/hr (n=4, s.d.=4.1), on average, and consumed 34 liter of diesel/hr (n=13, s.d.=8.5) and 0.4 liter of oil/hr (n=8, s.d.=0.16). Hence, to transport 10,200 m^3 of logs, $6,546 was spent in diesel and $628 in oil. **Truck:** Logging trucks with a capacity of 4.28 m^3 consumed 0.86 liter of diesel and 0.014 liter of oil for each km travelled. Hence, the total fuel cost to transport 10,200 m^3 a distance of 100 km was $94,279 plus $12,478 for oil.

Table 3. Cost and profits in small, family-run, circular saw mills in the Lower Amazon River and estuary.

Production Costs:	
Depreciation [1]	$118
Maintenance [2]	$787
Fuel and oil [3]	$1,139
Labor [4]	$5,058
Raw material [5]	$5,883
Transport [6]	$1,721
Capital investment cost [7]	$89
Total Cost of Production	**$14,795**
Value of Production [8]	$17,550
Expressions of Profitability:	
Net Profit	$2,755
Profit Margin	17%
Net Present Value (6% interest rate) [9]	$34,044
Net Present Value (12% interest rate)	$20,754
Internal Rate of Return [9]	124%

[1] The cost for a new circular saw mill was $2,959 and included a motor ($1,704), a 40-inch circular saw ($208), a mount for the saw ($368), a carriage for the logs ($177), rails for the carriage ($204), and a protective structure ($298). To calculate depreciation, we considered the use-period to be 20 yrs and the residual value to be 20%.

[2] Maintenance costs were $787/yr and included a motor overhaul every two years, periodic saw and belt replacements, and the purchase of files.

[3] Mills operated for 180 days/yr (15 days/month, n-61, s.d. - 7) and consumed 21 liters of diesel during each day of operation (n-17, s.d.-10.7) and 0.8 liters of oil (n -17, s.d.-0.9). These inputs cost $0.23/liter and $1.87/liter, respectively. Hence, the total annual expenditure was $1,139.

table 3, cont.

[4] These small mills employed 5 men on average (n-60, s.d.-2.0). These laborers received \$3.93/day plus \$1.69 for food. Considering 180 days of work/yr, the total labor cost was \$5,058.

[5] These small mills used two classes of várzea wood: "white" and "red". The cost of white-wood logs was \$1.95/m^3 (n-3, s.d.-0.68) versus \$4.40/m^3 for red-wood logs (n-5, s.d.- 1.4). In visits to 65 small mills, we observed that 43% used, exclusively, red wood, 26% used only white wood and 31% worked with both. Here, we considered that the mill under analysis used equal parts of both wood types, paying, on average, \$3.18/m^3. Hence, to buy the 1,850 m^3 (n-54, s.d.-1874) of roundwood used each year, the mill would spend \$5,883.

[6] We considered that logs are transported to the mill from a distance of 11 km (average, n-16, s.d.-3) in a small log rafts containing 50 m^3. Two men in a small (5 t) boat transported all the logs needed for one year in 60 days. Hence, total costs for transport was \$1,721, including \$235 for boat depreciation, \$566 for boat maintenance and raft materials (cables, pins, etc.), \$157 for capital investment costs, \$674 for labor costs, and \$89 for fuel and oil.

[7] The cost of capital investment for the mill was calculated using a 6% interest rate and a 20-yr use period.

[8] These small mills produced, on average, 650 m^3 of sawn wood (n-61, s.d.- 717). The value of "red" woods on the local market (where 83% of all sales occur) was \$33/m^3 (n-12, s.d.-9.1) and "white" woods, \$21/m^3 (n-5, s.d.-3.1). Hence, the average price, considering equal sales of both wood types, was \$27/m^3.

[9] Net Present Value and Internal Rate of Return were calculated considering a use-period of 20 years .

Table 4. The effects of timber source (terra firme vs. várzea), transport mode, and market destination on production costs and profits for a bandsaw mill that produces 3,500 m^3 of processed boards/yr in the Lower Amazon River and estuary.

	MODEL		
	1	2	3
Source of timber:	Várzea	Terra firme	Terra firme
Transport mode:	Raft	Barge	Truck
Market destination:	Natl/internatl	Natl/internatl	National
Distance form forest to mill (km):	100	100	10
Production Costs:			
Cost of logs [1]	\$91,800	\$183,600	\$183,600
Log transport [2]	\$11,034	\$80,989	\$53,591
Log processing [3]	\$203,000	\$203,000	\$203,000
Cost of capital [4]	\$5,160	5,160	\$5,160
Total Cost of Production	\$310,994	\$472,749	\$445,351
Value of Production [5]	**\$371,000**	**\$686,000**	**\$476,000**
Expressions of Profitability:			
Net Profit	\$60,006	\$213,251	\$30,649
Profit Margin	16%	31%	6%
Net Present Value (6%)	\$523,016	\$2,008,305	\$156,577
Net Present Value (12%)	\$275,970	\$1,174,131	\$25,256
Internal Rate of Return	37%	62%	14%

[1] Bandsaw mills use, on average, 10,200 m^3 of roundwood/yr, expressed in "real" volume. They pay \$18/m^3 for logs from the terra firme forest placed at the edge of the river or at roadside (n=9, s.d.=3.8) and \$9/m^3 for logs from the várzea (n=4, s.d.=2.5) at river's edge.

[2] For Models 1 and 2 we use a transport distance of 100 km. This is typical of bandsaw mills that rely on fluvial transport. For Model 3, where three trucks are used, the transport distance is approximately 10 km in accord with what we observed in the field. See Table 2 for an analysis of log transport costs.

table 4, cont.

[3] The average production of bandsaw mills was 3,500 m^3 and the cost of production was estimated at \$58/m^3 of sawnwood (Veríssimo *et al*, 1992).

[4] The capital necessary to install a bandsaw mill was estimated at \$172,000 (Veríssimo *et al*, 1992) and the cost of capital was calculated considering a 6% interest rate.

[5] **Model 1:** The bandsaw mills that process wood from the várzea sell one-third of their production to the external market at top price, \$185/m^3 (n - 5, s.d.-22), another one-third (somewhat lower quality) to this same market at \$103/m^3 (n-7, s.d.- 33), and the last third to the domestic market at \$30/m^3. Hence, the average sale price for these várzea woods is \$106/m^3. **Model 2:** In this model the mill sells one-third of its production, the best, to foreign customers for \$300/m^3 (n-27, s.d.- 53), one third (somewhat lower quality) to this same market at \$153/m^3 (n-21, s.d.-22), and the last third to the domestic market at \$136/m^3. Hence, the average price is \$196/m^3. **Model 3:** In this model, the bandsaw mill sells all wood on the domestic market where the average price for terra firme woods was \$136/m^3 (n-4; s.d.-19).

Table 6. Number of jobs generated by timber extraction, log transport, and wood milling activities in the Lower Amazon River and esturary.

Type of enterprise	Mill Workers	Loggers	Total	%
Small mills [1]	5,955	7,618	13,573	53%
Medium-size mills [2]	2,940	2,888	5,828	23%
Large mills [3]	3,936	2,063	5,999	24%
TOTAL	12,831	12,569	25,400	100%

[1] The 1,191 small mills in the Lower Amazon River and estuary had an average of 5 employees and generated 5,955 mill jobs. Logging activities also generate jobs. Each of these mills consumed, on average, 1,850 m^3 of roundwood/yr. Of the total of 1,191 mills, 972 were using wood from várzea forests. Várzea logging teams were composed of 3.3 men (Table 1) and produced 873 m^3/yr. Hence, 2.12 teams or 6.99 men would be required to produce the 1850 m^3 that each small mill requires (Table 3). The other 219 mills processed wood from terra firme forests. In this case, logging teams had 4.7 members, on average, and produced 2,311 m^3 of roundwood/yr (Table 1). Hence, in this case, 0.8 teams or 3.76 men supplied the wood needs of the small mills using terra firme wood. Overall, the logging activities necessary to supply the small mills with wood employed 7,618 men (972 mills x 6.99 men) + (219 mills x 3.76 men).

[2] There were 98 medium-size, bandsaw-type mills in the study region. These mills employed, on average, 30 people (n-40, s.d.-24) for a total of 2,940 mill jobs. The mills consumed, on average, 10,200 m^3/yr. Forty-eight mills used wood from the várzea; the other 50 mills relied on wood supplied by terra firme logging teams. See Note 1 for calculation proceedure.

table 6, cont.

[3] There were 6 large veneer/plyboard mills in the study region. They employed a total of 3,936 people (656 employees/mill; n - 5, s.d.- 312). Each large mill consumed, on average, 90,980 m^3 of logs from the várzea and, therefore, required the equivalent of 104.2 logging teams (90,980 m^3/873 m^3/team) or 344 loggers (3.3 men/team x 104.2 teams) or 2,063 workers for all six large mills.

Table 7. Sawmill number, annual production, and value of production in the Lower Amazon River and estuary and in Pará State as a whole.

	Nº of Industries		Annual Production		Value of Production	
	Nº	%	m^3	%	$	%
Lower Amazon and estuary:						
Small mills [1]	1,191	63%	774,150	18%	$20,902,050	4%
Medium-size mills [2]	98	5%	343,000	8%	$45,598,000	8%
Large mills [3]	6	0.3%	203,160	5%	$54,446,880	9%
Total	1,295	69%	1,320,310	31%	$120,946,930	21%
Rest of Pará State [4]	579	31%	2,979,690	69%	$457,334,294	79%
All of Pará State	1,874	100%	4,300,000	100%	$578,281,224	100%

[1] The 1,191 small mills present in the Lower Amazon River and estuary produced, on average, 650 m^3 of wood/yr at an average price of $27/$m^3$ (Table 3). Hence, the total value of production from these small mills was $20,902,050.

[2] The 98 medium-size, bandsaw mills present in the study region produced 3,500 m^3/yr. The value of this wood varied with wood quality and market destination as follows: $106/$m^3$ for the 48 mills that relied on wood from várzea forest and sold to the domestic and export markets (Model 1, Table 4, note 5); $196/$m^3$ for 19 mills that used wood from terra firme forest and sold to the domestic and export market (Model 2, Table 4); and $136/$m^3$ for the remaining 31 mills that processed wood from the terra firme forest and sold to the domestic market (Model 3, Table 4).

[3] The six large veneer/plyboard mills in the study region produced, on average, 33,850 m^3 of veneer/yr with an average value of $268/$m^3$ (n=5, s.d.= 36.3).

Table 7, cont

[4] According to A. Veríssimo (pers. comm.), Pará State had 1,874 industries in 1991 that produced 4.3 million m^3 of sawn wood. The total wood production outside of our study region, therefore, was 2,979,690 m^3. Of this total, 2,738,807 m^3 were sold on the domestic market; 94,674 m^3 was mahogany for export and 146,209 m^3 were other veneers and boards for export (AIMEX, Associação das Indústrias Exportadoras de Madeiras do Estado do Pará). We consider that the sale price of wood for the internal market was \$136/m^3; for the export market, the average price of mahogany was \$433/m^3 and the average price for other exported wood was \$300/m^3. Hence, the total value of the wood produced in Pará state but outside the study region was \$457,334,294 (\$2,738,807 m^3 x \$136) + (94,674 m^3 x \$433) + (146,209 m^3 x \$300).