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Synthesis

Collaborative Monitoring of Production and Costs of Timber Harvest Operations in the Brazilian Amazon

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ABSTRACT. Timber companies and policy makers in the Brazilian Amazon urgently need financial information on forest management. Results from a few experiments, case studies, and surveys have been groundbreaking, but are insufficient. A strategic partnership between timber companies and research organizations is needed to generate additional information. This paper presents a tool for monitoring production and costs of forest operations to facilitate such collaboration. The tool provides useful information for companies and, at the same time, generates reliable data for research. Selected results are presented on production, capacity, and costs to demonstrate the usefulness of the information that can be generated. These results are based on the first 2 years of implementation by a company in the State of Pará, Brazil. This pilot project confirmed that the tool is simple and relevant. Its successful implementation requires significant investment, and will be applicable only to companies interested in changing from conventional logging to reduced-impact logging, especially those seeking Forest Stewardship Council certification. Successful implementation of the tool will also depend on it generating readily understood and highly relevant results for the companies, and receiving extensive support during the first 2 years.

Key Words: *Brazilian Amazon; costs; forest operations; monitoring; productivity; reduced-impact logging*

INTRODUCTION

Although about 60 million ha of Amazonian forests have been converted to other land use since the first roads were opened in the 1970s, the Brazilian Amazon is still the world's largest remaining primary forest (Lele et al. 2000, Laurance et al. 2001). About 400 million ha of untouched forests have an estimated stock of more than 60 billion m³ of tropical hardwood. During the 1992 Earth Summit in Rio de Janeiro, sustainable forest management was identified as the preferred option to develop the economic potential of the region, while preserving the environmental value of the forests and addressing international concerns about deforestation (UNCED 1992).

Timber companies play a key role in utilizing Amazonian forests. Current annual production is estimated at about 28 million m³, generating a gross product of about one billion US dollars (Smeraldi and Veríssimo 1999, IBAMA 2002, Sobral et al.

2002). The sector is still dominated by family-run businesses. Nearly 75% of about 7600 mills are estimated to consume less than 4000 m³ of logs per year (IBAMA 2002, Lentini et al. 2003). Over 90% of Amazonian timber is derived from privately owned forests, and very few companies harvest their own forests. Privately negotiated logging concessions of 1 to 5 year's duration are common, and companies are continually searching for new harvesting areas to ensure their timber supply. Only a small proportion of the timber is logged in Forest Management Projects formally approved by the responsible government agency, the Brazilian Institute for Environmental and Renewable Natural Resources (IBAMA). In addition to illegal logging on private or unclaimed federal land, a significant proportion of the timber comes from deforestation activities from legally planned land conversion. It is often sourced from smallholders suffering severe economic problems. As a result, violence and social unrest characterize the situation along Amazonian logging frontiers (Cotton and Romine 1999, Lima

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et al. 2003).

Commercial timber harvesting in the Amazon has a very negative impact on future productivity and environmental values, resulting from a lack of law enforcement and infrastructure, deficiencies in education, corruption, and tenure conflicts (Embrapa 1996, Johns et al. 1996, Blate et al. 2001, Smith 2002). Unplanned use of skidders and bulldozers by unskilled operators causes enormous environmental damage (Barreto et al. 1998, Vidal et al. 2002). Most logging operations do not respect sensitive areas, such as riverbanks, and much timber is left behind in the forests due to lack of control and inadequate felling techniques. Fire and repeated logging further degrade the forests, and cattle ranchers and settlers often convert logged forests into agricultural land.

Reduced-impact logging (RIL) techniques have been developed to reduce the environmental impacts of timber harvesting, to avoid damage to future crop trees, and to improve the production efficiency of harvesting operations (Boltz et al. 2003). In contrast to conventional logging, RIL includes planning activities, such as area mapping, forest inventory, harvest block mapping, selecting and mapping harvest trees, planning infrastructure and skid trails, as well as applying specific felling techniques, and monitoring forest development after harvesting (Dykstra and Heinrich 1996, Sabogal et al. 2000, Wellhoefer 2002). However, only a few of the timber companies in the Brazilian Amazon, those seeking Forest Stewardship Council (FSC) certification, have adopted RIL practices. The timber industry is far from being a catalyst of sustainable development: indeed, socioeconomic and environmental problems in rural regions often become worse when industry is active on the Amazonian frontiers (Nepstad et al. 1999, 2000, Andersen et al. 2002).

Against this background, various policy recommendations have been suggested. One position supports sustainable forest management as the key to development of the Amazon region (Pearce et al. 2003, Boltz et al. 2003). Veríssimo et al. (2002) estimated that approximately 50 million ha are economically attractive for sustainable forest management, and the Brazilian government is planning to open up nearly 30 million ha of National Forests for timber harvest (MMA 2001). A second position suggests more attention be paid to subsistence and cultural values of forests by

emphasizing small-scale forest management concepts (Lima et al. 2003, Nepstad et al. 2004). Another position questions whether private companies can be convinced to provide the long-term investments needed for sustainable forest management, given that commercial incremental growth rates of natural forests do not exceed 2 m³/ha/yr (Rice et al. 2001).

This paper argues that, despite some excellent previous studies, existing information about sustainable forest management in the Amazon is not sufficient to adequately discuss these options. In particular, financial information is missing. Timber companies will only be persuaded to adopt sustainable forest management practices if it can be shown that RIL will generate financial profits. The managerial capabilities of the owners of most timber companies also need to be enhanced, as most have little or no training in management or forestry operations. We present here a tool for analyzing production and costs of forest operations. This tool, designed to be applied collaboratively by private timber companies and researchers, will initiate communication and learning for both parties, and will generate and distribute information about Amazonian forests needed by policy makers for decision making.

The paper briefly reviews different approaches applied to financial analysis of timber harvesting in the Amazon, and describes a tool for collaborative monitoring of production and costs. It demonstrates the tool's analytical potential through a series of results from its pilot application by a timber company in the eastern Amazon, and discusses to what extent the tool can be further applied on a broader scale.

LITERATURE REVIEW: METHODS AND RESULTS OF FINANCIAL ANALYSIS IN THE BRAZILIAN AMAZON

Studies of commercial timber logging in the Amazon began in the 1970s when the timber resources of the region became accessible to the timber centers in southern Brazil through the construction of the first Amazonian highways (Table 1). The Brazilian Organization for the Development of the Amazon (SUDAM), supported by the Food and Agricultural Organization (FAO) of the United Nations, conducted the first study of the technical and financial potential of forest

management for the Amazon (SUDAM 1978). In the 1980s and 1990s, timber harvesting expanded greatly along old and new logging frontiers, but it was only at the end of the 1990s that the first financial analyses of environmentally sound forest management techniques became available for the region (Barreto et al. 1998, Holmes et al. 2000). Before these analyses, there were several reports on the timber sector and conventional logging (see Scholz 2001 for a comprehensive review), but the financial aspects of management were not studied. The few financial studies available give very different results (Table 2). For example, Costa Filho and Ferreira (1991) calculated costs of less than US$8 per m³ for conventional logging in western Pará, and Muehlsiegl and Pokorny (1998) reported logging costs for the certified timber company, Mil Madeireiras, at nearly US$40 per m³ due to extremely high administrative costs. Veríssimo et al. (1995) estimated that costs for highly selective mahogany harvesting in southern Pará were approximately US$150 per m³. However, these three studies do not provide representative cost estimates for logging in the Amazon. The first study suffered from a lack of transparency in its methodology and does not allow recovery of the underlying cost types. The other two studies were very specific and cannot be generalized.

Other studies differ greatly in detail, although they show similar overall cost estimates averaging US$17–37 per m³ (Table 2). Aside from the specifics of particular forests (i. e., species composition, forest structure, relief) and enterprises (i. e., staff, machines, work processes, enterprise organization), these differences are caused by differences in the methods of cost calculation and the methodological approach used for data collection. A closer inspection of these aspects reveals the limited compatibility of the studies, and explains the practical difficulties faced by companies and decision makers in using existing information.

Cost Calculation

All the studies consider costs for capital items (capital costs, depreciation, maintenance), labor, material, administration, and stumpage fees, but costs for risks and imputed salaries are ignored. Also, they look at the whole sequence of activities related to forest operations, including cutting,

skidding, landing activities, and transportation. Costs for construction and maintenance of infrastructure (landings, and primary and secondary streets) are also included. Most studies also take into account costs of transportation from the Forest Management Unit to the sawmill along public roads. The RIL studies include additional costs for planning, e. g., area mapping, forest inventory, harvest block mapping, selecting and mapping harvest trees, and planning infrastructure and skid trails.

Differences occur mainly in the way the studies calculate costs. Some analyze only overall costs, but others define costs for selected activities. The studies also differ considerably in how they treat and distribute costs for administration and technical coordination. Most critically for comparison purposes, some studies use standard costs for labor and machinery, but others rely on enterprise-specific data. Finally, only some of the studies consider timber waste as a cost factor. Barreto et al. (1998) added a general surcharge of 25% to the costs of conventional logging for timber waste, whereas Holmes et al. (2000) used the potential value of the waste measured in the forest. The different treatment of timber waste by these researchers, rather than the different measurements of productivity in the field, resulted in greater differences in the overall result of their studies.

Methodological Approaches

The method used for data collection strongly influences the reliability and usefulness of the study results. Studies presented in Table 3 can be structured into (a) interview surveys, (b) in-depth case studies, and (c) experiments. Each approach has characteristically strong and weak aspects, resulting in a specific quality of the captured data.

Surveys: Mailed surveys are a popular and effective means of industry–researcher collaboration in developed countries (e. g., Dillmann 1978). The costs to both parties are relatively low, as surveys are designed to take as little time as possible. Options such as stamped, self-addressed envelopes lower obstacles and increase responses. Unfortunately, mail-in surveys are difficult for the majority of timber companies in the Amazon and the expected response rate is close to zero (C. Sabogal, N. Silva, and J. Zweede, pers. comm.) This methodology may

Table 1. Characteristics of selected research on financial aspects of commercial timber harvest (RIL and CL) in the Brazilian Amazon

Author	Year	Type of study	Sample size	Type of logging	Costs considered	Location
SUDAM	1978	Experiment	unknown	CL	Harvest and transport	Curuá Una, PA
Costa Filho & Ferreira	1991	Case study + time study	3 companies	CL	Harvest and transport	Curuá Una, Jarí, Flona Tapajós, PA
Veríssimo et al.	1992	Survey (brief) Survey (in-depth)	238 companies 33 companies	CL	Harvest and transport	Paragominas, PA
Veríssimo et al.	1995	Survey Field measurements	66 companies 1 team, 3 x 100 ha	CL (mahogany)	Harvest	Tucumá, PA
FAO Wellhoefer	1997 2002	Experiment	10 ha RIL, 10 ha CL	CL & RIL	Harvest and transport	Itacoatiara, AM
Barreto et al.	1998	Experiment	105 ha RIL, 75 ha CL	CL & RIL	Harvest	Paragominas, PA
Stone	1998a	Survey	40 companies	CL	Harvest and transport	Paragominas, PA
Muehlsiegl & Pokorny	1999	Case study + time study	1 company ~ 80 cycles	RIL	Harvest	Itacoatiara, AM
Holmes et al.	2000	Experiment	100 ha RIL, 100 ha CL	CL & RIL	Harvest	Paragominas, PA
Pokorny & Sousa	2000	Case study + time study	1 company ~70 cycles	CL	Harvest and transport	Tailândia, PA
de Graaf et al.	2002	Case study + time study	1 company	RIL	Harvest	Itacoatiara, AM

RIL = Reduced Impact Logging; CL = Conventional Logging
AM = Amazonas State, PA = Pará State

be an important option in the future as communication networks improve, but currently creates biases in the responses that must be taken into account. Therefore, personal interviews are used to capture information. Regardless of survey details, the common denominator of this approach in the Brazilian Amazon is data collection from short, focused interviews, usually not exceeding 45 minutes. Numerous companies can be surveyed over a relatively short period and the data collected are the most broad and representative available. Because of their relative ease of application, surveys have been used in many of the research efforts in the timber industry (e. g., Veríssimo et al. 1992,

1995, Stone 1998a, 1998b, Nepstad et al. 1999). The advantage of easy and fast information access, however, is to some extent reduced by the unknown quality of the responses. This is especially true of financial information about commercial forest operations, as Amazonian timber companies characteristically are run by self-made managers who have little business management training, deficient bookkeeping practices, and restricted financial control of forest operations (Arima and Veríssimo 2002, Pearce et al. 2003). Companies tend to focus their interest on mill processing and sales, not on forest operations.

Table 2. Harvest and transport costs (US$/m³) in selected studies.

Study	Year	Type of logging	Stumpage Fee	Inventory	Infra-str.	Felling	Skidding	Landing	Other	Subtotal Logging	Transport	TOTAL[b]
		CL Tapajós	n.r.	0.65	0.42	0.46	1.48	n.r.	1.30	4.31	3.37	7.68
Costa Filho & Ferreira	1991	CL Jarí	n.r.	0.65	2.94	0.41	1.96	n.r.	2.50	8.46	3.89	12.35
		CL Curuá Una	n.r.	0.65	2.09	0.56	1.77	n.r.	2.18	7.25	2.86	10.11
Veríssimo et al. [a]	1992	CL small scale	1.90	n.r. [a]						11.11	8.42	21.43
Veríssimo et. al.	1995	Mahogany	40.00	4.60			23.80		7.60	36.00	75.90	151.90
		CL small scale	5.00	n.r. [a]						12.60	20.09	37.69
Stone [a]	1998	CL large scale	5.00	n.r. [a]						10.34	18.09	33.43
		CL small for '92	2.21	n.r. [a]						13.93	13.39	29.53
		RIL	5.00	1.87	0.28	0.25	1.31	2.59	4.18	10.48	11.00	26.48
Baretto et al.	1998	CL	5.00	0.00	0.40	0.40	1.37	2.53	4.18	8.88	11.00	24.88
Muehlsiegl & Pokorny	1998	RIL	5.00	4.04	3.03	2.72	3.78	2.83	15.-25	36.65	3.22	39.87
Pokorny & Sousa	2000	CL	4.95	n.r.						10.69	6.27	21.91
		RIL	7.61	1.18	0.32	0.62	1.51	1.28	1.07	5.98	10.00	23.59
Holmes et al.	2000	CL	9.09	0.00	0.57	0.65	1.99	2.01	0.97	6.19	10.00	25.28
Wellhoefer	2002	RIL	n.r.	2.50	n.r.	5.00	12.00	n.r.	n.r.	19.50	4.50[c]	24.00
Pokorny & Steinbrenner	2004	RIL Implementation	4.81	0.84	0.69	0.97	2.75	2.06	0.68	7.37	4.23	17.28

RIL = Reduced Impact Logging; CL = Conventional Logging.
n.r. = not reported
[a] Both Veríssimo (1992) and Stone (1998a, b) calculate costs per item rather than by activity: i. e. salaries and benefits, fuel, maintenance, depreciation, capital costs, forest tax, and estimated management costs.
[b] The total costs correspond to value in US$ given by the authors for the period of each study. They have not been adjusted to the present because of the difficulty of addressing the effects caused by the change of currency (Cruzeiro to Real, 1994) and the devaluation of the Real against the US dollar since then. It is quite probable that the effect of inflation is partly offset by the effect of devaluation. That said, it is important that the relative costs be examined with the caveat that the values are not fully comparable.
[c] For an estimated distance of 30 km

Table 3. Advantages and disadvantages of previous research methodologies

Methodology	Advantages	Disadvantages
Survey	Statistically significant; broad; expert-based; timely; cost effective; huge sample size possible	Dependence on secondary information, thus data of unknown quality
Case Study	Close contact with personnel; broader questions; and in-depth questions possible	Only applicable to few cases; expensive; dependence on secondary information and knowledge by personnel; includes many assumptions
Experiment	Control over data quality; allows for the testing of a variety of alternate scenarios and ideas	Only applicable on a limited scale; expensive; upward bias through extrapolation; specific; individual; and non-comparable assumptions between experiments

Case studies: Case studies are an important option in production research (e. g., Yin 2002). Through direct access to the documents and the opportunity to ask specific questions of company staff, including managers, information from case studies is significantly more reliable than that captured by surveys. Nevertheless, case studies also suffer from reliance on company-based information of unknown quality. Much more time is needed, making the process more expensive, and because only a limited number of companies can be considered, the applicability of the findings is restricted.

Experiments: In contrast to surveys and case studies, the researcher has greater control over the data quality in experiments, but experiments also have drawbacks. They are expensive and specific, and can therefore only be applied on a restricted scale over a limited time. This has various implications. Factors present under operational working conditions, such as accidents, illness, unfavorable weather, problems with machinery, and bureaucratic transaction costs, are widely ignored. Experiments are normally well organized and workers tend to work more consistently under intensive observation. The harvested volume can vary widely in different areas due to heterogeneity of tropical forests. For example, the average yields measured by Barreto et al. (1998) and Holmes et al. (2000) in their 100-ha study areas in Paragominas district varied from 25.4 m³ to 38.6 m³ per ha, which impacted significantly on their financial results. Another obstacle for the replication of experimental results is the difficulty in obtaining an accurate estimate of forest areas not

suitable for harvesting because of slopes, rivers, or species availability. These exclusion areas vary greatly, depending on forest quality, markets, and commitment of companies to legislation. Indirect costs resulting from social services, coordination of forest operations, and maintenance of equipment depend on a variety of very specific company parameters such as organization, logistics, and harvesting techniques. It is nearly impossible to adequately consider these specific factors in experiments, which is why the cited studies differ considerably in this aspect. Generally, experiments run the danger of introducing a bias in methodological design, data analysis, and interpretation of results. These difficulties imply that results must be extrapolated with care and that there is a risk that linear extrapolation may underestimate actual costs. Sensitivity analysis or the consideration of scenarios on productivity and costs are possible ways to address this problem.

Notwithstanding efforts to date, there continues to be an urgent need for reliable data on forest management in the Amazon. Specifics of methodological design and underlying data make it difficult for relevant actors to base their decisions on information provided by existing studies. Company managers need information on their own operations in accordance with their local conditions and taking into account specific depreciation periods, levels of salaries, stumpage fees, and annual interest rates. Banks depend on data reflecting the diverse conditions of forest companies as a basis for applying their cost calculation models. Data on forest operations in the Amazon are also

needed to feed decision-support tools such as RILSIM (www.blueoxforestry.com) or to design cost models with regional validity for policy makers. To satisfy these demands for reliable data, long-term studies are needed to provide information on the diversity of technical, socioeconomic, and environmental conditions of timber companies in the Amazon.

COLLABORATIVE MONITORING

Following the principles of the Integrated Natural Resource Management approach as outlined by Lal et al. (2001) and Sayer and Campbell (2001, 2003), active involvement of timber companies in research is fundamental to ensure relevance and local ownership of the research process, and to increase acceptance of research outcomes. In fact, most studies of commercial forest management, independent of the methodological approach chosen, have collaborated with timber companies in an attempt to generate realistic and relevant information. In many cases, researchers became technical supervisors for the timber company being observed. There are many long-term partnerships: for example, in Sabah, Malaysia; Labanan and Bulungan, Indonesia; the BOLFOR project, Bolivia (see Enters et al. 2002); as well as the International Tropical Timber Organization (ITTO) project related to this study. These partnerships assist the companies in implementing more sustainable forest management regimes, often with the intention of establishing demonstration sites and generating manuals, scientific publications, and computer tools related to the promotion of sustainable forest management (see, for example, the FAO (http://www.fao.org/forestry), ITTO (http://www.itto.or.jp/), and Center for International Forestry Research (CIFOR) (http://www.cifor.cgiar.org/) websites.

The uptake of available information and tools by timber companies outside these "research" partnerships is quite limited for various reasons. Many timber companies are simply not interested in innovations and prefer to continue with their well-tried and lucrative harvesting concepts (Scholz 2001), or they do not have the capacity to apply scientific results to their own situations, to understand publications written in scientific jargon, or to use existing computer tools (Barreto and Arima 2002). Also, the partnerships have often been only short term and focused on environmental issues that are not a priority for companies.

It is important to have collaboration between timber companies, as owners and users of financial information on forest management, and researchers with the capacity to interpret and analyze the information. This collaboration should have a long-term perspective and aim to initiate learning processes for both parties; for researchers to have a better understanding of the realities of commercial logging in the Amazon, and for timber enterprises to enhance managerial capabilities needed for the innovative management that is fundamental for implementing sustainable forest management. Simple tools are needed to support such strategic partnerships.

Since 1998, there has been scientific cooperation between the Brazilian Research Organization for Agriculture (EMBRAPA) and CIFOR in collaboration with the Brazilian subsidiary of the Tropical Forest Foundation (FFT) and the Brazilian timber company Juruá Florestal Ltda (referred to as Juruá). This partnership developed a tool to systematically monitor the production and costs of forest management operations. "Collaborative monitoring" is the term used to describe a long-term association where companies apply a simple tool to systematically collect data needed for financial analysis, and researchers provide assistance in data interpretation and receive reliable data for their research. It is expected that examination of financial aspects of their own forest management operations will increase the sensitivity and interest of forest companies in innovations to increase operational efficiency and reduce environmental damage. For the researchers, this collaboration will facilitate a better understanding of timber companies as a basis for improved recommendations and research.

Guiding Principles

Simplicity, continuity, and precision are the three guiding principles to ensure practical relevance and adequate data quality.

Simplicity: Illiteracy is common in the Amazon region, and to circumvent this obstacle numerical codes were used to report workers' names, machines, and activities. Numerical codes also facilitate the data entry and reduce input error. Only team leaders, usually those most literate, had to complete data forms. Only basic information was

sought, such as daily production, team composition, and working time. However, complete input accounting was required for each machine.

Continuity*:* Forest operations suffer from a wide variety of disturbances and irregularities, such as rain, broken machines, or waiting time for equipment; thus, point sample information may vary significantly from reality. This is especially true for badly organized forest operations with poorly maintained equipment, and in extreme environmental conditions prevalent in the Amazon. A continuous daily documentation of the working process over the whole year was used to capture this irregularity.

Precision: Amazonian timber companies, due to a lack of organization and qualification, may overlook important factors in their cost accounting, such as capital costs, temporary workers, employees related to general services, costs related to social services, and small machinery. Cost monitoring had to guarantee a complete consideration of all relevant factors based on systematic accounting.

Data Collection

The above principles have been put into practice in a monitoring process involving three system components: reports, database, and administration routines. Production of different forest operations, and relevant forest expenses and consumption were systematically documented in five reports:

1. daily field reports showing the daily production, location of work, team composition, and working time for each working team;

2. overview sheets providing a monthly overview of the presence of forest workers and supporting staff;

3. machine reports documenting maintenance and consumption, including oil and diesel.

4. machine overview sheets giving a monthly overview of application for heavy machines, chainsaws, and vehicles; and

5. expenditure sheets of chronologically occurring expenses not directly related to

specific workers or machines, but with relevance to the forest sector.

All data were transferred to a database, which enabled analysis of monthly and average production and costs for different activities, teams, machines, and projects. This process required continuous updating of data, such as lists of forest workers and their monthly salaries; lists of machines, their prices, and depreciation periods; lists of monitored activities and measurement units; and lists of parts and material and their prices. Beyond this, constant, company-specific parameters were defined, such as duration of the harvesting period and the firm's interest rate. The data bank designed with the Microsoft Office software ACCESS was transformed into a professional freehand software.

Clearly defined administration procedures for data collection, processing, and control are fundamental for effective monitoring. The complexity of the tasks requires an information manager to support and supervise the whole monitoring process.

The following process elements have been identified (Fig. 1):

1. At the end of each day, each production team leader must fill in the field reports. Those responsible for the machine operators update the machine reports regarding consumption of diesel, lubricants, and spares.

2. Reports are collected and checked by the information manager, who must also complete the overview sheets for workers and machinery. Any uncertainties or questions should immediately be addressed.

3. Field reports, machine reports, and overview sheets are sent to the administration office on a predetermined, regular schedule.

4. Office personnel must check report quality, and also document on the expenditure sheets all expenses related to forests. Machine-related expenditures should be documented separately for each machine.

5. All data should immediately be transferred to the database. Automatic checks in the software identify inconsistencies, which are

Fig. 1. Schematic of collaborative monitoring process.
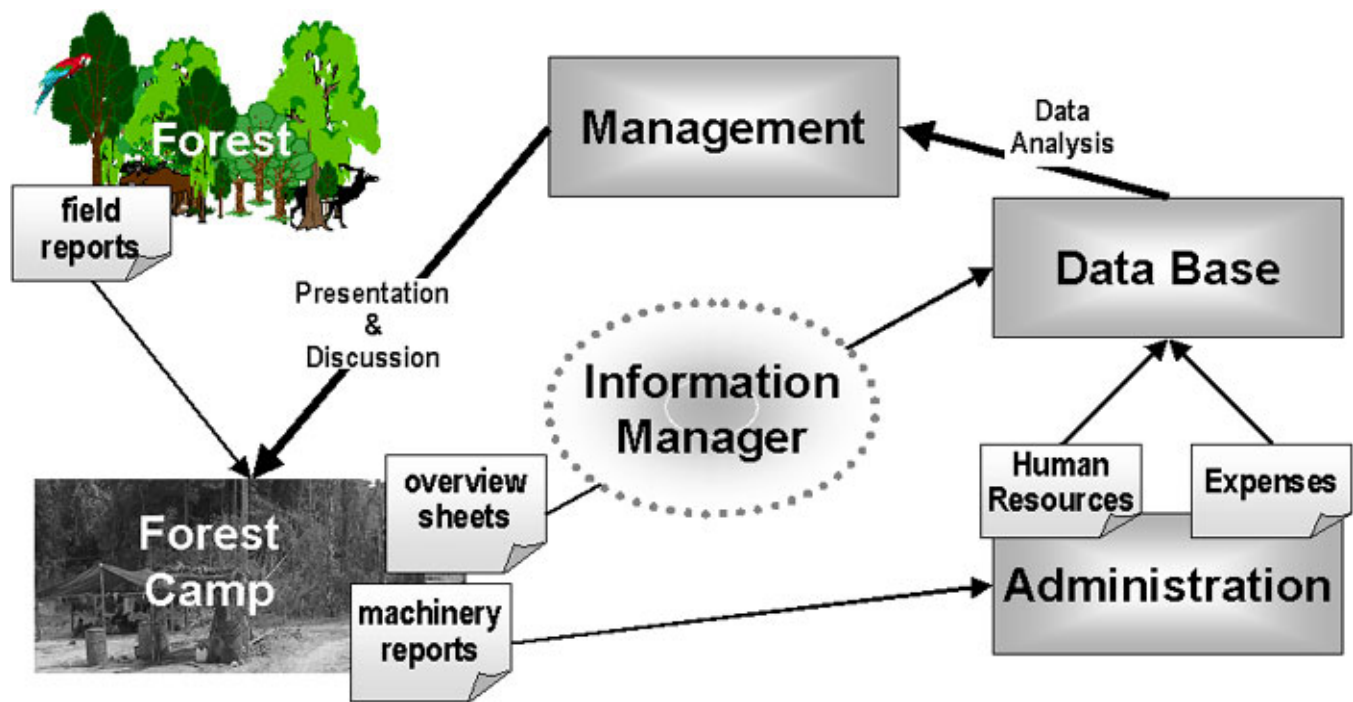
listed, and must be reported immediately to the information manager. Due to a high turnover rate, data on employees must be updated continually. The list of machinery must also be updated.

6. The software enables generation of standardized results on monthly production and costs, which should be reported to management. The cost calculation considers the following elements: human resources, capital costs, equipment, material, depreciation, and general expenses related to the forest sector. The company defines interest rates and depreciation periods. Expenditures outside the harvesting period are totaled and distributed throughout the harvesting period.

7. Managers should review the results and have the opportunity to discuss them with the information manager and forest workers. This feedback ensures interest in the monitoring process, and provides a learning experience.

Data presented in this paper span the period from August 2000 to July 2002, during which there was a transition from conventional logging to RIL. Daily field reports were completed for each operation, in particular for: cutting line establishment, inventory, infrastructure planning, road construction, landing construction, tree marking, felling, skid trail planning, skidding, loading, and permanent sample plot establishment. All calculated costs were based on information collected in conjunction with the company. Inconsistent, false, or missing data, a common occurrence during preliminary application of tools under development, were accounted for by using averages or plausible estimates.

Research Site

Juruá's head office is located near Belém, the state capital of Pará. The company has two sawmills. The Forest Management Unit in this study is located 50 km west of the town Tailândia and is approximately

Fig. 2. The location of the Forest Management Unit "Santa Marta" managed by the Brazilian timber company Juruá Florestal Ltda.
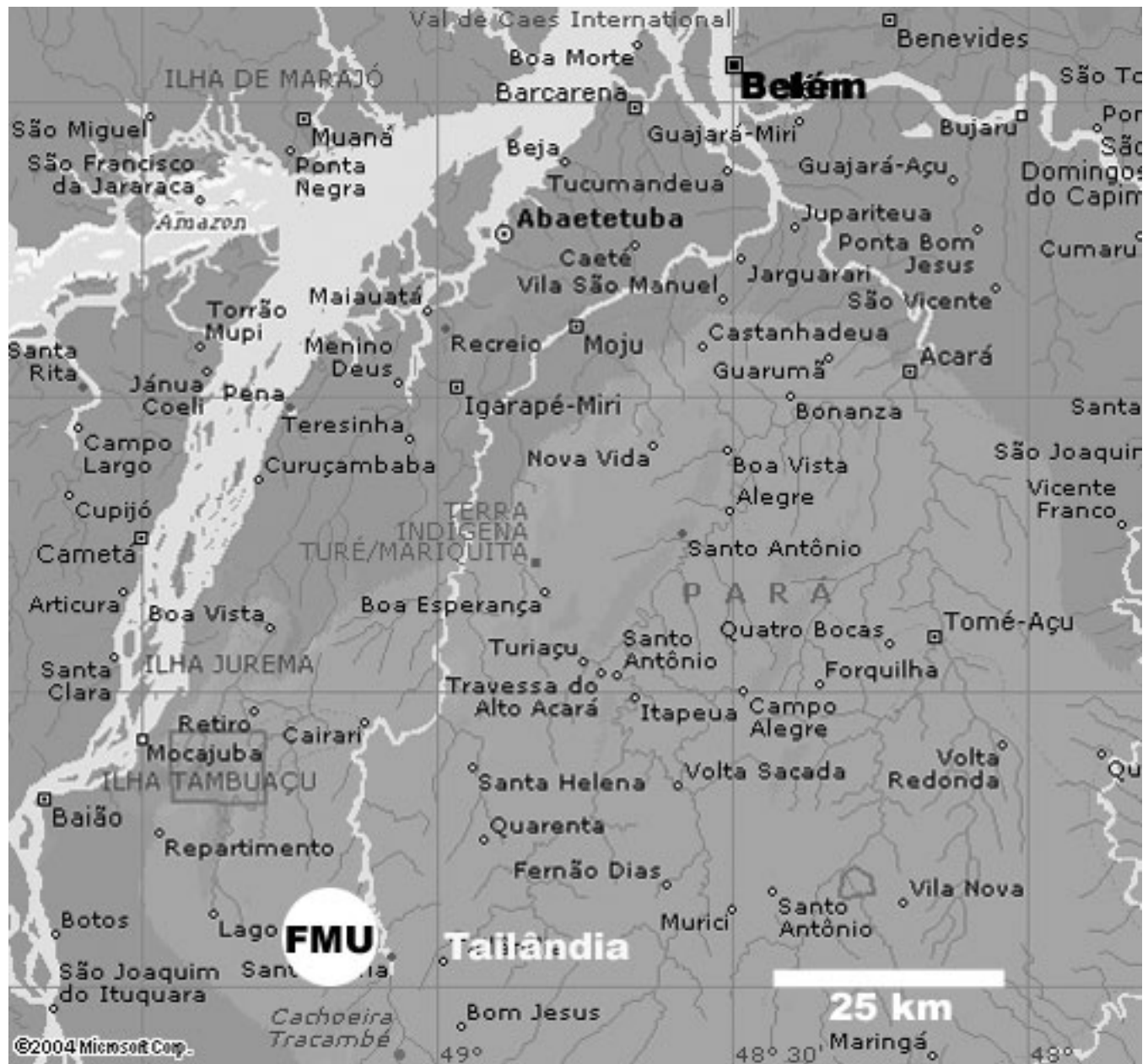
12 000 ha in extent (Fig. 2). Its topography is flat to moderately undulating, and crossed by many small rivers. The soils are red and yellow Latosols. Mean annual rainfall is about 2000 mm, and mean annual temperature is 26–27°C (Köppen and Geiger 1954). The characteristic vegetation type in the area is *Floresta Tropical Ombrófila* upland forest. Harvesting operations are restricted to the drier season (June to November) because of heavy rain from December to May. The Forest Management Unit was divided in six annual coupes, each 2000 ha. The company applied conventional logging

techniques, characterized by repetitive and unplanned extraction of a few commercial tree species until 2000 when, under the auspices of the ITTO project, it started to manage 400 ha under RIL guidelines (Sabogal et al. 2000). The quality of harvesting operations improved considerably, and in 2001, Juruá was awarded FSC certification for its entire operation.

During the harvest period, up to 50 people worked in the Forest Management Unit. The approximate harvest volume was 40 000 m³ per year. The company deployed the following machinery: three CAT 518 skidders (all 1994 models), two loaders (CAT 930, CAT 935; both 1995 models), one D6D bulldozer (1993 model), one Volkswagen 7100 Truck (1994 model) for personal transport, and several chainsaws. All heavy machinery was bought in 1999 for about US$100 000/machine. Most timber companies in the Amazon depreciate heavy machinery only for tax declarations, and not for cost calculation. Due to lack of capital, they usually purchase second-hand machines past their depreciation period, as defined by the manufacturer. According to the value of these capital items to the companies, this study included machinery depreciation for the second-hand machinery based on purchase date and value and a depreciation period of 6.5 years from date of acquisition, which corresponds to the expected lifespan stated by the company manager. Capital costs have been calculated at an interest rate of 9.7%, set by the Central Bank of Brazil (Banco Central) in accordance with the norms of the National Monetary Committee (Conselho Monetário Nacional) for the relevant period.

RESULTS

Although there have been various adaptations to the monitoring tool since its inception in 1999, the 2 years of data permit an in-depth analysis of the harvesting operations, including the effects of RIL implementation and FSC certification. This section presents selected results to demonstrate the utility of the information for timber companies, which is a precondition to promote interest and stimulate learning. These examples show how the monitoring provides companies with information needed to plan finances and operations, to detect training needs, to evaluate effects of innovations, and to decide on investment in capital items. To indicate the potential for scientific analysis, the examples chosen interpret the financial impact of RIL for the company.

Production

Average daily productivity results for the principal harvesting activities are shown in Table 4. Inspection of minimum and maximum levels indicates the overall variability in daily production. This variability can be attributed to changing working conditions, techniques, and team composition over the observation period. The frequency of observations over 2 years makes it feasible to estimate realistic means for daily production of all monitored activities. This is fundamental for financial and operational planning. For example, Fig. 3 shows the development of the daily mean productivity of three felling teams for the harvest periods in years 2000 and 2001. At the beginning of 2000, the teams were trained to use directional felling techniques aiming at greater safety, less damage to future crop trees, and less timber wastage from felled trees. The switch to directional felling required working with maps, increased attention to safety, and application of specific felling techniques. These changes reduced daily felling rates significantly (by more than eight trees). The teams needed more than 2 months' practice to consolidate their productivity. This positive trend, interrupted by the start of the wet season in December, continued in 2001, although productivity rates never reached the level of conventional felling. The example reveals the importance of monitoring the effects of new technologies, of identifying possible difficulties in a timely manner, and of devising appropriate measurements. It also shows the need to realistically estimate productivity and costs as a prerequisite for planning operations.

Figure 3 also shows a regular productivity pattern for forest operations in the Amazon, characterized by an increase to the midpoint of the harvest season, followed by a decrease as difficult conditions take their toll on workers and machines. Harvest operations are further hindered, and finally stopped, by the onset of the rainy season. Monitoring this trend helps determine when a specific activity should be stopped for financial reasons.

Productivity is sensitive to changing working

Table 4. Average monthly production in the principal harvesting activities for the period August 2000 – December 2001

Activity	Unit	Mean[a]	Min	Max	SE%	n
Establishing cutting lines	meters	1863	100	5428	40	579
Inventory'	trees	147	10	331	42	334
Constructing roads (without planning)	meters	498	110	1000	60	240
Constructing landings (without planning)	landings	3	1	8	62	110
Marking trees	trees	51	12	117	36	56
Felling	trees	16	1	50	39	1039
Planning skid trails	trees	43	3	148	52	285
Skidding	logs	40	2	104	47	585
Loading	m³ Francon[b]	196	4	441	44	282
Establishing Permanent Sample Plots	plot	1	0.1	2	38	91

[a] Rounded to nearest whole figure
[b] A historical anomaly of the Pará timber industry is the use of m³ Francon to express the log-volume, calculated by the formula length x diameter x diameter x 4. In addition, diameter and lengths are reduced according to species-specific indices established by IBAMA or the regional market, the real—geometric —volume is therefore underestimated; on average 1 m³ Francon corresponds to about 0.75 m³.

conditions, such as weather, stocking density, crop-tree diameter, quality of maps, and equipment. There are also significant differences between teams, so by examining the teams individually, further benefits can be obtained. There was great variation in the daily productivity of the teams (Fig. 4). Team 3 felled nearly two trees per day more than the other teams. This suggests an opportunity to improve the performance of the other teams by internal training or other measures.

Unused Capacity

Timber company managers in the Amazon perceive machines as an important cost factor, but seldom have control of their performance and effects on costs. Analysis of the proportion of lost workdays for three skidders during two harvest periods revealed that, on average, only 63% of machine capacity was used (Table 5). About 12% of potential working time was lost due to operator absenteeism and general breaks on Sundays, while another 15%

loss resulted from mechanical failures. A comparison with the results of skidding trails in the USA, where a skidder worked at peak productivity more than 90% of the workday (McDonald and Rummer 2001) indicates the extent of lost capacity. Most surprising in our study was the high proportion of time spent in support work, which was mainly towing trucks through impassable stretches of roads. This non-skidding activity is primarily at the beginning and end of the harvest season when rain affects the movement of loaded trucks. The loss of a third of the existing skidding capacity had serious repercussions on costs. This increased costs per harvested cubic meter of timber by more than 10%, using estimated average costs for capital, depreciation, and the working team of about US$150 per day. Quantifying in detail the effects on costs of technical problems and inappropriate use of machines could stimulate companies to review their investment in adequate maintenance, new machinery, and operator training.

Fig. 3. Daily production and overall means of three felling teams during the harvest periods 2000 and 2001, affected by the implementation of directional felling as part of RIL in September 2000.
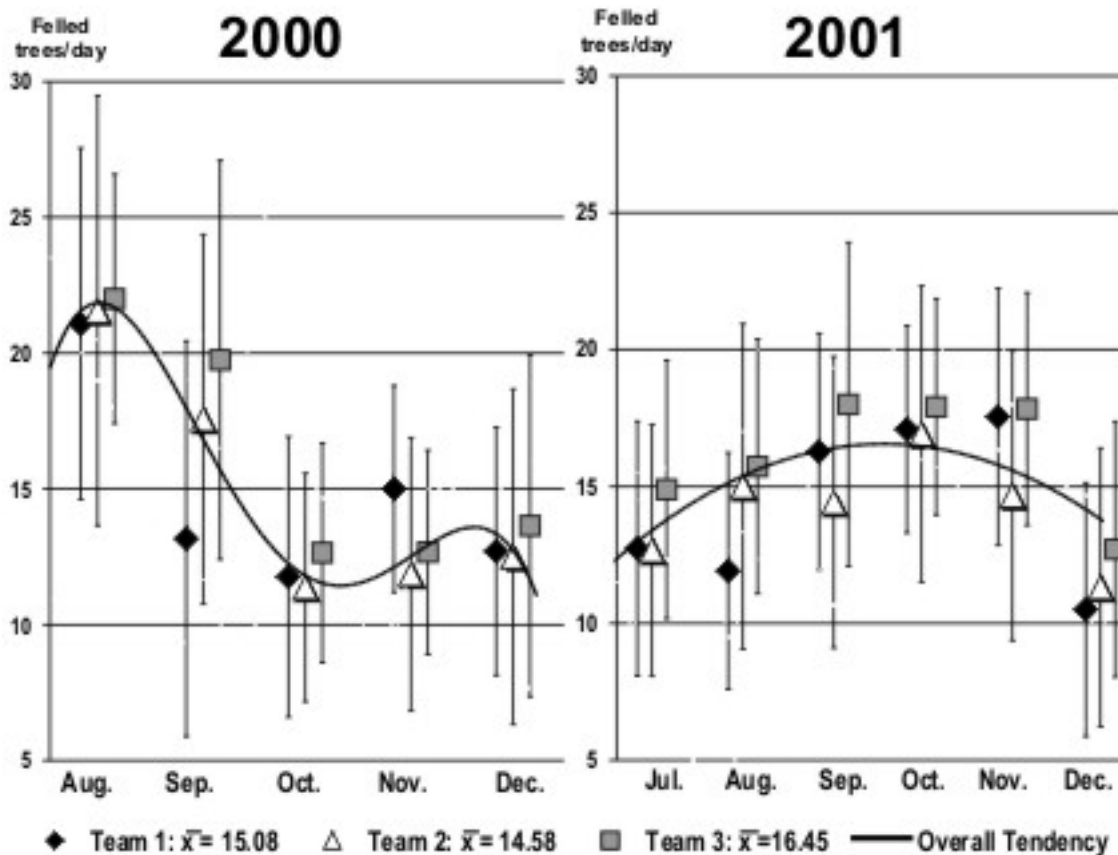
Costs

During the years 2000 and 2001, Juruá harvested nearly 16 500 trees, representing a volume of about 80 000 m³ on 5500 ha of primary forests. This corresponds to a logging intensity of 14.5 m³/ha and an average volume of about 5 m³/tree. The fact that Barreto et al. (1998) and Holmes et al. (2000) measured double this harvest volume per hectare in their experiments confirms the methodological difficulty of extrapolating data from small-scale experiments to the larger areas of Forest Management Units. The net harvestable area was less than 70% in the Forest Management Unit we studied.

Using these factors and the information provided by the daily reports for each logging activity, the costs per cubic meter were calculated for each of the principal forest activities. We used the historical monthly average Interbank Exchange Rates to transform the Brazilian currency (Real) into US dollars (http://www.oanda.com/converter).

Skidding and landing activities accounted for more than 60% of all operational costs (Table 6). Another 20% came from infrastructure construction and felling, activities requiring a significant use of machinery. The contribution of labor-intensive activities, however, was relatively small. Nearly 60% of total costs was directly related to machines, including over 7% by chainsaws. In general, due to the age of the machines, the proportion of variable costs for maintenance and consumption were higher

Fig. 4. Daily productivity of three felling teams during the harvest periods 2000 and 2001, by productivity classes.
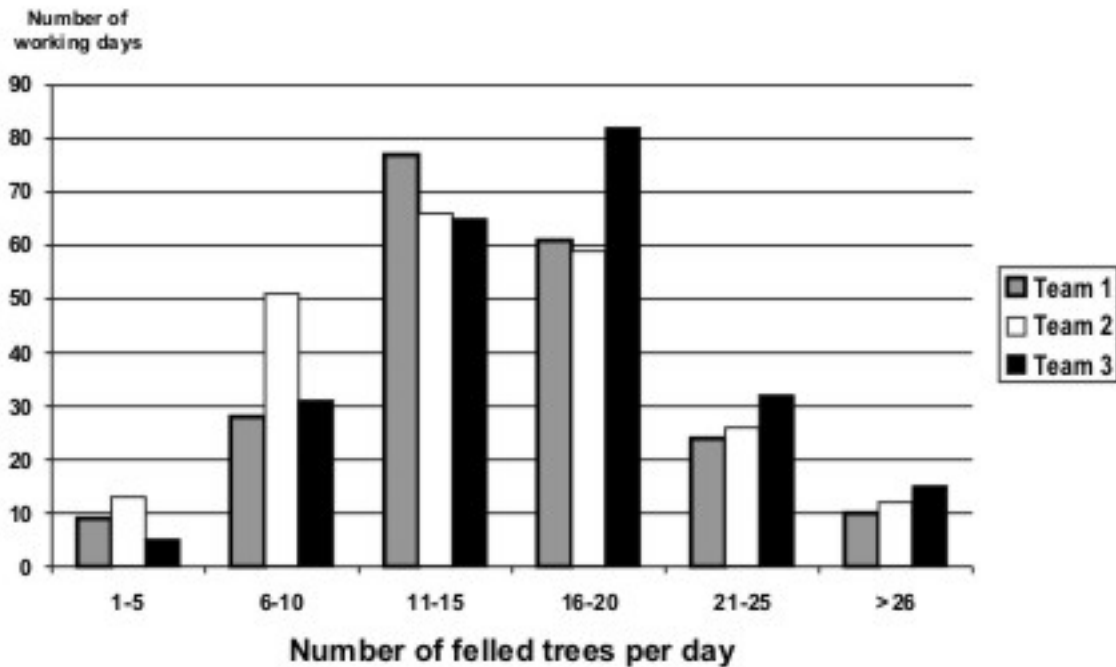

Table 5. Proportion of lost workdays for three skidding teams for the period August 2000–December 2001

Machine	Potential wo-rking days[a]	Misc. stoppage[b]	Defect	Subtotal wor-king days	Active skidding days	Support work[c]	Percentage of days skidding
Skidder 1	325	46	20	259 (80%)	231	28	71 %
Skidder 2	327	25	71	231 (71%)	184	47	56 %
Skidder 3	285	44	36	205 (72%)	179	26	63 %
Total	937	115	127	695 (74%)	594	101	63 %

[a] Days when the skidder was available in the Forest Management Unit during the harvest period
[b] Miscellaneous delays caused by operator absenteeism, working breaks during the weekends, or rainy days (only counted when skidder was not stopped because of defects)
[c] Support work consists primarily of extracting trucks that are stuck on poor roads during the rainy days

Table 6. Average harvesting cost per m³ of round wood and the participation of different cost types (without transport and fees)

| | Costs per m³ | | Proportion of costs (%) | | | | |
| | | | Labor | | Machines | | |
Reported Activities	US$	%	Field teams	Support	Fixed	Variable	Misc.
Cutting lines	0.49	6.6	37	33	0	0	30
Inventory, vine cutting	0.35	4.7	51	28	0	0	21
Tree marking	0.03	0.5	50	23	0	0	27
Felling	0.93	12.6	23	15	5	25	32
Infrastructure planning	0.05	0.7	30	26	2	3	38
Infrastructure construction	0.58	7.8	8	4	32	47	9
Skid trail planning	0.29	3.9	33	26	0	0	40
Skidding	2.46	33.2	8	5	28	49	10
Landing activities	2.06	27.8	12	6	27	42	13
Infrastructure maintenance	0.06	0.8	9	3	56	20	13
Monitoring (PSP/ damages/waste)	0.05	0.8	43	24	1	2	30
Others (Research etc.)	0.02	0.4	36	23	0	0	41
			17	**10**	**20**	**36**	**17**
TOTAL	**7.37**	**100**[a]		**(27)**	**(56)**		**(17)**

[a] May not add up due to rounding

than the costs for capital and depreciation. About 17% of overall costs were related to miscellaneous costs, such as administration, food, supporting vehicles, and small equipment. Only a quarter of the overall cost was attributed to labor, including coordination and support staff, such as forest technicians, a driver, and a cook. These results should help convince managers of the importance of adequate training for their staff, especially machine operators, and retention of trained staff by paying appropriate salaries.

The trend of skidding costs per log during the harvest periods in 2000 and 2001 (Fig. 5) is an example of a more detailed analysis of a specific activity. This includes the implementation of RIL techniques during September 2000. Both years, in accordance with the productivity pattern already observed for felling operations, show similar cost trends, characterized by high daily costs at the beginning and end of the harvesting season, and lower daily costs in the middle. Work is often temporarily disturbed by rainfall and technical problems during the beginning and end of the harvest season. The high costs attributed to Team 1 in October 2001, Team 2 in August 2000, and Team 3 in October and November 2000 resulted from technical problems with machines. This highlights the effect of insufficient maintenance. Implementation of RIL contributed to the significantly lower average cost per log in 2001 (Figure 5). Skidding costs decreased by more than US$7 per log despite the cost for skid trail planning of about US$0.29/

Fig. 5. Costs for skidding a log during the harvest periods 2000 and 2001, affected by the implementation of planned skidding as part of RIL in September 2000.
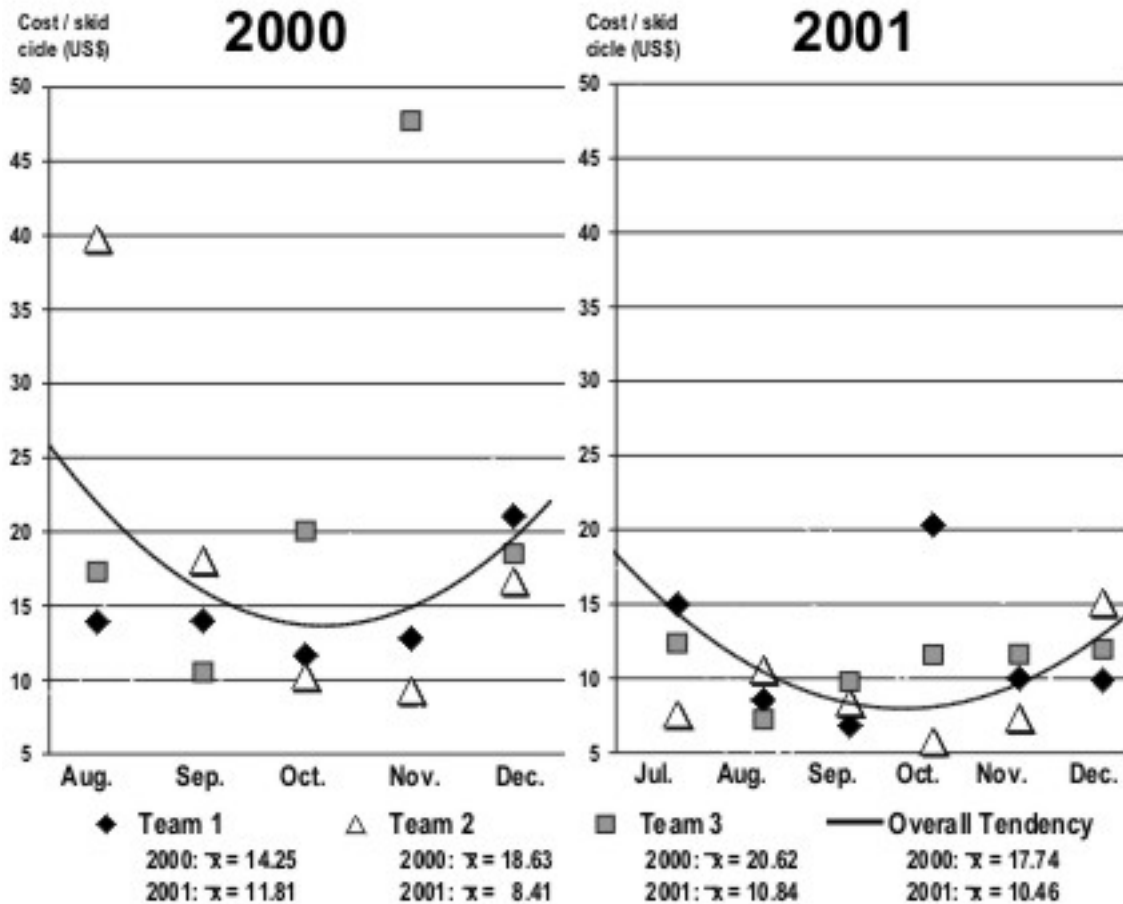
m³. Again, strong differences among the teams were detected. Such insights provide excellent opportunities to enhance operational performance.

DISCUSSION

We designed the tool for collaborative monitoring of production and costs to be applied by companies in their day-to-day activities to provide them with useful information, and at the same time, to generate reliable data for research. Experience gained during its development, however, revealed some difficulties affecting its more general application:

1. *Field reports.* Initially, there was considerable apprehension and mistrust on the part of the workforce, but after a few days, all workers completed the daily reports in less than one minute. Nevertheless, continuous supervision and training of newcomers were necessary. The codification system was rapidly assimilated, but lack of awareness and communication often caused serious confusion, when new workers received their numerical codes.

2. *Chainsaws.* Numbering of chainsaws caused significant problems. They were documented

correctly in the field reports only after they were permanently marked.

3. *Machinery.* Estimating fuel and lubricant consumption caused some difficulties when measuring devices were not available at filling points. Training was necessary to ensure accurate estimation of consumption. Documentation of spares was the most difficult task, and their complete documentation was not practical, as there was an incredibly large number of items for each machine, including minor pieces such as screws and lines. It is necessary to have a separate bookkeeping system for spares to provide more general information about the costs for each machine needed for the cost monitoring. Documentation by the operators in the forests was meaningful only for specific items, such as fuel and chains.

4. *Database.* Use of the database by the company regularly caused problems. As the monitoring tool was developed and tested during the FSC certification process, the company's capacity for data processing was completely absorbed by data generated in inventories, permanent sample plots, and chain of custody required as a matter of priority by the certifiers. Several times, field reports were collected but not processed. This delay interrupted data and communication flow, and often it was not possible to make a timely check of suspect field data or acquire missing information. Also, the lists and codes for employees and machines were not continuously available, and this confused employees and resulted in mistakes in field reports.

5. *Bookkeeping system.* The bookkeeping system did not allow costs to be kept separately for each machine. It took several attempts before the reluctant administration adapted their bookkeeping routines to resolve this problem.

Most difficulties described above resulted from a lack of clearly defined competencies and data management routines. The employees, already fully occupied with their daily work, perceived the monitoring system as an additional burden, and the enterprise's management concentrated strongly on

obligations imposed by the FSC certifier. Discussions with the company management and the staff involved revealed the need for a well-trained information manager to coordinate the various elements of the monitoring system. After significant resistance, the company agreed to employ such a technician, with responsibilities also for other monitoring mechanisms. Experience shows that identification of specific benefits based on the analysis of enterprise-specific data by company personnel will be necessary to convince timber companies to invest in qualified staff and adequate computer equipment. Hence, data should be checked carefully for opportunities to demonstrate benefits of the system, especially in the initial phase of financial monitoring.

CONCLUSIONS

Existing financial information on natural forest management in the Brazilian Amazon is insufficient for decision making at both company and policy levels. Due to special economic and ecological conditions in the region, forest companies need financial information about their own forest operations to enable informed decisions and efficient use of resources.

Timber companies need external support because they lack the expertise required to capture and analyze financial data; researchers need field data from harvesting operations to evaluate the economic viability of sustainable forest management. To address this problem, a tool for monitoring production and costs of forest operations was developed and tested to facilitate collaboration between companies and researchers. Using this tool, the first long-term documentation of commercial harvest operations in the Amazon showed the competitiveness of RIL for a specific enterprise. The study also confirmed the importance of effective utilization of heavy machinery to partially compensate for lower productivity and additional planning costs when implementing RIL. Due to the ecological and economic heterogeneity of the region, as well as the technical and logistical specifics of the timber enterprises, production and cost data from other Amazonian enterprises are necessary to define more general trends regarding RIL and sustainable forest management.

The tool is simple and provides relevant information for investment decisions, technology selection,

operational planning, and detection of difficulties and opportunities to improve a company's performance. Successful implementation, however, depends on significant investment in staff and modified administrative procedures, requirements that currently exceed the willingness and capacity of most timber companies in the Amazon.

Generating easily understood and highly relevant results is essential to interest potential clients. It is necessary to have adequate facilities to train technicians as information managers. Training should include basic principles of cost accounting, financial analysis, and investment calculation, as well as communication and information management.

Our experience suggests the tool will be replicable only to highly motivated companies with qualified management staff and an interest in moving from conventional logging toward RIL. It has special relevance for those involved in FSC certification or those who own their own forests or have long-term concessions. Success will also depend on external supervision, especially during the implementation phase. We estimate about one month is needed to get the system working, followed by more extensive support during at least two harvesting seasons.

Successful implementation of the collaborative monitoring approach depends on active support of organizations interested in sustainable forest management, such as certification agencies, development and conservation projects, and governmental organizations responsible for environment and rural development. They must acknowledge that, beyond environmental, technical and social issues, financial aspects are crucial to sustainability. Forest Stewardship Council certifiers, in particular, should include production and cost monitoring as a fundamental prerequisite for certification.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol10/iss1/art3/responses/

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