Source*:* **Enters, T., Durst, P.B., Applegate, G., Kho, P.C.S., Man, G., eds.** 2002. Applying reduced impact logging to advance sustainable forest management: international conference proceedings 26 February to 1 March 2001, Kuching, Malaysia. RAP Publication no. 2002/14. Bangkok, Thailand, FAO Regional Office for Asia and the Pacific.

17 Financial costs of reduced impact timber harvesting in Indonesia: case study comparisons

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INTRODUCTION

Indonesia is harvesting large areas of its production forests using ground-based tractor logging techniques, primarily to provide raw material for its plywood industry. In 1999, the industry estimated that it required 1.6 million ha of forest annually for Indonesia to produce about 8 million m^3 of plywood, most of which is exported and worth about US$ 2.7 billion. The Chairman of the Indonesian Plywood Producers Association, Mr Abbas Adhar, was reported to have said that the value of plywood exports for 2000 would be similar to that of 1999 (Jakarta Post, 2000).

The negative impact of large-scale, poorly-applied, and tractor-based logging practices on residual tropical forests has been well documented since the late 1950s (Fox, 1968; Gilmour, 1967; Nicholson, 1958; Nicholson, 1979; Gullison and Hardner, 1993; Jonkers, 1987). Efforts to improve logging practices and the associated benefits have been well publicized for a number of years (ITTO, 1992; Andrewartha *et al.*, 1998; Applegate *et al.*, 1994; Applegate and Andrewartha, 1999; Aulerich, 1994; Bertault and Sist, 1995; Putz, 1994; Pinard *et al.*, 1995; Putz *et al.*, 2000b). Various studies suggest that the damage to the residual stand can be reduced by as much as 50 percent through the implementation of reduced impact logging (RIL) practices, but some would argue such benefits come at considerable cost (Elias, 1998; Applegate *et al.*, 1994; Pinard and Putz, 1996; Pinard, 1995). Most technical aspects of RIL are well known and are contained in many documents readily available worldwide (Poore *et al.*, 1998; FAO, 1999; Caulfield, 1982; Cassells and Bonnell, 1984; Applegate *et al.*, 1994; Applegate and Andrewartha, 1999; Commission, 1994; Vanuatu Department of Forests, 1997; Dykstra and Heinrich, 1996). Stakeholders are now turning their attention to the costs of implementing RIL to determine under what conditions costs differ among locations and if any cost saving is possible with RIL compared to conventional logging (CL). The interactions, causal influences and cost implications of the various RIL components, and the beneficiaries of RIL are also important in providing solutions to the impediments to adopting improved forest practices (Hammond *et al.*, 2000; Putz *et al.*, 2000b).

Several Indonesian plywood industry companies involved in logging are beginning to adopt improved harvesting practices, particularly those components where there are perceived savings in skidding-related costs (APHI, 2000; Prayudi, 2000). In Indonesia, a number of organizations and individuals have undertaken analyses of the costs and impacts of implementing selected RIL components (Bertault and Sist, 1997; Elias, 1996; Sist and Bertault, 1998). These analyses include cost estimates of the impact of RIL compared with CL. This work has been undertaken in an attempt to provide support for

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the adoption of the various RIL components. While there is a general consensus on the benefits of RIL to the forest environment (and possibly logging companies) compared to CL (Bertault and Sist, 1997; Sist and Bertault, 1998; Sist *et al.*, 1998; Elias, 1996), there is considerable disparity in the estimates of the financial costs of RIL in comparison to CL in Indonesia (Elias, 2000; Hariyatno *et al.*, 2000; Karsenty, 1998; Matikainen and Herika, 2000; Ruslim *et al.*, 2000; Sist and Bertault, 1998).

This paper summarizes the results from four case studies of harvesting operations undertaken in the closed forests of East Kalimantan in Indonesia where selected components of RIL have been implemented.

LOCATION AND METHODOLOGY

The four case studies were conducted in similar dipterocarp-dominated lowland and hilly forests in East Kalimantan, Indonesia (Figure 1). The studies were undertaken in Berau (Site A) (Matikainen and Herika, 2000); Kutai Induk (near Kutai National Park), (Site B) (Ruslim *et al.*, 2000a); PT Sumalindo Lestari Jaya IV concession (Site C) (Elias, 1998; Elias, 2000); and the Center for International Forest Research (CIFOR) Bulungan Research Forest, Malinau District, (Site D) (Hariyatno *et al.*, 2000). The analysis compared the costs of the components measured in the four studies.

Similarities of case studies

International donors and the private sector funded the studies conducted from 1996 to June 2000. The studies had many similarities including:

- similar forest types, elevation and topography;
- conducting harvesting in accordance with the FAO Model Code of Forest Harvesting Practice;
- tree selection in accordance with the Indonesian Selective Logging and Replanting System (TPTI); and
- log extraction using conventional ground-based skidding machinery (200 HP tractors).

Most of the studies used machinery manufacturer's recommendations for the machine costs, thus minimizing some of the variation due to sampling error in cost estimates among studies.

The selected RIL studies had the felling compartments outlined in the harvesting plans, which were based on accurate topographic maps of between 1:2 000-5 000 scale, with contour intervals of between 5 and 10 m. The harvesting plans identified planned skid trails and landings and individual tree locations. The trees were felled using directional felling techniques, with some operations marking "potential crop trees"[1]. All RIL operations involved some training prior to commencement.

Most CL activities on the sites used for the case studies did not have adequate maps for implementing harvesting activities. There was no planning of skid trails, and directional felling techniques were not employed.

Plot size varied (1-100 ha) and only one study attempted to quantify error limits on cost estimates and reported on selected pre-harvesting RIL activities, training and supervision costs (Hariyatno *et al.*, 2000).

[1] Potential crop trees are those trees marked, according to certain criteria, to be protected from felling and skidding damage as they form part of the stock for the following cutting cycles.

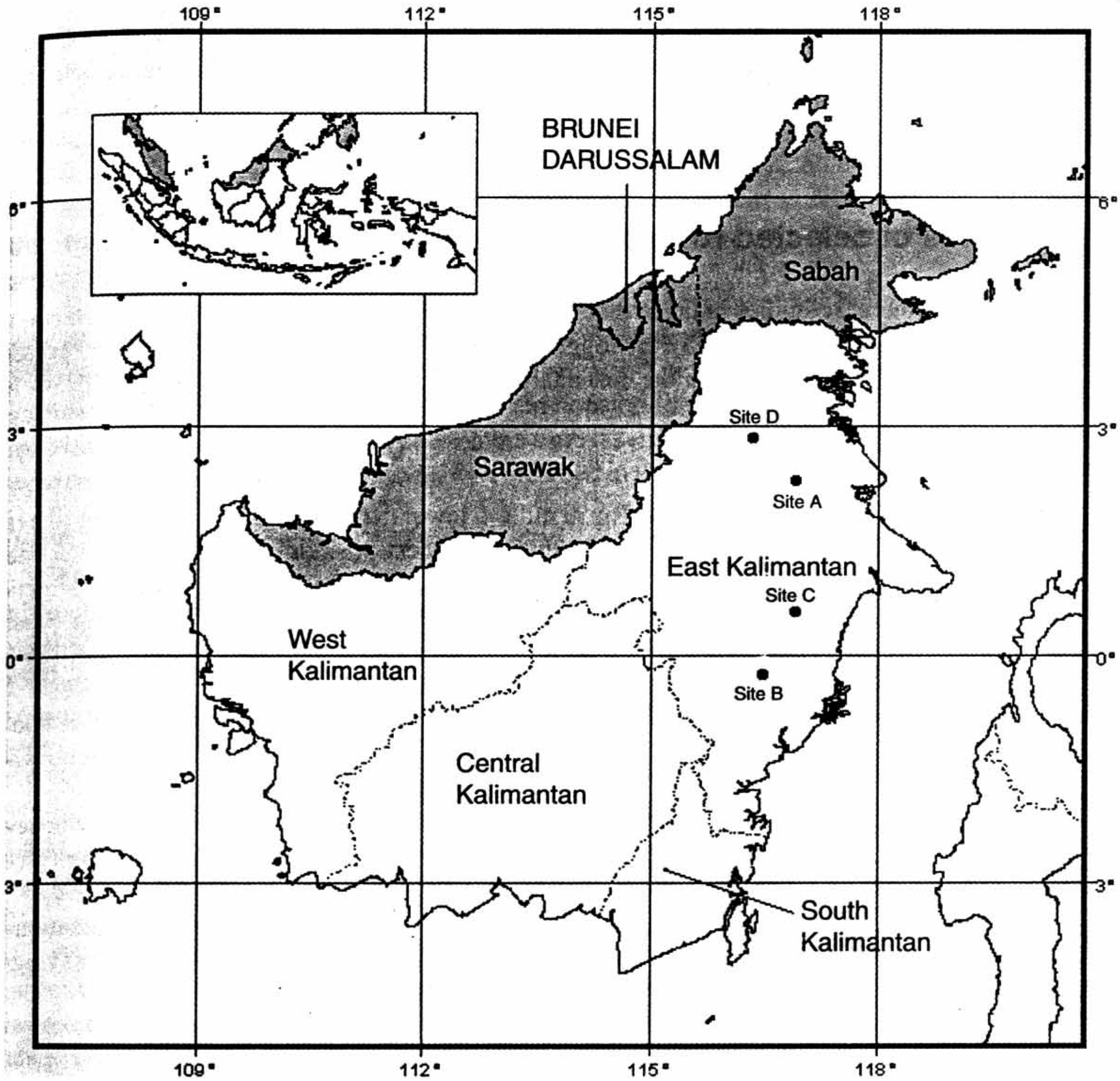

Figure 1. Location of case study sites in East Kalimantan, Indonesia

Differences among case studies

There was a large variation in the measured components of RIL, with one study concentrating only on skidding costs. Many apparent inconsistencies exist among case studies in estimating costs. Hence, the comparisons of the component costs should be viewed with caution and with a full understanding of the activities and how unit costs were estimated[2].

Costing details of the case studies

Most of the case studies concentrated on the cost estimates of two aspects, namely felling and skidding (and associated activities). The following list summarizes the key aspects of each study:

- Site A – costing of skidding and skidding-related activities for RIL and CL.
- Site B – costing of selected pre-harvest planning activities, felling, skidding and related activities for RIL and CL.

[2] Exchange rate (January 2001) US$1 = Rp 9,400.

- Site C – costing of selected felling, skidding and related activities for RIL and CL.
- Site D – costing of selected pre-harvest planning activities, felling, skidding (and related activities), training, and supervision for RIL. No training or supervision costs were estimated for CL. The research undertaken on this site estimated error limits on the mean-cost estimates for the activities analysed.

Cost estimates of selected RIL activities

The reports from the four case studies indicate that RIL produced the desired outcome (i.e. a reduction in the damage caused to the residual stand by the logging operations, estimated to be close to 50 percent) (Pinard, 1995). However, the results from the cost analyses are inconsistent (Table 1).

Site A

The cost of skidding using RIL techniques was Rp 50 million lower than CL over a 100-ha gross area (i.e. a reduction of 33 percent) (Matikainen and Herika, 2000). The cost of skidding was much lower under RIL (Rp 34 200/m^{3}and Rp 51 300 /m^3 respectively) than under CL, with the cost of skid trail construction under CL estimated to be 2.8 times higher than in RIL (Table 1). The running time for a tractor (tractor running hours[3] cost approximately Rp 400 000) is a major cost component (Matikainen and Herika, 2000). In this study, the skidding costs accounted for the time taken for skid trail construction.

The lower costs of skidding under RIL are attributable to reduced tractor running time, due to fewer unproductive delays (unnecessary, costly and poorly constructed skid trails and downtime when the tractor operator sought suitable skid trail locations); this is a result of better planning.

The methodology used in the cost estimates takes account of the actual machine cost (i.e. whenever the machine is operating, pulling logs, idling, or moving soil for skid trail construction, it incurs a cost that is reflected in the cost of delivering one cubic meter of log to a specified location).

The study also analysed the costs of RIL using different machines, including a combination of tractor and rubber-wheeled skidders. The use of the two machines in combination resulted in a saving of Rp 20 000/m^3 compared to tractor logging (Matikainen and Herika, 2000).

Site B

Data in this study are based on a logging team working for a month and covering an area of approximately 30 ha with measurement plots of 1 ha. Only a selection of activities involved in the pre-harvest component were costed. These included inventory, map preparation, skid trail planning and marking in the field. The findings from this site indicated that pre-harvest operations cost Rp 943/m^3 and Rp 2 282/m^3 for CL and RIL, respectively.

Felling costs in the analysis included all costs, but in the cost tables of the report, the felling costs (Rp 2 212/m^3) for both RIL and CL are equal (Ruslim *et al.*, 2000). Skidding under RIL reduced productivity by 15 percent compared to CL. However, the costs of the RIL felling and skidding components were Rp 2 813/m^3 more expensive than under CL (Table 1).

The costs for the various activities are based on measurements of time taken for specified activities (Ruslim *et al.*, 2000). There appears to be no account of non-productive machine time and stoppages and the effect this has on production costs. Winching was included in the skidding operations when the skidding costs were estimated. For the components and activities costed, the study found that RIL was more expensive than CL by Rp 4 152/m^3.

[3] The cost of tractor-running hours is a function of fixed costs and variable costs. In many calculations, only variable costs are included; hence actual logging costs are higher than those calculated.

Site C

In this study, pre-harvest operations were undertaken, but their costs were not reported (Elias, 1996; 2000). The study reported very low felling costs compared to the other case studies (Rp 1 141/m³ and Rp 1 080/m³ respectively for CL and RIL) (Table 1). This may be a result of the methodology used to estimate costs. The costs were calculated by using the volume produced divided by the time taken to fell a tree. Hence, it is apparent that the estimates may not include the full cost (i.e. transport for fellers and assistants).

The cost of skidding was also low compared to the other case studies, in part because of the low rates used for machine running costs. The cost of skidding under RIL was slightly more expensive than for CL (Rp 10 728/m³ and Rp 10 972/m³, respectively). In determining the cost of skidding, no allowance was made for the cost of the machine time when not skidding logs. This results from the methodology used, where productivity was based only on the time taken for a round trip from stump to log landing. It is apparent that skid trail construction may be included in the estimates for RIL but not for CL operations.

Site D

This study reported some estimates of pre-harvesting activities. The study compared the pre-harvesting costs of RIL and CL and found that there was only a small increase in costs for RIL (Rp 217/m³). The report indicates a 28 percent and 25 percent increase in productivity for felling and skidding respectively under RIL compared with CL. Felling costs were reported as being the same for RIL and CL (Rp 1 500/m³).

Skid trails and landings were reduced in area by 54 percent and 18 percent, respectively, under RIL. Therefore, a large savings in machine operating time compared with CL could be expected. Skidding costs were also low compared to other studies. The operating costs of the machines used in the calculations were about 30 percent lower than for similar machines in other studies. The costs of skidding in CL and RIL were Rp 22 310/m³ and Rp 16 165/m³, respectively.

For the components analysed, the costs of RIL and CL were Rp 22 800/m³ and Rp 26 035/m³, respectively (including pre-harvest planning, felling, skidding and training). The study found that there was a direct financial benefit from the reduction in logging waste under RIL with an estimated added value of Rp 23 235/m³ (Hariyatno *et al.*, 2000).

Impacts of methodology and parameters on cost estimates

While many operators are aware of the technical components of RIL, it is apparent from the review of the studies that the methods for estimating costs are poorly understood. The methods applied and basic assumptions in estimating costs are also very diverse, and provide quite divergent results, even for something as basic as estimating the full cost of skidding one cubic meter of wood to a log ramp.

A major issue regarding the cost estimates for harvesting operations conducted to date in Indonesia is the limited components and activities analysed. In one case study (Site A), only skidding costs were analysed and reported. This is symptomatic of most studies and is a major weakness, especially if the information is intended to identify the full cost of RIL with a view to looking at financial benefits and possible adoption of these improved practices by industry. In many cases, some components were only partially recognized as being part of RIL, but the activities within the components were not fully costed, thus leading to underestimates. In most studies, the rates for machine operating costs have been underestimated and therefore are not a true reflection of actual harvesting costs.

The methods adopted by the studies do not enable investigating the interactions and relationships among different RIL components and activities and taking cost implications into account (e.g. influence of roads). Road design, location, density, construction and maintenance standards influence harvesting costs considerably (Burgess, 1971; Gullison and Hardner, 1993). In a number of cases, researchers have based the cost estimates on productivity and have only measured time to undertake a task as the basis of the costs. This artificial approach inadequately accounts for the size of the harvest area (net or gross),

Table 1. Financial cost estimates from four logging studies in East Kalimantan, Indonesia

Site Characteristics	SITE A		SITE B		SITE C		SITE D	
	Conventional Harvesting	Reduced Impact Harvesting	Conventional Harvesting	Reduced Impact Harvesting	Conventional Harvesting	Reduced Impact Harvesting	Conventional Harvesting	Reduced Impact Harvesting
Min. cutting limit	50 cm dbh	50 cm dbh	50 cm dbh	50 cm dbh	50 cm dbh	50 cm dbh	50 cm dbh	50 cm dbh
Ground-based skidding machines	Komatsu D85E -SS and Caterpillar 525 Wheel skidder		Komatsu D85E -SS and Caterpillar D7G		Komatsu D85E -SS and Caterpillar D7G		Caterpillar D7G	Caterpillar 527
Plot size (ha)	100	2 x 100	3 x 1	2 x 1	10 x 1	10 x 1	244	138 ha
No. of trees harvested (net area)	-	-	12 trees/ha	11 trees/ha	-	-	5.9 trees/ha	6.9 trees/ha
Volume harvested (net area)	-	-	67.2 m^3/ha	62.7 m^3/ha	-	-	52.8 m^3/ha	60.9 m^3/ha
Costs (Rp/m^3)	Based on gross area	Based on gross area	Based on 30 ha /month/team	Based on 30 ha /month/team	Based on gross area	Based on gross area	Based on gross area	Based on gross area
Pre harvest planning	-	-	943	2 282	-	-	2 225	2 442
Vine cutting	-	-	-	-	-	-	-	1 018
Felling	-	-	2 132	2 132	1 141	1 080	1 500	1 500
Skidding to landing	51 300	34 200	23 210	26 023	10 728	10 972	22 310	16 165
Supervision	-	-	-	-	-	-	438	846
Training	-	-	-	-	-	-	-	1 678

Note: 50 cm diameter breast height (dbh) is based on Ministry of Forestry of Indonesia, silvicultural harvesting guidelines for production forests.

machine operating costs (fixed and variable), opportunity cost of capital, repairs and maintenance, depreciation, non-productive time, occupational health and safety, training, log segregation and processing, and associated travel costs.

Another vital issue relates to the perspective from which the costs are determined. Many studies undertaken to date in Indonesia are ambiguous on this point. Are the costs determined from the operator's perspective, the concessionaire's, the forest owner's or that of the Government of Indonesia? If these parameters are not identified clearly, cost estimates for RIL will remain misleading.

In the case studies where felling costs for RIL and CL are similar, it appears that there are no cost savings for (i) marking trees for directional felling; (ii) training on efficient felling techniques (potential saving on reduced medical costs due to higher skill levels); or (iii) skid trails marked and/or constructed, thus making it easier and quicker for the feller to locate trees. The estimates for felling on Site D appear to be determined artificially, as felling stopped when the daily quota of 100 m^3 was reached. The inadequacies of such approaches make comparisons of felling costs among studies impossible.

Another fundamental problem with the current methods is the lack of allowance for identifying where costs would change if different methods or procedures for harvesting timber were adopted. The cost estimates for skidding in the case studies do not enable determination of whether it is more efficient to construct skid trails before or after felling. Therefore, it is not possible to understand the interrelationships of the various activities and how they influence costs.

Logging waste and unrecovered logs are other examples of major additional costs. More efficient felling, associated techniques and skidding could be solutions (Hariyatno *et al.*, 2000). The problem has been solved elsewhere, with minimized waste and maximized revenue when the logs are sold at the stump and not on the landing as practised in many countries (Alan Davis, pers. comm). This approach may reduce the cost of waste and supervision, and allow for an improved, more equitable basis for paying fellers and skidders, often cited as essential to facilitate the adoption of improved harvesting practices in Asia (Hahn-Schilling, pers. comm.).

Impacts of harvesting operations on costs

The major impact on these research results was the selective nature of the activities and components included in the cost calculation. The observed inconsistencies and differences do not allow for comprehensive and meaningful comparisons.

While it is recognized that there are tremendous logistical and resource issues involved in obtaining estimates of impact and analysing harvesting costs on a meaningful operational scale, the small number of components and activities and inconsistencies between similar activities in the studies highlight the problems of comparing costs. The problem is not only related to comparisons of RIL and CL, but also to other activities across the sites where the methods and systems used for basic harvesting activities are also similar.

Systems dynamics approach to determining harvesting costs

The results of the case studies indicate the following:

- difficulties in determining harvesting costs by component and activity that reflect the reality of commercial operations;
- inadequate provision of realistic cost estimates; and
- the need to understand the cost implications of the interrelationships among harvesting components.

The problems are not specific to Indonesia. They are not only related to the methods used, but also to the scale of the operation measured (plot size), assumptions used and the difficulties of obtaining accurate data on harvesting costs. The issues of scale, method and selectivity of components and the difficulties involved in capturing the interrelationships among components are common to many studies

(Putz *et al.*, 2000a; Karsenty, 2000; Tay, 1999). There are also ecological-economic linkages involved that are not possible to capture with this conventional approach to cost estimates.

The conventional approach to estimating RIL costs is data intensive. While the analyses undertaken in some countries such as Brazil (Holmes *et al.*, 1999; Barretto *et al.*, 1998) may have yielded very accurate and precise statistical relationships on component costs, causal relationships have not been identified during the process and neither have the impacts of these relationships on costs been determined.

A different approach that takes account of the causal relationships among the different cost variables and places less emphasis on the development of real cost data in a linear manner, may provide the answers for a more informed basis for promoting the implementation of improved harvesting practices.

A systems dynamics approach to analysing RIL costs, which is better suited to developing hypotheses than testing hypotheses may provide a solution to overcoming some deficiencies with the conventional approach to costing operations. Such an approach is useful in identifying different scenarios and addressing interrelationships among components and activities. It may provide estimates that are more operationally based. It assists in providing relevant information to forest managers and reviews incentives and disincentives for RIL. It will also provide information for decision-makers on relative benefits far beyond the range of currently available cost data.

An empirical systems model using standard computer software, STELLA[4], is a potential management software tool that can be used to model and track the causal relationships among different cost and production variables and their flows (feedback and interactions). The process of developing a systems model is intuitive and provides a useful technique for building consensus amongst stakeholders (industry, researchers, and operators) on harvesting system functions and ecological-economic relationships. Involving discussion and consensus among stakeholders during the model building process is important, as it assists with developing sound partnerships essential to providing critical reviews and to furthering our understanding of the complexity of logging operations.

At a recent international workshop, one such approach to systems dynamics modelling of RIL was undertaken. Based on their personal experiences, participants from a number of countries discussed and identified the important variables and assembled them using a systems thinking approach. The process began with scoping a model using STELLA and identifying the various components and major output (stocks) flows, converters and connectors, activities and basic relationships of RIL. A small STELLA model was developed, which assisted in bringing a formal approach to the various mental models of RIL. Figure 2 provides an example of the STELLA diagram depicting a systems approach to the post-harvesting operations involving the following activities: road and skid trail closures, camp and workshop cleanup, protection, road maintenance, monitoring and evaluation and post-harvest report. At this stage, the costs for the various parts of the model are incomplete and only the system and linkages have been developed. The work is to be continued to develop an operating model for different physical, institutional and economic conditions.

RECOMMENDATIONS

Most logging operations in tropical forests cause damage to soils, increase sedimentation rates in watercourses and damage potential future crop trees. During the past decade, information has been produced about best practices and their benefits, in an ongoing effort to improve logging. Unfortunately, adoption of these techniques has been limited. In recent years, a number of projects have been implemented to test, demonstrate and measure the benefits of improved practices, compared to conventional logging. Research results indicate that applying RIL can, in some cases, increase efficiencies and reduce costs of some operational harvesting components. It can also help to reduce logging waste and safeguard future harvests and the environment. However, RIL can also result in either direct costs or opportunity costs associated with foregone timber yields) to timber producers (see also Tay *et al.*, in this volume). The costs represent

[4] STELLA modeling software is available from High Performance Systems Inc. Hanover, New Hampshire at http:// www.hps-inc.com/.

a significant impediment to the adoption of RIL practices. However, the damage resulting from poor logging practices can have long-term negative impacts on the potential of forests to provide sustained yields of timber, non-timber forest products and environmental services.

A better understanding of the costs and benefits of specific RIL components is required. The environmental impacts of logging need to be known and it needs to be clarified from whose perspective (the logger, the concessionaire, the local community, the global community, etc.) costs are assessed to reveal the impediments to the adoption of RIL.

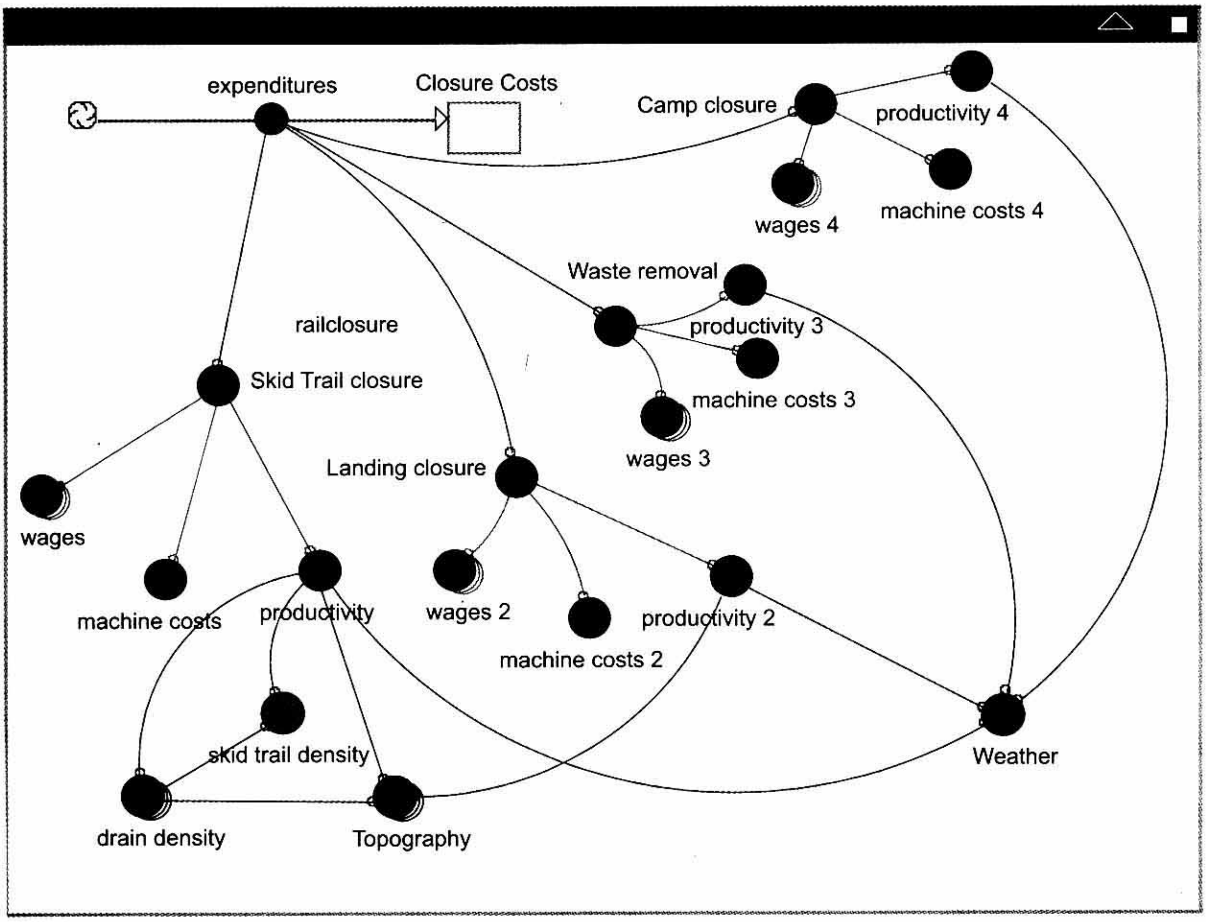

Figure 2. An empirical model using STELLA showing the causal relationships among variables of post-harvesting activities

To assist with increased adoption of improved harvesting practices, it is recommended to:

- gain support and partners to develop a better understanding of the costs and benefits of improved harvesting practices and/or poor practices. This information would provide a foundation for designing strategies to overcome impediments to adoption of better logging practices, and provide the necessary financial and economic data to guide the development of incentive systems for the adoption of these practices; and
- explore the use of a systems dynamics approach involving forestry-sector stakeholders to determine the costs and benefits of improved logging practices. This approach can assist in identifying the key variables and interrelationships of such practices, all of which will provide a foundation for policy and management changes to increase the adoption rate of improved logging methods in tropical forests.

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