Who Pays for and Who Benefits from Improved Timber Harvesting Practices in the Tropics?

Lessons Learned and Information Gaps

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Abbreviations and Acronyms

AusAID	Australian Assistance for International Development
BOLFOR	Proyecto de Manejo Forestal Sostenible en Bolivia
CIFOR	Center for International Forestry Research
CL	Conventional Logging
COLP	Code of Logging Practice
Dbh	Diameter at breast height (1.3 m)
FCT	Future Crop Trees
FFT	Fundação Florestal Tropical
FORMISS	Forest Management Information System - Sarawak
FSC	Forest Stewardship Council
IFF	International Forum on Forests
ILO	International Labour Organisation
IPF	International Panel on Forests
ITTO	International Tropical Timber Organization
LEI	Lembaga Ekolabel Indonesia (Indonesian Ecolabelling Institute)
PCT	Potential Crop Trees
RIL	Reduced-Impact Logging
SFM	Sustainable Forest Management
SFMP	Sustainable Forest Management Project
SFMS	Sustainable Forest Management System
SPC	South Pacific Commission
STY	Sustainable Timber Yield
TFF	Tropical Forest Foundation
UNCED	United Nations Convention on Environmental Development
UNFF	United Nations Forum on Forests

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Summary

Although reduced-impact logging (RIL) techniques are well known and generally endorsed by tropical foresters, rates of adoption of RIL by loggers have been less than encouraging. The principal impediment to proper planning of logging operations, training and supervision of forest workers, and the other components of RIL is apparently the belief on the part of loggers that these improvements are costly to implement. Although there are reasons to doubt that many forest managers and forest operators are fully aware of the costs of each component of their timber harvesting operations, it cannot be disputed that there are additional costs of implementing some aspects of RIL for some forest stakeholders over some time periods. It should therefore be useful to all parties concerned to disaggregate RIL into its components and to analyse the costs and benefits of each from different perspectives. For example, if timber harvesting companies only obtain a portion of the benefits of RIL, then from their perspective it may not be appropriate to pay all of the supplementary costs associated with implementing RIL practices. To explore this issue in detail, we analyse four components of improved timber harvesting practices (stock and topographic mapping, directional felling, road planning and construction, and skid trail and road closure) on the basis of who pays the costs of implementation and who derives the benefits over both short and long terms. We hope that the information generated will assist in efforts at identifying which improved timber harvesting practices may require incentives and which can reasonably be considered the intrinsic responsibility of the timber harvesting company or contractor.

Introduction 1

Discussions about the potential contributions of well-managed forests to conservation in the tropics are often burdened by lack of clarity about what constitutes 'good' management. In particular, the contributions of reduced-impact logging (RIL) to sustained timber yields (STY) and the more encompassing and elusive goal of sustainable forest management (SFM) are not always clear (Rice *et al.* 1997, Poore *et al.* 1998, Pearce *et al.* 2002). There are conflicting claims in the literature about the costs and benefits of RIL (Barretto *et al.* 1998, Holmes *et al.* 2002, Healey *et al.* 2000, Applegate 2001). In this report we endeavour to clear up some of this confusion by disaggregating RIL into its principal components and then by analysing the costs and benefits of these components from the perspectives of forest workers, logging contractors/forest concession holders, forest owners (state or private), and the global community.

1.1 Contribution of Reduced-Impact Logging to Sustaining Timber Yields and Sustainable Forest Management

The goal of sustainable forest management (SFM) will forever remain elusive. It will only be possible to claim in retrospect and with complete knowledge that a forest was managed sustainably. Sustaining timber yields (STY), once the principal goal of many forest management plans, is now generally recognised as only one of a multitude of sometimes-conflicting objectives of SFM. Leaving aside the vagaries involved in defining SFM, it seems important to consider the extent to which following RIL guidelines contributes to achieving both STY and SFM. One factor complicating this analysis is that while many RIL principles are likely to be common across forest types, the actual guidelines should be tailored to suit local forest conditions and explicit management objectives. What may represent excessive and avoidable damage in one forest (e.g., soil scarification) may be prescribed in another forest to promote regeneration of a harvested or otherwise desirable species. To frame this discussion, three forest types have been selected on the basis of differences in climate, terrain, harvesting intensities, and modes of regeneration of the principal commercial timber species (see Table 1).

Given the wide range of conditions in the three forest types described in Table 1, it should not be surprising that only some components of the generic RIL guidelines under consideration are generally applicable, several are of little concern in some forests, and others would actually be contrary to the

Table 1. Selected Characteristics that Influence the Costs of Implementing RIL, in Three Very Different Types of Vegetation

Characteristics	Forest Types		
	Lowland Dipterocarp Forest	Dry Deciduous Forest	Miombo Woodland
Location	Indonesia, Malaysia	Bolivia	Zambia, Tanzania
Rainfall	2000–3000 mm/yr	1000–2000 mm/yr	400–1000 mm/yr
Dry Season Duration	0–3 months	3–4 months	4–8 months
Terrain	Hilly	Flat	Flat
Harvesting Intensity	80–120 m^3/ha	1–15 m^3/ha	1–4 m^3/ha
Principal Modes of Tree Regeneration	Advanced regeneration	Seeds and coppice	Coppice

goals of STY and SFM, if followed. In contrast, activities that result in excessive soil erosion, such as blading skid trails on steep slopes, and those that endanger workers, are undesirable regardless of forest type or whether the forest is destined for conversion to some other land use. It is obvious, for example, that prohibitions on harvesting on steep slopes and during wet weather do not pertain to areas where the terrain is flat, soil is well drained and logging operations are only conducted during a pronounced dry season (e.g., Miombo woodlands and dry Amazonian forests). As an example of RIL guidelines that are inappropriate under some forest conditions, we suggest that the goal of minimising soil surface disturbance may be misdirected in forests where light-demanding and small-seeded commercial timber species regenerate preferentially on exposed mineral soil in clearings (e.g., many species in dry deciduous forests in the Amazon). Under these conditions, tree regeneration might be enhanced by carefully managed soil surface scarification in unstocked felling gaps.

Following RIL guidelines that reflect appropriate silvicultural practices for a specific forest condition represents a necessary, but not sufficient, step towards the goals of STY and SFM (Applegate 1997a, Applegate and Andrewartha 1999b). The potential contribution of RIL to both sustaining timber yields and satisfying the multitude of criteria for SFM varies substantially among forests. Timber harvesting should be considered one of many potential silvicultural treatments, given that the way a forest is harvested will greatly influence post-harvesting forest structure and composition. It is unreasonable to expect this one treatment to achieve all the goals of both STY and SFM. However, if RIL guidelines are not followed, the silvicultural interventions required to return the forest to the paths of STY and SFM are likely to be substantial, costly, and problematic. Furthermore, it should be recognised that the goals of STY and SFM are themselves sometimes at odds, depending on the values of the person defining SFM.

1.2 Who Pays for and Who Benefits from Improved Forest Harvesting Practices?

Although in some forests and for some forest stakeholders, non-timber forest products are extremely valuable, timber harvesting in tropical production forests is generally the largest source of forest-based revenue. It also has the greatest primary and secondary impacts. Because of the extent of harvesting operations and their impacts on tropical forests, there are worldwide and well-justified concerns about the intensities and methods of timber harvesting. Although many managers of logging companies are aware of ways that they could reduce worker injury rates and minimise the deleterious environmental impacts of their operations, few adopt RIL techniques out of enlightened self-interest.

One of the impediments to adoption of improved timber harvesting practices is that the financial costs and benefits of applying these practices vary according to the perspectives of the various stakeholders. While recognising that there are many different beneficiaries of reduced damage to tropical forests from which timber is harvested, we focus on forest workers, owners of timber harvesting operations (contractors or concession holders), and forest owners (private individuals or the state). We also recognize the range of stakeholders who benefit from or are concerned about environmental services provided by forests, as well as those concerned about social welfare and the long-term economic viability of forest management. In undertaking this analysis, we hope to clarify where the benefits and costs accrue, and thus identify how changes to costing and economic rent payment structures might increase the rate of adoption of various components of RIL by timber producers.

Timber Harvesting in the Tropics

2

Large-scale industrial timber harvesting first began in the tropics after World War II, when bulldozers became readily available (Dawkins and Philip 1998, Dykstra 2001) and initially concentrated on heavy and cabinet-grade woods (Kartawinata *et al.* 1998). Harvesting was usually based on the allocation of concession areas to private companies, while governmental agencies focused on developing forest regulations and controlling the operations. Timber harvesting in the tropics increased rapidly in the 1970s in response to the development of large plywood manufacturing and sawmilling industries in both producer and consumer countries (Sayer and Byron 1996). Forest policies in many tropical countries were initially developed to promote large-scale industrial development as part of a broader goal of supporting national development (Sayer and Byron 1996; Kartawinata *et al.* 1998). Because of such pro-development policies, a situation developed in which demand for industrial output in many tropical countries exceeded the sustainable supply (Brown 1999). The result was rapid overcutting of forests and forest degradation due to poor harvesting practices and lack of appropriate silviculture (Poore *et al.* 1998). It is ironic that where effective silvicultural treatments were developed and applied at large scales, such as in the lowland dipterocarp forests of Peninsular Malaysia (Manokaran 1998), the forests have long since been converted to oil palm plantations and other more intensive non-forest uses.

2.1 Recognition of the Need for Improved Timber Harvesting Practices

For more than 40 years, tropical foresters have expressed concern about forest loss and degradation caused by poor timber harvesting practices (Dawkins 1958; Nicholson 1958, 1965, 1979; Gilmour 1967; Fox 1968; Dawkins and Philip 1998; Putz *et al.* 2000b). The critical connection between forest planning and sustainability was expounded as early as the 1970s and 1980s (Nicholson 1979; Ewel and Conde 1980). In response to widespread forest degradation resulting from poor timber harvesting practices, many authors recommended the introduction of guidelines designed to reduce the negative impacts of logging on residual stands and soil and water resources, with the aim of sustaining forests for future harvesting (Redhead 1960, Ewel and Conde 1976, Hendrison 1990, Dykstra and Heinrich 1992, Dykstra *et al.* 1996). Since at least the early 1980s, RIL guidelines have been implemented to some degree in various parts of the tropics, most notably in Australia (Queensland DoF 1983, 1988; Ward and Kanowski 1985).

The total area of tropical forest harvested annually continues to be large, with the volumes removed estimated in the late 1990s to be 80–120 million m^3 annually (FAO 1997). The amount of damage sustained by the residual forest has increased with the size of the machinery used in harvesting operations, and with increasing volumes of timber removed (Bruijnzeel and Critchley 1994). In response to the extent of destructive logging practices in tropical forests, international and local pressures on forest agencies to promote sustainable forest management are increasing. FAO (1995) recognised that '…well-planned and carefully controlled harvesting systems are superior economically, environmentally and silviculturally'—a point reiterated by many others (Hendrison 1990, Dykstra and Heinrich 1992, Pinard *et al.* 1995, Sayer *et al.* 1995, Bruenig 1996, Marsh *et al.* 1996, Moura-Costa 1997).

Demands on tropical forests are numerous and expanding, with many external factors causing increased pressure on forest resources, including demographic changes, perverse tax incentives, and globalisation of forestry industries. These competing and increasing demands have stimulated the world community to take an active interest in tropical forest management. Concerns have been highlighted in a

number of major initiatives, including the United Nations Conference on Environment and Development (UNCED), the Intergovernmental Panel on Forests (IPF) and its successors, the Intergovernmental Forum on Forests (IFF), the United Nations Forum on Forests (UNFF), and the International Tropical Timber Organisation's (ITTO) 'Target 2000.' While it is recognised that improved timber harvesting practices do not constitute SFM, they are a necessary step towards this goal (Palmer and Synnott 1992).

2.2 Experience with Improved Harvesting Practices in the Tropics

Research on improved timber harvesting practices in the tropics has been underway for several decades (e.g., Nicholson 1958, Gilmour 1967, Cassells and Bonnell 1984, Gilmour and Applegate 1984, Queensland DoF 1988). Research in Australia, Brazil, Guyana, Indonesia, Malaysia, Vanuatu, and Fiji contributed to the development of formal codes of harvesting practice for many countries in the Asia-Pacific region and other parts of the tropics (Applegate and Andrewartha 1999a, Dykstra 2001). These guidelines were developed to promote the use of harvesting practices that improve efficiency and mitigate the adverse social and environmental impacts of timber harvesting (Korsgaard 1985, South Pacific Commission 1994, de Vletter 1995, Pinard *et al.* 1995, Dykstra and Heinrich 1996, Applegate 1997b, Asia-Pacific Forestry Commission 1999, Applegate and Andrewartha 2000). Key guidelines for improved timber harvesting address: forest management planning (strategic, tactical, and operational levels); pre-harvesting activities; harvesting activities; post-harvesting activities; and monitoring and evaluation procedures designed to measure improvement in operating standards and training.

The first formal code of practice for harvesting tropical forests was apparently completed in Fiji in 1990 (Fiji Ministry of Forestry 1990). The Fiji Code was developed by a national committee composed of representatives from the Forestry Department and the timber industry and staff from the International Labour Organisation (ILO). It emphasised operator safety and training. During the1990s, many other countries began to develop formal codes of logging practices (Applegate and Andrewartha 1999a).

Several RIL demonstration and research projects have been carried out recently in various regions of the tropics. Some of these are listed in Appendix I, along with some of the findings and contact addresses of those involved. Given the problems with scaling up from small research plots to industrial logging operations, we also note the approximate areas to which RIL techniques were applied in these studies.

2.3 Guidelines For Improved Timber Harvesting

A number of countries in the tropics have begun to document their improved harvesting practices as codes of practice, while others have developed reduced-impact logging guidelines, or both. Codes of practice for forest harvesting are sets of standards and norms applied in forests designated primarily for timber production. They are minimum standards and technical requirements for implementing various components of the harvesting operations. The codes are usually designed to target traditional land users, landowners, industry/concessionaires/ contractors and the government agency responsible for forest policy implementation and monitoring (ITTO 1992, Dykstra and Heinrich 1996, Blate 1998, Applegate and Andrewartha 1999a, Department of Forestry and Wildlife 1999). Reduced-impact guidelines are complementary to codes of practice insofar as they detail how the code of practice should be implemented.

The codes of timber harvesting practice for tropical forests developed over the past decades typically include the following components:

- That prescriptions for logging should be based on knowledge of the ecology of commercial tree species;
- Pre-harvest inventory of timber stocks and maps showing the locations of existing roads and skid trails;
- Improved road planning, construction and maintenance to increase efficiency of log hauling;
- Reduced areas of skid trails and log landings to minimize soil erosion;
- Climber cutting to minimise collateral damage to residual trees and to increase the efficiency and safety of timber extraction;
- Training to improve overall timber harvesting efficiency, reduce accident rates and reduce

negative impacts on residual stands and soils;
- Tree marking and mapping to improve the efficiency of timber extraction, minimise wood waste and decrease the likelihood of losing logs;
- Directional felling to improve worker safety, reduce wood waste and improve efficiency of timber extraction;
- Restrictions on harvesting operations on wet soils to minimise damage to machines, residual stands and soils;
- Marking and mapping of trees to be harvested, potential future crop trees and trees near skid trails and log landings that skidder drivers should avoid;
- Post-harvest operations to include closure and drainage of skid trails, roads, log landings and quarries as well as revegetation of quarries and log landings;
- Post-harvest assessment and reporting on the status of residual stands, including damaged trees and the quality of post-harvest road and skid trail drainage, rehabilitation of log landings and camp closures.

It is widely agreed that forests harvested according to well-formulated RIL guidelines are better able to supply society with goods and services. It is therefore reasonable to ask why RIL techniques are not being more widely adopted. To answer this question, it is important to determine the costs of the various components of RIL at operational scales, to consider who is paying for which activities within each component, what benefits the investors derive from these expenditures, and who are the non-paying beneficiaries of investments in RIL.

3 Components of Reduced-Impact Logging

Although there are common principles and minimum standards for improved timber harvesting operations, there is no one set of RIL guidelines for all of the tropics. Furthermore, there are many reasons why a logger might choose to adopt some components of RIL and not others. Disaggregration of the costs associated with these different components might therefore help timber producers make more informed decisions and also assist policymakers and forest owners to understand the costs involved in implementing different components of a RIL programme. This information may also be useful in determining the specific aspects of RIL that need to be enforced by regulation or encouraged through incentives, and which should be adopted out of enlightened self-interest.

3.1 Pre-Harvest Activities

The following is a summary of the principal pre-harvest activities that are generally required for successful implementation of RIL.

Training represents a fundamental prerequisite for success in implementing a programme of improved timber harvesting. Training is required to improve institutional capacity as well as the capabilities of all those involved in production, from forest workers to environmental monitors. The institutional development and training required to implement improved timber harvesting involves three vocational levels: policymakers and senior managers; middle-level managers and forest supervisors; and forest operators and field staff. Training is needed before commencing a RIL programme. It is then typically adapted while the programme is underway and additional training needs become apparent.

Topographic maps at a high level of accuracy are required for harvest planning. These maps need to clearly indicate the location of all existing roads, skid trails, log landings, stream crossings, and areas that are environmentally sensitive due to steep slopes, proximity to water bodies, or poor drainage.

Pre-harvest inventory of the forest provides an estimate of the timber available for harvesting. Estimates of potential harvestable volumes, as well as information about species composition and the location of areas where the commercial volume is concentrated, are all needed for proper planning of harvesting operations.

Stock mapping and tree marking involve locating trees on the relevant maps. Stock maps are used by fellers, skid-trail planners and skidder operators to locate trees in the field. Stock maps reduce the time required to find trees, provide a foundation for efficient skid trail layout and reduce the number of logs lost in the forest. In addition, stock maps facilitate auditing and provide the information necessary for harvesting by species to meet specific market demands.

Planning of new roads and stream crossings defines their design, cost, and location. Planning and implementing the plan can reduce the costs of road construction, use, and maintenance while minimising the negative impacts on soil and water. Planning skid trail layouts and landings (location and size) has been shown to increase productivity and reduce the cost of skidding.

Exclusion zones should be marked on harvesting plans to indicate where timber harvesting is prohibited. These zones may include areas that contribute to biodiversity conservation and areas where the terrain is too steep or rocky for safe logging operations. Stream and road buffers (exclusion zones) are required to protect hydrological functions and other buffer zones are needed to protect cultural or religious sites.

Pre-felling vine cutting is sometimes necessary to minimise damage to residual trees during harvesting, to protect workers, and to reduce post-harvest vine proliferation. The cost of vine cutting varies with the density of vines, their sizes, wage rates, topography, and accessibility. To avoid the costs of

multiple entries by work crews, vine cutting is best carried out at the time of the forest inventory, no later than 6 months prior to timber harvesting.

3.2 Timber Harvesting Operations

Construction and maintenance of roads and log landings determines road width, surfacing, landing locations and dimensions, drainage, river and stream crossings, and culvert locations and sizes. These parameters influence the financial costs and environmental impacts of logging, as well as the efficiency of harvesting operations.

Skid trail opening and use defines skid trail width, wet weather usage, machinery to be used, surface blading, and timing of operations. Skidding logs to landings with minimal environmental impact to soil and the residual stand involves additional training of operators, but these costs may be offset by reduced machine maintenance costs, less downtime, and increased efficiency.

Tree felling. Directional felling to avoid unnecessary damage to the residual stand also facilitates yarding operations and reduces danger to fellers. Costs incurred include training of fellers and the use of specialized equipment.

3.3 Post-Harvest Operations

Closure of roads and skid trails primarily involves stabilising soil and water movement on roads, skid trails, and landings after the machines have completed the removal of logs from the site. The activities to be undertaken include constructing cross drains on skid trails and roads, removing temporary watercourse crossings (bridges and culverts), draining landings and quarries (rehabilitating the sites with revegetation where necessary), and physically closing roads where appropriate.

Camp/workshop clean up is undertaken after the harvesting activities are completed and the area is no longer in use. Removal of camp structures and rehabilitation of these sites is usually undertaken by the concessionaire or contractor.

Monitoring and evaluation of harvesting operations and closure of skid trails and camps are usually undertaken by the forest manager or forest owner after all activities have been completed. The inspections are used to monitor the operators for compliance with the codes of practice and any required silvicultural prescriptions. **Reporting** is generally the final activity in RIL but is critical for the continued improvement of harvesting operations. Reports on harvesting operations are often prepared for different purposes by contractors, concessionaires, and forest owners. The report compiled by the forest owner should contain information on the forest, including volumes and species removed, status of the harvesting operations, names of the concessionaire/contractor, equipment used for logging, and maps indicating the areas actually logged as well as the locations of skid trails and landings. A post-harvest inventory and a general description of post-harvest forest condition should also be included in the report. This is valuable information required for the determination of the second cutting cycle and the need for silvicultural treatments.

4 Incentives for and Constraints on The Adoption of Improved Timber Harvesting Practices

On the basis of the frequently cited financial and other benefits of RIL (Jonkers 1987, Holmes *et al.* 2002, Klassen 2001), the failure of most loggers to spontaneously adopt the practices described above represents something of a paradox. In fact, it appears that improved harvesting practices have usually only been adopted when outside forces intervene. These forces are in place when loggers are forced to post performance bonds, when criteria for good forest management practices are enforced due to requirements for forest product certification and labelling, when funds are available from forest-based carbon offset projects, and when researchers effectively control logging practices in their research plots.

Loggers and concessionaires gave researchers (Blate 1997, Putz *et al.* 2000a, Klassen 2001) the following reasons for their hesitation to adopt improved harvesting practices:

- RIL is too expensive;
- There is nothing wrong with current logging practices;
- Markets do not demand that RIL practices be implemented;
- Lack of governmental incentives to change logging practices (or failure to enforce regulations);
- Forest will be converted anyway;
- Available equipment is unsuitable for RIL;
- Lack of training and guidance by RIL experts;
- Lack of focussed pressure for better logging from environmental groups.

These reasons vary in their defensibility and seemingly in their importance to decision-making processes, but the first stands out as most prominent. Unfortunately, discussions about the cost-effectiveness of RIL have been hampered by a lack of clarity about a number of critical factors. The apparently unjustified generalisations about the financial benefits of RIL to those harvesting the timber have also reduced the credibility of its proponents. One has simply to review the contrasting conclusions about cost-effectiveness of RIL drawn by Tay (1999), Healey *et al.* (2000), and Holmes *et al.* (2001), to realise that the reluctance of loggers to adopt RIL practices might be financially justified under some conditions.

Whether or not cost savings during timber harvesting result from following RIL guidelines varies with the perspective of the stakeholder, time scales, sectoral and extrasectoral policies, and the particular components of RIL under consideration. In the following sections we deal with some of these issues, focussing on the short-term financial costs and benefits of RIL adoption. Longer-term silvicultural consequences of different logging practices are not considered here, nor are the environmental and social benefits derived from RIL (for a discussion of these 'externalities' see Pearce *et al.* 2002).

4.1 Calculating the Financial Costs of Logging Using RILSIM

RILSIM, a 'Reduced-Impact Logging Simulator,' is an open access software package developed by D.P. Dykstra to calculate the costs of any sort of logging (http://www.blueoxforestry.com). It was designed to be user-friendly and flexible enough to allow comparisons of RIL and conventional logging under a wide variety of conditions. The RILSIM source code is available on the web for those who want to modify the program, but most users should find all they need in the users' manual. The two scenarios worked through in detail in the users' manual are based on data from Brazil (Holmes *et al.* 2002) and a combination of data sets from Indonesia and Malaysia (Tay 1999, Healey *et al.* 2000, Ruslim *et al.* 2000 and others).

The user interface of RILSIM is a series of electronic data forms in which users fill in data about a logging operation they have done, plan to do, or otherwise want to consider. Information about the area harvested, interest rates, volumes extracted,

equipment used, difficulty of the terrain, productivity rates, and personnel costs are used to calculate the financial cost of a logging scenario. RILSIM was developed partially in response to requests from forest industry representatives for a way of disaggregating the costs of applying different techniques designed to reduce the deleterious impacts of logging. It should be useful to logging contractors, forest owners, and anyone else interested in estimating the costs of timber harvesting using a variety of methods.

4.2 Distributions of the Costs and Benefits of RIL

To understand better the apparent hesitation of loggers to adopt improved harvesting practices, it seems worthwhile to examine the issue from the points of view of forest workers (e.g., fellers and skidder operators), timber harvesting contractors, forest owners, and forest authorities. For example, if adherence to RIL guidelines requires that timber harvesting operations cease when the soil is wet following heavy rain, while they would typically continue in conventional harvesting operations, the incomes of forest workers paid by days worked or volumes harvested are reduced. In contrast, the same wet weather shutdowns might financially benefit the logging contractor who pays for road and skid trail maintenance and whose costs increase substantially if roads are used during wet weather. Another example is the cost of safety equipment. While logging contractors might be expected to pay for chainsaw safety equipment (e.g., helmets, protective pants, and steel-toed boots), the safeguarded workers would be the primary beneficiaries. Where insurance premiums and the like are not at issue, which is the case in much of the tropics, calculating the financial benefits of safety equipment is challenging. Nevertheless, logging contractors clearly benefit from their outlay of funds for safety equipment if their workers suffer fewer accidents and thus are more productive.

Although we are aware of the importance of different perspectives regarding the costs and benefits of RIL, our analysis pertains mostly to logging contractors and their equivalents. Limiting our evaluation of RIL to its strict financial and short-term aspects is misleading insofar as it downplays the benefits to worker safety and environmental protection, as well as long-term benefits to the production of forest goods and services. Our justification for this focus is that it is the timber harvesting contractors who are principally responsible for adopting RIL, which makes their perspective of critical importance. In this analysis, we make the implicit assumption that most logging contractors or companies involved in timber harvesting are not fully aware of the total costs of their current timber harvesting operations. Consequently they may not be able to appreciate some of the financial advantages they could obtain from adopting RIL techniques.

To what extent do timber harvesting companies employ unnecessarily destructive harvesting practices because they are unaware of the inefficiencies of their operations and the financial benefits they could derive from following RIL guidelines? Do these companies have the information needed to assess and improve the efficiency of their current operations? The answer to these seemingly simple questions varies among companies and could be influenced by unwitting biases of researchers, ourselves included. Although it is an oversimplification, it sometimes appears that researchers either assume that timber harvesting companies require the enlightenment that research can provide or, conversely, that these companies operate as completely rational firms. Addressing this issue is further complicated by the common practice of keeping 'double books' or otherwise obfuscating true costs, in order to avoid taxes and more 'informal' levies.

Overall, it appears that many timber harvesting companies do not know, and really have no way of knowing, many of the component costs involved in delivering their product to the point of sale. For example, where timber harvesting operations in some forest types are not guided by 100% stock maps, and particularly where felling and yarding (skidding and landing) operations are not closely co-ordinated, a distressing number of marketable logs are left lying on the forest floor. Published estimates of felled trees that are missed during harvesting operations are certainly substantial enough to command attention (Dykstra 1992). For example, in one study in Brazil, 7 m^3/ha, or 20% of extracted volume, was felled but never skidded to the landing (Uhl *et al.* 1997). In another study in Amazonia, 6.6 m^3/ha, or 22% of the commercial timber volume, never made it to the log landings during conventional

logging operations (Winkler 1997). Similarly, in Sarawak, 11 m^3/ha (20%) of the harvested volume was simply missed by skidder drivers (Mattsson-Marn and Jonkers 1981). Despite the comparable figures for Asia and South America in the studies cited, there is as yet no way of knowing whether these estimates are typical or if they represent extremes of inefficiency. In any event, the estimates are large enough to have attracted the attention of timber harvesting interests in Brazil (Blate *et al.* 2001) and should likewise influence timber harvesting elsewhere in the tropics.

More complex than measuring volumes and values of timber lost due to poor organisation of harvesting operations is calculating the financial costs and benefits of training and, alternatively, the often hidden costs of not training workers. It is easy to determine the costs of trainers, training facilities and reduced productivity during training sessions. But as J. Zweede from Fundação Florestal Tropical (FFT) in Brazil regularly points out, it is much harder to estimate the costs of allowing untrained workers to adjust chainsaws, fell trees, and drive expensive skidders. Similarly, although some log breakage during felling operations is unavoidable, feller training typically results in 10–15% higher volume recovery due to fewer broken logs, lower stumps, and improved bucking techniques (Dykstra and Heinrich 1996). One study in Brazil reported substantial reductions in wasted timber associated with felling and bucking following introduction of improved practices (Winkler 1997).

Variations in the quality of training delivered to harvesting crews and managers also makes it difficult to calculate the corresponding costs and benefits. One could equate the time and money invested in training with the quality of the instruction, but this might be misleading. Instead we suggest competency-based evaluations of quality (Box 1).

4.3 Does Adoption of RIL Necessarily Reduce Timber Harvests?

Timber harvesting intensities in 'selectively' logged tropical forests range over three orders of magnitude in volume (<1 m^3/ha to >100 m^3/ha; Putz *et al.* 2000b) and nearly as much in number of trees harvested (<1 to >20 trees/ha). This variation makes it hard to generalise about the likely effects of RIL. Because the per unit costs of harvesting timber decrease with increasing timber volumes harvested per unit area, logging intensity may very well influence

Box 1. Competency-based Training for Improved Timber Harvesting

The institutional development and training required to implement improved timber harvesting practices involves three vocational levels:

- Policymakers, senior managers;
- Middle-level managers/supervisors;
- Forest operators, contractors, landowners, and field staff.

Traditional training in forest management usually involves fixed learning periods with variable outcomes. This approach to training has typically met with limited success in areas requiring radical change in timber harvesting procedures. An approach to training that involves measuring minimum performance outcomes after different amounts of training may be more appropriate.

A competency-based approach to training recognises that people learn at different rates and through different means, partially because they have different backgrounds and experiences. This approach requires that individuals achieve and demonstrate specific knowledge and skills in relation to specified competency-based standards. Thus, it also formally recognises prior learning. A certificate of achievement can be issued to the trainee once competency is acquired in a certain task (Andrewartha *et al.* 1998; Applegate and Andrewartha 1999a).

The main purpose of competency-based training in improved timber harvesting is to ensure that the 'certificate' issued is based on reaching and demonstrating competence rather than just participating in a specified training event. It represents a shift away from the traditional emphasis on the process involved in training (inputs) and focuses on the outputs. This approach is appropriate for forest managers and supervisors, as well as for landowners and field crews.

the relative costs and benefits of RIL and conventional approaches to timber harvesting. For example, if following RIL guidelines requires the use of concrete bridge abutments for logging roads or manufactured culverts on principal skid trails, the costs of these improvements, per unit volume harvested, declines with increasing harvest rates or timber volumes accessed using these infrastructural improvements. The issue of whether calculations of costs and benefits are based on the net area logged or the total area designated for possible logging is explored in Box 2.

Contributing to the difficulty in generalising about the costs and benefits of RIL relative to conventional timber harvesting practices is the fact that there is no one sort of conventional harvesting. Similarly, RIL guidelines can and do vary with forest conditions (see Box 6). For example, there are no reductions in harvest yields resulting from RIL-required wet weather shutdowns in areas where rainfall is distinctly seasonal and logging operations typically shut down for the rainy season. In contrast, the rate of logging can be reduced substantially where loggers are required by RIL guidelines to cease their operations during wet weather, while conventional loggers continue harvesting.

4.3.1 Impact of topography and other constraints on logging cost calculations

There are many difficulties involved in providing realistic and credible financial cost-benefit analyses of RIL and conventional logging. Of the many forest characteristics that appear to influence the comparative financial benefits of RIL, topography is prominent. The scale or size and heterogeneity of areas used to determine costs also affect financial cost estimates.

The influence of topography on ground-based skidding and yarding costs is a major consideration for determining relative costs of RIL. Although reliable data are scarce, logging is clearly more costly and more damaging on steep terrain. RIL guidelines typically set limits on the slopes that can be accessed by ground-based yarding equipment. Such limits for skid trails range from a 17° slope limit suggested by Dykstra and Heinrich (1996) and 15° for major skid trails and 25° for minor skid trails suggested in the Code of Practice for Forest Harvesting in the Asia Pacific (APFC 1999), to the 35° slope limit used by the Forest Department of Sabah, Malaysia (Pinard *et al.* 1995). If, by adhering to these slope restrictions, timber harvesting companies following RIL guidelines harvest less timber than would be expected in conventional harvesting operations, then they could argue that the value of the foregone timber should be considered as a cost. In contrast, forest owners and stakeholders concerned about environmental damage and sustainability of forest management are unlikely to accept that compliance with the law represents a redeemable cost.

A similar difference in perspective is likely in calculating the costs of respecting harvest exclusion areas, such as stream buffer zones, as well as RIL-related restrictions

Box 2. Area Estimation for Tropical Forest Harvesting Operations

Accurate estimates of loggable forest areas are essential in yield prediction, since any errors in area estimates are directly proportional to errors in final yield estimates. Portions of most logging areas cannot be logged, at least using ground-based yarding equipment, due to adverse slopes, boulders or soils of extremely low trafficability. But because different RIL guidelines call for different set-asides, buffer zones and other restrictions, which vary in their impact on the total area logged, being clear about this issue is critical for the evaluation of the costs and benefits of RIL.

Gross Productive Area is determined directly from 1:50 000 maps as areas designated to be logged and 'zoned for logging' on zoning or management maps. Gross Productive Area is unsuitable for sustained yield computation because it includes areas that will not be logged under any circumstances. Maps at 1:50 000 (1 mm = 50 m) cannot show minor areas that are not to be logged or that were logged in the past. Use of such maps could lead to significant overestimation of the timber harvesting area.

Sampling and more thorough mapping must be carried out within the Gross Productive Area to account for areas of inaccessible terrain, patches of rock, stream buffers, and other set asides to determine the **Net Productive Area**. This is the actual 'on ground' area of loggable forest used for yield calculations.

Box 3: Reduced-Impact Harvesting and Portable Sawmills in the Pacific Region

The number of mobile or portable sawmills in the Pacific has increased dramatically in recent years. Their costs range from US$230 for chainsaw mills to US$17 000 for large mobile bandsaw mills. Most of the mills are operated by landowners or by communities and play important roles in local development in Papua New Guinea, Solomon Islands, New Caledonia, Vanuatu, Fiji and Samoa. Often the mills operate illegally, without timber licences, without proper agreement from landowners and without adherence to the relevant codes of logging practice. The mills are moved frequently from one location to another and disputes over ownership of trees and the resultant sawn timber are very common. The impact of these small mills on forests is substantial because they are commonly operated without control over species harvested, tree sizes or number of trees harvested per hectare. Marketing of the sawn timber is often problematic due to poor quality control. While most operators can cut 4–5 m^3 per day and make a profit of US$50, there is often little understanding of the problems of cash flow and loan repayment, costly breakdowns, poor maintenance and lack of spare parts.

To mitigate some of the problems associated with mobile sawmills, the Forestry Department in Vanuatu has now issued Mobile Sawmill Timber Licences that specify volumes to be harvested on a given area for a period of two years. They have also started training programmes on the technical aspects of mill operation and seasoning of sawn boards, as well as training on the code of practice for logging in Vanuatu.

on harvesting trees of some species or sizes. In forests in which such areas and trees abound, the profitability of RIL will be reduced as compared to conventional logging, but it is not clear how these 'costs' should be dealt with in financial comparisons of RIL and conventional logging.

4.3.2 Organisation of Timber Harvesting Operations

The manner in which timber harvesting operations are coordinated may influence, in ways that need to be explored, the cost-effectiveness of RIL compared with conventional logging. For example, in many conventionally harvested areas in lowland Bolivia (mean harvesting intensity of 1–3 m^3/ha), tree finders (tree spotters) spend the months of the rainy season searching for trees to be harvested. They mark trails to each tree, and then later direct the skidder drivers to the trees to be harvested. While few trees are lost and the long skid trails are typically narrow, this organisation of harvesting operations falls far short of a full RIL treatment. In contrast, felling and skidding operations in conventionally logged forests in Indonesia and Malaysia are typically disconnected and very wasteful; tree fellers cut the trees and then the skidder drivers traverse the forest on their machines searching for canopy gaps to locate the felled trees. These practices, coupled with logging intensities several times greater than those typically observed in Bolivia, make RIL implementation comparatively more urgent in Southeast Asia.

In most conventional harvesting operations in many parts of the tropics, planning teams, timber harvesting teams, tree markers, cutters and skidder operators all work quite independently of each other. For example, even if harvest planners with access to accurate and detailed maps plan harvesting operations, these plans are seldom provided to the field operation's managers. Commonly, field managers do not have sufficient skills to take advantage of the information provided and are untrained in many aspects of professional timber harvesting operations. The main aim of most logging supervisors is to maintain log supplies to processing mills or points of sale.

When logging contractors and forest workers are paid on the basis of the volume of timber delivered to landings or log ponds, they are quite reasonably reluctant to adopt practices that reduce their productivity. An obvious prerequisite for implementation of RIL techniques is therefore the institution of payment systems that maintain profitability but reduce the damage workers do to themselves and the residual forest.

4.3.3 Effects of Forest Harvesting Regulations

Direct and indirect benefits of violating or following forest harvesting regulations need to be considered carefully when carrying out financial comparisons of RIL and conventional logging operations. Should profits obtained from logging prohibited species,

undersized trees, or areas to which timber harvesters are denied access by law or RIL guidelines be included in cost-benefit comparisons? Whatever the answer to this question, researchers need to be very explicit about their assumptions and data analysis methods. In many cases, it is difficult to judge whether or not regulations are being violated, because the regulations themselves are vague.

A common situation in which compliance with laws and other regulations is somewhat confusing pertains to cutting trees or constructing skid trails on slopes that exceed a designated limit. A regulation that might seem easy for a trained forester to apply is made problematic when the length of slope over which the calculation is determined is not specified. Calculating the slope on which a tree is growing obviously depends on whether the slope is averaged over 10 m, 100 m or 1000 m. Large areas with steep slopes can generally be identified on 1: 50 000 topographic maps and deleted from harvesting operations before they commence. More problematic are small areas of steep slopes and areas of relatively flat terrain that can only be reached by traversing areas that exceed slope limits. Harvesting contractors generally claim that they should be compensated for timber they would normally harvest, but to which they are denied access by RIL codes of practice; but the state and other stakeholders just as reasonably view this situation differently. How this dilemma is resolved makes a huge difference in cost comparisons between RIL and conventional logging.

Ambiguities in the interpretation of regulations cannot be totally avoided, no matter how detailed the guidelines. Although it complicates the analyses, we recommend that cost-benefit comparisons of RIL and CNL keep separate the profits derived from timber harvested illegally, and account separately for the timber foregone by compliance with RIL guidelines.

4.3.4 Influence of Forest Sector Policies

A wide range of forest sector policies need to be considered when making financial comparisons between RIL and conventional logging, especially when the results of these comparisons are to be generalised. It is relevant, for example, whether timber harvesting contractors/concessionaires pay landowners for stumpage or for harvesting rights without regard to the volume of timber extracted. High-grading and wastage may be favoured when timber harvesters pay forest owners on the basis of timber volumes delivered to the mill gate, but this will be not be a significant problem if measured logs are sold at the stump. Area-based fees, depending on the availability of the timber resource, can promote either careful or destructive timber harvesting practices.

Installed timber processing capacity and demand for timber that exceed the forest's ability to provide the raw material both tend to increase the price of timber, and often lead to increased harvesting pressure. This is a current problem in many parts of Indonesia, for example. The problem is further exacerbated by poor monitoring and control of logging operations by forestry officials, communities and other forest owners.

There is an increasing emphasis in the tropics on devolving much of the decision making about forest management and harvesting to rural communities (e.g., White and Martin 2002). From a forest management perspective, this process has been successful where communities have the necessary skills to manage the forest and negotiate contracts with contractors and log buyers (Box 4). Some communities have even benefited from developing processing capacities through pit sawing, small-scale mills, or portable sawmills. In too many places, however, the transfer of management and user rights to rural communities has far exceeded their institutional and technical capacities. Often, soon after communities take control of their forests, the displaced concessionaires simply return as contractors to harvest the timber. When this happens, these companies are usually no longer responsible for implementing RIL guidelines because they are no longer the managers. In all too many cases, the resulting timber harvesting operations have had more substantial negative impacts on the physical environment than were suffered prior to devolution of forest control to local communities (see Iskandar *et al.* in review). Furthermore, communities that choose to process their own timber often do so with relatively low-cost portable sawmills with very low recovery rates of sawn timber. Although the use of portable sawmills usually results in less soil disturbance than extraction of logs from the forest, it also promotes high-grading of the forest and utilization of only small portions of the merchantable stems.

Box 4. Improved Forest Practices in Highly Disturbed Forests owned by Communities

The majority of forests in Vanuatu are owned by customary landowners, not by the national government (Alatoa *et al*. 1984). Customary owners and those villagers related to them are therefore the fundamental stakeholders in any decision-making process related to land or forests in Vanuatu. The two major biophysical challenges for forest managers in Vanuatu are invasive vines such as *Merremia* spp. and the destructive force of cyclones that regularly hit the island. Many of the valuable tree species (for timber and non-timber products) are at least moderately light-demanding and regenerate, along with vines, after the forest is pounded by cyclones. As was described for lowland Bolivia in Box 6, on Vanuatu there is a need to reduce the damage to the forest during timber harvesting, but not to such an extent that high light-demanding regeneration of valuable timber species is inhibited.

In the past, conventional logging in Vanuatu caused excessive damage to advanced regeneration and resulted in large canopy openings, vine infestations, and exposed soil that often covered more than 50% of the harvested area (Applegate 1992). There was an obvious need to develop harvesting techniques that maintained basic forest canopy integrity, while providing for gaps of appropriate size for the regeneration of valuable species. Following collation of ecological data and a consultative process involving timber processing companies, customary landowners, non-governmental organisations and staff from the Department of Forests, silvicultural prescriptions and RIL practices were developed for a number of 'silvicultural forest harvesting types'. The recommended changes in harvesting practices included raising the cutting limit for species that grow mainly in clumps (e.g., *Endospermum* sp), thereby reducing gap sizes with the aim of reducing vine infestations. A contrasting change was the lowering of the minimum cutting limit for *Castanospermum* sp. on the western, drier parts of the island, where they become less merchantable once they reach a large diameter.

These recommended practices resulted from an understanding by concerned stakeholders of the practical realities of the forest types and climatic conditions and the need to maintain a forest for both timber and non-timber products and services. These needs were balanced with the ecological requirements of both the wanted and unwanted species, resulting in the development of harvesting practices that are socially acceptable, technically feasible, and effective.

4.3.5 Influence of Extrasectoral Policies

It is often difficult to determine in advance which policies might influence the relative cost-effectiveness of RIL and conventional logging. For example, in Brazil, where tractor-mounted winches and other tools useful for implementing RIL incur a high import duty, adoption of this equipment for winching logs from the stump, an important component of reduced-impact logging, is impeded (J. Zweede, pers. comm.).

Land tenure security, concession security and forest security also greatly influence concessionaires' and landowners' decisions about investing in future timber yields by following RIL guidelines. Where security is lacking, it is financially rational to harvest as rapidly as possible, without regard to the environment or future productivity.

4.4 Lack of Agreement on Costs

4.4.1 Potential Cost Savings of RIL

There is considerable confusion about the costs of implementing RIL guidelines. On one side of the debate, environmentally concerned researchers and advocates broadcast the message that when RIL guidelines are implemented, profit margins are higher (Holmes *et al.* 2002). In contrast, Healey *et al.*(2000), using the data from Tay (1999), show why, under some conditions, timber harvesting companies might justifiably doubt the veracity of this claim. Part of the reason for this apparent dilemma is a lack of uniformity in calculating the financial costs of RIL in comparison with the cost of conventional timber harvesting (Buenaflor 1989, Barretto *et al.* 1998, Holmes *et al.* 2002, Matikainen and Herika 2000, Putz *et al.* 2000a, Applegate 2001). Different analysts include different components of the logging process and may use different methods in the financial analyses. For

example, interest on pre-harvest operation expenditures (e.g., stock mapping) influences the overall costs from the perspective of the logger, but is often not considered. Hopefully the availability of the RILSIM software package will lead to standardization in the way forest harvesting cost data are analysed.

Another challenge in making comparisons between RIL and conventional logging is deciding how to deal with activities that are linked in ways that influence their costs and benefits. Furthermore, the cost of one of the linked components often depends on the quality of the implementation of the other. For example, roads have large impacts on the efficiency of timber harvesting operations, as well as on the forest environment. Roads that are poorly located, poorly designed and poorly constructed lead to increased costs of road maintenance, bridge construction, skid trail construction, skidding and log transportation. Planning and constructing roads carefully, therefore, can greatly reduce costs of other harvesting operations in comparison to roads that are designed from the seat of a bulldozer, a far too familiar practice in the tropics. RILSIM allows for such connections to be considered during cost analyses, but data are often lacking.

Another problem to be confronted in comparing the costs of RIL and conventional timber harvesting practices is the lack of knowledge of the costs of the various components. This problem involves both lack of knowledge of true costs and failure to consider costs of all harvesting activities (Pulkki 1997). Incompleteness of evaluations and undervaluing the harvesting operation can lead not only to misrepresentation of the total costs of the improved practices, but also invariably result in miscalculations of the true costs of conventional harvesting (Pearce *et al.* 2002). Cost and benefit comparisons of improved and conventional harvesting practices are made even more difficult when the various cost components and activities are lumped together (Elias 2000, Matikainen and Herika 2000, Ruslim *et al.* 2000) and the beneficiaries are not specified. By using RILSIM, some of these problems are alleviated, and the accompanying user's guide provides data that can be used in place of actual data from the logging operation being considered.

4.4.2 Influence of Spatial and Temporal Scales of Harvesting on Cost

Scaling-up to commercial timber harvesting operations (1000 ha or more harvested per year) the results of costing studies based on 10 ha or even 100 ha research plots, involves difficulties that need to be considered carefully. This issue is especially pertinent if research plots are not well-replicated or are located to avoid steep terrain, river margins and other areas that should not be harvested under RIL guidelines but would be harvested under conventional operating conditions. Furthermore, the location and quality of major roads influence a range of components of timber harvesting operations in ways that may not be immediately obvious, but that are not considered adequately in small plot-based studies. Finally, small plot-based methods of determining costs seldom include all the harvesting activities.

The temporal scale of harvesting operations, the impact of topography, and the question of how representative various areas are of the overall operational conditions under which logging takes place, substantially influence costs. Much of the cost analysis work to date has been carried out on small areas (Holmes *et al.* 2002, Matikainen and Herika 2000, Ruslim *et al.* 2000) and does not take into account the huge variation in roading costs across an area of forest involving thousands of hectares. Specifically, roading costs vary from location to location within a concession as a result of differences in topography, soil type and geology. In contrast, on more favourable terrain and in low rainfall zones, road design and location may have little impact on the relative costs of reduced-impact and conventional logging. For these reasons, results of financial evaluations based on small plot-based studies in which plots are located in such a way that the costs associated with timber harvests foregone (e.g., resulting from excluding adverse terrain or ecologically important areas) are not taken into account, are obviously biased and should be scrutinised carefully (Holmes *et al.* 2002, Elias 2000, Ruslim *et al.* 2000, Applegate 2001, Dagang *et al.* 2001).

5 Disaggregation of Costs and Benefits of Improved Harvesting Practices by Component

Disaggregation of component costs of improved timber harvesting practices is essential to determine who pays for and who benefits from different aspects of RIL. Benefits may accrue to timber harvesting contractors, concessionaires, or forest owners, while other benefits accrue to spatially or temporally remote stakeholders, including future generations.

To the extent possible, we will identify the likely beneficiaries of the evaluated components of RIL so as to inform debates about using incentives to promote better harvesting practices. What makes the disaggregation of RIL components difficult is that timber harvesting operations are complex and integrated. Hence cost-cutting inputs for one set of activities might result in substantially increased costs in another. For example, a timber harvesting contractor might initially save money by not bothering to plan road layouts, but these savings will later be lost due to increased yarding and hauling costs. With this caveat in mind, in this section we propose a breakdown of harvesting operations that we hope will be useful in cost accounting, and then consider four components in more detail. These components were selected from different stages in a typical timber harvesting operation and seem relevant as examples of activities for which different financial and economic factors must be considered. The four examples, which also pertain to a range of beneficiaries over different time scales, are:

- Topographic and Stock Mapping;
- Road Planning and Construction;
- Directional Felling;
- Skid Trail and Road Closures.

Box 5. Malinau Research Forest: Science And Sustainability

The Ministry of Forestry (MOF) in Indonesia designated 321 000 ha of forest in East Kalimantan, Indonesia, to be developed as a long-term model of exemplary research-based forest management by the Center for International Forestry Research (CIFOR). Research is designed to identify the range of values of the forest to forest-dwelling people as well as its value to those outside the immediate area. Researchers are also assessing the level of dependence on what the forest has to offer and the various trade-offs likely if the use of the resource is to be optimised. As conflicts over land allocation and use continue to increase in the model forest area, developing the principles and mechanisms required to manage conflict as part of the process of developing a joint vision for the management of the resource is also of utmost importance. It is also critical to determine how conflicts and negotiations influence progress towards the goal of more sustainable land use. Given that many new districts in Indonesia lack the institutions required to deal with decentralization, training in the tools and methods of government is critical, as is the development of policies to support decision-making. The strengthened institutions will then be better prepared to draft and implement community-based management plans.

In the context of current Ministry of Forestry policies in Indonesia, concessionaires must work towards sustainable forest management practices in the framework of ITTO's Target 2000. A partnership involving INHUTANI II (a concessionaire operating in the model forest), local authorities, and communities provides the opportunity to improve the capacity to undertake improved forest management. Training in RIL practices and on measuring the effects of logging is underway. The integration of RIL and improvements to silvicultural regimes requires an understanding of tree regeneration mechanisms, as well as monitoring of permanent sample plots. Studies are also underway to identify regulations that constrain the adoption of RIL, such as local community access to information, harvesting cost, taxes, and lack of trained staff. This research involves interviews and systems modelling to determine costs and benefits of improved practices. A comparison between the constraints to adoption of best practice in the model forest and in other tropical forests will be undertaken to identify common constraints to improved tropical forest management.

5.1 Topographic and Stock Mapping

High quality maps suitable for timber harvest planning are rare in many tropical countries. To adequately plan harvesting operations, small-scale (1:2000–1:10 000) maps are required, with contour intervals of 5–10 m. Additionally, the locations of trees to be harvested and those to remain for subsequent harvests are also often required. Access to quality maps facilitates planning of roads and skid trail locations and, if used by trained technicians to plan and implement harvesting operations, can greatly improve the efficiency of these operations.

5.1.1 Stock Mapping

Mapping of trees to be harvested, and those that should be protected for future harvests, involves costs that are generally borne by the concessionaire/contractor. Typical short-term benefits of stock maps include fewer lost logs and more efficient skid trail layout. In addition, the existence of a stock map creates the opportunity to harvest by species and size classes to meet specific market demands. When future crop trees (FCTs) are mapped and marked in the forest, damage to these trees during felling and skidding can be reduced substantially (Kreuger 2004). The benefits and beneficiaries of this longer-term impact vary with concession policies (e.g., duration or transferability), tenure or resource use security, markets, and various sectoral and non-sectoral factors. The impediments to adoption of the stock mapping component of RIL are related to the issues of who pays for the mapping and who benefits, in both the long and short terms, from this activity.

5.1.2 Topographic Mapping

In the tropics there is a general lack of maps suitable for timber harvest planning (1:5000 or more detailed). In a few places this problem has been solved by using computer-generated maps with slope data obtained during the pre-harvest inventory (Klassen 2001). These maps are also important for the accurate designation and delineation of exclusion zones and protected trees. Furthermore, the existence of accurate topographic maps is a prerequisite for effective mapping of trees to be harvested and future crop trees.

5.1.3 Benefits of Mapping

Access to accurate topographic and stock maps provides benefits during planning of timber harvesting, during harvesting and during future harvests. Quality maps:

- Assist with the location of trees for harvesting, which is especially useful where harvestable trees are widely scattered;
- Reduce the number of merchantable trees that inadvertently remain unharvested and the number of logs that should have been yarded that are left on the forest floor;
- Serve as a basic tool for efficiently locating roads, skid trails, and landings to reduce costs of skidding;
- Assist with the location of individual species (permitting response to specific market demands);
- Assist with monitoring and evaluation of operations by both tree harvesting supervisors and forest owners;
- Are inexpensive to produce relative to the benefits derived and the overall cost of harvesting.

5.1.4 Direct Financial Costs of Mapping

The following direct costs are attributed to the mapping operations:

- Tree identification training is required, which is costly but necessary for accurate stock mapping;
- Training in surveying techniques is required to ensure the field measurements are accurate and made as efficiently as possible to reduce costs;
- Full stock surveys or censuses are required, but these are inexpensive relative to overall logging costs;

Contour map preparation, including the costs of hardware, software and printing are generally borne by harvesting companies.

5.1.5 Other Issues Related to Improved Mapping

While some of the main costs of mapping have been outlined, there are other issues that influence the use and value of maps as management tools:

- Stock maps are less cost-effective if logs are sold at the stump;
- Stock maps are useful where trees are spread relatively evenly in the harvesting area, forest workers are competent at tree marking, and trees are marked for felling as well as for retention;
- Mapping costs are directly related to the number of species and the minimum diameter of trees included. Considering future harvest trees that

are currently in precommercial size classes can increase mapping costs considerably;
- Detailed stock maps are less critical where foresters traverse the forest systematically before, during, and after harvesting operations;
- Maps are seldom used where there are few formal links between the planners and the implementers of harvesting operations;
- Mapping is often done by poorly trained and low-paid staff, thus leading to poor quality maps that are not very useful and not often used;
- Stock maps are often drawn with little concern for precision (or are entirely fabricated) and used only to comply with administrative requirements;
- Although computing software is costly, many companies are now using satellite imagery coupled with Geographical Positioning Systems (GPS) and Geographic Information Systems (GIS) to prepare maps.

5.1.6 Who Benefits from and Who Pays for Mapping?

While there are a number of issues related to the quality of maps and their use, there are others related to the costs and benefits of map preparation:
- Mapping is more likely to represent a net cost to the timber harvesting company if they are not used fully or if the harvesting techniques used are poor;
- Mapping is more likely to result in net benefits to loggers if their field crews are competent in their use;
- The financial benefits of mapping to loggers are greater if the trees to be harvested are very valuable and widely scattered;
- Over the long term, to the extent that the use of accurate maps reduces environmental damage, both forest managers and society as a whole benefit.

5.2 Road Planning and Construction

Most of the direct environmental impacts of timber harvesting operations on forest ecosystems are related to the design, location, construction, maintenance, and use of roads. Erosion from road surfaces, cut-and-fill slopes and bridge abutments contribute most of the sediment that ends up in streams that pass through timber harvesting areas (Wells 2001). Landslides also tend to be concentrated along roads, particularly near roads that are improperly sited, poorly constructed and insufficiently drained. Road building and maintenance are also among the most costly of forest harvesting operations. In hilly terrain, for example, the construction of a kilometre of logging road may cost US$30 000 or more. Our goal here is not to review the engineering standards for logging roads, which are readily available (e.g., Keller and Sherar 2003) and generally figure prominently in RIL guidelines, but rather to consider why poor road building and maintenance practices typify many tropical forest harvesting operations. Nevertheless, it is important to point out that compliance with the engineering standards for tropical forest road construction, as outlined in many codes of practice, depends on the availability of accurate and precise maps (Asia-Pacific Forestry Commission 1999, Wells 2001).

Road building, like other timber harvesting activities discussed, does not occur in isolation but instead is intimately linked to other operations. Because of these interconnections, specifying the costs and benefits of proper road design, engineering, construction and maintenance represents a considerable challenge. For example, uphill skidding is generally recommended for safety reasons and to reduce soil erosion. The willingness of timber harvesting contractors to skid predominantly uphill obviously depends on road locations. Similarly, the relative distances logs are moved within a forest by skidders vs. loaded on log trucks depends on the road layout.

5.2.1 Benefits of Improved Road Planning and Construction Techniques

Some of the benefits of improved road design, layout, and construction include:
- Increased efficiency in hauling logs to the point of sale or processing facility;
- Improved access for monitoring timber harvesting operations by forest owners;
- Decreased road maintenance costs during logging;
- Decreased road maintenance costs for the forest owner after timber harvesting operations are completed;
- Decreased maintenance costs to local authorities if timber harvesting roads are used as part of the regional transportation network;
- Reduced soil erosion and stream sedimentation;

- Reduced impacts on residual stands because less forest is cleared for road construction;
- Reduced likelihood of invasion of light-demanding weeds because the forest road openings are narrower;
- Reduced impacts on wildlife;
- Reduced vehicle maintenance costs;
- Reduced risk of fire spread into logged forest.

5.2.2 Issues That May Influence Adoption of Improved Roading Practices

The following issues influence the adoption of improved roading standards:

- The degree to which managers consider the costs of production delays caused by road closures, reduced hauling capacities of trucks due to poor road surface conditions, and truck damage and subsequent unavailability;
- Inefficiencies such as the presence of idle machinery and inefficient deployment of machines in use;
- The presence of engineers with experience in tropical forest road design and construction;
- Poor road location and design due to inexperienced staff, which results in excessive side cutting (increased cost), numerous watercourse crossings and steep grades, and may exacerbate land disputes;
- The cost of gravel for road surfacing. However, even if this is expensive, judicious use often reduces overall roading costs;
- Supervision: properly exercised, this can improve construction efficiency;
- Availability and use of appropriate machinery for road construction and maintenance are critical. For example, it is not efficient to use bulldozers for grading and compacting roads.

5.2.3 Who Benefits from and Who Pays for Improved Roads?

There are many benefits and beneficiaries of improved road design and construction, but in most cases it is the timber harvesting company that pays the costs. Some of the issues relating to the benefits and beneficiaries of improved roading include:

- Benefits of training in road design and construction are enjoyed by harvesting contractors, timber harvesting companies, forest owners, and the general public, who may use the road for commerce and tourism;
- Good roading benefits current and future timber harvesting companies, as well as society at large, due to reduced erosion, siltation and water pollution;
- Other environmental benefits of good roading include less wasted wood, less damage to the forest structure resulting from narrower roads, increased residual growing stock and reduced damage to future crop trees;
- Benefits also accrue to local government authorities if they take over the roads after harvesting, because good roads require less maintenance.

5.3 Directional Felling

Securing all the various benefits of directional felling requires investment in the appropriate equipment as well as the training of fellers and tree markers. While some of the direct financial benefits of directional felling (e.g., efficient skidding) accrue to timber harvesting contractors and operators, forest owners and the global community also benefit from reduced damage to the residual stand, increased carbon retention, and biodiversity conservation. Adoption of directional felling techniques by tree markers and fellers is influenced by the payment system (daily wage vs. per cubic metre yarded), safety issues, equipment, and recognition of the benefits of the practice. Adoption of directional felling techniques is also somewhat dependent on the organisation of harvesting and by the manner in which the logs are sold (i.e., at the stump, landing or millgate).

5.3.1 Benefits of Directional Felling

The benefits of tree marking and directional felling include the following:

- Enables implementation of a 'herringbone' pattern of planned skid trails on flat land in order to reduce yarding costs;
- Reduces log breakage by avoiding felling trees on top of one another, across streams or over boulders;
- Reduces damage to future crop trees;
- Improves worker safety. International Labour Organization (ILO) data on fatalities and injuries to fellers suggest that directional felling and the associated training reduce harvesting-related accidents. With improved practices will come

more accurate reporting of injuries;
- Increases direct financial benefits to loggers from improved timber recovery from harvested trees and improved operational productivity;
- Facilitates yarding because logs are orientated to facilitate skidding, to minimise skidding distances and to obviate the need for log rotation during yarding, which reduces damage to the log and nearby trees.

5.3.2 Issues That May Influence Adoption of Directional Felling Techniques

Training of fellers results in their having a heightened sense of professionalism, which may stimulate demands for higher wages, benefits and safety equipment. Although satisfaction of these demands incurs direct costs, compliance should result in fewer accidents and lower insurance costs. Feller training and licensing, as required in some countries, further promotes professionalism, which in Sweden and Tasmania resulted in increased adoption of improved timber harvesting practices.

- When directional felling reduces production rates, especially if production is further reduced due to work stoppages during wet weather, it may be necessary to develop incentive systems beyond simple payment on the basis of volumes felled or yarded to the roadside;
- Availability of trainers and training materials that are appropriate for field crews can influence the adoption of directional felling techniques. Field guides to directional felling such as those produced by BOLFOR, the Vanuatu Sustainable Forest Utilisation Project, and FFT in Brazil, coupled with professional training by qualified consultants, increase understanding of the need for directional felling and encourages its adoption.

5.3.3 Who Benefits from and Who Pays for Directional Felling?

Among the issues related to the benefits and beneficiaries of directional felling, the following seem most critical:

- The financial benefits of directional felling derived from increased log recovery, reduced breakage and decreased yarding costs are often shared by logging contractors and workers;
- Training costs could be borne by fellers, contractors, forest owners or outside agencies such as NGOs;
- Benefits of training in directional felling accrue to fellers, timber harvesting companies, forest owners and the general public.

5.4 Skid Trail and Road Closure

The main aims of purposeful post-logging road closure, prohibiting vehicle access to logging areas, and stabilising skid trails and landings after completion of harvesting operations, are to minimise erosion and facilitate forest regeneration. The

Box 6. A Silvicultural Paradox: Benefits of Increasing (Some) Impacts of Logging in Bolivia

Regeneration of many light-demanding tropical timber species is promoted by opening the canopy substantially and exposing mineral soil. Paradoxically, avoiding the creation of large clearings and minimising soil disturbances are explicit and important goals of many sets of RIL guidelines. Where light-demanding timber species are being harvested, and sustaining timber yields of the same species is a goal of management, care is warranted when developing RIL guidelines that are appropriate for local conditions (Fredericksen and Putz 2003, Fredericksen *et al*. 2003, Putz *et al*. in press).

Many commercial timber species in the dry and moist forests of Bolivia, including the most valuable (*Swietenia* sp., *Cedrela* sp., and *Amburana* sp.), regenerate best in severely disturbed areas (Pinard *et al*. 1999). Because logging intensities in Bolivia are typically very low (1–3 trees/ha or 1–5 m^3/ha), and most logging operations are carried out with rubber-tyred skidders on fairly level terrain during the pronounced dry season, stand damage caused by even the most destructive commercial logging operations is seldom sufficient to provide the conditions required to secure regeneration of the harvested species. Even worse, the logging damage that does occur often promotes development of vine tangles rather than stimulating commercial tree regeneration. And finally, widespread wildfires, which are presumably promoted by logging, can result in severe stand degeneration. The silvicultural challenge is therefore how to promote regeneration of light-demanding commercial timber trees without exacerbating these other environmental problems.

logging contractor is typically responsible for installing diversion drains on roads and skid trails, erecting physical barriers to stop road access by vehicles, removing temporary stream crossings, and stabilising log landings through ripping compacted soil, installing drains, and planting cover crops.

5.4.1 Benefits of Skid Trail and Road Closure

The main benefits from draining and closing skid trails and roads following harvesting are:

- Stabilising the surfaces of the skid trails and roads to reduce erosion;
- Improving natural regeneration of the bare soil areas by reducing soil movement;
- Reducing the incidence of timber and wildlife poaching;
- Reducing the likelihood of forest ignition by people;
- Reducing the time taken for forest recovery, which favours both biodiversity conservation and future production.

5.4.2 Issues That May Influence Adoption

The timber harvesting contractor is the main contributor to this activity and incurs most of the costs apart from some supervision and monitoring, which may be borne by the forest owners or the government. Consequently, efforts to increase adoption of road and skid trail closure operations should focus on the firm, individual or community responsible for carrying out the closure activities. Some of the issues that influence the adoption of these activities are:

- Availability of direct financial compensation for costs associated with closure operations;
- Costs of closure operations relative to timber revenues;
- Appropriateness of mandated closure operations to local conditions. For example, local people may object to bridge removal if it reduces access to their community;
- Anticipation of forest closure requirements during forest harvest planning. For example, if forest managers know that they will be required to remove bridges, they might design them to facilitate this operation;
- Use of compliance-motivating policies such as initially assigning small fines but increasing them if noncompliance continues;
- Inclusion of closure operations as part of the Harvesting Agreement.

5.4.3 Who Benefits from and Who Pays for Closing Skid Trails and Roads?

Two groups typically pay for forest closure operations:

- Timber harvesting contractors or concessionaires who do the work and pay for the machinery, operator time and associated overheads. The company also pays for training of operators and field staff to ensure compliance with the technical specifications of closure requirements;
- Forest owners who pay to monitor compliance with closure regulations.

The major beneficiaries of forest closure are:

- Forest owners who obtain the benefits of having bare soil surfaces stabilised, which helps to ensure future production;
- Forest owners who benefit from reduced illegal logging and hunting;
- Society members who live off-site benefit from the effects of reduced soil erosion, reduced sedimentation and minimisation of hydrological changes that might otherwise result in property damage or even loss of life;
- Governments that gain considerable cost savings from these practices, with improved longevity of dams and a secured supply of clean water;
- The public, who derive health benefits from reduced mosquito breeding in ponds above collapsed culverts and bridges;
- Stakeholders who derive all or part of their livelihood from the forests and or the rivers that flow through them benefit directly from reduced environmental damage from harvesting.

6 Variation in Costs and Benefits of Implementing RIL Among Different Forest Types

The costs and benefits of improved harvesting practices relative to conventional logging are determined by which RIL components are required and how much they cost, which varies by forest type. Many components of RIL are essential in almost all forest types and in harvesting operations of all sizes. In contrast, the importance of other RIL components varies with forest type and harvesting system.

6.1 Forest Type-Dependent Factors

Some of the components and activities associated with improved harvesting practices that vary with forest type and conditions include:

- Harvesting intensity, which is related more to the silvicultural regime applied than harvesting practices and greatly influences logging damage. The higher the harvesting intensity, the greater the disturbance to the soil and residual stand and hence the greater the need to implement harvesting practices that are designed to meet the silvicultural requirements of the residual stand. These standards may include specifying the number of trees to be felled in a clump, the density of landings and skid trails, and sequencing of harvesting activities and areas to be harvested. It is critical to note that if the silviculturally appropriate intensity of harvesting is exceeded, even strict adherence to RIL guidelines will not assure sustainable forest management (Sist *et al*. 2003).
- Forest characteristics, in particular topography, greatly influence the importance and cost of a number of RIL activities. Where forests occupy steep slopes, better planning and construction of roads, skid trails and landings can significantly reduce the negative impacts of timber harvesting. In contrast, in areas where the topography is relatively flat, with few streams, the planning of roads and skid trails and improved standards of construction to minimise earthworks and stream crossings are far less important. Under these conditions, roads and skid trails can even be arranged in regular grids. For example, in areas such as the Miombo woodlands of Africa, where harvestable trees tend to be scattered in flat, open forest and where logs are hauled on trailers or by small, rubber-tyred tractors, improving the quality of skid trail planning and construction is not of much concern.
- Seasonality of rainfall influences implementation of the different harvesting components. Many RIL guidelines include prohibitions on ground-based yarding when the soil in the forest is wet and during periods of rain. Where logging is carried out only during the dry season, some RIL components related to wet-weather shutdowns become irrelevant.
- Soil compaction is of less concern where timber harvesting occurs on well-drained soils during the dry season.
- Regeneration requirements incorporated into silvicultural prescriptions should be supported by the appropriate harvesting practices. For example, reducing the impact of timber harvesting by minimising gap size will benefit forests with commercial species that regenerate in small gaps, but not forests managed for more light-demanding species that require larger gaps and exposed mineral soil for regeneration. It is therefore important to understand the silvicultural requirements of the species for which the forest is being managed before setting RIL specifications.

6.2 Forest Type-Independent Factors

Most of the components outlined in generic codes of harvesting practice (e.g., Dykstra and Heinrich 1996, Asia-Pacific Forestry Commission 1999) are intended to be guiding principles and, as such, are mostly relatively independent of forest conditions, the institutions involved in timber harvesting and the species harvested. Some of the components and activities that are little influenced by forest type include the following:

- Training is universally necessary for the adoption and implementation of improved harvesting practices. Training and awareness raising are required for senior management, middle-level management, and field supervisors and operators (Asia-Pacific Forestry Commission 2000). While the types of training differ for each group, it is imperative that all stakeholders involved understand the need for improved forest harvesting practices, which activities are appropriate for their forests, their relative costs and benefits, and the beneficiaries of improved practices.
- Harvest planning is required for all harvesting operations. Plans should include information on the inventory of the growing stock, species to be harvested and areas to be harvested, as well as the network of roads and skid trails to be built and the locations of stream crossings and log landings.
- Exclusion Zones, which are areas where harvesting is prohibited due to excessive steepness, susceptibility to erosion, or biodiversity conservation, are required in most forest types.
- Recommended harvesting practices that do not vary with forest type include tree marking (including the direction of fall), sound felling techniques (to ensure low stump heights and to reduce waste from breakage and poor crosscutting), and avoidance of damage to potential crop trees. In open forests and woodlands where crop trees are less dense, directional felling is still required to facilitate extraction. Techniques that minimise soil disturbance are also important, irrespective of forest type, and involve improved roading and skid trail design and layout, watercourse crossings, and log landing size, location, and use.
- Worker health and safety, as well as camp hygiene, are important for society and forestry personnel in all forest harvesting operations. For example, correct handling of fuels and disposal of unwanted material from machinery workshops and log landings is important for reducing pollution and other deleterious environmental impacts.
- Post-harvesting operations involving closure of skid trails, log landings and roads, along with camp site restoration, are essential for reducing the adverse impacts of harvesting.
- Supervision, monitoring and regular evaluation are important for maintaining and improving standards as well as for providing a mechanism for identifying training needs.

7 Conclusions and Recommendations

The capacity to determine the actual costs, to logging contractors, forest workers, forest owners, and society at large, of implementing or failing to implement improved harvesting practices, is a critical prerequisite for improving forest harvesting practices. Use of RILSIM facilitates the calculations of the financial costs of harvesting operations, but detailed and reliable data are needed on each of the component activities. Such data, when available, will allow any interested party to evaluate the costs of implementing changes in harvesting practices, including major changes in equipment and worker deployment as well as minor changes in sequencing of activities. Some improved practices are likely to be adopted out of enlightened self-interest whereas the adoption of others will require policy change and enforcement. Researchers and decision makers need to recognise that the applicability of different RIL techniques varies with forest conditions, management structures, and silvicultural goals. Understanding this variation is necessary for identifying the impediments to adoption of better timber harvesting practices.

Given that RIL guidelines are presumably being followed in the substantial forest areas certified as well-managed by the Forest Stewardship Council, it seems reasonable for researchers to start treating entire logging areas as replicates in large-scale comparisons. Admittedly, when working at such scales, some experimental control of extraneous variables is sacrificed. However, researchers need to address what Francis Crome (1996) called 'wicked real problems instead of tame toy problems, the former being large, complex, and multidimensional whereas the latter are simple, small, well-structured, and controllable.'

Efforts at reconciling differences among forest owners, logging contractors, forest workers, neighbouring communities, and society at large will be enhanced if it is recognized that the costs and benefits of using improved forest harvesting techniques vary among stakeholders. As deforestation and forest degradation due to poor management practices continue in the tropics, this reconciliation becomes ever more critical.

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Appendix I. Some Recent and Ongoing Projects for Improving Harvesting Practices in The Tropics

Project Name	Description	Products	Findings/Lessons	Comments
Vanuatu Sustainable Forest Utilisation Project and the Vanuatu Department of Forestry Director of Forestry Department of Forestry, Vanuatu	Improved forest management through: • RIL Guidelines for Vanuatu • Vanuatu Code of Logging Practice (COLP) • Training for COLP • Trainer-training for COLP • Policy and legislation for COLP • Improved timber utilisation • Landowner awareness raising • Improved silvicultural regimes • Demonstration and training forest	• Over 100 internal project reports and training manuals, policy documents, COLP, RIL guidelines and silvicultural regimes for Vanuatu. • Demonstration and Training Forest developed 1 hour's drive from Port Vila	• RIL and COLP development is practical • Training is possible for all stakeholders in COLP and RIL • Legislation to support COLP is possible • COLP is being practised	Vanuatu is a small timber-producing country and is therefore ideal for the development of systems for COLP implementation as models for other places in Melanesia and Asia.
Forest Trees Program (SPC) South Pacific Island countries Mr Kanawi Pouri kanawio@spc.int Pacific Island Countries/SPC/AusAID	Strengthen national capabilities in Pacific Island countries and assist with development of forest resources on sound and sustainable basis to enhance quality of life	• Numerous project reports • Training reports on COLP • Trainer-training reports • Quarterly newsletter	• Training is successful on a regional basis for training of trainers in COLP and RIL.	Regional training on common subject matter is very efficient. Training of trainers is also cost-effective on a regional basis.

Appendix I. Continued

Project Name	Description	Products	Findings/Lessons	Comments
Forest Management Information System Sarawak (FOMISS) Sarawak Forest Department, Kuching Samling Strategic Corporation Sdn.Bhd, Miri	To develop a Sustainable Forest Management System (SFMS) and implement RIL on 2000 ha of forest.	• Project reports • Demonstrations of reduced- impact logging activities. • Timber harvesting costs	• Economic incentives required • Training of field staff (felling, winching) • RIL is beneficial in reducing negative environmental impacts • RIL requires involvement of all players • Incentives required at government and private sector levels • RIL needs to be backed by overall SFM approach with monitoring and evaluation of impacts including economic and financial impacts in the long and short terms to promote adoption	Project commenced in 1996. Many outcomes reported with 2000 ha of forest logged under reduced-impact logging. Payment system for logging team is important for RIL implementation. Payment now based on productivity – not conducive to RIL.
Sustainable Forest Management Project (SFMP Samarinda) P.T. Limbang Ganeca, Kanwil DepHutBun Samarinda	Implementation of specific RIL components: inventory, planning, felling, skidding, closing-up, control/block inspection wages (incentives)	• Model forest for SFM implementation • Comparative study: RIL vs. CL • Developed guidelines for topo survey • RIL Tractor Logging p73 and SFMP No. 1 • Timber Cruising SFMP No.16 • RIL practical Guideline SFMP No. 10 • Timber harvesting cost studies	• RIL not difficult at planning and operator level • RIL requires intensive control • RIL needs financial incentives • RIL skidding is lower productivity, but planning makes it more efficient • RIL is not linked to TPTI in field • RIL is key indicator for LEI-FSC • RIL is important for certification	Need to gather relevant information and from various regions in the tropics and analyse why RIL is not standard procedure.

Appendix I. Continued

Project Name	Description	Products	Findings/Lessons	Comments
Sustainable Forest Management on private lands in the Wet Tropics of North Queensland, Australia Queensland Forest Research Institute, Australia	Conservation of native forests on private lands, by implementing sustainable forest management practices, including timber harvesting while maintaining other forest values. Need for RIL and other practices to be applied to private tropical forests	• Proposal based on NQ Sustainable Forest Management System for tropical forests • Results of numerous RIL studies • Growth and yield information based on a large number of permanent sample plots	• Incentives rather than legislative regulation are more practical for management	Demonstration forest in NQ for tropical countries developed by Grahame Applegate and Mark Annandale Proposal discussed with Government of Australia and state government in Queensland
North West Guyana Sustainable Timber Production Programme Barama Company Ltd Edinburgh Centre for Tropical Forests Government of Guyana	Sustaining the forest whilst selectively harvesting a major natural resource for the benefit of the company, people and Government of Guyana through a programme of research and monitoring	• Written reports, unpublished and published (available on request) • RIL research results • Inglis *et al*. (1996)	• Improved skid trail construction is efficient • RIL skilled staff is difficult to find and retain - incentives part of the solution • Need for monitoring, training and supervision for RIL to work • Need to address all RIL components, not just cutting and skidding • Wood waste and skid trail design are important issues	
Iwokrama Director PO Box 10830, Georgetown Guyana	To develop partnerships required for the sustained production of a wide range of goods and services with high standards of environmental stewardship and social responsibility The sustainable management of tropical rainforests aims to demonstrate how forests can be conserved, utilised, and yield economic and social benefits	• Road Management Plan • Zoning Plan for Wilderness Reserve and Sustainable Utilisation Area • Greenheart distribution model using topographical and multivariate analysis • Spatial and temporal biomass comparisons of different forest types	• Iwokrama's governance is international so it focuses on all forest values and follows an integrated approach to conservation and development.	Iwokrama focuses on sustainable development and demonstrates how rainforest ecosystems can be conserved while contributing to local and national development

Appendix I. Continued

Project Name	Description	Products	Findings/Lessons	Comments
Management of Miombo Woodlands CIFOR, Harare, Zimbabwe Professor W.S. Abeli Sokoine University of Agriculture Morogoro, Tanzania	To assess the productivity of conventional harvesting methods, production of residues and environmental impact of harvesting in woodland. To develop strategies for the improved harvesting practices and management of the timber/ wood component of the woodlands in Tanzania and Zambia.	• Draft report on appropriate timber harvesting practices for Miombo woodlands in Tanzania and Zambia • Tree productivity and biodiversity of a communal Miombo woodland in Handeni District, Tanzania.	• Strengthened links between the Sokoine University of Agriculture and Copperbelt University in Zambia	Preliminary results from the harvesting impact studies are available. This is a unique opportunity to investigate appropriate harvesting practices in woodland communities as most studies are undertaken in the high tropical moist forests in Africa, Asia and Latin America.
Tropical Forest Foundation (TFF) Indonesia Manggala Wanabakti, Blk IV 9th Floor, Jakarta, Indonesia	The Tropical Forest Foundation (TFF) is an international NGO with a mandate to promote reduced-impact logging through information dissemination, training and extension in Southeast Asia.	• Training course in RIL techniques • Manuals for RIL operations	• Corporate sector is the key to adoption of RIL • Lack of understanding in industry of benefits of RIL • Lack of training and education is a major impediment to adoption of RIL	Forest managers and forest companies must accept a greater responsibility for the achievement of improved forest management and the adoption of RIL
Innoprise Corporation Innoprise Corporation Sdn Bhd Kota Kinabalu, Sabah, Malaysia	The Innoprise Corporation, in association with the New England Power, developed and implemented reduced-impact logging guidelines on 2400 ha of dipterocarp-dominated forests in Sabah	• Reduced-Impact Logging Guidelines developed and applied over 40000 ha • Cost estimates of carbon retention from RIL • Financial assessment of RIL • Training for over 2000 workers implemented	• RIL reduces damage on soils and residual forest by 50% • RIL is more expensive than CL in hilly terrain • RIL reduces net loggable area, which is substantial in hilly terrain • Current mode of payment of forest workers an impediment to adoption of RIL	The Sabah site provides evidence that RIL can be operational, but also indicates where modifications may be required if RIL is to be readily adopted in very hilly terrain. Alternatives to ground-based timber harvesting operations may also need to be considered in very hilly terrain

Appendix I. Continued

Project Name	Description	Products	Findings/Lessons	Comments
Proyecto de Manejo Forestal Sostenible en Bolivia (BOLFOR) http://bolfor.chemonics.net/	BOLFOR is a multifaceted forest conservation and development project that includes research on and implementation of RIL as one of its components.	• Trained field crews in RIL techniques from 1994 • Established large-scale (27 ha) and replicated silvicultural treatment plots with different intensities of silvicultural treatments • Assisted in development of the technical standards for implementation of the 1996 Forest Law	• Coupled with new marketing strategies, many components of RIL are cost-effective • Loggers who are aware of the benefits of RIL adopt some of the components spontaneously (e.g., stock mapping and some vine cutting) • Various publications on RIL, SFM, and STY	BOLFOR will end in 2004 but most of the forestry-related activities will be continued by its counterpart organisations, including the Superintendencia Forestal and the Museo de Histora Natural Noel Kempff Mercado in Santa Cruz, Bolivia.
Fundacão Florestal Tropical (FFT) Brazil Johan Zweede Belem, Brazil	TFF and its Brazilian subsidiary Fundação Florestal Tropical (FFT) are becoming widely recognised for establishing demonstration models and training to show the advantages and teach the principles of sustainable forest management through RIL in Brazil.	• Trained large numbers of personnel in RIL techniques from 1995 • Established several 100 ha harvesting demonstration models • Training programmes on RIL • Training manuals on RIL	• RIL reduces damage to residual stand and soils • RIL creates fewer roads and skid trails, reduces soil disturbance and protects biodiversity • RIL is seen as an integral part of forest certification and may provide low-cost options for carbon sinks • Paper on 'Financial Costs and Benefits of Reduced Impact Logging in the Eastern Amazon'	The TFF has programmes being implemented in other parts of Latin America, namely Guyana S.A., as well as Indonesia, and there are plans to expand to Africa.

Appendix I. Continued

Project Name	Description	Products	Findings/Lessons	Comments
Malinau Research Forest Ministry of Forestry Indonesia and CIFOR	The Ministry of Forestry in Indonesia designated 321 000 ha of forest in East Kalimantan, Indonesia, for the Center for International Forestry Research (CIFOR) to be developed as a long-term model forest of exemplary research-based management. Research is designed to characterise the coordination and decision-making processes among stakeholders to determine sustainable use of the forests and to determine and implement sustainable forest management in the model forest area	• Analysis of logging damage comparison between CL and RIL. • Cost-benefit analysis of RIL • Biodiversity and geographical information for improved land use decisions; multidisciplinary landscape assessments • To provide a better knowledge of forest products and of forest people in the model forest area • Action research on negotiating conflict and community empowerment in forest areas; participatory mapping of the villages along the Malinau River, East Kalimantan • *Reduced Impact Logging Guidelines for Lowland and Hill Dipterocarp Forests in Indonesia*, which provided the minimum standards for the components of the RIL vs. CL experiments. • *Reduced Impact Guidelines for Indonesia*	• Comparative analysis of RIL vs. CL on 300 ha using sample plots. The results showed that RIL reduced the damage by 50% and that felling intensity of 7–9 trees per ha caused damage to the residual stand and soil and water resources at acceptable levels. • A comparative analysis of the economic and financial costs of selected components of RIL and CL found that a productivity increase in felling and skidding of 28% and 25% respectively was possible. RIL was less expensive than CL under these conditions. • Data produced from landscape assessments for land use planning and biodiversity assessment • Agro-economic survey was also completed in 5 villages, which showed the degree of dependency of different communities on forest products • Development of models to identify trends in forest dependence, how changes in forest condition might affect livelihoods • Adaptive co-management of forests action research on conflict resolution and community empowerment in the model forest area	The CIFOR commitment and research is ongoing. CIFOR welcomes scientists to collaborate with us in working in the Malinau Forest, East Kalimantan, Indonesia.