H

HARVESTING

Contents

Forest Operations in the Tropics, Reduced Impact Logging

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Introduction

In recent years considerable efforts have been made in introducing improved forest harvesting practices to tropical forests to support sustainable forest management. However, only a small proportion of forests in the tropics is actually being managed on a sustainable basis. Environmental groups and, increasingly, the general public have called for refined harvesting systems and techniques so as to utilize wisely forest resources, thereby maintaining biodiversity and keeping forest stands intact in order to provide forest goods and services for the present as well as for future generations. The application of reduced impact logging (RIL) systems and techniques seems to have gained increasing importance in meeting environmental challenges and providing economic and social benefits.

Forest Operations in the Tropics

In tropical countries, harvesting operations are fundamentally different from those applied in temperate zones. Stand densities in temperate forests are considerably higher than in the tropics, generating much higher potentials for commercial timber volumes per hectare. There is less diversity of tree species in temperate zones, and the utilization of commercial tree species permits simplified forest operations. Due to the application of both selective and clear-cutting as well as the higher standing timber volumes per hectare, harvesting densities in general greatly exceed those in the tropics. Directional felling is easier to carry out in temperate zones due to the usually smaller-sized trees and crowns; and soil conditions are better for skidding operations. In spite of varying seasons, climatic conditions allow the appropriate implementation of harvesting operations throughout the whole year.

In the tropics, forest operations are generally more complex to organize and implement than in temperate zones. Natural forests in the tropics are characterized by a higher abundance of different species with many diverse sizes of timber and ample stand densities with only a few species of commercial interest. The harvestable wood volumes per hectare vary considerably depending on the occurrence of commercial tree species. The situations that most often complicate harvesting operations are the following:

- large trees with large crowns
- low carrying capacity and high vulnerability of forest soils
- extensive variety of timber sizes
- high precipitation rates, which often contribute to soil erosion
- lack of forest road and skid trail infrastructure
- long transport distances on poorly paved roads due to scarcity of appropriate road construction material.

Preharvest Planning

The main objectives of preharvest planning are to optimize harvesting operations and to minimize

environmental impacts. A harvest plan should consist of a written description of the planned operation and a detailed topographic map of the harvesting operation area. Preharvest plans should also include information on harvestable tree species, as well as data on other factors to be taken into consideration in harvesting planning, such as soil and terrain conditions or existence of watercourses. Detailed information about specific working equipment and the workforce involved plus careful attention to the integration of local communities in the projected operation are additionally preconditions for well-planned harvesting operations.

Forest Road Engineering

The goal of forest road engineering is to provide reliable access to the forest for management purposes and for silvicultural and harvesting operations. It involves specifying design standards and field layout, followed by construction and maintenance of forest roads including setting of skid trails, location and layout of landings as well as constructing subsidiary structures, such as bridges and culverts.

Forest roads are unquestionably the most environmentally problematic feature of timber harvesting operations, since a major part of the total soil erosion can be attributed directly to them because of inadequate design and construction standards, as well as poor maintenance practices.

Tree Felling and Cutting

Tree felling and cutting includes all activities from felling the standing tree to its preparation into logs for wood extraction. These activities include the felling process itself, cutting off tree crowns and limbs, crosscutting stems into logs and sometimes debarking of logs.

In tropical regions, trees may be large and heavy with huge crowns and might be connected by strong vines to each other. They fall with a tremendous force which can uproot neighboring trees; and stems may shatter, bounce, and roll uncontrollably. Therefore felling operations are both the most hazardous part of harvesting operations for the labor force. They are also a major cause of damage to the forest stand and result in the generation of a large amount of wood waste.

Wood Extraction

Extraction of wood is the process of moving trees or logs from the felling site to a landing or roadside. Extraction practices can be distinguished by the system used and the harvesting equipment employed (**Table 1**). Regardless of the type of logging system used, extraction can inflict substantial damage on forest ecosystems.

In the tropics the most common method of wood extraction is the ground-skidding system. A conventional set of ground-skidding equipment consists of ground-dependent machines, which may consist of either crawler tractors, wheeled or tracked skidders, or a combination of them. They are generally equipped with winches.

The use of draft animals, such as elephants, oxen, horses, or water buffaloes, can be economically attractive, particularly in remote areas. They are often used by local communities in small-scale operations and in forest stands with smaller-sized trees.

Cable systems are a preferred method for wood extraction in hilly to steep terrain. With this method, logs are transported either partially (as in ground and high lead operations), where logs may drag on the ground causing soil disturbance, or fully suspended in the air (as in skyline operations). Ordinarily, the

Table 1 Advantages and disadvantages of different extraction systems

Extraction system	*Advantage*	*Disadvantage*
Ground skidding	Low cost extraction system	Tendency to cause the greatest environmental problems
	Short training requirement	
	Simple technology	High density of skid trails
		Limited by slope gradient and soil conditions
Draft animals	Low soil and stand damage	Limited extraction distances
	Extremely narrow skidding paths	Mostly limited to small timber sizes and small-scale operations
	Low investment and maintenance costs	
Cable	Low density of roads	High investment costs
	No skid trails	Laborious assembly and disassembly of the cable system
	Very low environmental impact when properly done	
Helicopter	High production rates	Very expensive
	Low density of forest roads	Thorough planning and precise organization needed
	Very low environmental impact	Extremely highly skilled team of workers needed
Manpower	Narrow skid trails	Hard and slow work
	Necessary equipment very simple	Limited extraction distances
	Cheap	

timber is transported by carriages which are moving on a cable. The power source – a winching machine, also called a yarder – is located either at the top or the lower station, depending on the type of system used.

Helicopter systems are the most productive as measured by cubic meters of timber produced per hour or day and yet are the most expensive wood extraction system. Helicopters are only used in difficult and steep terrain where high-value tree species are extracted and where intensive forest road development would be too expensive and not appropriate.

With the introduction of the crawler tractor, log skidding by manpower has almost disappeared in tropical Africa. However, it is still being used in Asia and in the Pacific region where it is called kuda-kuda. Short wooden wedges, driven into the sides of the log, give the men a hold to control and push the log lengthwise over wooden cross-skids. Skidding distances may exceed 1 km where there are no alternative methods of extraction.

Landing Operations

Work on landings include all activities in connection with sorting, storing, and preparing the extracted stems or logs for further transportation to the processing facility or any other final production destination. Landings are always connected to roads so as to provide access to the stored timber by transport vehicles.

Transport Operations

At present the most common form of log transport in the tropics is by means of logging trucks. In remote areas, however, often a combination of land and water transport is used: hauling timber from the landing to an embarkation point by trucks, where the journey is continued by water transport, using barges or rafts. In some rare cases, railways are an alternative means of transport.

Harvesting Intensity

Harvesting intensity is a decisive criterion that influences the degree of impact on forests. Generally the total standing timber volume may range from 50 to over 200 $m^3 ha^{-1}$ in the tropics. Harvesting intensity in tropical forests varies considerably between regions, countries, and even within countries. In Africa a low logging intensity forest operation is usually practiced with a mean extracted timber volume of 8–25 $m^3 ha^{-1}$. Medium and moderately high logging intensity operations as practiced in South America often reach 10–50 $m^3 ha^{-1}$ of harvested timber. In Asia and the Pacific region, logging intensity is higher than in the other two regions, reaching about 40–100 $m^3 ha^{-1}$.

Reduced Impact Logging

Definition of Reduced Impact Logging and Conventional Logging

Reduced impact logging (RIL) may be defined as an intensively planned and carefully controlled implementation of harvesting operations used in order to minimize impact on forest stands and soils, usually in cutting individually selected trees. In contrast to RIL, conventional logging systems are carried out without much concern about possible environmental impacts to the forest stand and soils and the sustainable utilization of forest products and services.

The aim of RIL is to introduce environmentally sound forest operations and to avoid negative impacts that could occur in conventional logging systems. Besides following the forest operation suggestions described above, other improvements can be obtained by applying RIL techniques in order to decrease impacts and increase benefits. The main characteristics of RIL are shown in **Table 2** and described below.

The idea behind RIL is not a new one. It is actually a collection of environmentally sound forest practices already used in some temperate and tropical forests. Techniques such as preharvest inventory, worker training, directional felling, prescribed skidding or advanced road construction are well-established practices in a number of countries. Additional practices specific to tropical forests are, for example, mapping of individual crop trees and preharvest cutting of vines.

Stand Entries at Predetermined Cutting Cycle

In order to provide sufficient time for the regeneration of remaining forest stands and to guarantee a sufficient amount of timber for future harvesting operations, a predetermined cutting cycle for stand entries should be defined and observed. This is a

Table 2 Main characteristics of reduced impact logging techniques

Stand entries at predetermined cutting cycle
Worker and supervisor training
Safety regulations
Favorable working conditions
Preharvest operational inventory, including tree marking and location mapping of potential crop trees
Vine cutting when required
Advanced road construction
Minimize extraction trails
Directional felling
Maximum utilization of all trees felled
Landings planned
Damage to residual stand minimized
Postharvest assessment
Rehabilitation of sites of negative impacts

major aim of sustainable forest management. A minimum interval has to be determined by silviculturists based on knowledge of local growth rates and an assessment of the degree of damage caused to the residual stand by the harvesting operation.

Worker and Supervisor Training

Forest workers are in many cases underpaid and poorly skilled. This fact results in negative environmental impacts and economic losses. Forest companies often involve local communities in the workforce for harvesting operations, because they are the only available workers in remote forest areas.

The implementation of training programs for logging and supervisory personnel at all levels is essential to improve the working conditions. Perhaps the lack of skilled workers is one of the main reasons why a successful application of RIL in tropical forests has failed to materialize on a large scale so far.

Safety Regulations

Training programs for workers, protective clothing, and properly serviced equipment contribute to significantly improved labor safety and health conditions. Safety has tended to be neglected due to economic difficulties. Accidents occur mainly during the felling process. Often, forest management does not know the real costs of accidents: many of the indirect costs resulting from inadequate safety regulations are difficult to determine, but they can be up to six times higher than the direct costs.

Favorable Working Conditions

Environmentally sound forest operations can only be carried out under favorable weather and soil conditions. Wet soils and heavy rainfall considerably hamper the use of ground-dependent machinery, and cause substantial soil disturbance and compaction. Preharvest plans need to consider alternative systems, should forest operations be hampered by weather, soil, and terrain conditions in a specific area.

Preharvest Operational Inventory

A preharvest operational inventory should estimate the timber volume and its distribution over the forest production unit as well as the number and the condition of potential crop trees. In tropical forests identification, marking, and mapping of each individual crop tree is essential to ensure efficient location of crop trees so as to increase the productivity of harvesting operations and to protect potential future crop trees.

Vine Cutting

Vine cutting, when required and properly implemented, can be an effective measure for improving the safety of the workforce during felling and for reducing crown damage to remaining trees. It generally should be done far enough in advance of felling to ensure that the vines have died and fully decomposed. Otherwise, safety may be compromised by vine cutting that has not been properly carried out.

Advanced Road Construction

The objective of advanced road construction is to minimize the clearing width, while at the same time ensuring that the width is adequate to permit the expected traffic to operate safely. In areas of high precipitation it is common to clear an area of forest alongside the road to allow sunlight to penetrate so that it can dry out the road surface after rainfall. The amount of roadside clearing can be reduced if appropriate drainage systems are used and properly maintained.

Minimizing Extraction Trails

In conventional skidding operations, uncontrolled driving to each harvestable tree or log due to the lack of skid trails can cause substantial soil disturbance and compaction. A system of skid trails, predetermined in the planning phase, should be adopted to minimize soil compaction by forest machines. Tracked and wheeled wood-extraction machines should stay on those skid trails. When using wheeled skidders the use of low-pressure and high-flotation tires further helps to minimize soil compaction.

Directional Felling

Directional felling is a specific tree-felling technique in which the direction of fall is determined by the operator prior to cutting. Where possible, trees should be felled in the direction of existing canopy gaps in order to reduce damage to nearby standing timber. In general, trees should be felled either towards or away from skid trails, preferably at an oblique angle to the skidding direction. Felling away from the skid trail will reduce problems for the extraction crew when tree crowns are large, whereas felling towards the skid trail can reduce the extraction distance substantially.

Maximum Utilization of Trees Felled

Most of the logging waste in forest operations occurs in both felling and cutting operations; some also occurs in skidding operations. Appropriate felling and cutting techniques include directional felling, cutting stumps low to the ground, and optimal

crosscutting of stems into logs. Following RIL practices, such as mapping of felled trees and controlled skidding, wood waste due to lost logs very seldom occurs in skidding operations.

Landings

The location and design of landings should be done at the same time as road location and design. In many places, a small clearing at the side of the road is used for the landing rather than creating an entire landing structure.

Postharvest Assessment

Postharvest assessments can serve as an operational feedback for forest managers, technicians, and workers to determine the degree to which the objectives of RIL guidelines have been achieved, and to obtain information on how to improve forest operations in future. These include evaluation of stand and soil damages, as well as an assessment of costs and productivity of harvesting operations.

Minimizing Damage to the Residual Stand

Impacts on soil and forest stands arise inevitably from the use of heavy-duty machinery in forest operations. By following RIL practices and through proper implementation of harvesting operations, such damages can be minimized, thus leaving residual stands in better condition regarding future forest operations.

Rehabilitating Forests after Negative Impacts

Observation of the operating areas disturbed by roads, landings and skid trails, and also of the degree of soil disturbance, will provide an indication of whether rehabilitation is needed. If necessary, the areas with exposed soil should be revegetated with grass or other ground cover to prevent soil erosion. When harvesting only a few tree species, enrichment planting is often needed to guarantee diversity of species.

Benefits of RIL

Although a considerable number of studies on environmental impact assessment have already been carried out in tropical forests, many authorities have called for more comprehensive knowledge and information on the environmental, social, and economic benefits of forest operations. Unquestionably it has been proved that RIL significantly reduces damages to the remaining stand, soil, and watercourses. It has also been shown that RIL increases profitability on a larger scale, and considerably improves efficiency, recovery rates of timber, and safety standards for workers. Since higher recovery rates of felled timber generally can be achieved in RIL as compared to conventional logging systems, smaller areas of natural forest are subsequently affected by harvesting operations while at the same time the same amount of timber is recovered (**Table 3**).

RIL reduces the percentage of wood waste, thus increasing productivity and the economic return of operations. Minimized road length subsequently lowers maintenance and transportation costs, and contributes to a reduction in harvesting operation expenses, thus increasing financial benefits. Moreover, RIL has less impact on the residual stand and site, which enhances regeneration, allowing earlier re-entries with higher recovery rates in wood volume in m^3 in second cuts. However, overall costs for forest operations increase due to the expensive and comprehensive planning activities, which cost less in conventional logging systems. Overall, it is assumed that RIL practices are generally worthwhile (**Table 3**), but concerning specific financial benefits, the evidence of RIL experts is inconclusive.

Future Outlook

At present RIL is used by only a small number of forest companies and operators in the natural forests

Table 3 Mean values for various parameters in conventional and reduced impact logging systems obtained from examples in the scientific literature from the last 30 years

Parameter	*Unit*	*Conventional logging*	*Reduced impact logging*
Logging intensity	$m^3\,ha^{-1}$	45	37
Logging intensity	$trees\,ha^{-1}$	8	8
Logging cycle	years	35	34
Costs			
Planning	$US\,m^{-3}$	1.44	1.72
Felling	$US\,m^{-3}$	0.60	1.16
Skidding	$US\,m^{-3}$	4.64	4.46
Damage			
Residual stand	% of residuals	49	29
Stand	trees/trees felled	22	9
Site	% of area	18	8
Canopy opening	% of area	25	16
Lost timber	% of removals	25	15
Utilization rate	% of felled timber	47	60

Source: Data compiled from ITTO (2001) *Tropical Forest Update*. http://www.itto.or.jp/newsletter/Newsletter.html and Killmann W, Bull GQ, Pulkki R, and Schwab O (2001) Does it cost or does it pay? *Tropical Forest Update* 11(2): http://www.itto.or.jp/newsletter/vlln2/index.html

in the tropics. There are still many unknown aspects concerning RIL, and the major obstacle to the implementation of RIL is the common lack of knowledge about its benefits. The belief that RIL is more expensive is one of these obstacles.

Despite the research, data collection, and field studies that have been done so far, more effort needs to be dedicated to emphasizing the importance of RIL. Forest managers have expressed the need for research on a larger scale so as to provide reliable information concerning the benefits of RIL, especially the financial benefits. Comparative studies on RIL and conventional harvesting systems are necessary in order to acquire adequate data that would demonstrate, with examples, to forest companies and logging operators the numerous advantages of RIL. Consequent implementation of training programs for forest personnel at all levels and the availability of technical assistance are additional inducements for spreading the acceptance of RIL.

Through the application of RIL techniques, at least one source of negative impact on tropical forests from logging pressures could be partly reduced. Sustainable tropical forest management has to secure the existence and the continuity of the tropical forest ecosystems. RIL is a very important contribution to this end.

See also: **Environment**: Environmental Impacts. **Harvesting**: Forest Operations under Mountainous Conditions; Roading and Transport Operations. **Operations**: Logistics in Forest Operations. **Plantation Silviculture**: Sustainability of Forest Plantations. **Silviculture**: Natural Stand Regeneration. **Sustainable Forest Management**: Overview.

Further Reading

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Harvesting of Thinnings

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Introduction

When thinning a forest, loggers operate under such peculiar conditions that special techniques and equipment are required. In principle, thinning teams face two main constraints: the low value of the harvest and the permanence of a residual stand that hinders machine movements. Of course, the impact of these factors largely depends on thinning type. The first thinning is most critical, because it yields very small trees and releases the densest residual stand. In contrast, the second and third thinnings are somewhat easier to implement: harvest trees are larger and may yield valuable products, while the residual stand is not excessively dense and offers more space for maneuvering. In fact, one often speaks of commercial thinning and precommercial thinning, according to whether the operation is sustainable from a commercial viewpoint or not. In precommercial thinning, the value of the harvest does not cover the overall harvesting cost, and the operation configures as a subsidized activity, performed with the aim of increasing future profit and improving forest stability. The first thinning is more likely to be conducted on a precommercial basis, whereas later thinning can offer some profit. At any rate, such profit is much inferior to that obtained from the final harvest, because the value of the harvest is lower and the harvesting cost higher – often twice as high.

Good Reasons for Thinning

Why thinning, then? There are several reasons. First, appropriate thinning allows released trees to grow healthier and larger than if they were left to compete with the removed trees, which increases the value of