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REDUCED IMPACT LOGGING IN TROPICAL FORESTS

Literature synthesis, analysis and prototype statistical framework

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This paper is one of a series of working papers on forest harvesting and engineering produced by FAO's Forest Harvesting and Engineering Programme. The purpose of these working documents is to provide early information on on-going activities and programmes – and to stimulate discussion.

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FOREST HARVESTING AND ENGINEERING PROGRAMME

REDUCED IMPACT LOGGING IN TROPICAL FORESTS

Literature synthesis, analysis and prototype statistical framework

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 2004

FOREWORD

Forests provide multiple products and services, with the potential to contribute to employment and income generation. It is important for countries to increase the value and sustainable use of forest goods and services in harmony with national resource conservation and environmental protection goals. This calls for the use of environmentally sound harvesting, engineering and processing methods and appropriate trade and marketing strategies.

The use of reduced impact logging (RIL) is becoming more and more widespread in tropical regions, and there is an urgent need for careful assessment of its impact. In addition, the costs of each logging phase and the costs for road construction or other development are not well documented or modelled for application to general conditions.

For these reasons, governments are now imposing stricter regulations on forest harvesting and wood markets, and are insisting on responsible harvesting practices as can be seen, for example, in the growth of demand for certified wood products. Given the political and market demands for change, the nature of RIL needs to be more clearly defined. Some important questions must be addressed, such as: What have harvesting studies, so far carried out, been telling us and, perhaps even more important, what have these studies not told us? What should researchers do to continue promoting or not promoting reduced impact logging? Finally, does RIL cost or does it pay?

To address all these questions, the present Working Paper No. 1 of the Forest Products Service has been prepared, based on a review of articles dealing with logging intensities, logging cycles and waste, residual stand and site damage and the economics of forest operations. The initial review on logging impacts, conducted in 1997 for the FAO Global Fibre Supply Model (Pulkki, 1997) was updated in 2000, and again in 2003. It now contains over 300 entries.

In Appendix 1 of the Working Paper, a variety of definitions of RIL are collected. Appendix 2 includes tabular summaries on location, descriptive information, logging intensity and cycle, residual density and utilization, site damage, economic aspects and the source of the information. A summary of each report reviewed can be found in Appendix 3.

There are still serious data deficiencies with regard to planning and inventory, and there is a serious lack of standardization in data collection. Therefore, readers are invited to send their inputs to Forest-Harvesting@fao.org and participate in the future development of a forest harvesting information system. It is hoped that this study will contribute to the ongoing worldwide dialogue on reduced impact logging.

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1. INTRODUCTION

There has been an increasing interest in reduced impact logging (RIL), particularly in tropical forests over the last decade. A number of developments have led to the concept of RIL: a political focus on sustainable development at the highest levels, a general consensus about the necessity to manage forests more sustainably, and recognition that better technology is now available to monitor harvesting practices and forest conditions. There is a general desire to reduce negative environmental impacts all the way down to the operational level. It is also generally recognized that many conventional logging systems will not continue to produce sustainable yields of the same volume and/or quality of timber, particularly in non-coniferous tropical forests (NCTF). For these reasons governments are now imposing stricter regulations on forest harvesting and wood markets, and demanding more responsible harvesting practices. The demand for certified wood products has continued to grow. Given the political and market demand for change, there is a commensurate desire to further articulate the nature of RIL.

The objectives of the paper are to:

- Provide a definition and characteristics of RIL;
- Summarize a review of existing literature on logging intensities, residual stand and site damage, and wood waste associated with conventional logging (CL) and RIL;
- Present basic terminology related to logging methodologies;
- Provide a tabular summary of bibliographic material by country and source and;
- Generate an annotated bibliography covering the existing literature on logging systems in NCTF.

2. REDUCED IMPACT LOGGING (RIL)

In most cases, non-coniferous tropical forests (NCTF) are managed under polycyclic silvicultural systems. Unfortunately, selective cutting (i.e., high grading) and not `true' selection cutting is most often practiced. According to Johns (1992), the most effective management of most tropical forests entails the protection and encouragement of advanced growth in optimally sized canopy gaps created during logging, with planting of gaps where no advanced growth exists. Critical for the sustained management of these forests is the implementation of reduced impact logging (RIL) techniques (Nicholson 1965, Putz 1994, ISTF 1995, Marsh *et al*. 1996, Weidelt 1996, Stokes *et al*. 1997). Palmer and Synnott (1992) state; "*while the merits of various forest management systems are being debated, tropical silviculturalists are of one voice in advocating the use of RIL techniques*."

Various authors (Armstrong and Inglis 2000; Dykstra and Heinrich (1996), Elias 2000, Van der Hout 1999, Reid and Rice 1997, Ruslim *et al*. 1999, Sist *et al*. 1998, Sist 2000, Vanuatu Department of Forests 1999, Webb 1997) have proposed definitions or aspects of reduced impact logging. They are fully described in Appendix 1. Summarizing the work of these authors, RIL is defined as:

`*Intensively planned and carefully controlled implementation of harvesting operations to minimise the impact on forest stands and soils, usually in individual tree selection cutting.'*

RIL is generally characterized by having stand entries only at a predetermined cutting cycle, which generally should be no shorter than 20 years. No more than one-third of the basal area should be removed at one entry and a pre-harvest operational inventory is strongly recommended. Access road construction should be done well in advance of harvesting, and climber cutting, if required, should be done up to two years before harvest. Planning should consist of tree marking, location mapping and planned felling direction, and this should be linked with the layout of a minimal number of extraction trails. Once the logs are removed, they should be placed on landings of minimal size. The logging operations should only be conducted under favourable conditions (e.g. when soils are dry). The forest workers and supervisors should be well trained so that they can ensure minimal negative impacts on the site; maximum utilization of the trees felled; minimum damage to residual trees and advanced regeneration; and rehabilitation of negative impacts that may have occurred on the site. Finally they should be well qualified to conduct a post-harvest assessment.

RIL generally includes, but is not limited to, the following:

- Pre-harvest inventory and mapping of individual crop trees;
- Pre-harvest planning of roads, skid trails, and landings to provide access to the harvest area and to the individual trees scheduled for harvest while minimizing soil disturbance and protecting streams and waterways with appropriate crossings;
- Pre-harvest liana cutting in areas where lianas inter-connect tree crowns;
- The use of appropriate felling and bucking techniques, including controlled felling;
- Construction of roads, landings and skid trails that adhere to engineering and environmental design guidelines;
- Winching of logs to planned skid trails and ensuring that skidding machines remain on the skid trails at all times;

- Conducting a post harvest assessment in order to provide feedback to the concession holder and logging crews and to evaluate the degree to which RIL guidelines were successfully applied.

RIL techniques are not difficult to implement. At the operational scale, the savings due to more efficient operations (when compared to conventional logging practices) will generally offset any additional costs in planning, layout and control, and make it at least cost neutral (Andel 1978, Mattsson-Marn and Jonkers 1981, Tabudar 1984, DeBonis 1986, Hendrison 1989, Pinard *et al*. 1995, Sayer *et al*. 1995, Bruenig 1996, Moura-Costa 1997). However, the implementation of RIL has been sporadic in practice and sustainable management of tropical forests is rare (FAO 1989a, Buenaflor 1990, Jonsson and Lindgren 1990, Tuomela *et al*. 1996). Where RIL techniques are not implemented, the volumes extracted in second and third cuts will be much reduced from those of the first cut. This is reflected in the logging intensities from natural (previously unlogged) and semi-natural (previously logged) forests (FAO 1997).

3. SUMMARY OF EXISTING LITERATURE

A total of 345 studies and articles on reduced impact logging or conventional logging conducted in closed broad-leaved tropical forests and published since 1950 were reviewed and classified in this paper. The majority of these studies were published in the last decade, but were not presented according to a standardized system. In the 1970s, the number of publications on conventional logging (CL) increased rapidly whereas RIL was covered in only few publications prior to 1980.

3.1 Logging Intensity and Stand & Site Damage

Minimizing the damage to the residual trees and advance regeneration during logging is essential for the success of all polycyclic silvicultural systems. In practice though, very little consideration is given to this. Referring to Appendix 2, it is quite apparent that damage to the residual stand in conventional logging operations is excessive. Damage to residual trees ranges from 33-70% in areas with higher (e.g. >30 m^3/ha) logging intensities (Nicholson 1958b, Fox 1968, Burgess 1971, Tinal and Palenewen 1978, Abdulhadi *et al*. 1981, Masson 1983, Yeom 1984, Korsgaard 1985, Ayres and Johns 1987, Uhl and Viera 1989, Pinard *et al*. 1995, Dykstra *et al*. 1996, Elias 1996, Greiser-Johns 1996, Berthalt and Sist 1997). In areas with lower logging intensities (e.g. in Africa with removal of 1-2 trees/ha), residual stand damage generally ranges from 10-20% (Ola-Adams 1987, White 1994, Cordero and Howard 1996, Scharpenberg 1997). However, tree damage does not increase in direct proportion to felling intensity (Verissimo *et al*. 1987). Levels of damage typical of conventional logging operations are unacceptably high.

Implementation of RIL has resulted in the reduction of residual tree damage from 50-200% (Mattsson-Marn and Jonkers 1981, Bote 1983, Reyes 1983, Malvas 1987b, Buenaflor 1989, Hendrison 1989, Johns *et al*. 1996, Berthault and Sist 1997, Moura-Costa 1997). With the implementation of RIL techniques, logging intensities can be significantly increased and still result in less damage to residuals. For example, Buenaflor (1989) found 67% of residuals damaged in uncontrolled logging with 23 m^3/ha removed, while in a controlled logging area 22% of residuals were damaged with 32 m^3/ha removed.

Some damage will always occur with the felling of trees and it can be expected that with careful felling approximately 200 m^2 of forest area will be damaged with each felled tree (Weidelt 1996). Therefore, there is a maximum logging intensity threshold beyond which maintaining stand integrity is difficult in selection cutting. For example, Watanabe (1992) gives this threshold as 30% of stand basal area. Skid trails are also required, but skidding damage can be minimized by planning the trails, utilizing the optimum trail spacing, keeping the trails straight, directional felling of trees on an angle towards trails, keeping the skidders on the trails, utilizing the winch more, limiting skidding operations during wet periods, using the correct size of skidder (i.e. not too large and not too small), skidding log lengths, and utilizing bumper trees where required. The skill and work ethic of both fellers and skidder operators are also critical in minimizing damage.

As with residual stand damage, site impacts in conventional logging of NCTF are excessive. In high logging intensity and uncontrolled logging areas, 30-75% of the area can be serious impacted with roads, tractor trails, landings or just otherwise bulldozed (e.g. when gathering logs with the blade) (Chai 1975, Kartawinata 1978, Neil 1984, DeBonis 1986, Buenaflor 1989, Bruenig 1996, Dykstra *et al*. 1996, van der Hout 1999). However, typically in higher logging intensity areas (e.g. 30-50 m^3/ha), 10-25% of the area is impacted by roads, skid trails and landings

(Nicholson 1958a, Borhan *et al.* 1987, FAO 1989b, Hendrison 1989, Uhl and Viera 1989, Malmer and Grip 1990, Sim and Nykvist 1991, Verissimo *et al.* 1992, Cannon *et al.* 1994, Ohn *et al.* 1996, Winkler 1997, van der Hout 1999). In lower logging intensity areas the soil disturbance is from 6-13% of the area (Bullock 1980, Uhl *et al.* 1991, White 1994, Agyeman *et al.* 1995, Scharpenberg 1997). Bruenig (1996) states that with excessive roading and skidding, and thus excessive compaction and erosion, felling cycles of 25-50 years are not sustainable and 60-100 years is more realistic. Tropical soils are also highly susceptible to degradation when physically disturbed, and exposed to the sun and/or the direct impact of heavy tropical rains (Poore and Sayer 1987).

3.2 Logging Intensity and Wood Waste

Better wood utilization efficiency in both harvesting and mill processing can greatly enhance the sustainability of the tropical timber industry (Noack 1995). The extent of logging waste reported in the literature generally ranges from 30% (Silitonga 1987, Bhargava and Kugan 1988, Gerwing *et al.* 1996, Muladi 1996, Scharpenberg 1997) to 50% (Virtucio and Torres 1978, Dykstra 1992, Noack 1995) of the extracted log volume.

Through a review of tropical countries Dykstra (1992) estimated felling recovery rates to be 54% in Africa, 46% in Asia/Pacific, 56% in Latin America and the Caribbean, and 50% on average for all tropical areas. A similar study by Noack (1995) in Ghana, Cameroon East Kalimantan and Sarawak found that on average 53.5% of the tree was extracted; of the remaining volume 4.6% was stump, 5.2% buttress, 10.4% stem off-cuts and 26.3% were parts of the crown with diameter >20 cm. Variations in felling recovery rates reported in the literature are due to operational efficiency and skill of workers, available markets for lower grade logs, and differences in the definition of merchantable wood.

One source of logging waste is felled and bucked trees which are not found during the skidding operation. For example, Mattsson-Marn and Jonkers (1981) found that 11 m^3/ha (20% of extracted volume) of logs could not be found by the skidder in current operations. In a planned harvesting block the volume lost was reduced by 100% to 5.5 m^3/ha. Gerwing *et al.* (1996) found that 6.6 m^3/ha (22% of extracted volume) of usable timber was felled but never skidded. A similar result was found by Uhl *et al.* (1997) who reported 7 m^3/ha (20% of extracted volume) felled and never recovered. Through RIL techniques, and mapping of felled trees and felling directions the loss of logs can more or less be eliminated.

Logging wastes also develop due to poor work methods, and felling and bucking techniques which result in the splitting and breaking of felled trees (Hendrison 1989). High stumps, felling above the buttress and topping at too large a diameter also result in excessive waste (Balachandra 1988, Gerwing *et al.* 1996). Brotoisworo (1991) attributes the low skill of workers to part of the 35-40% of the logging waste he found. The estimated volume of waste due to felling and bucking losses is about 6.5-8.5% of the utilizable stem volume (FAO 1989a, Winkler 1997). In addition to volume loss due to poor felling and bucking techniques there can be significant value losses.

A problem outlined by Quirós *et al.* (1997) is that loggers are paid based on the volume removed. Therefore, they only take out the best and largest logs, resulting in 20-25% of the cut volume not being extracted due to felling damage or poor quality. In many cases the logging waste left is suitable for supplying local markets through small-scale sawmilling. Hendrison (1989) also found that serious wood damage and quality loss can occur during positioning and collecting (bunching) logs with the blade of a skidder.

Logger training is a key factor in reducing logging waste and value loss. Uhl *et al.* (1997) found that trained loggers were able to achieve a 300% reduction in waste associated with felling a bucking, while Winkler (1997) found a 120% reduction. DeBonis (1986) also found that a 15-30% increase in wood volume at the mill could be realized through proper felling and bucking techniques. Cross-cutting training programs have also shown that log values can be increased by 10-50% (Dykstra and Heinrich 1996).

Wood volume losses or waste also occur at roadside landings, export ports, mill yards and in manufacturing itself. For example, Kilkki (1992) found in a study in Papua New Guinea that 10-35% of the export volume was left at the harbour as not fulfilling export grade rules. Bethel (1984) states that overall product yield from a tree can be as low as 10 to 20%, and typically averages no more than 30%. This is supported by Buenaflor and Karunatilleke (1992) who state that 70% of the wood being logged from natural forests is wasted owing to both poor harvesting and mill processing, and the non-availability of markets for all wood.

Mill process yields have been reported to be as low as 33% of delivered log volume (Barros and Uhl 1995, Gerwing *et al.* 1996, Uhl *et al.* 1997). Noack (1995) reported sawmill lumber recovery factors (LRF) ranging from 36% to 57%. In other reports reviewed, the LRF reported varied from 45-55% (Silitonga 1987, Kilkki 1992, Verissimo *et al.* 1995, Muladi 1996). When sawing large diameter tropical hardwood logs the LRF should be at least 50% (Uhl *et al.* 1997), and yields of 56-68% should generally be expected (Niedermaier 1984).

3.3 The Economics of RIL

While the benefits of RIL are widely acknowledged, the incremental costs of adopting RIL practices are commonly viewed as a principal impediment to their adoption by loggers. RIL requires increased investments in training and planning. This in turn results in a more efficient logging operation and optimal use of logging equipment (e.g. reduced skidding distances and improved log recovery). The development and application of the CELOS system in Suriname showed that planned logging could be cheaper than conventional logging due to reduced skidding costs (Hendrison 1990). Barreto *et al.* (1998), using a modification of the CELOS system developed by IMAZON, confirmed this result. However, another study in Brazil, near Manaus in the state of Amazonas, found that environmentally sound forest harvesting was moderately more expensive than the traditional logging system (Winkler 1997). This may have been due to a modified skidding system which utilized both pre-skidding and skidding phases. In Guyana, van der Hout (1999), showed that the cost of RIL was almost identical to the cost of conventional logging.

When harvesting intensity is considered in the economic analysis, increased initial costs of RIL may be recovered in decreased machine and labour costs and decreased logging waste (Uhl *et al.* 1997, Holmes *et al.* 2002). Johns *et al.* (1996) provide evidence of a net increase in profits of 1% for RIL in Paragominas, Brazil when harvest efficiency is considered. However, in areas with high biodiversity values or steep slopes, the balance of costs and benefits may be different due to the large quantity of foregone timber. High wages relative to machine costs may also contribute to higher costs for RIL compared with conventional logging. From the viewpoint of the forest owner, RIL may be advantageous, as reduced damage to regeneration will translate into a higher yield in the second cycle of logging. Whether cost savings demonstrated in relatively small experimental settings would be achieved when RIL is applied to large-scale operations remains to be seen. It should also be realised that applying RIL changes the distribution of costs and benefits among stakeholders.

4. CONCLUSION

Throughout all of the literature there is consensus that the vast majority of logging in NCTF continues to be inefficient, wasteful and excessively destructive to both residual trees and the site itself. In some cases (e.g. Nicholson 1979) there is evidence that logging has become more destructive with increased reliance on high horsepower equipment than on technical competence. The benefits and techniques of RIL are well documented in all parts of the tropics, but full implementation of RIL is rare. Logging as currently practiced in NCTF is non-sustainable and this is reflected in the GFSS database with considerable reductions in veneer log and saw log logging intensity in the second cutting cycle. It is expected that if current logging practices continue the third cut will be still lower or even non-existent.

On the other hand, with the implementation of RIL logging techniques and silvicultural systems such as CELOS and CATIE, many studies indicate there will be cost savings due to more efficient operations. As experience grows with the implementation of RIL it is expected that at least a cost neutral situation will occur. The major benefit, however, will be stable future yields and sustainable forest management operations. This will result in future income, which otherwise will be lost.

Actual logging intensities vary considerably between regions, countries and even within countries (e.g. Appendix 2). The cutting cycle also varies considerably, but many reports are suggesting 40 years. This allows for the ingrowth of trees into the next higher diameter class; for example, from the 40-60 cm into the 60-80 cm dbh class (average diameter growth of 0.5 cm/year). Based on the literature, and with the implementation of RIL and appropriate silvicultural treatments, it is felt that an average logging intensity of 20 m^3/ha on a 40-year cycle is possible in closed NCTF in Africa, and Latin America and the Caribbean. Sundberg (1978) gives a logging intensity of 20 m^3/ha as the economic threshold, below which the relative logging cost increases exponentially. This economic threshold becomes very important with the extraction of lower value logs and species, and with the implementation of RIL. In the dipterocarp forests of Asia/Oceania an average logging intensity of 40 m^3/ha on a 40-year cycle should be easily achievable. In must be remembered though, that these are conservative and general averages, and the actual logging intensity and cutting cycle will depend on the condition of the forest itself and the species involved. In addition to the full implementation of RIL, a wider range of species must be commercialized and the utilization of felled trees improved.